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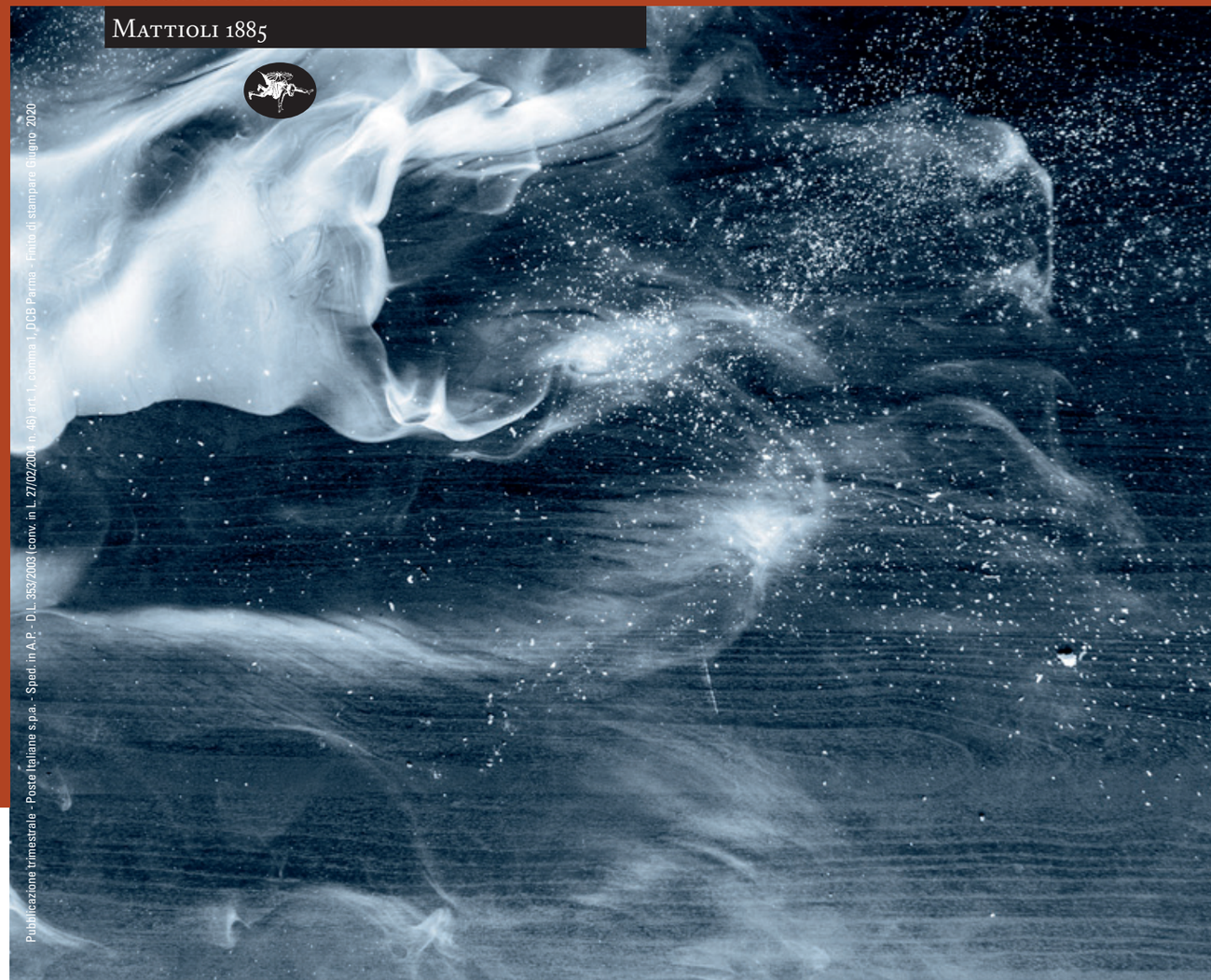

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Original articles

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Greetings from the SERTOT President

Dear Members,

we are going through a difficult period in every aspect, which has seen us to react to the epidemic aggression and then to reconstruct what has been damaged or destroyed. In the phase of overcoming the period of "heroic" activity, the risk is that there will be a tendency to tiredness and renunciation. We have to react and regain our personal and professional strength and even the SERTOT must react.

Because of this, it is with great pleasure that I introduce the volume 4-2020 Acta Biomedica Supplement - Advances in Orthopaedics, Traumatology and Rehabilitation - SERTOT.

The vitality of our Scientific Society is demonstrated by its ability to publish scientific papers also in this particular period of the life. This is the first issue in 2020 but I am confident that our Society will publish also to the second one. SERTOT has always stimulated their members to send articles to the magazine focused on different orthopaedics and traumatologic topics. For these reasons I am very happy that, also in this circumstance, contributions have arrived particularly numerous.

A special thanks to the Deputy Editors Francesco Pogliacomi and Paolo Di Benedetto for the personal commitment and passion dedicated to the magazine and to the sponsors who have guaranteed the release of this journal in the past years and this year.

Sincerely

Enrico Vaienti

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Review

The Painful Hip in Young Adults Between Impingement and Mild Dysplasia: Clinical and Instrumental Diagnostical Criteria

Paolo Lorenzon, Andrea Scalvi, Enrico Scalco

Ospedale Civile di Cittadella, U. O. di Ortopedia e Traumatologia, Centro Regionale Specializzato per la Prevenzione, lo Studio ed il Trattamento dell'Artrosi deformante dell'Anca, Cittadella (Padova), Italy

Summary Femoroacetabular impingement and developmental dysplasia of the hip are among the main causes of hip arthritis. In absence of degenerative alterations of the hip, there is the chance of a surgical conservative treatment. This study aims to show the clinical and imaging criteria to a correct and prompt diagnosis. (www.actabiomedica.it)

Key words: Impingement, Dysplasia, Hip arthritis.

It is well known that alterations in the shape of the hip joint lead to an early hip osteoarthritis (1,2,3). This trend is amplified by the contemporary lifestyle, which often implies an intense sport activity: indeed, strong physical training may accelerate those degenerative processes (4,5). The existence of surgical procedures which may correct the deformities of the hip joint, and thus prevent its degeneration in osteoarthritis, makes it crucial to identify this condition in its early phase. This paper aims to offer the most relevant instruments to evaluate the painful hip in the young adult, and identify the possible presence of joint deformities, both in case they were responsible of femoroacetabular impingement (FAI), or of developmental dysplasia of the hip (DDH), before they show evidence of arthritis. The systematic list of all radiographic signs is out of the scope of this paper.

FAI and Dysplasia

The two main causes of early hip osteoarthritis are FAI, and hip dysplasia. Hip dysplasia is characterized by an ill-oriented acetabular articular surface, with loss of coverage (anterior or global) of femoral head. The consequently reduced contact area leads to an excessive and eccentric acetabular load, with the development of early degenerative chondral alterations (6,7).

Dysplasia, which is a long renown disease, is often treated in childhood, and so its incidence has been drastically reduced nowadays. Yet it remains crucial to identify the cases of mild dysplasia, which may still be found in our population.

Femoroacetabular impingement is characterized by an early and pathologic contact during hip joint motion between skeletal prominence of the acetabulum and the femur. It is indeed a dynamic pathological mechanism, which comes from a limitation of the range of movements. Depending on the morphological alteration, we may distinguish two kinds of impingement. The first is the so-called Pincer type, where there is an abnormal acetabular morphology with a focal or general overcoverage of the femoral head; in this type of impingement, the initial damage is labral and involves the circumferential cartilage, while afterwards, due to the posterior subluxation, the chondral damage affects the posterior part of the acetabulum and of the femoral head. The second type of impingement is called Cam, and it is due to a lack of sphericity in the femoral head-neck junction, with decreased head-neck offset. The contact of the aspherical head-neck junction with the acetabulum leads to an abrasion of

the acetabular cartilage or its avulsion from the subcondral bone, a process which is usually localized in the anterosuperior portion of the acetabulum (8,9,10).

The two kinds of impingement, Pincer and Cam, are combined in most patients (more than 80%): it is called 'Mixed Pincer and Cam impingement'. Impingement can be consequence also of an early extraarticular bone pathological contact.

The modern surgical treatment of DDH was described by Ganz (11): the technique is performed through a modified Smith-Petersen approach, and four periacetabular osteotomies and a controlled fracture are performed, in order to completely mobilize the acetabulum from the innominate bone. These osteotomies allow a substantial acetabular reorientation, with three rotational degrees of freedom. The posterior column of the true pelvis remains intact, maintaining stability through an intact continuity of the pelvic ring, and allowing for minimal internal fixation of the fragment.

The surgical treatment of femoroacetabular impingement was first described by Ganz (12). He suggests an approach using a trochanteric flip: the hip is exposed anteriorly and dislocated in the same direction; respecting the integrity of the external rotator muscle and giving full protection to the vascular supply of the femoral head. This procedure offers the best view of the hip joint. Subsequently, other approaches have been used: the Hueter direct anterior approach, and the arthroscopic approach.

In any way, the surgical treatment in cam impingement lies mainly in removing any nonspherical portion of the head, improving the neck offset and subsequent clearance (femoral neck osteoplasty).

For pincer impingement, this includes reducing the anterior over coverage by excising the bony prominence at the rim or in some case of severe acetabular retroversion a reorientation with a reverse periacetabular osteotomy.

In the contact region between femur and acetabulum, the torn or degenerate area of the labrum is also excised, and the remainder of the labrum is reattached to the rim using suture anchors.

Many other disorders of hip joint can superficially mimic impingement and dysplasia but they do not depend on articular deformity. Among these, we can list rheumatological diseases, osteonecrosis of femoral head, transient hip osteoporosis, stress fractures, infiltrative bone disease, articular hyperlaxity.

Clinical presentation

The patients are young and active, usually in their 20s-40s, and suffer from painful hip. Pain may be differently localized: it may be felt like a knife sharp pain in the groin, or sometimes a pain irradiates to trochanteric or anterior thigh region, pelvic posterior region, gluteus and sacroiliac. Occasionally, it arises after an acute traumatic episode; yet it often occurs insidiously and tends to worsen with time (13). High sport and heavy work activity are surely a relevant cofactor to consider in the clinical history, but they do not represent essential conditions to this pathology. Indeed, it sometimes arises in sedentary patients. Generally, the pain does not relieve spontaneously. In the impingement, at a first stage, the symptoms are felt after or during physical activity, or in case of activities with an extreme range of movements; later, they occur also during a longtime sitting position. The hip with biomechanical abnormalities may also produce limp, a sensation of instability and weakness, articular clicks or sensations of locking in the hip. In impingement cases it is often present a hip with limited range of motions due to articular morphology. For example, most sportive patients have never been able to make a correct split, and they have always been limited in stretching. On the other side, patients affected by impingement involved in high range of movement demanding activities (free climbers, dancers, martial artists, etc.) may show a normal or increased articular mobility, especially if impingement is associated with hyperlaxity.

Patients live together with their deformities since childhood and they are used to them; for this reason, they do not often refer spontaneously many important symptoms, and it is necessary to ask them directly.

In clinical examinations, it is relevant to use specific tests (14,15)

Impingement test: the hip is positioned in 90° of flexion ad forced in internal rotation and adduction, then the hip is tested in many degrees of flexion. A

positive test (pain) is present for anterior femoroacetabular impingement, but sometimes is present also in dysplastic hip, in relation with degenerative labrum tear.

Posterior impingement test: the patient is in supine position with the hip positioned in maximal extension; the test is positive when there is painful forced external rotation, and it is related with chondral damage in the posterior area of acetabulum in patients affected by impingement.

Apprehension test: the patient is in supine position with the hip positioned in extension; the test is positive when there is instability sensation in external rotation. The test is positive in dysplastic hip with reduced anterior acetabular coverage.

Radiographic evaluation

Standard conventional radiographic imaging in evaluating the alterations in the shape of the hip joint is not only a primary role, but also cost-effective and of rapid execution.

It represents the first step after clinical examination, while MR and MR arthrography are second stage exams, as they are useful for a more accurate morphological definition of the deformity, or for an evaluation of the degenerative state.

Standard radiographic technique includes two radiographs: an anteroposterior pelvic view and an axial cross-table view of the proximal femur. In this exam, a correct positioning of the patient and an accurate radiographic technique are crucial for an accurate result.

For the anteroposterior pelvic view the patient is in supine position with the legs 15° internally rotated; the film-focus distance is 1.2 m., and the central beam is directed to the midpoint between a line connecting anterosuperior iliac spines and the superior border of the symphysis (16,17,18).

The axial cross-table view of the proximal femur is obtained by placing the leg internally rotated, with a film focus distance of 1.2 m., and with the central beam directed to the inguinal fold. An alternative to the axial view is a Dunn view, in 45° of flexion.

Moreover, a faux profile of Lequesne may be used for quantification of anterior coverage; this exam is more useful for dysplasia than for FAI; sometimes, it may be of use a lateral view of the pelvis, to determine the individual pelvic tilt: it is an angle formed by an horizontal line and a line connecting upper border of symphysis and the sacral promontory. A neutral tilt is a pelvic inclination angle of 60°.

Radiographic reference values of acetabulum (19)

Position, orientation and width of acetabular surface are relevant for a healthy hip. Undercoverage (developmental dysplasia of the hip [DDH]) and overcoverage (such as "pincer"-type femoroacetabular impingement) are two opposite kinds of acetabular pathological morphology. Both of them can lead to degenerative hip changes, until arthritis.

Pathomechanism differs in each of these conditions: static overload in undercoverage may cause higher joint contact pressures and subsequent degeneration of the articular cartilage, while dynamic conflict in overcoverage may lead to early pathological contact between the acetabulum and the femoral head-neck junction, that may cause chondrolabral damage.

The radiographical parameters listed below are considered in the study of acetabular anatomy; all these parameters, except the crossover sign, differ among overcoverage and undercoverage; among them, lateral center-edge angle (LCE), anterior and posterior coverage increase steadily from dysplasia, through physiological condition, to overcoverage and severe overcoverage. In contrast, extrusion and acetabular index, Sharp angle decrease from dysplasia to severe overcoverage.

Lateral center-edge angle (LCE): the angle formed by a line parallel to the longitudinal pelvic axis and a line connecting the center of the femoral head with the lateral edge of the acetabular sourcil (figure 1).

Dysplasia < 22°, normal 23°-33°, overcoverage (FAI) 34°-39°, severe overcoverage < 40°.

Acetabular index: angle formed by a horizontal line and a line through the most medial point of the sclerotic zone of the acetabular roof and the lateral edge of the acetabulum (figure 2).

Dysplasia < 14°, normal 3°-13°, overcoverage (FAI) -7°to 2°, severe overcoverage < -8°.

Extrusion index: percentage of uncovered femoral head in comparison to the horizontal head diameter.

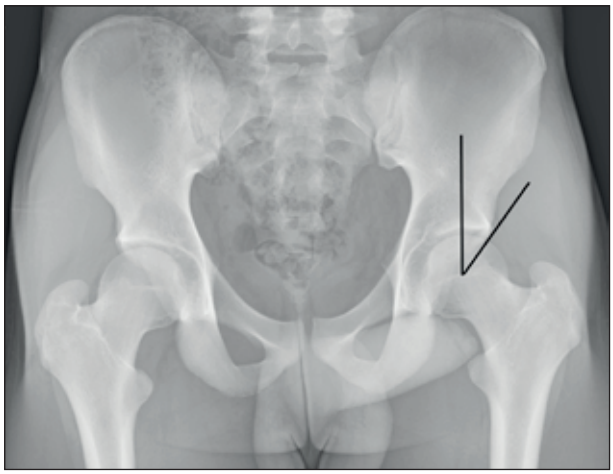

Figure 1. Lateral center-edge angle (LCE): the angle formed by a line parallel to the longitudinal pelvic axis and a line connecting the center of the femoral head with the lateral edge of the acetabular sourcil.

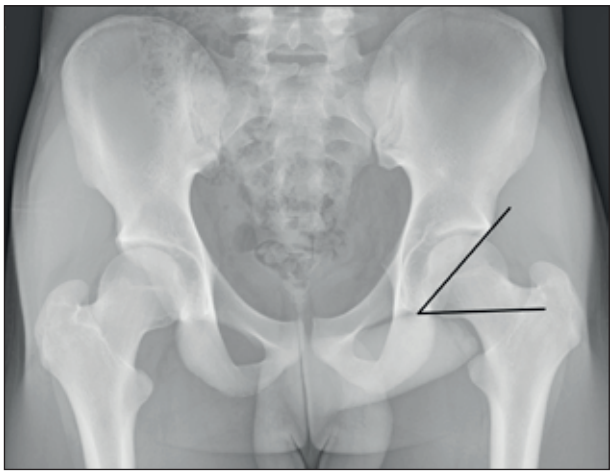

Figure 3. Sharp angle: angle formed by horizontal line and a line through the caudal tip of the teardrop and the lateral edge of the acetabulum.

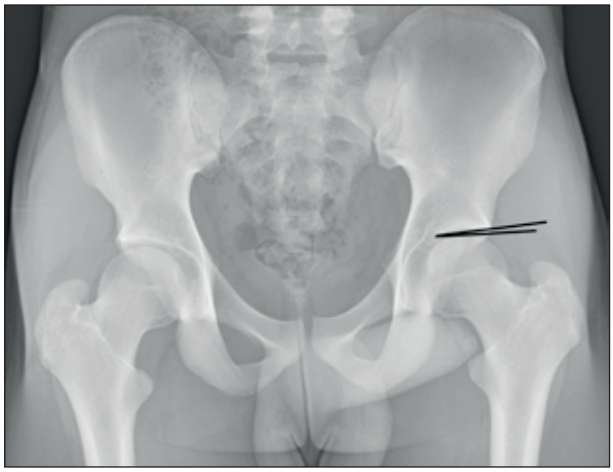

Figure 2. Acetabular index: angle formed by a horizontal line and a line through the most medial point of the sclerotic zone of the acetabular roof and the lateral edge of the acetabulum.

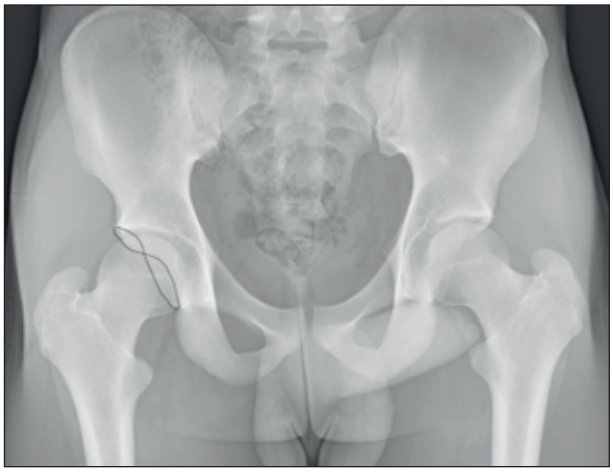

Figure 4. Crossover sign: positive if the projected anterior wall crosses the posterior wall.

Dysplasia > 27, normal 17-27, overcoverage (FAI) 12-16, severe overcoverage < 11.

Sharp angle: angle formed by horizontal line and a line through the caudal tip of the teardrop and the lateral edge of the acetabulum (figure 3).

Dysplasia < 43°, normal 38°-42°, overcoverage (FAI) 34°- 37°, severe overcoverage < 34°.

Crossover sign: positive if the projected anterior wall crosses the posterior wall (figure 4).

Dysplasia < 14°, normal 3°-13°, overcoverage (FAI) -7°to 2°, severe overcoverage < -8°

Posterior coverage: the percentage of femoral head covered by the posterior acetabular rim in posteroanterior direction.

Dysplasia < 35, normal 36-47, overcoverage (FAI) 48-55, severe overcoverage < 56.

Posterior wall sign: positive if the posterior acetabular rim is projected medial to the center of the hip.

Anterior coverage: the percentage of femoral head covered by the anterior acetabular rim in AP direction.

Dysplasia < 14, normal 15-26, overcoverage (FAI) 27-32, severe overcoverage < 33 (Table 1).

Table 1. Radiographic Reference Values for Acetabular Under- and Overcoverage

Parameter	Dysplasia	Control	Overcoverage	Severe overcoverage
LCEA (degrees)	< 22	23–33	34–39	< 40
Acetabular index (degrees)	< 14	3–13	–7 to 2	< –8
Sharp angle (degrees)	< 43	38–42	34–37	< 34
Posterior wall sign (percent positive)	Positive	Positive	Positive or negative	Negative
Anterior coverage (percent)	< 14	15–26	27–32	< 33
Posterior coverage (percent)	< 35	36–47	48–55	< 56
Extrusion index (percent)	> 27	17-27	12-16	< 11

Coxa profunda: the floor of the fossa acetabuli touching or overlapping the ileoischial line medially (figure 5).

Protrusio acetabuli: the femoral head is overlapping the ileoischial line medially.

Prominence of ischial spine: in clinical practice, when a cross over sign is seen, the ischial spine also is seen as a prominence in the pelvic cavity. There is a high correlation between the cross over sign and the prominence of ischial spine, that is easily visible on the AP radiograph as a projection in the pelvic cavity and is not easily confused, making it a reliable radiographic landmark for retroversion (20).

Radiographic reference values of proximal femur (17)

In Cam impingement, there is an aspherical part of femoral head. This osseous bump develops on the head-neck junction, and it leads to a decrease of head-neck offset.

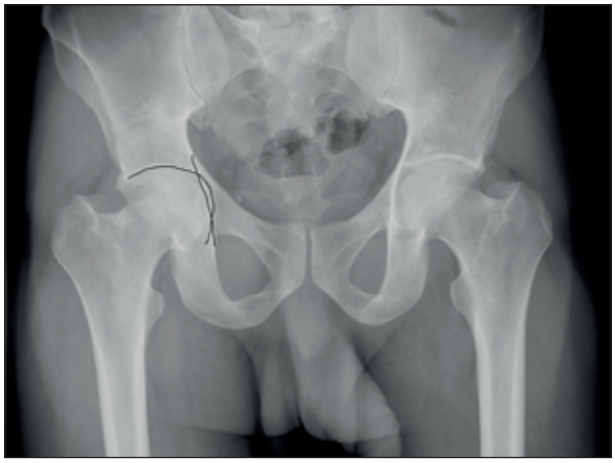

Figure 5. Coxa profunda: the floor of the fossa acetabuli touching or overlapping the ileoischial line medially.

Pistol-grip deformity: flattening on radiographs of the usually concave surface of the lateral aspect of the femoral head due to an abnormal extension of femoral epiphysis (figure 6).

Angle α: the angle between the femoral neck axis and a line connecting the head center with the point of beginning asphericity of head-neck contour (figure 7). It is useful to quantifies the amount of asphericity of

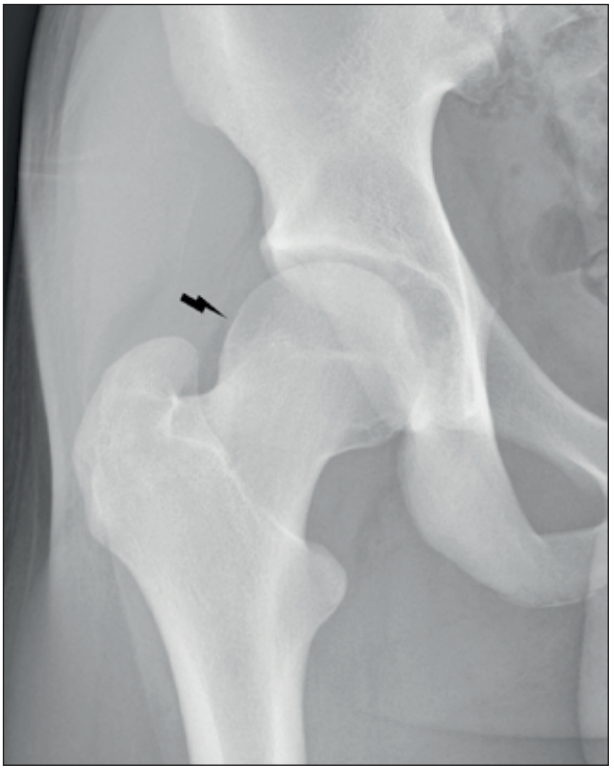

Figure 6. Pistol-grip deformity: flattening on radiographs of the usually concave surface of the lateral aspect of the femoral head due to an abnormal extension of femoral epiphysis.

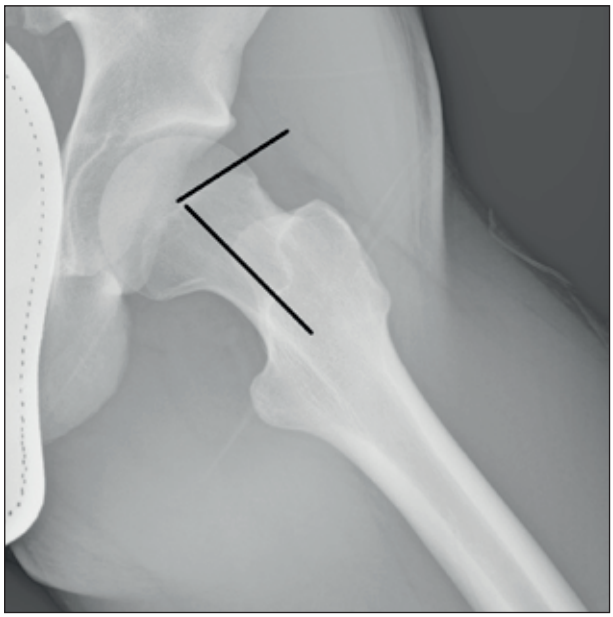

Figure 7. Angle α: the angle between the femoral neck axis and a line connecting the head center with the point of beginning asphericity of head-neck contour.

femoral head. An angle exceeding 50° is an indicator of an abnormal shape.

Anterior offset: the difference in radius between the anterior femoral head and the anterior femoral neck on a radiographic axial view.

Normal 11.6 +/- 0.7 mm, FAI 7.2 +/- 0.7 mm

Offset ratio: the ratio between the anterior offset and diameter of the head.

Normal 0.21 +/- 0.03, FAI 0.13 +/- 0.05

Coxa vara: centrum collum diaphyseal angle less than 125°, has been recognized as a cause of a cam or an extraarticular impingement.

Shenton line: is an imaginary curved line drawn along the inferior border of the superior pubic ramus (superior border of the obturator foramen) and along the inferomedial border of the femoral neck. This line should be continuous and smooth. Interruption of the Shenton line can indicate developmental dysplasia of the hip.

Secondary radiographic changes of the Hip

Untreated hip dysplasia or impingement leads to degenerative changes of the hip, reactive ossification, sclerosis of subchondral bone, cysts, osteophytes, narrowing of the joint space.

The Tönnis classification of osteoarthritis is not at issue here: it is just mentioned to say that if degenerative alterations of the joint are that evident, then the surgical treatment is not resolutive (21).

At any rate, secondary hip changes are radiographically evident also in early stages of the pathology:

Ossification of labral basis and osseous apposition of acetabular rim, related to recurrent impingement (figure 8).

Stress fracture of the acetabular rim, with separation of a prominent bone fragment from adjacent bone margin (os acetabuli), because of abnormal stress in impinging hips (figure 9).

Double contour of acetabular rim, for additional reactive bone apposition at the osseous rim of acetabulum, still related with impingement (22).

Linear indentation: reactive cortical thickening in anterior portion of femoral neck, in axial view, depending on early and pathologic contact during hip joint motion between skeletal prominence of the acetabulum and the femoral neck (figure 10-11).

Herniation pit: radiolucency area surrounded by sclerotic margin, typically located in the anterior

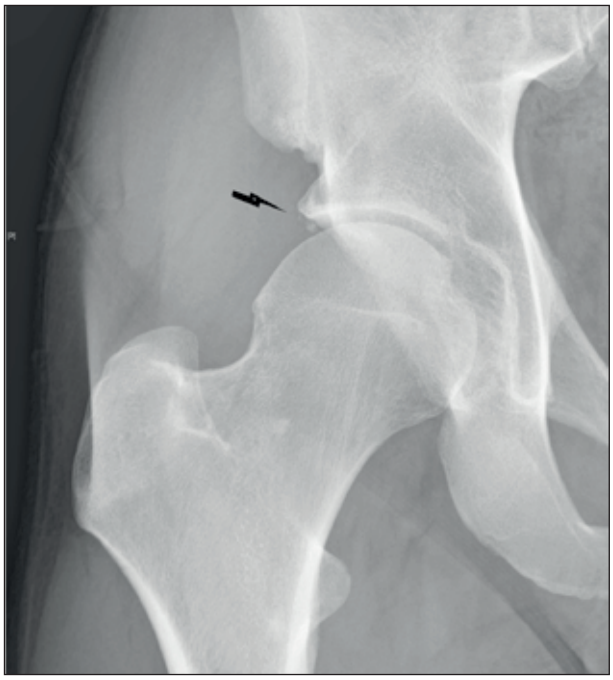

Figure 8. Ossification of labral basis and osseous apposition of acetabular rim.

Figure 9. Stress fracture of the acetabular rim, with separation of a prominent bone fragment from adjacent bone margin (os acetabuli).

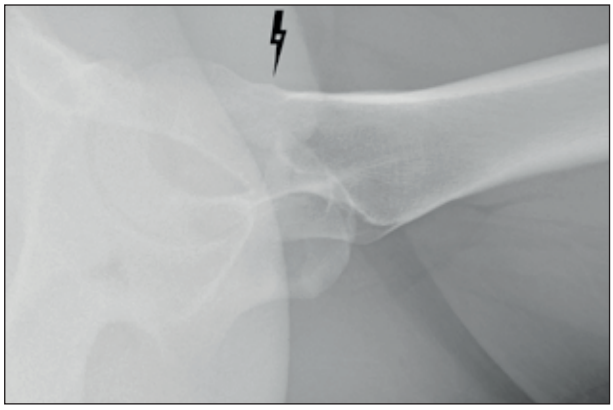

Figure 10. Linear indentation: reactive cortical thickening in anterior portion of femoral neck, in axial view, depending on early and pathologic contact during hip joint motion.

proximal superior quadrant of femoral neck (figure 12-13) (23,24). It occurs in impingement, but herniation pits are not always associated with symptomatic impingement.

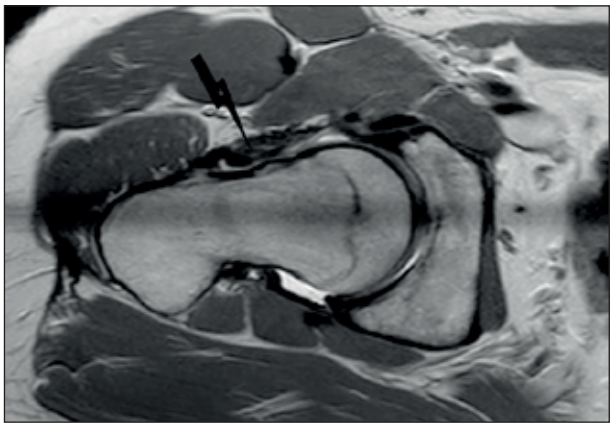

Figure 11. Linear indentation: reactive cortical thickening in anterior portion of femoral neck (MR arthrography view). It is also appreciable cartilage damage in the posterior joint.

Figure 12. Herniation pit: radiolucency area surrounded by sclerotic margin.

Ultrasound

Ecography is a valuable tool to answer specific questions regarding soft tissues hip pathology.

It is useful to asses bursae, tendons or joint effusion. Moreover, it is helpful as a guide for diagnostic or therapeutic interventional procedures such as aspiration of synovial fluid, or injection of steroids or anesthetics.

Nevertheless, it is not useful to the diagnosis of impingement or developemental dysplasia of the hip in adult.

Computed tomography

The high spatial resolution of CT provides an excellent representation of cortical and trabecular bone and joint bone anatomy, but it is not of routine use in these pathologies.

It may be useful in studying femoral retroversion, which may occur as a primary entity or be posttraumatical, and can be related with femoroacetabular impingement.

Magnetic Resonance

The role of MR is early detection of many hip pathologies, and exclusion of osteonecrosis, transient hip osteoporosis, stress fractures, infiltrative bone disease, septic arthritis, osteomyelitis if are suspected.

Anyway, RM arthrography has a better spatial resolution in defining intraarticular degenerative changes.

RM arthrography

After clinical examination and conventional radiographic imaging, the second level investigation is RM arthrography that better evaluates the hip for abnormality associated with impingement and dysplasia, but also can be used to confirm or exclude labral tears, cartilage damage or other signs of joint degeneration.

RM arthrography protocol has been developed by Locher and coll. and provides to obtain over the standard sagittal, axial and coronal images, also radial images obtained through the axis of femoral neck.

In this kind of patients, the evaluation of the degree and localization of chondral and labral damage is of primary importance in planning a surgery. In cases of lesion or detachment of the labrum, or chondral lesions, the infiltration of contrast medium is evident (figures 13-14) (25,26).

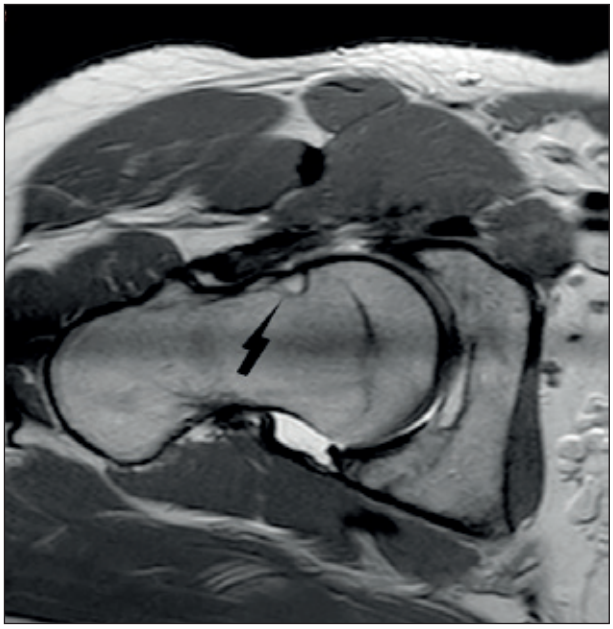

Figure 13. Herniation pit (MR arthrography view).

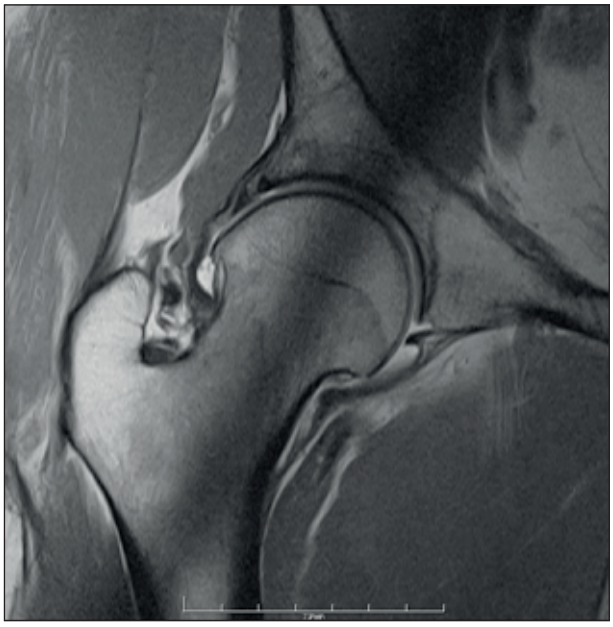

Figure 14. MR arthrography, chondral and labral damage.

Quite wide, even if not at full thickness, abrasions of cartilage lead to a migration of femoral head inside the chondral defect. This may be observed in RM arthrography, with an asymmetry of joint spaces characterized by a reduction of joint space in correspondence of the chondral defect (generally anterior, or anterosuperior), and by the infiltration of contrast medium in the opposite joint space (generally posterior).

The migration of the femoral head is evidence of advanced pathology; in this case surgery is contraindicated.

Discussion

The onset of hip disorders related with DDH and FAI is often slow and insidious. The habit to small limitations makes it sort of a second nature, but later, with the beginning of degenerative changes, pain leads the patient to the doctor.

The insidious nature of the pain makes important to distinguish its source, whether it raises from the hip or from another district. Symptoms may be irradiated from the back, or be related to periarticular disorders such as bursitis, tendinitis, muscular disbalance, or also depend on non orthopedic origin like inguinal hernia. Moreover, pain often irradiates from the hip to the knee, gluteus and sacroiliac. A good way to identify disorders of hip joint is impingement test: it has a high sensibility and specificity in pain from the hip, but it is less specific in discerning the different pathologies of the hip. In a second moment, specific radiographic parameters can be used to confirm the diagnosis of this entity with timely delivery of treatment.

The described reference values are used to support the choice of the most appropriate surgical option for symptomatic hips. This can be very helpful in mild DDH, in borderline cases of mixed DDH and pincer pathomorphologies, or in the evaluation of acetabular coverage.

We emphasize that these reference values apply only to symptomatic patients. Diagnosis and treatment in these patients must be used in addition to patient history, clinical findings, and hip morphology. Sometimes, patients with typical radiographic features of femoroacetabular impingement or mild hip dysplasia may be asymptomatic. In these situations, the recourse to surgical treatment is under discussion for asymptomatic dysplastic hips, while this option is not taken into account for impingements.

Recognition of FAI and DDH in their first stages, i.e. before the degenerative process is advanced, and its early treatment, is likely to have a considerable impact on the natural history of the disease, delaying the onset of end-stage arthritis in these young patients.

Surgical treatments of femoroacetabular impingement and hip dysplasia focus on correcting the deformities of the hip joint, in the former case improving the clearance of hip motion and alleviating of femoral abutment against acetabular rim, in the latter reorienting acetabular version. The results of these treatments are good. After correction of impingement, Steppaker and coll. have found decreased pain and improved function in a vast majority of patients with a survival rate of surgery of 80% at 10-year follow up (27,28), and cumulative survivorship of the hip at 20-years was 60%, and at 30-years was 32% after periacetabular osteotomy in dysplastic hips (29,30). An important predictive factor for good results is a non-arthritic joint.

To avoid the degeneration in osteoarthritis, it is critical to identify these conditions in their early phase, in order to intervene with a surgical treatment.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Ganz R, Leunig M, Leunig-Ganz M, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. Clin Orthop Relat Res. 2008; 466: 264–72.
2. Parvizi J, Campfield A, Clohisy JC, Rothman RH, Mont MA. Management of arthritis of the hip in the young adult. J bone Joint Surg. 2006; 88B, n. 10: 1279–85.
3. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res. 2003; 417: 112–20.
4. Siebenrock KA, Behning A, Mamisch TC, Schwab JM. Growth plate alteration precedes cam-type deformity in elite basketball players, Clin Orthop Relat Res. 2013; 471(4): 1084–91.
5. Murray RO, Duncan C. Athletic activity in adolescence as

an etiological factor in degenerative hip disease. J Bone Joint Surg Br. 1971; 53: 406–19.
6. Bombelli R, Osteoarthritis of the hip: pathogenesis and consequent therapy, Springer, Berlin 1976.
7. Murphy SB, Ganz R, Muller ME. The prognosis of untreated hip dysplasia: factors predicting outcome. J Bone Joint Surg Am. 1995; 77: 985–89.
8. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. J Bone Joint Surg Br. 2005; 87: 1012–18.
9. Eijer H, Podeszwa D, Ganz R, Leunig M. Evaluation and treatment of young adults with femoro-acetabular impingement secondary to Perthes' disease. Hip Int. 2006; 16: 273–80.
10. Harris WH. Etiology of osteoarthritis of the hip. Clin Orthop Relat Res. 1986; 213: 20–33.
11. Ganz R, Klaue K, Vinh TS, Mast JW. A new periacetabular osteotomy for the treatment of hip dysplasias: technique and preliminary results. Clin Orthop Relat Res. 1988; 232: 26–36.
12. Ganz R, Gill TJ, Gautier E, Ganz K, Krugel N, Berlemann U. Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. J Bone Joint Surg Br. 2001; 83: 1119–24.
13. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res. 2003; 417: 112–20.
14. Ganz R, Gill TJ, Gautier E, Ganz K, Krugel N, Berlemann U. Surgical dislocation of the adult hip: a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. J Bone Joint Surg Br. 2001; 83: 1119–24.
15. Hozack WJ, Parviz J, Bender B. Surgical treatment of hip arthritis: recostruction, replacement, revision, Sanders Elsevier, Philadelphia 2010.
16. Tannas M, Mistry S, Steppacher SD, Reichenbach S, Langlotz F, Siebenrock KA, Zheng G. Radiographic analysis of femoroacetabular impingement with Hip Norm-reliable and validated, J Orthop Res. 2008; 26: 1199–205.
17. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis—what the radiologist should know. AJR Am J Roentgenol. 2007; 188: 1540–52.
18. Tannast M, Fritsch S, Zheng G, Siebenrock KA, Steppacher SD. Which radiographic hip parameters do not have to be corrected for pelvic rotation and tilt? Clin Orthop Relat Res. 2015; 473(4) 1255–66.
19. Tannast M, Hanke MS, Zheng G, Steppacher SD, Siebenrock KA. What Are the Radiographic Reference Values for Acetabular Under- and Overcoverage? Clin Orthop Relat Res. 2015; 473(4): 1234–46.
20. Kalberer F, Sierra RJ, Madan SS, Ganz R, Leunig M. Ischial spine projection into the pelvis: a new sign for acetabular retroversion. Clin Orthop Relat Res. 2008; 466: 677–83.
21. Tönnis D, Heinecke A. Acetabular and femoral anteversion: relationship with osteoarthritis of the hip. J Bone Joint Surg Am. 1999; 81: 1747–70.
22. Corten K, Ganz R, Chosa E, Leunig M. Bone apposition of the acetabular rim in deep hips: a distinct finding of global pincer impingement. J Bone Joint Surg Am. 2011; 93 (Suppl 2): 10–6.
23. Leunig M, Beck M, Kalhor M, Kim YJ, Werlen S, Ganz R. Fibrocystic changes at anterosuperior femoral neck: prevalence in hips with femoroacetabular impingement. Radiology 2005; 236: 237–46.
24. Gao Z, Yin J, Ma L, Wang J, Meng Q. Clinical imaging characteristics of herniation pits of the femoral neck. Orthop Surg. 2009; 1: 189–95.
25. Hanke MS, Steppacher S, Anwander H, Werlen S, Siebenrock KA, Tannast M. What MRI Findings Predict Failure 10 Years After Surgery for Femoroacetabular Impingement? Clin Orthop Relat Res. 2017; 475(4): 1192–207.
26. Czerny C, Hofmann S, Neuhold A, Tschauner C, Engel A, Recht MP, Kramer J. Lesions of the acetabular labrum: accuracy of MR imaging and MR arthrography in detection and staging. Radiology. 1996; 200: 225–30.
27. Steppacher SD, Anwander H, Zurmühle CA, Tannast M, Siebenrock KA. Eighty percent of patients with surgical hip dislocation for femoroacetabular impingement have a good clinical result without osteoarthritis progression at 10 years. Clin Orthop Relat Res. 2015; 473: 1333–41.
28. Steppacher SD, Huemmer C, Schwab JM, Tannast M, Siebenrock KA. Surgical hip dislocation for treatment of femoroacetabular impingement: factors predicting 5-year survivorship. Clin Orthop Relat Res. 2014; 472: 337–48.
29. Steppacher SD, Tannast M, Ganz R, Siebenrock KA. Mean 20-Year Follow-up of Bernese Periacetabular Osteotomy. Clin Orthop Relat Res. 2008; 466(7): 1633–44.
30. Lerch T, Tannast M, Steppacher S, Siebenrock KA. Thirty years follow up after bernese periacetabular osteotomy, Orthopaedic Proceedings 2018; 9-B supp 4: 122.

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Review

The Mako™ robotic arm-assisted total hip arthroplasty using direct anterior approach: surgical technique, skills and pitfalls

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Summary. In the last decades many innovations have improved the hip replacement and the hip reconstruction surgery such as the introduction of the robotic-arm assisted surgery associated with the direct anterior approach (DAA). This surgical approach for total hip arthroplasty (THA) is growing in popularity and its effectiveness has been demonstrated to improve patients' outcomes, especially regarding more accurate implant placement, less post operative pain, faster recovery and lower of prosthesis dislocation risk. The robotic-arm assisted surgery is another really great innovation for the orthopedic surgeons. It allows to create a patient-specific THA pre-operative planning and to perform a much more accurate surgical procedure. This article outlines authors' surgical technique of performing accurate pre-operative planning and robotic-assisted THA using direct anterior approach based on the experience of 534 patients and to discuss details of this technique. (www.actabiomedica.it)

Key words: total hip arthroplasty, robotic technology, direct anterior approach, Mako system, surgical technique.

Introduction

Total hip arthroplasty (THA) is the surgical treatment of choice for patients with end-stage osteoarthritis that significantly reduces pain and improves hip function and quality of life.

Despite good functional outcomes achieved for the majority of patients, malpositioning of the components still remains the most biomechanical issue associated with this procedure, which can results in mechanical failures including component impingement, hip dislocation, leg length discrepancy, accelerated bearing surface wear with peri-prosthetic bone resorption, and altered hip biomechanical function. (1–4).

Over the years, robotic technology has been widespread used in the medical world, involving the orthopaedic specialty, particularly in the adult hip and knee reconstructive surgery. The robotic arm-assisted surgical system allows to make a patient's specific pre-operative planning and to perform a robotic surgery based on a three-dimensional (3D) computed tomography (CT) models of the patient's hip. This new surgical technique is innovative allowing to minimize the potential human errors, reducing the intra-operative complication rates (5).

In addition, there is a debate if the surgical approach might have an influence on implant successful outcome. The concept of minimal invasive approach is expressed not only to reduce the size of the incision, but also in less muscle damage and a better respect of the soft tissues. The use of the direct anterior approach (DAA) in total hip arthroplasty seems to gain popularity thanks to a careful respect of soft tissues using an anatomical inter-muscular approach (6). Thanks to

this surgical approach, the patient might have a quicker recovery, a shorter hospitalization and can start with an earlier rehab program (7).

In recent studies, it has been shown that the DAA allows an improvement in clinical outcomes in the first 6 weeks, which seems to level out after that (8-11).

The purpose of this study is to describe the surgical technique in performing a robotic arm-assisted THA (Mako Robotic Arm assisted Total Hip™, Stryker, Warsaw, Indiana USA) using the DAA based on the experience of 534 patients and to discuss details of this technique.

Surgical technique

Pre-operative planning

Pre-operative CT scans of pelvis and both knees need to be obtained. Specific anatomical data are imported into a preoperative workstation to be evaluated creating a virtual planning and allowing the surgeon its execution. The MAKO® robotic arm-assisted system uses CT scan data to create a patient-specific pre-operative planning for proper component size selection and accurate intra-operative stem and cup positioning. Furthermore, 3D models of patients' pelvis and knees provide informations about the native anatomy, including the pelvic tilt, leg length and hip offset (12).

This technology offers a virtual preoperative planning and the role of the robot is to assist the surgeon during the stem and cup placement and in the final check.

Surgical technique

Patient position: The patient, under spinal or general anesthesia, is positioned supine on a standard operating room table with a gel cushion under the buttock of the operative side.

The lower extremities are prepared separately using a bilateral sterile limb drapes, allowing for manual comparison of lengths intraoperatively and for stability testing. This drape completely covers the two legs leaving the anterior part of the iliac crest and the anterolateral region of the thigh on both side on view and protected by a sterile and transparent adhesive drape.

The surgeon requires an assistant and a theatre nurse. A third assistant is not essential. The presence of an experienced biomedical engineer during the pre-operative planning and surgery is nevertheless mandatory.

Positioning of the robotic system – Pre-operative planning: The robotic arm should be located on the operative side of the patient and aligned at the same level of the anterior superior iliac spine (ASIS). The approach angle between the robotic arm and the operating table should be about 45°. An infrared camera is positioned next to patient's head and it can be moved intra-operatively. The computer screen showing in real time the operative planning is positioned in front of the surgeon whereas the biomedical engineer's bench is in a corner of the operating room (Figure 1).

Every pre-operative planning is made using the "enhanced" procedure. The patient-specific pre-operative planning enables an accurate choice of the size and position of stem and cup prosthesis, thanks to a virtual 3D model of the patient's joint that considers the new implant on three spatial dimensions. This allows to rebuild the articular geometry correctly and to know the combined version (CV), planned on the patient's hip anatomical features. The CV value is calculated summing the stem and cup version. Knowledge of precise CV and center of rotation (COR) means to create a stable and well-balanced implant without any impingement between the components or muscular

Figure 1. Author's operating room: infrared camera at the head of the table, next to patient's head, the computer screen in front of the surgeon and the biomedical engineer in the corner of the operating room

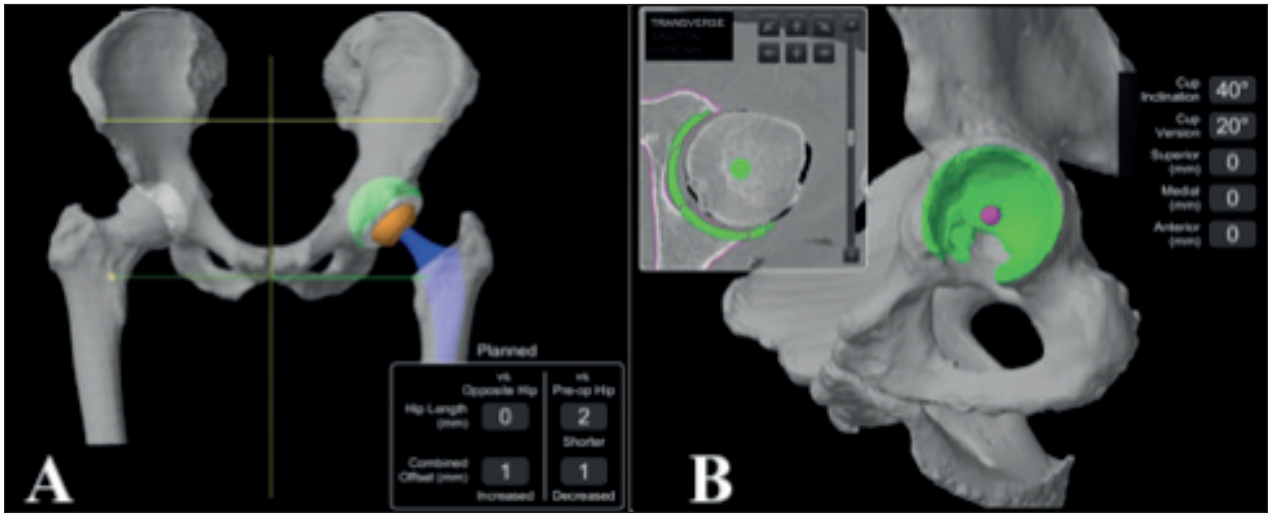

Figure 2. The 3D preoperative model based on patient's CT data. On panel A estimated hip length and combined offset are compared to opposite hip. On panel B the orientation and depth of the acetabular component in the transverse view of the hip joint are showed.

forces imbalances due to an incorrect muscle levers (13-16).

In the pre-operative step, the surgeon can modify the planning (size and position of the components) in order to optimize the offset values and the leg length (17) (Figure 2).

Surgical incision (the direct anterior approach): The use of the direct anterior approach with the robotic technique requires to slightly modify the direction of the classical surgical incision. In contrast to the manual technique, the incision should be more oblique and distal towards the thigh, allowing a reduction in muscle tension in order to have a better view and a comfortable working space to the anterior trochanteric region. In the meantime the assistant makes two small stab skin wounds with 11 blade, over the anterior edge of the contralateral iliac crest, about 1 cm apart from each other and 2 threaded pins are inserted into the thickest portion of iliac crest (they must protrude from the skin by about 10 cm). After the two pins have been fixed, the pelvic attachment device is inserted onto the pins. This allows a connection between the surgeon and the software through the infrared camera, during the acetabular registration phase.

The skin incision, on the affect side, starts 2 cm below and lateral to the anterior superior iliac spine (ASIS). It must be continued distally and laterally towards the greater trochanter region for about 10 cm,

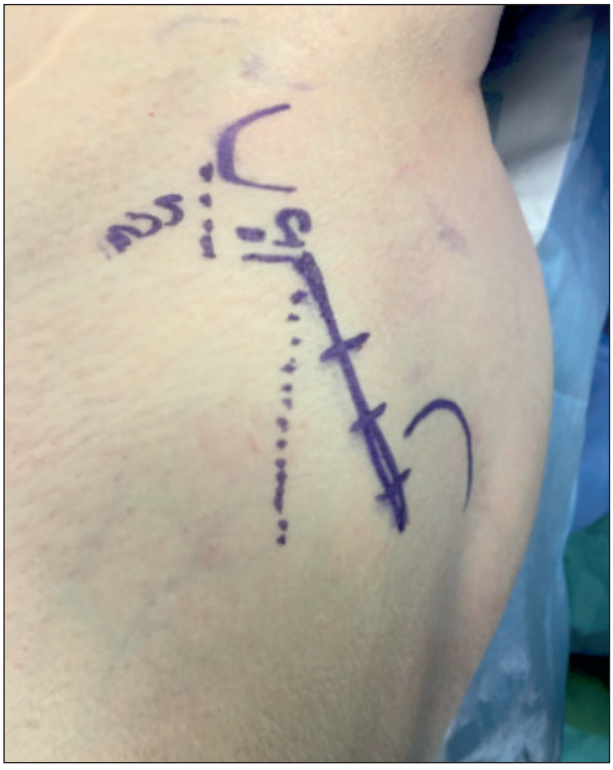

Figure 3. Planned incision of modified direct anterior approach.

with an oblique course (the length of the incision can vary related to the dimension of the patient) (Figure 3).

Under the skin there is an adipose layer placed over the thin band of the tensor fasciae latae muscle. The fat

tissue is taken out and the band is cut in the direction of the muscle fibers. The upper portion of the fascia is bluntly dissected from the muscular belly and using a finger is possible to release it and identify the intermuscular septum between the tensor fasciae latae muscle and the sartorius muscle. Deeply is well recognizable the anterior and proximal part of the rectus muscle and the "unnamed fascia". The fascia must be cut in lengthwise and under it there is the vascular bundle originating from the lateral circumflex femoral artery. The vascular bundle must be tied up and cauterized otherwise it could be a bleeding source. Two retractors are placed around the greater trochanter respectively in the medial and lateral part of it and a third Homann fixed on the top of the acetabulum creating a wide working area. A C-shape capsulotomy is performed. It runs from lateral to medial side along the anterior edge of the acetabulum and encircling the femoral neck till the lesser trochanter. We don't remove the capsule entirely because we consider it useful in protecting the medial vascular bundle and the nervous structures from the surgical tools. At the end of the surgery, if the condition of the capsule is good we could suture it.

Screws placement: Once the capsule has been opened the surgeon using a drill makes a hole on the anterolateral part of the greater trochanter and inserts two screws of different size. The smaller screw called "check point" needs to verify the accuracy of bone registration and a second larger screw used for holding the array required for connection with the infrared camera (Figure 4). Both screws are positioned close together and it is essential to check their stability. If they become loose, the accuracy and registration are not valid, and the measure of the leg length and offset values becomes inaccurate.

Femoral registration: In order to complete the femoral registration, the surgeon has to touch thirty two required points all around the anterior part of the femoral head and the proximal femur (from the femur neck to the lesser trochanter), as identified by the software and showed on the computer screen. The required points are took using a specific probe. This is an essential step in verifying the compliance with skeletal geometry. The registration must be done very precisely with a margin of error less than 0.5 mm (Figure 5), otherwise it will not be valid. Once kept all

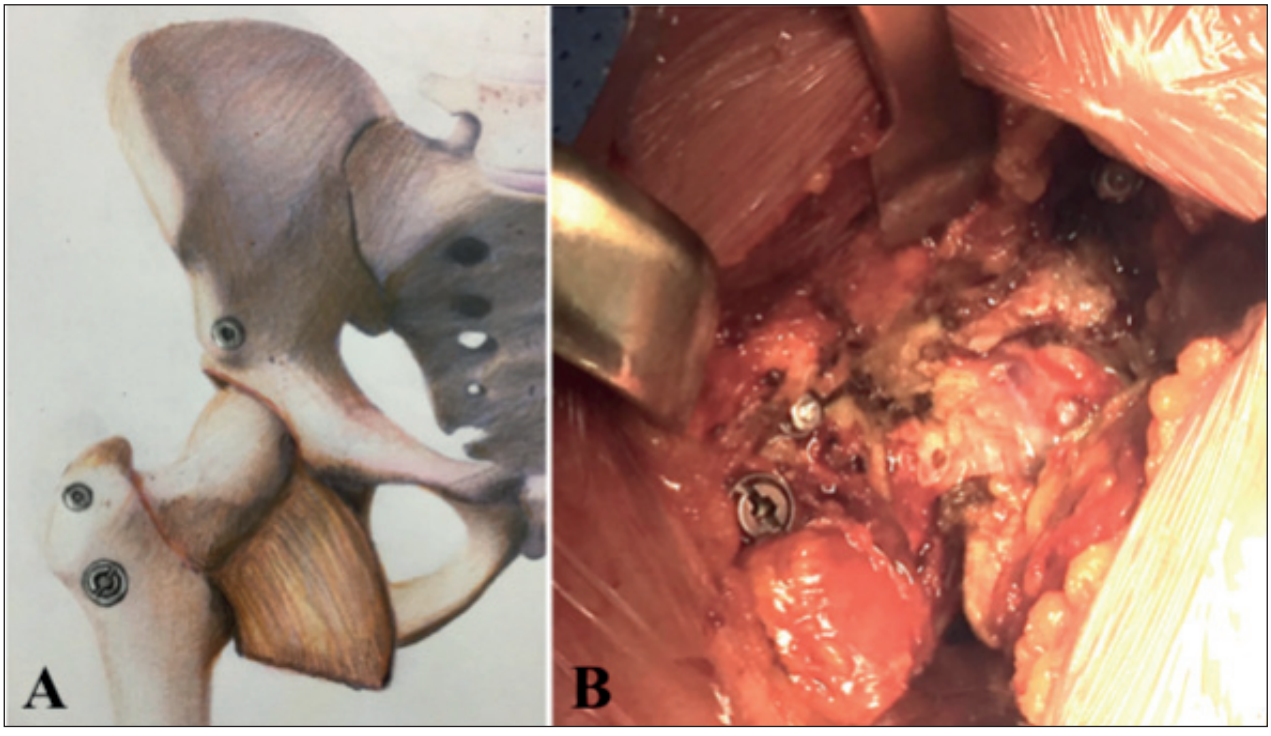

Figure 4. A: schematic representation of acetabular and femoral checkpoint. B: trochanteric screw is showed

points and completed the registration, the cutting line of the femoral neck will be showed on the display and the surgeon will marked it on the bone with a bovie tip, following precisely the line on the screen (Figure 6).

The osteotomy is performed using an oscillating saw. Once the neck is completely cut the femoral head is extracted carefully using a corkscrew device.

Femoral preparation: The femur is always prepared first. A correct exposure of the proximal femur is fundamental because it allows the surgeon to work comfortably avoiding complications, including canal perforation, calcar and greater trochanter fractures. Three retractors are placed around the trochanteric area after freeing the greater trochanter bone from the capsule. The first retractor is placed medially above the lesser trochanter, the second under the greater trochanter and the last one, a sharp retractor, is placed above the acetabulum in order to elevate the rectus femoris muscle and iliocapsularis muscle groups.

With the help of the assistant, the limb, initially in an extended position, should be gradually externally rotated and adducted. In the same time the first surgeon lifts the proximal femur up by a small hook previously inserted at the level of the osteotomy rim. The ischiofemoral ligament is exposed (Figure 7) and partially detached to release the apex of the greater trochanter from the posterior part of the acetabular rim (posterolateral release). A curved retractor is placed under the greater trochanter and applying a gentle force on it allows to expose completely the proximal femur.

At this point the limb is placed in a figure-4 position under the contralateral leg by the assistant surgeon. It is advised to apply a pressure on the knee to further externally rotate the femur and facilitate the preparation with the dedicated broaches. When the femoral release is particularly difficult, the piriformis tendon, which is often retracted in long-standing osteoarthritis, can be released in order to avoid a fracture of the greater trochanter.

Femoral version registration: During the femoral preparation, it is important to pay attention to the first broach position, it must be in line with the femoral canal. The correct enter point is at the bottom and slightly posteromedial side of the greater trochanter (Figure 8). Removing part of the cortical bone in the central part of the trochanter recommended to allow an easier approach to the canal.

The femoral canal is prepared using sequentially increasing size broaches. Concerning the rotation of

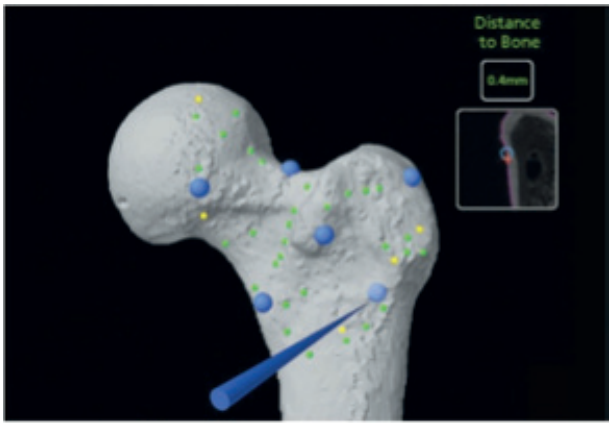

Figure 5. Surgeons map femoral checkpoint with a probe

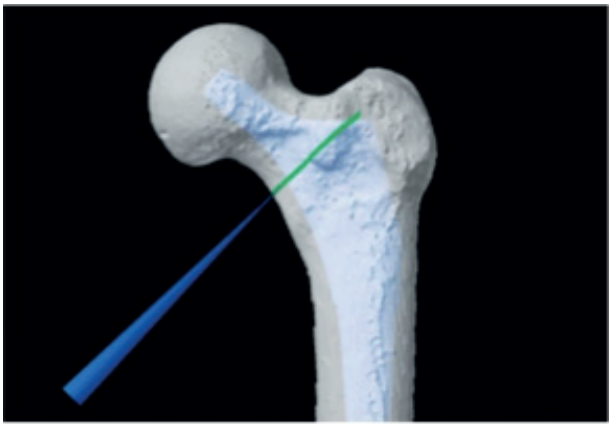

Figure 6. Resection neck level can be identified on computer screen

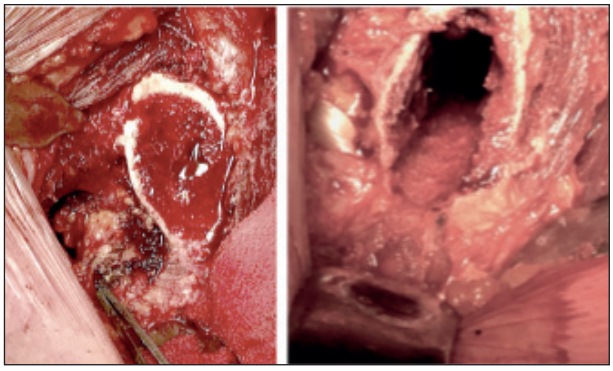

Figure 7. The ischiofemoral ligament consists of a triangular band of strong fibers on the posterior side of the hip joint

Figure 8. A and B: two different views of femoral neck resection

the rasp, it should be chosen based on the native femoral version (NFV, the angle between the axis of the femoral neck and the epicondylar axis of the knee), as detected on the preoperative 3D CT scans. Once the femur has been done, the definitive broach will be leave in place and the surgeon will insert on its top a trial neck that has three small holes (two on its base and one on its top). With the probe, the three points will be touched to measure (in millimetres) the femoral version, the off-set and leg length. In choosing the femoral version, it is mandatory to consider the native femoral canal anatomy in order to obtain proper alignment and a correct stem fixation.

Acetabular registration: Before starting with the acetabular registration, a pelvic check point is inserted outside the acetabulum cavity, just above its superior rim (the check point is essential to give spatial anatomical information to the software). Thirty-two points placed into the cavity and all around the acetabulum edge are taken using the probe. The surgeon touches precisely all the points displayed on the computer screen. An error of more than 0,5 mm is not accepted and thus the required points must be retaken again.

The preoperative position of the cup (inclination and anteversion) is planned based on the stem version value (SV) recorded before during the femoral version registration (18, 19). The software advices a CV range for the male and female patients (25°-35° men and 30°-50° women) (13, 20).

Acetabular reaming and cup implantation: Before starting to map the acetabulum area, the surgeon must take out the soft tissues present all around the rim and inside the cavity. Osteophytes should not be removed to avoid altering the bone registration. First, three landmarks are kept as indicated by the software and subsequently carrying on with the sequence of 32 points scattered around and inside the cavity. Once the request points have been recorded, osteophytes can be removed. Now the surgeon, using the robotic arm is ready to ream the acetabulum cavity. The reaming is done using the planned socket plus one size more (1 mm) to achieve the final right size. During this step the reamer remains constrained to the plan so it cannot go out of bounds in the superior, medial and anterior-posterior directions. The reaming is line to line and is very precise. The surgeon must keep doing with the reaming until all the COR numbers on display are zero and the colour of the reamed area on the digital screen becomes green. This confirm that the process is completed, and the correct depth and the acetabular centre of rotation planned is reached. If the surgeon tries to ream 1 mm over the robotic arm it will turn off. Once this step is over the final cup (Trident PSL HA™, Stryker, Warsaw, Indiana USA) is loaded onto the robotic arm and it is inserted into the acetabular area. A haptic tunnel keeps the planned version and inclination and prevents the surgeon going off-line or too deep. Every step is followed on the computer screen. The cup is implanted into the acetabulum by hitting the impactor with a mallet. The final position cup is checked with a probe in terms of its inclination and anteversion. This control is done by touching five points on the cup edge implanted and displayed on the screen (there is a tolerance, compared to the parameters planned of 2 degrees, which can be considered "physiological"). Once the check has done a standard plastic liner is inserted into the cup.

Leg length discrepancy and stability: The definitive femoral stem (Accolade II ™, Stryker, Warsaw, Indiana USA) is inserted into the canal manually and fully seat with a specific instrument. Once cleaned

and dried the neck taper, a trial head is placed onto the taper. The hip is reduced, and the femoral array is placed into the femoral screw so the surgeon can check range of motion, prosthesis stability, leg length and offset values indicated on the software screen. The hip stability and the leg length are two priorities which must be adjusted in case of excess or defect length in order to get a hip biomechanically correctly working. Once the balance is found, the computer will communicate the final values on the screen. A few millimeters of leg-length discrepancy could be physiological, and the procedure should be considered over.

The surgeon must pay attention when the operative limb is initially longer than the contralateral one. In these cases, it is better to avoid increasing the initial leg-length discrepancy or, if possible, to reduce it, preferably using a dual mobility head to guarantee a greater implant stability.

All arrays, screws and check points are removed. The definitive head is placed onto the taper. Pulse lavage is done in the surgical site, the hip is reduced, and subcutaneous tissues are given closing by layer.

Discussion

Performing a successful hip prosthesis implant requires an accurate pre-operative planning, choosing prosthetic components suitable for the specific clinical case and a correctly performed surgical procedure. These are three conditions that allow to regain the physiological range of motion, to restore the periarticular muscle balance and to correct any leg length discrepancy.

Restoring a biomechanically balanced hip prosthesis should enable less stress on the implanted components and a great stability and durability.

Orthopedic surgeons' attention and interest in robotic surgery has recently increased thanks to the promising clinical outcomes recorded on the field. This technique allows to abolish conventional pre-operative planning with templates, decreasing round-off error. Pre-operative digital planning does not be linked exclusively to the surgeon's practical experience, but it depends upon a pre-operative patient-specific procedure (21).

Robotic technique combined to direct anterior approach can be considered an excellent combination, able to give patients a quicker and satisfactory post-surgical recovery.

The pre-operative planning includes 3D CT scan of the pelvis and the both knee joints, according to the established protocol.

In order to create a specific planning, it is important to identify femoral and acetabular morphological features, to detect osteophytic areas and the presence of cystic bone lesions or necrotic bone areas. In the pre-operatively step the surgeon studies the planning shown by the software through a 3D graphical display. The robotic software provides several data such as the final size of the prosthetic components, skeletal spatial orientation, inclination and version of acetabular cup and femoral stem. These data must always be compared with the contralateral hip and correct them in case of anatomical discrepancy.

It is essential to know the values of the femoral version and the inclination/version of the acetabular cup in order to establish the optimal combined version.

Using the traditional surgical technique these data are not available because not measurable. For these reasons, the surgeon might have in his hands a system that allows him to perform a stable and biomechanically balanced prosthetic implant, limiting mechanical failures due to components impingement and hip dislocation.

The Mako™ protocol provides a pre-established range values relating to the combined version adapted to gender (25°-35° for men and 30°-50° for women) and to the version and inclination of the acetabular cup (version 20°, inclination 40°). These ranges remain the same for any preferred surgical approach.

Data such as prosthetics version, off-set, leg length are editable during surgery depending on anatomical hip features and surgeon's decisions.

At the beginning of the experience with DAA, the surgeon is inclined to respect the Mako™ range advised. However, improving surgical skills, surgeons may get away from this range, creating a personalized "Combined Version range", based upon intra operative findings and functional outcomes. The decision to slightly modify the protocol ranges raises because intra-operatively an impingement between femoral prosthetic neck and acetabular cup during hip rotation is sometimes observed, with a decreased range of motion. Modifying these parameters can be a great choice

because it avoids a prosthetic dislocation but also to use liner with antidislocation shoulder anymore.

In order to verify this potential improvement, the combined version data (pre and postoperatively) in 534 patients operated by computer-arm assisted THA with DAA between November 2016 and March 2020 were furtherly analyzed.

Being aware of the risk of anterior dislocation using DAA, the values of the combined version by varying the acetabular cup version before considering the version of the femoral stem were intentionally modified. The hypothesis was that the version of femoral stem should be close to zero degree and consequently the acetabular cup anteversion could be reduced.

As regards the femoral stem orientation, the target is to achieve a value close to zero (neutral position) if the femur is originally retroverted, otherwise if the femur is anteverted it is advised to reduce the femoral anteversion respecting the physiological limits (5°-20° using Paley classification) (22). A recent multicenter study has been published, involving three orthopaedic centers working with the robotic system. A huge variability of the human native femoral version is reported (23). In this study, between 2012 and 2016, 362 patients underwent THA using the Mako™ robotic system. The collected data about the native femoral version confirm this wide variability ranging from –22° to +49°. Only with a robotic system it is possible to analyse the relationship between the acetabulum and the pelvis avoiding the surgeon to make mistakes for the inaccurate information of hip anatomy.

In the early phase of our experience with Mako™ system, we used the anterolateral approach, and the values of combined version were different (30°-32°). In 2016, shifting the approach to DAA and considering functional outcomes, we reduced combined version to 24°-26°.

Therefore, combined version is related to the surgical approach. In direct anterior approach CV should be 23.36° +/- 4.58°, in posterolateral approach CV should be 37.59° +/- 4.62° while using anterolateral approach CV should be 28.55° +/- 6.91° (23, 24, 25, 26, 27). These values show significant differences attributable to the surgical approach and to hip's morphological features.

Recording our data, native femoral version presented variability range from -18° to 36°. After reaming and stem implant, we register values in a range between 0 and 2 degrees.

For the acetabular cup mean inclination was 40°/42° and acetabular anteversion was 16°-32°. The final average of CV ranged effectively from 22°to 28°.

Differences of final off-set compared to the preoperatively values were between -3 and +4 mm, while leg-length discrepancy values were between -2 and +3 mm. Following planned values, over 95% of cases had a final femoral head with neutral length and 36 mm of diameter. Mean inclination of femoral neck was 127°.

In patients with a stiff lumbosacral hinge or lumbar vertebral arthrodesis, it must be considered that the pelvic tilt is absent (change from sitting to standing position). In this case a lesser cup anteversion must be planned in order to increase the anterior coverage of the femoral head.

Conclusion

In the last decades many innovations have improved the hip replacement and reconstruction surgery. The modern prosthetic designs and new materials guarantee durability. To improve the survival of the implants, it should be necessary to eliminate the outliers that should influenced the surgeons' technical accomplishment. Furthermore, it is also necessary to consider the limits of human performance especially when a mechanical operation is done in a biological contest.

The robotic guide navigation could be the right solution to improve the outcomes because it provides reproducible and predictable results and it can be useful for the surgeon in his performance.

By robotic navigation and using a patient's specific pre-operative planning it is allowed to plan the correct combined anteversion of the stem and cup, to have a correct hip center of rotation and to restore the physiological off set and leg length. This is extremely important to avoid complications and early mechanical failures like hip impingement, dislocation or muscle imbalance.

Finally, the system is safe for acetabular preparation and cup implantation.

In the choice of a surgical approach it is important to consider and respect the ranges values of the combined version, fundamental in order to obtain a stable joint.

Robotic-arm-assisted surgery can be considered to potentially improve hip joint biomechanics being a valuable innovation for total hip arthroplasty.

Conflict of interest: Authors declare that they have no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

References

1. Bozic KJ, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am 2009;91:128e33. https://doi.org/10.2106/JBJS.H.00155.
2. Kroell A, Beaule P, Krismer M, et al. Aseptic stem loosening in primary THA: migration analysis of cemented and cementless fixation. Int Orthop. 2009;33:1501–1505. https://doi.org/10.1007/s00264-008-0701-1.
3. Anakwe RE, Jenkins PJ, Moran M. Predicting dissatisfaction after total hip arthroplasty: a study of 850 patients. J Arthroplasty 2011;26(2):209-13. https://doi.org/10.1016/j.arth.2010.03.013.
4. Lee YK, Yoo JJ, Koo KH, et al. Metal neck and liner impingement in ceramic bearing total hip arthroplasty. J Orthop Res. 2011;29:218–222. https://doi.org/10.1002/jor.21246.
5. Jewett BA, Collis DK. High complication rate with anterior total hip arthroplasties on a fracture table. Clin Orthop Relat Res 2011;469(2):503-7. doi: 10.1007/s11999-010-1568-1.
6. Light TR, Keggi KJ. Anterior approach to hip arthroplasty. Clin Orthop Relat Res 1980;152:255-60.
7. Poehling-Monaghan KL, Kamath AF, Taunton MJ, Pagnano MW. Direct anterior versus miniposterior THA with the same advanced perioperative protocols: surprising early clinical results. Clin Orthop Relat Res 2015;473(2):623-31. doi: 10.1007/s11999-014-3827-z.
8. Rodriguez JA, Deshmukh AJ, Rathod PA, Greiz ML, Deshmane PP, Hepinstall MS, Ranawat AS. Does the direct anterior approach in THA offer faster rehabilitation and comparable safety to the posterior approach? Clin Orthop Relat Res 2014;472(2):455-63. doi: 10.1007/s11999-013-3231-0.
9. Seng BE, Berend KR, Ajluni AF, Lombardi AV Jr. Anterior-supine minimally invasive total hip arthroplasty: defining the learning curve. Orthop Clin North Am 2009;40(3):343-50. doi: 10.1016/j.ocl.2009.01.002.
10. Spaans AJ, van den Hout JA, Bolder SB. High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. Acta Orthop 2012 Aug;83(4):342-6. doi: 10.3109/17453674.2012.711701.
11. Zawadsky MW, Paulus MC, Murray PJ, Johansen MA. Early outcome comparison between the direct anterior approach and the mini-incision posterior approach for primary total hip arthroplasty: 150 consecutive cases. J Arthroplasty 2014;29(6):1256-60. doi: 10.1016/j.arth.2013.11.013.
12. Domb BG, El Bitar YF, Sadik AY, et al. Comparison of robotic-assisted and conventional acetabular cup placement in THA: a matched-pair controlled study. Clin Orthop Relat Res. 2014;472(1):329-36. doi: 10.1007/s11999-013-3253-7.
13. Dorr LD, Malik A, Dastane M, Wan Z. Combined anteversion technique for total hip arthroplasty. Clin Orthop Relat Res 2009;467(1):119-27. doi: 10.1007/s11999-008-0598-4.
14. Bargar WL, Jamali AA, Nejad AH. Femoral anteversion in THA and its lack of correlation with native acetabular anteversion. Clin Orthop Relat Res 2010;468(2):527-32. doi: 10.1007/s11999-009-1040-2.
15. Imai H, Miyawaki J, Kamada T, Takeba J, Mashima N, Miura H. Preoperative planning and postoperative evaluation of total hip arthroplasty that takes combined anteversion. Eur J Orthop Surg Traumatol. 2016; 26: 493-500. doi: 10.1007/s00590-016-1777-8.
16. Widmer KH, Zurfluh B. Compliant positioning of total hip components for optimal range of motion. J Orthop Res 2004;22(4):815-21. doi: 10.1016/j.orthres.2003.11.001.
17. Hirata M, Nakashima Y, Hara D, Kanazawa M, Kohno Y, Yoshimoto K, et al. Optimal anterior femoral offset for functional range of motion in total hip arthroplastya - a computer simulation study. Int Orthop 2015;39(4):645-51. doi: 10.1007/s00264-014-2538-0.
18. Abdel MP, von Roth P, Jennings MT, Hanssen AD, Pagnano MW. What safe zone? The vast majority of dislocated THAs are within the Lewinnek safe zone for acetabular component position. Clin Orthop Relat Res 2016;474(2):386-91. doi: 10.1007/s11999-015-4432-5.
19. Barrack RL. Dislocation after total hip arthroplasty: implant design and orientation. J Am Acad Orthop Surg 2003;11(2):89-99. doi: 10.5435/00124635-200303000-00003.
20. Dorr LD, Wan Z, Malik A, Zhu J, Dastane M, Deshmane P. A comparison of surgeon estimation and computed tomographic measurement of femoral component anteversion in cementless total hip arthroplasty. J Bone Joint Surg 2009;91(11):2598-604. doi: 10.2106/JBJS.H.01225.
21. Elson L, Dounchis J, Illgen R, et al. Precision of acetabular cup placement in robotic integrated total hip arthroplasty. Hip Int Hip Int 2015;25(6):531-6. doi: 10.5301/hipint.5000289.
22. Paley D. Principles of deformity correction. Berlin Heidelberg: Springer; 2002
23. Marcovigi A, Ciampalini L, Perazzini, Caldora P, Grandi G, Catani F Evaluation of Native Femoral Neck Version and Final Stem Version Variability in Patients With Osteoarthritis Undergoing Robotically Implanted Total

Hip Arthroplasty. J Arthroplasty 2019;34(1):108-115. doi: 10.1016/j.arth.2018.06.027.
24. Kiernan S, Hermann KL, Wagner P, Ryd L, Flivik G. The importance of adequate stem anteversion for rotational stability in cemented total hip replacement. Bone Joint J 2013;95-B(1):23-30. doi: 10.1302/0301-620X.95B1.30055.
25. Herrlin K, Pettersson H, Selvik G, Lidgren L. Femoral anteversion and restricted range of motion in total hip prostheses. Acta Radio 1988;29(5):551-3.
26. Yoshimine F. The safe-zones for combined cup and neck anteversions that fulfill the essential range of motion and their optimum combination in total hip replacements. J Biomech 2006;39(7):1315-23. doi: 10.1016/j.jbiomech.2005.03.008.
27. Patel AB, Wagle RR, Usrey MM, Thompson MT, Incavo SJ, Noble PC. Guidelines for implant placement to minimize impingement during activities of daily living after total hip arthroplasty. J Arthroplasty 2010;25(8):1275-81.e1. doi: 10.1016/j.arth.2009.10.007.

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Review

Total ankle replacement in young patients

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Summary. High physical demand and younger age are currently considered contraindications for total ankle replacement. The number of Total Ankle Replacements (TAR) is widespread increasing and indications are expanding thanks to a steady improvement in prosthetic designs and better outcome. *Commentary of the literature:* in 1999 a study of 100 uncemented STAR™ (Waldemar-Link, Hamburg, Germany) prostheses showed a survival rate of 75% at 6.8 years in patients under 50 years old. Other studies (es, Barg et Al.) shows the risk of failure age-related in young patients compared to older group. A report of 780 TAR from the Swedish Ankle Register showed patients with primary or post-traumatic osteoarthritis under 60 years of age to have a 1.8 higher chance of revision compared to older patients. *Discussion:* ankle replacement has been traditionally reserved for patients older 50 years old and with low physical demand. Contrariwise this belief, TAR have already been used with a wide range of ages, sometimes even patients younger than 30 years old. Most of the "negative" score and results showed before are related to "second-generation" prosthetic designs, while recent studies used a "third-generation" prosthetic design. *Conclusions:* recent evidences showed better clinical results and higher satisfaction in people under the age of 50 compared to ankle arthrodesis with comparable rate of complications and survivorship. Younger people will have however a higher rate of reoperation but in the meantime, they will prevent progressive degeneration of adjacent joints. (www.actabiomedica.it)

Key words: End-stage ankle osteoarthritis, Ankle replacement, Age at surgery, Survivorship rate.

Introduction

The number of Total Ankle Replacements (TAR) is widespread increasing [1-3] and indications are expanding thanks to a steady improvement in prosthetic designs and better outcome.

Historically, relative contraindications for TAR were: avascular talar osteonecrosis/loss of bone stock [4-5], smoking, diabetic neuroarthropathy, poor skin conditions [6-7], osteoporosis, non-compliant patient[8], high physical demand/obesity[7-8] and age over 50 years old [9-10].

The "optimal" patient for TAR is said to be physically low-demanding, non-obese, older (at least over 50) with end-stage non traumatic primary ankle arthritis and good bone stock.

End-stage ankle osteoarthritis despite being relatively uncommon if compared to hip and knee osteoarthritis is associated with worse mental and physical disability[11].

A substantial difference from hip and knee osteoarthritis is the primary cause; from recent studies overall 80% of ankle osteoarthritis is post-traumatic [12-13].

This difference is especially important because patients are usually younger with higher physical demands and therefore in these cases TAR would bear more stress[14].

In the past, thanks to the belief that arthrodesis has a better outcome in younger patients, TAR was reserved to older people with low physical demand [15]. This was due to reports of low clinical scores and early failure rates with so-called first and second generations TAR.

Recent studies have shown moreover that, when compared with ankle arthrodesis, ankle arthroplasty can provide similar pain relief and better functional outcome [16].

Therefore, such traditional beliefs have slowly been disenchanted in the last years thanks to a constant improvement of the biomechanical model and prosthetic designs and, nowadays, an ankle joint replacement, as well in other districts, is no more a surgery reserved only for old and inactive people. Various authors started to utilize TAR in patients under the age of 50 and with high-spicily demand [17-19].

However, there's still controversy in literature about this specific topic and there are very few studies that directly compared results between younger and older patients. The goal of this commentary is to summarize the current evidence about age related factors in patients undergoing TAR.

Commentary of the literature

Younger age at surgery might influence longevity of the implants in two main ways:

1 The prostheses will need to function longer (higher life expectancy of the patient).
2 The patient will be more active, and this has been proved to be associated with a larger amount of polyethylene wear in hip prostheses [20].

A special consideration should be given to patients with inflammatory joint disease (IJD) because of the fact that even if they are younger, they are less active due to multiple joints affected [21].

Only few authors directly studied the effect of age on results of TAR. In 1999 a study of 100 uncemented STAR™ (Waldemar-Link, Hamburg, Germany) prostheses showed a survival rate of 75% at 6.8 years in patients under 50. The group over 50 showed a survival rate of 81% at 6 years of follow up [22].

Barg et al. [23] found that age under 70 is an independent predictor of failure of the Hintegra™ ankle prosthesis (Integra™ Neurosciences Implants, Sophia Antipolis, France) (average follow up of 6.3 years). Another study showed that patient's underage of 54 had a 2.65 times greater risk of failure compared to older patients. Their estimated rate of survival at 61 months was 0.74 for the younger group vs 0.89 of the older group [24].

A report of 780 TAR from the Swedish Ankle Register showed patients with primary or post-traumatic osteoarthritis under 60 years of age to have a 1.8 higher chance of revision compared to older patients [27].

Nevertheless, on the other hand, a review of 103 Salto third generation prostheses [25] (Salto Talaris™, Integra Lifescience Corporation, Austin TX, USA) specifically compared patients under 50 age and over 50 age. In this study both age groups had an equivalent AOFAS score (26.7 points vs 27.0 points) and a significative post-operative increase in AOFAS score was seen ($p<0.001$). However, this increase was significantly higher in the younger group (mean 66.8 points vs 62.8 points). There was no significative difference with the preoperative Range Of Motion (ROM) values in both groups and both groups had their ROM significantly improved at follow-up ($p<0.001$) but the younger group had a significantly higher ROM (37.2° vs 33.9°; $p=0.020$). There was no difference between major complications and survival.

Wand et al. reported outcomes of a cohort of 395 primary Inbone (Inbone™, Wright Medical Group NV, Memphis TE,USA), Salto Talaris and Star prostheses divided into 3 groups: under 55, between 55-70 and over 70 [26] with an average follow up of 3.5 years. There were no differences about wound complications, reoperation and revisions.

Discussion

There's conflicting evidence of the influence of age on TAR survival and, over time, more and more studies have been published. Ankle replacement has been traditionally reserved for patients older 50 years

old and with low physical demand under the assumption that the prostheses would have to bear less stress preventing early failure.

Contrariwise this belief, TAR have already been used with a wide range of ages, sometimes even in patients younger than 30 years old [27-28-29]. The total ankle arthroplasty in young patients requires technical peculiarities such as: removal of the osteophytes, assessment of the joint instability, removal of the medial and lateral impingement, subtalar stiffness, gastrocnemius contracture and axial deviation (Figure 1).

Most of the "negative" score and results showed before are related to "second-generation" prosthetic designs, while recent studies used a "third-generation" prosthetic design[30,31]. Despite this, there's still no consensus as to which is the appropriate age to perform TAR and most of the studies conclude that the treatment should be patient-specific [32].

A recent review comparing ankle arthrodesis and ankle replacements over the last decade showed an overall higher complication rate of ankle arthrodesis but a higher reoperation rate for TAR [33]. This is especially true in younger patients who are physically more active and with higher life expectancy. Besides ankle arthrodesis is associated with poorer results and lower patient satisfaction score [34-35].

Altogether, younger patients will live longer with a high physical demand and, even if they'll need a second reoperation, TAR will allow them to gain time and live a better quality of life while sparing adjacent joints from progressive degeneration.

Recent reports showed that younger patients displayed better clinical and functional score while the rate of complications (minor, such as skin necrosis/ intraoperative malleolar fracture or major as reoperations) did not statistically differ compared to older patients [25-29,32].

There are however some limitations and the results don't have a unique interpretation.

First, in most of the studies patients are evaluated by different surgeons. Second, the number of the younger patients are significantly lower if compared to older patients.

Even the average follow-up, especially if we consider "third generation" prostheses, is short, usually within 2 years. Another inconsistency is the used scores, that differ among the studies. The most widely used is the AOFAS score which, unless it allows direct comparison, has already been criticised for what concerns the validity of its clinical-base score [35-36].

Last, almost no one of the studies went in-depth about the exact cause of the reported implant failures.

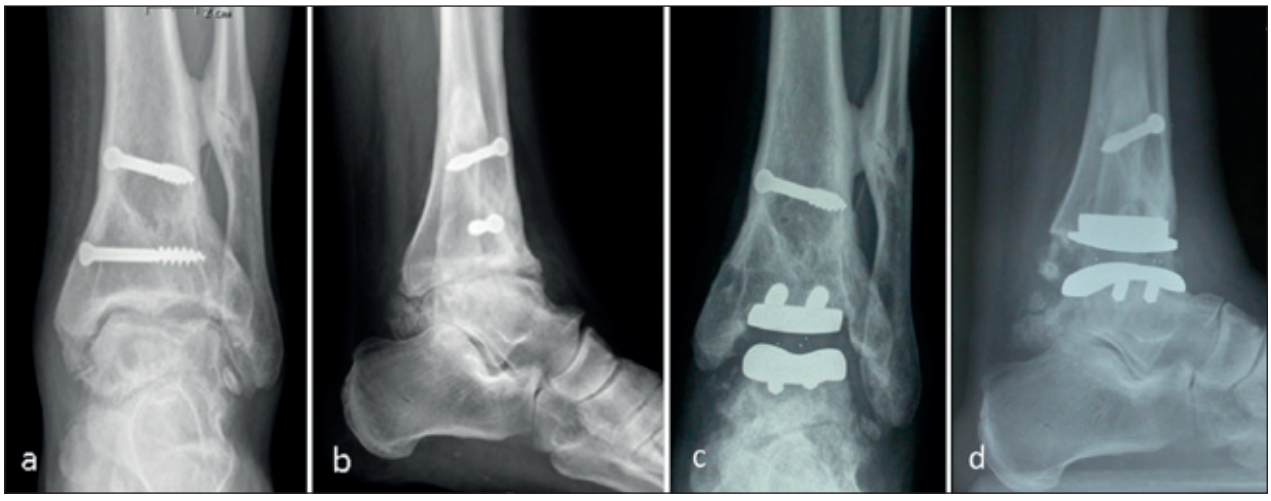

Figure 1. Clinical cases of a 43 years old male affected by post-traumatic osteoarthritis of the left ankle following a pilon fracture 4 years before; a-b: Antero-posterior and lateral view X-ray of the ankle pre-operatively; c-d: X-ray at 3 years follow-up after removal of the impingement and the implant of a total ankle replacement (Box prosthesis).

Conclusions

The reported results might support the hypothesis that ankle replacements are a valid and effective treatment for young and physically active patients. Recent evidences showed better clinical results and higher satisfaction in people under the age of 50 compared to ankle arthrodesis with comparable rate of complications and survivorship.

Younger people will have however a higher rate of reoperation but in the meantime, they will prevent progressive degeneration of adjacent joints.

Choosing between TAR and ankle arthrodesis should be however patient-specific because other factors (as patient expectation and activity level or other comorbidities such as diabetes, neuroarthropathy or inflammatory joint disease) might have an important role.

Lastly, further studies and longer follow-ups are needed.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Henricson A, Nilsson JA, Carlsson A. 10-year survival of total ankle arthroplasties: a report on 780 cases from the Swedish Ankle Register. Acta Orthop. 2011;82(6):655–659
2. Singh JA, Ramachandran R. Time trends in total ankle arthroplasty in the USA: a study of the National Inpatient Sample. Clin Rheumatol. 2016;35(1):239–245
3. Tomlinson M, Harrison M. The New Zealand Joint Registry: report of 11-year data for ankle arthroplasty. Foot Ankle Clin. 2012;17(4):719–723
4. Doets HC, van der Plaat LW, Nelissen R. The current and future role of total ankle arthroplasty in the treatment of the arthritic ankle. A review. Minerva Ortop Traumatol. 2007;58(5):401–421
5. Krause FG, Schmid T. Ankle arthrodesis versus total ankle replacement: how do I decide? Foot Ankle Clin. 2012; 17(4):529–543.
6. Doets HC, van der Plaat LW, Nelissen R. The current and future role of total ankle arthroplasty in the treatment of the arthritic ankle. A review. Minerva Ortop Traumatol. 2007;58(5):401–421
7. Alvine FG. The agility ankle replacement: the good and the bad. Foot Ankle Clin. 2002;7(4):737–53, vi.
8. Doets HC, van der Plaat LW, Nelissen R. The current and future role of total ankle arthroplasty in the treatment of the arthritic ankle. A review. Minerva Ortop Traumatol. 2007;58(5):401–421
9. Gougoulias NE, Khanna A, Maffulli N. History and evolution in total ankle arthroplasty. Br Med Bull. 2009;89: 111–151
10. Conti SF, Wong YS. Complications of total ankle replacement. Clin Orthop Relat Res. 2001;391:105–114
11. Glazebrook M, Daniels T, Younger A, Foote CJ, Penner M, Wing K, et al. Comparison of health-related quality of life between patients with end-stage ankle and hip arthrosis. Journal of Bone and Joint Surgery American Volume 2008;90(March (3)):499–505
12. Saltzman CL, Salamon ML, Blanchard GM, Huff T, Hayes A, Buckwalter JA, et al. Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic center. Iowa Orthopaedic Journal 2005; 25:44–6.
13. Valderrabano V, Horisberger M, Russell I, Dougall H, Hintermann B. Etiology of ankle osteoarthritis. Clinical Orthopaedics and Related Research 2009;467(July (7)):1800–6.
14. Buckwalter JA, Saltzman C, Brown T. The impact of osteoarthritis: implications for research. Clinical Orthopaedics and Related Research 2004;(October (427 Suppl.): S6–15.
15. Hintermann B, editor. Total ankle arthroplasty: historical overview, current concepts and future perspectives. New York: Springer Wien New York; 2005
16. Saltzman CL, Mann RA, Ahrens JE, Amendola A, Anderson RB, Berlet GC, et al. Prospective controlled trial of STAR total ankle replacement versus ankle fusion: initial results. Foot and Ankle International 2009;30(June (7)):579–96
17. Knecht SI, Estin M, Callaghan JJ, Zimmerman MB, Alliman KJ, Alvine FG, et al. The Agility total ankle arthroplasty. Seven to sixteen-year follow-up. Journal of Bone and Joint Surgery American Volume 2004;86-A (June (6)): 1161–71.
18. Valderrabano V, Pagenstert G, Horisberger M, Knupp M, Sports Hintermann B. recreation activity of ankle arthritis patients before and after total ankle replacement. American Journal of Sports Medicine 2006;34(June (6)):993–9.
19. Wood PL, Prem H, Sutton C. Total ankle replacement: medium-term results in 200 Scandinavian total ankle replacements. Journal of Bone and Joint Surgery British Volume 2008;90(May (5)):605–9.
20. Hosman AH, Mason RB, Hobbs T, Rothwell AG. A New Zealand national joint registry review of 202 total ankle replacements followed for up to 6 years. Acta Orthop. 2007;78(5):584–591
21. Hurowitz EJ, Gould JS, Fleisig GS, Fowler R. Outcome analysis of agility total ankle replacement with prior adjunctive procedures: two to six year followup. Foot Ankle Int. 2007;28(3):308–312
22. Kofoed H, Lundberg-Jensen A. Ankle arthroplasty in pa-

tients younger and older than 50 years: a prospective series with long-term follow-up. Foot Ankle Int. 1999;20(8): 501–506
23. Barg A, Zwicky L, Knupp M, Henninger HB, Hintermann B. HINTEGRA total ankle replacement: survivorship analysis in 684 patients. J Bone Joint Surg Am. 2013;95(13):1175–1183
24. Spirt AA, Assal M, Hansen ST Jr. Complications and failure after total ankle arthroplasty. J Bone Joint Surg Am. 2004;86-A(6):1172–1178
25. Rodrigues-Pinto R, Muras J, Martín Oliva X, Amado P. Total ankle replacement in patients under the age of 50. Should the indications be revised? Foot Ankle Surg. 2013;19(4):229–233
26. Demetracopoulos CA, Adams SB Jr, Queen RM, DeOrio JK, Nunley JA 2nd, Easley ME. Effect of age on outcomes in total ankle arthroplasty. Foot Ankle Int. 2015;36(8): 871–880
27. Henricson A, Nilsson JA, Carlsson A. 10-year survival of total ankle arthroplasties: a report on 780 cases from the Swedish Ankle Register. Acta Orthop. 2011;82(6):655–659
28. Wood PL, Prem H, Sutton C. Total ankle replacement: medium-term results in 200 Scandinavian total ankle replacements. Journal of Bone and Joint Surgery British Volume 2008;90(May (5)):605–9.
29. Valderrabano V, Pagenstert G, Horisberger M, Knupp M, Sports Hintermann B. recreation activity of ankle arthritis patients before and after total ankle replacement. American Journal of Sports Medicine 2006;34(June (6)):993–9
30. Giannini S, Romagnoli M, O'Connor JJ, Catani F, Nogarin L, Magnan B, Malerba F, Massari L, Guelfi M, Milano L, Volpe A, Rebeccato A, Leardini A. Early clinical results of the BOX ankle replacement are satisfactory: a multicenter feasibility study of 158 ankles. J Foot Ankle Surg. 2011;50(6):641–7
31. Magnan B., Samaila E., Bartolozzi P. Protesi di tibio-tarsica. Evoluzione degli impianti. In Magnan B., Ceccarelli F., Malerba F. Patologia degenerativa del retropiede, Timeo Editore Bologna, 2009, vol.18, 103–113.
32. Laurens W van der Plaat, Daniël Haverkamp. Patient selection for total ankle arthroplasty. Orthopedic Research and reviews 31 July 2017
33. Cort D.Lawton, Bennet A.Butler, Robert G.Dekker, Adam Prescott, Anish R. Kadakia. Total ankle arthroplasty versus ankle arthodesis-a comparison of outcomes over the last decade. Journal of Orthopaedic Surgery and Research (2017) 12:76
34. Easley ME, Adams Jr SB, Hembree WC, DeOrio JK. Results of total ankle arthroplasty. Journal of Bone and Joint Surgery American Volume 2011;93(August (15)):1455–68
35. Esparragoza L, Vidal C, Vaquero J. Comparative study of the quality of life between arthrodesis and total arthroplasty substitution of the ankle. Journal of Foot and Ankle Surgery 2011;50(June–August (4)):383–7.
36. Guyton GP. Theoretical limitations of the AOFAS scoring systems: an analysis using Monte Carlo modeling. Foot and Ankle International 2001;22(October (10)):779–87.
37. Soo Hoo NF, Shuler M, Fleming LL. Evaluation of the validity of the AOFAS Clinical Rating Systems by correlation to the SF-36. Foot and Ankle International 2003;24 (January (1)):50–5.

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Review

Central metatarsal fractures: a review and current concepts

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Summary. Central metatarsal fractures (CMF) are common injuries. More frequently fractures are those of the fifth metatarsal, followed by CMF and therefore by the first metatarsal. Third metatarsal is injured most frequently than the others and up to 63% is associated with second or fourth metatarsal fractures and up to 28% with both. Anatomy and metatarsal kinematics merits attention due to its influence on function, injuries and treatment options. Diagnosis is based on the history of trauma and clinical examination, relating with instrumental exams. Fractures with less than 10° of angulation and 3-4 mm of translation in any plane are typically treated conservatively, while operative treatment is generally reserved for fractures out if these values. Intramedullary fixation with K-wires seem to be the most common and valid surgical treatment in simple fractures. Spiral fractures should be treated by interfragmentary screws, which positioning may result difficult due to the adjacent metatarsals. Therefore, an alternative approach is an osteosynthesis with a dorsal plate. Multiple metatarsal fractures often occur in the contiguous bones, so clinicians will also have to carefully inspect metatarsals and adjacent joints such as Lisfranc articulation. The clinical and functional outcomes are often influenced by the pattern of fractures and patient conditions and are reported in the literature up to 39% of poor results. (www.actabiomedica.it)

Introduction

Metatarsal fractures (MF) represent about 88% of all fractures involving foot and ankle, amounting up to 35% of all foot fractures and up to 7% of all skeletal injuries.[1-4] Older female gender is the most affected, with a female to male ratio of 2:1 in general population, while males appear more commonly affected in athletes.[1, 4-6]

These types of lesions have been frequently reported in second through fifth decade of life[4], but children also appear to be affected, accounting up to 61% of all fractures of the foot[7] and occurring in the fifth (41%) and the first (19%) by anatomical exposure.[7]

MF can be cause by an isolated injury, associated with other metatarsals fractures or Lisfranc joint injuries. Both direct and indirect traumas can lead to a MF but, generally, are the result of low-energy trauma;[4] however, high-energy crush injuries may occur quite frequently, involving soft tissues[2] and resulting up to 1% of all metatarsal open lesions.[5]

Other type of injury as stress fractures can occur in metatarsals, most commonly in the second but also in the third and fifth. They are usually reported in women with osteoporosis and people with repetitive stress injuries, ballet dancers and military recruits.[8]

MF can occur at any level of the metatarsal bone and there is no specific classification.[9] Proximal metaphyseal and central metatarsal base fractures are sometimes associated with Lisfranc injuries. Shaft fractures are usually oblique and they should be examined for shortening, angulation and displacement.[4, 10-12]

Metatarsals can be divided in 3 groups: first, central and fifth metatarsal. The second, third, and fourth metatarsals are distinct as central metatarsals (CM).[3]

More frequently fractures are those of the fifth metatarsal, followed by CMF and therefore by the first metatarsal. Several studies state that, among central metatarsals third metatarsal is injured most frequently than the others and up to 63% is associated with second or fourth metatarsal fractures and up to 28% with both.[4]

Although fractures of the first and fifth metatarsals are generally isolated fractures, multiple metatarsal fractures often occur in the contiguous bones, so clinicians will also have to carefully inspect metatarsals and adjacent joints such as Lisfranc.[4]

Central metatarsal fractures (CMF) are caused more frequently by direct trauma and less frequently by indirect torsional trauma. The central metatarsal bases articulate with the tarsal bones so diagnosis and management of this type of fractures may result difficult.[13]

Anatomy

The metatarsals constitute the skeleton of the foot adjoining the mid to forefoot regions positioned between tarsus and phalanges. All metatarsals include a base, shaft, and distal extremity or head. They are prismoid in shape, tapered distally and wider at the base. The base articulates with the tarsal bones and is wedge-shaped, the shaft is curved dorsally and has a rough surface for ligament insertion. The head has a convex articular surface which extends inferiorly more than superiorly, the plantar surface is ploughed by two articular eminences for the transit of flexor tendons.[14]

The second metatarsal is the longest among metatarsal bones with the base that has five joint facets and is grooved between the three cuneiform bones. The third and fourth metatarsals articulate with adjacent metatarsal and tarsal bones.[15]

Within the human foot metatarsal blood supply shows significant anatomic variation in first[16] and fifth ray[17], while the central metatarsals are generally vascularized by the plantar metatarsal artery that divides near the metatarsal heads into a medial and a lateral branch.[18] The primary nutrient artery of the CM come in laterally, more or less 3.1 cm from the distal joint cartilage.[19]

The CM have important ligamentous structures that connect each bone to their adjacent ones. The base of each central metatarsal enclose 3 ligaments (plantar, central, dorsal) that support and stabilize each respective metatarsal and the adjacent metatarsal, except between the base of the first and second metatarsal bases where there is a lack of connection. The Lisfranc ligament bestrides plantarly from the second metatarsal to the medial cuneiform to give stability. The dorsal and plantar interossei muscles, which provide metatarsophalangeal stabilization, originate mainly from these metatarsals, so that the extensor and the long flexor can have a correct muscle action.[20]

However, these muscles can also represent as a deforming force in case of metatarsal fractures. There is an increased motion through the tarso-metatarsal joints, having a peak in the fourth and fifth tarso-metatarsal joints. The adaptability to the ground by the metatarsal heads is allowed by the increase in movement in the sagittal plane in these central metatarsals. The tarso-metatarsal joints of the second and third ray are relatively hardy to this sagittal motion, and therefore, stress fractures are more common in the second and third metatarsals than in the remaining metatarsals.[9]

Biomechanics

Metatarsal kinematics merits attention due to its influence on function, injuries and treatment options. The metatarsal bone plays an important role in terms of posture and gait cycle. The first ray carries twice the load of each of the lesser ones during the stance phase of step giving it special biomechanical features. The joints at the basal extremity of the metatarsals concur to extension of the longitudinal arch during push-off phase.[21] Equally, position of the metatarsals and orientation of the joint facets determine distal arch rotation in relation to foot supination and pronation.[22] Kinematics of the foot can be affected by various factors such as age, pathological process and BMI.[23]

Anyhow, latest studies have provided significant information on the mechanical functioning of the foot during normal and pathological phases. The most significant evolution has been made with the

multi-segment kinematic model. Several studies based on normal patients confirmed these multi-segmental concepts, specially highlighting the dynamic relationship between the various segments during forefoot-hindfoot motion and arch elevation and drooping.[24]

Shereff reviewed pathological consequences of altered forefoot biomechanics.[25] During stance phase of the gait, CM support the same weight each other, metatarsal displaced fracture may change in a not plantigrade foot. Plantar dislocation of the distal fragment lead to overload that may bring an unmanageable plantar keratosis. Dorsal dislocation of the distal fragment decreases load on the respective metatarsal but this produces an overload metatarsalgia on the nearby metatarsal heads. Lateral dislocation of the fragment produces a mechanical conflict on the adjacent metatarsal or the formation of a possible interdigital neuroma. Finally, medial dislocation of the distal fragment of the first metatarsal or lateral dislocation of the fifth metatarsal produces a bone prominence that may cause problem wearing shoes.[26]

Stress fractures

CM are resistant to the sagittal motion, so stress fractures are more frequent in this site in professional athletes, military personnel and ballet dancers representing up to 23% of all stress fractures. Rarely stress fractures occur to the first and fifth metatarsals.[27-29]

Several studies showed that most of the second metatarsal stress fractures occur in the diaphysis or in the neck and in dancers these fractures may affect the base.[30-31]

Stress fractures are usually caused by recurrent traumas, low energy external forces, unintentional muscles contraction and bone weakness.[32] High longitudinal arch of the foot, leg length discrepancy and forefoot varus appear to be some of biomechanical factors associated with this type of fractures.[33] A long second metatarsal and an overly mobile first ray may contribute to an excessive repetitive load on the second metatarsal.[34]

On the other side a short first metatarsal produced abnormal overloading stress along the second metatarsal, particularly patients with a length of the first metatarsal 80% compared to the second metatarsal were more prone to fracture.[28, 35] Achilles contracture increases plantar pressure and the risk of stress fractures.[36] Ringham et al. demonstrated that excessive external rotation of the hip can produces a hyperpronation of the foot and this condition may increase the risk of stress fractures to the lower limb.[37]

It is therefore acceptable to observe that there is a complex articular interaction affected by metatarsal orientation, topography and kinematics. These ascertainment are not only relative to the trauma and orthopaedic surgeon but also maybe important for the rehabilitation therapist.[9]

Aetiology

CMF occur with either indirect or direct trauma.4, 38 Seldom crush injuries, typically occur within industrial workplaces, may cause this type of fractures, often associated with soft-tissue injury;4 instead, stress fractures commonly occur with a sustained and acute increase in the activity's intensity and are frequently related with endocrine or metabolic deficiency.39

It is important for the second and third metatarsal fractures to assess the intra-articular involvement or concomitant lesions such as Lisfranc's fracture. Furthermore, given the relatively limited soft-tissue structure around the metatarsals, assessment of possible suffering or defects communicating with the fracture site is highly recommended.[20]

Lindholm et al. showed that displaced CMF were uncommon due to the rigidity of the ligaments between metatarsals. Authors noted that diaphyseal metatarsal fractures rarely became displaced when interosseous and lumbrical muscles and ligaments insertion were intact. However, neck fractures could displace because of the action of flexor tendons that exert a force and dislocate the metatarsal head proximal or plantar.[26]

Although studies have reported an association between valgus deformity of the hindfoot and osteoporosis with fractures of the second metatarsal, none of these conditions explain the reason for the increased incidence of fractures in the non-proximal region of the metatarsal.[40-42] Boden et al. demonstrated that the

healing of a proximal fracture is generally longer than the non-proximal fracture and presents high risk of complications.[43-44]

Clinical evaluation and diagnosis

Diagnosis of CMF is based on the history of lesion mechanism, clinical examination and X-ray. Most commonly the lesion mechanism is a consequence of a fall from standing height or twisting injury with a stationary forefoot.[4] It is important to identify risk factors such as a corticosteroid use, amenorrhea and osteoporosis in case of suspicious of stress fractures; patients affected from these type of fractures usually present a history of pain in the forefoot.[27]

The clinical presentation of these fractures is characterized by swelling, pain and inability to weight bearing; bony deformity is subtle, unless there are concomitant Lisfranc joint injury, serial metatarsal fractures or attendant proximal/distal injuries.[45]

The initial clinical assessment reveals bruising, pain on palpation and pain exacerbation on forefoot weight bearing[46]; in case of open fracture, evaluation for neurovascular status is essential.

Clinical assessment of metatarsal fractures must include examination of the proximal and distal joints.[47] Another important sign to investigate in case of crush trauma and suspicious of Lisfranc injuries is plantar hematoma in the midfoot.[48]

Standard diagnostic X-rays should comprise antero-posterior, lateral and oblique (45°) views of the foot.[45] However, if associated fractures such as V metatarsal are suspected, it is recommended an additional fifth metatarsal base view obtained with an antero-posterior X-ray of the ankle which comprise the proximal part of the fifth metatarsal. Up to 23% of fifth metatarsal avulsion resulting not visible on the routine three views.[49] In case of doubt, optional radiographs are recommended for diagnosis such as contralateral foot view specially in paediatric patients.[45]

Moreover, it is important to identify accessory bones in the region to rule out avulsed fragments, such as os vesalianum, os peroneum, os inter-metatarseum and os cuneometatarsal.[50]

In some cases, stress fractures could not be evident on initial plain radiographs; these latest normally demonstrate evidence of radiolinear lucency and/or periosteal reaction in a time comprise between two and six weeks.[51] It is therefore appropriate to repeat the radiographs at 10 to 15 days may show evidence of resorption gap at the fracture site.[30]

Although they are occasionally utilized, magnetic resonance imaging (MRI) and nuclear medicine bone scan (NM Bone Scan) are seldom required in diagnostic study;[52] particularly, MRI is only recommended in occult fracture with clinical history or suspected stress fractures,[30] and is widely accepted as gold standard for the early diagnosis of metatarsal stress fractures with T1-weighted images that demonstrate decreased medullary signal with bone stress reaction and fracture delineation.[53]

Banal et al studied the use of ultrasound (US) in the early diagnosis of these fractures and demonstrated satisfactory level of diagnostic reliability with 83% sensitivity and 76% specificity, in addition to its low duration of execution, cost and immediate availability.[53]

When multiple and serial metatarsal fractures are present, they require a computerized tomography (CT) scan to ascertain the intra-articular involvement, comminution and integrity of the Lisfranc joint. A significant proportion of metatarsal fractures may be missed on initial radiographs and in case of polytrauma with complex foot and ankle injury a CT scan is indicated. A thorough evaluation built on an understanding of the injury mechanism and careful clinical examination matched with the standard three views foot X-rays remains fundamental in CMF diagnosis.[54]

Classification

CMF are classified topographically in relation to the location of the fracture site: base, diaphysis, neck and head.; however, these metatarsals have no specific classification, differently from fifth metatarsal fractures.[9] The AO classification divided these fractures in: type (A) extra-articular fracture, type (B) intra-articular fractures, type (C) dislocated fracture and type (D) pure metatarsal dislocation, the latest also called "floating metatarsal". Each of these types is in turn subdivided into proximal metaphyses, diaphyses and distal metaphyses.[55]

Management

The goal of the treatment is to obtain a correct healing of the fracture maintaining the metatarsal parabola, the sagittal position of the metatarsal heads and bone-to-bone contact in order to preserve a functional forefoot. The stability of the CMs is kept by the anatomical position and soft tissue which limits the displacement in multiple metatarsal fractures because these usually displace in unison and maintain their respective anatomical relationships, thus resulting in a decreased risk of subsequent complications.[45]

All undisplaced metatarsal fractures, including stress fractures, may be treated conservatively. The amount of the displacement of the CMF can influence the choice of the treatment and it is also correlated with the outcome of patients. Indeed, in their study Cakir et al. recorded that a displacement of more than 2 mm in any direction was associated with a poorer outcome.[1] The values of displacement or angulation that influence the choice of treatment (operative or non-operative) are still debated, although there is consensus that fractures with less then 10° of angulation and 3-4 mm of translation in any plane require a non-operative treatment.[2,56-59] Moreover, a conservative treatment can be implemented in case of CMT with a frontal plane displacement without shortening.[60]

A distal traction from the finger may be useful for the reduction in case of displaced fractures of the CMF. However, sometimes maintaining the reduction with external manoeuvres could be difficult and should be require proceeding with open reduction, and eventually using a percutaneous pinning.[2] Careful consideration should be given to the base metatarsal fracture that could be associated to a concurrent Lisfanc injury and may often require surgery.

In case of stress fractures, it is important to investigate the reason of their occurrence. Stress fractures in professional athletes have to be treated according to the functional requirement of the patient to avoid prolonged time of immobilization. Stress fractures of the metatarsal shaft or neck can be treated with a short-leg cast, cast boot or a stiff-soled shoe, with healing in 6 to 8 weeks. Moreover, in patients who have high risk for impaired stress fracture healing, Raghavan et al. demonstrated that Teriparatide may be useful in the clinical setting to accelerate the healing.[61]

Conservative treatment

Non-operative treatment frequently includes immobilization for 3-6 weeks with pain relief in the days

Figure 1. Clinical case of a 27 years old female affected by an undisplaced fracture at the base of the II, III and IV left metatarsals. a-b: AP and oblique X-ray after a crushing trauma; c-d: X-rays at 2-month FU after a conservative treatment with a good consolidation at the fracture site

immediately following the fracture.[1,9,62] In our clinical practice we usually perform a functional taping for 6 weeks (with a renewal of the taping after 3 weeks) wearing a talus shoe and weightbearing as tolerated (Figure 1).

Rammelt et al. described several non-operative treatments that include: taping plus a rigid sole with non-weightbearing of the metatarsal heads, a short leg walking cast, and a non-weightbearing cast for 3 weeks followed by walking cast for another 3 weeks.[45] Moreover, Sammarco and Conti proposed a non-weightbearing cast for 2 to 3 weeks followed by a walking cast for other 3 weeks.[63]

Zenios et al. conducted a prospective randomized study on 50 patients with acute metatarsal fractures treated with cast (n = 25) or taping (n = 25). The authors showed no substantial long-term (3 months) differences in pain score, mid-foot circumference, analgesic requirements, independent mobility and radiological union. However, patients treated with taping showed a significantly better AOFAS (American Orthopaedic Foot and Ankle Society) mid-foot scores ($p < 0.05$).[64]

The conservative treatment requires regular follow-up with serial x-rays (1st, 4th and 6th weeks) to prevent subsequent displacement of the fragments and follow the evolution of the fracture over time.

Surgical treatment

According to the literature, the reduction of any fracture with displacement of more than 3-4 mm and angulation of more than 10° is reccomended.[58] A close reduction or a mini-invasive reduction through a small incision is the preferred method. Indeed, open reduction may be associated with high risk of devascularization and wound complications. However, the classic open reduction followed by internal fixation is indicated when closed reduction and correct alignment cannot be maintained.

Surgery is required for the treatment of the acute, displaced, unstable, or multiple central metatarsal fractures. Intramedullary fixation with K-wires is considered today the gold standard treatment.[45]

There are different techniques to perform the pinning such as retrograde, antegrade and antegrade/retrograde.

Usually, retrograde intramedullary fixation with K-wire represents the most common approach to treat simple central metatarsal fractures. In this technique, K-wire should be inserted through the metatarsal head or the base of the respective proximal phalanx.[2, 45, 60] (Figure 2).

Instead of retrograde stabilization with K wire it is possible to stabilize the neck fracture with reabsorbable pin that has the advantage not to block the MTF joint requiring no hardware removal (Figure 3).

Baumfeld et al. demonstrated that percutaneous antegrade surgical treatment is a valid alternative to retrograde technique, with a lower incidence of complications such as risk of infection or chondral damage in the MTFJ caused by plantar position and crossing of the wire through the proximal phalanx base.[65] Also Kim et al. showed good results using closed antegrade intramedullary pinning for the reduction and fixation of metatarsal neck fractures. Full weightbearing is allowed 6 weeks after surgery, and the K-wire is usually removed between 6 to 8 weeks. [66-67]

Zarei et al. proposed an antegrade/retrograde technique. The K-wire is introduced in an antegrade configuration, proximal to the fracture, into the medullary canal, then the K-wire is drilled through the metatarsal head while its' edge exited from the plantar skin of the foot. Finally, the K-wire is introduced in a retrograde configuration to the proximal segment.[68]

Other surgical approaches for the treatment of neck and head fractures have been proposed. Regarding metatarsal neck fractures, Donahue et al. described a technique whereby the pin is introduced transversely from the fifth metatarsal as a lateral buttress for the other metatarsal neck.[69]

Verzin et al. proposed a modification of the Kapandji technique where the K-wire is introduced from distal and lateral to proximal and medial to carry out a buttress for the metatarsal head.[70] In case of multiple metatarsal fractures which require an open approach, Ozer et al. proposed transverse incision to reduce the risk of devascularization due to longitudinal incisions at each metatarsal.[71]

Spiral fractures should be treated by inter-fragmentary screws, which placement may result difficult

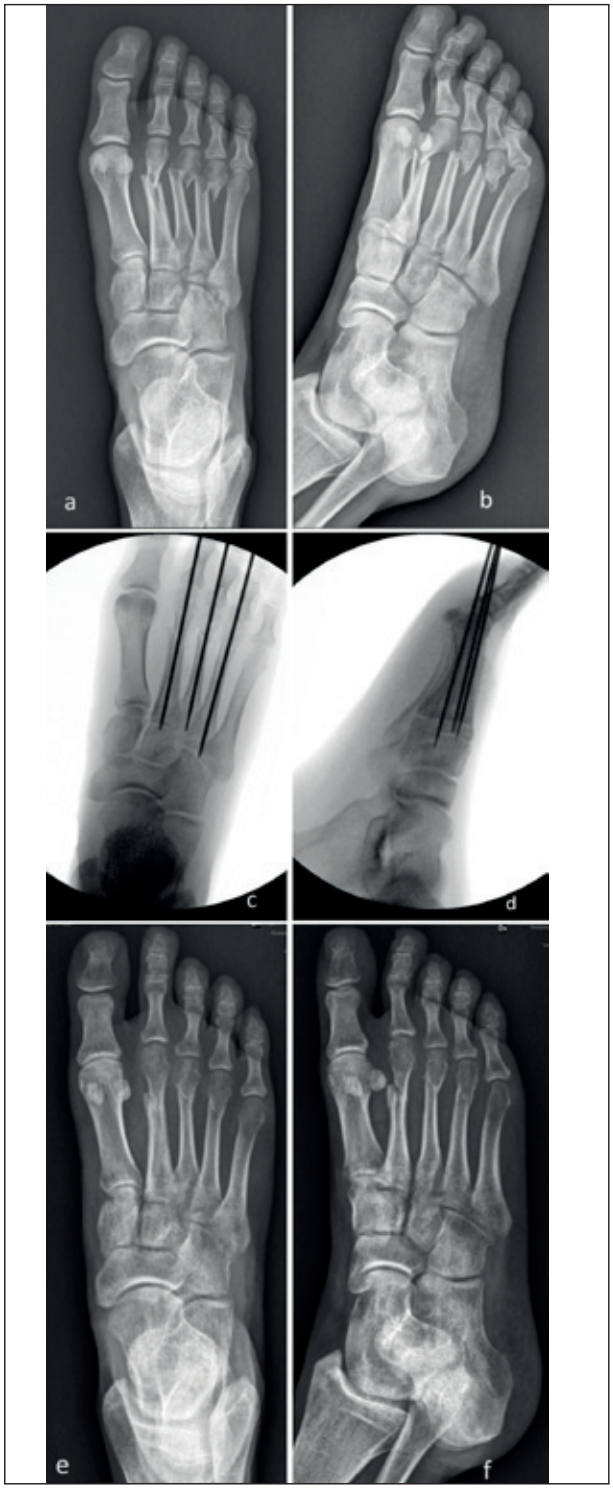

Figure 2. Clinical case of a 22 years old male affected by CMFs following a car accident. a-b: AP and oblique X-ray of multiple neck fractures of the right central metatarsals; c-d. intraoperative x-ray after reduction and fixation with K-wires; e-f. X-ray 2 months after surgery.

Figure 3. Clinical case of a 27 years old male affected by bilateral CMFs following a car accident. a-b: AP and oblique X-ray of multiple neck fractures of the central metatarsals bilateral; c-d. intraoperative x-ray after reduction and fixation with reabsorbable pin of the II, III and IV metatarsals bilaterally; e-f. X-ray 3 months after surgery.

due to the adjacent metatarsals. Therefore, an alternative approach could be an osteosynthesis with a dorsal plate. In comminuted metatarsal shaft fractures, as a result of high energy trauma, a bridge plate may be used to stabilize the fracture and avoid interfering with healing biology. Alternatively, external fixation is useful for stabilizing these fractures and this construct should be parallel to the metatarsal axis in order to prevent sagittal plane alignment and metatarsal malunion or non-union.[3]

Open fractures of the central metatarsals require a management according with Gustilo and Anderson protocols. These should be treated with wound irrigation and debridement, antibiotics, and skeletal stabilization with internal constructs or external fixation depending on soft tissue conditions.[3, 72]

Outcomes

In the literature there is a lack of studies in which functional and radiographic results of CMFs treatment are reported. Sánchez Alepuz et al. report the evolution and final results of 57 patients with CMF treated conservatively (36 cases) and operatively in 21 cases. Fractures were classified according to their-anatomic localization and whether they were closed (44 cases) or open (13 cases).[13] The functional results obtained according to the clinical criteria (pain when walking, pain intensity, type of shoes habitually used, post-fracture plantar hyperkeratosis, and deformities of the first toe) were: 39% poor results, 30% fair, and 32% good results (32%). Using the same criteria, of the open fractures: 64% poor results, 17% fair, and 17% good results.

Metatarsalgia was the most important long-term symptom in 56.8% of the patients. Pain was related to alterations of the residual metatarsal shaft displacement, Morton's neuroma (2 patients), metatarsophalangeal arthrosis (4 patients), and osteomyelitis (1 patient).[13]

The most frequent complication after non-operative treatment of CMF includes metatarsalgia secondary to mal-union or residual deformity and metatarsal parabola disruption. A delayed union may be observed, conversely non-union is uncommon thanks to the vascularization that promotes the healing and usually it occurs as a result of a long-standing stress fracture and not in case of acute injuries.[2]

When healing of a stress fracture is prolonged over time, surgery should be considered. Sarimo et al. have applied successfully the drilling technique to treat delayed union stress fracture on the base of second and third metatarsals to stimulate healing.[73]

A plantarly displaced fracture on the sagittal plane is correlated with a worse outcome causing painful callosities, mechanical metatarsalgia, and neuroma formation for the altered weight distribution on the metatarsal heads. Furthermore, the dorsal angulated fractures can cause dorsal soft tissue irritation. Conversely, a transverse plane mal-alignment is better tolerated but can cause irritation during gait and can cause post-traumatic valgus or varus deformities resulting in early degenerative osteoarthritis.[45, 60]

Healing could be affected by patient's initial condition and Cakir et al. showed that diabetes mellitus, overweight and female gender can impact negatively outcomes;[1] however, healing is often not necessarily caused by open or acute trauma. Murphy et al. showed that delayed union as a result of CMF is usually associated to non-traumatic factor (smoking, poor nutrition, systemic illnesses, and immune compromise).[74]

Conclusions

CMF are common injuries. The understanding of the injury mechanism and clinical evaluation matched with the standard three views foot X-rays remains fundamental in CMF diagnosis. MRI and CT scan are used respectively in stress fracture and patients with multiple, articular fractures. The conservative treatment by taping, cast or brace first without weightbearing for 3 weeks and then weightbearing for another 3 weeks is indicated in undisplaced fractures but requires regular follow-up with serial x-rays to prevent subsequent displacement of the fragments and follow the evolution of the fracture over time. Today, surgery represent the gold standard treatment for displaced, articular and multiple fractures with good outcomes. First attempt should be a

closed reduction and pinning and if fails a mini-open reduction and pinning is indicated. The clinical and functional outcomes are often influenced by the pattern of fractures and patient conditions.

Treating, operatively or non-operatively the central metatarsal fracture we should always keep in mind complications at follow-up as metatarsalgia secondary to mal-union or residual deformity and metatarsal parabola disruption.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Cakir H, Van Vliet-Koppert ST, Van Lieshout EM, De Vries MR, Van Der Elst M, Schepers T. Demographics and outcome of metatarsal fractures. Arch Orthop Trauma Surg. 2011;131:241–5.
2. Buddecke DE, Polk MA, Barp EA. Metatarsal fractures. Clin Podiatr Med Surg. 2010 Oct;27(4):601–24.
3. Clements JR, Schopf R. Advances in forefoot trauma. Clin Podiatr Med Surg. 2013 Jul;30(3):435–44.
4. Petrisor BA, Ekrol I, Court-Brown C. The epidemiology of metatarsal fractures. Foot Ankle Int. 2006; 27:172–4.
5. Urteaga AJ, Lynch M. Fractures of the central metatarsals. Clin Podiatr Med Surg.1995;12(4):759–72.
6. Vuori JP, Aro HT. Lisfranc joint injuries: trauma mechanisms and associated injuries. J Trauma. 1993;35(1):40–5.
7. Zwipp H, Ranft T (1991) [Malunited juvenile fractures in the foot region.] Orthopaede; 20(6):374–80.
8. Shindle MK, Endo Y, Warren RF, et al. Stress fractures about the tibia, foot, and ankle. J Am Acad Orthop Surg. 2012 Mar;20(3):167–76.
9. Boutefnouchet T, Budair B, Backshayesh P, Ali SA. Metatarsal fractures: a review and current concepts. Trauma. 2014;16(3):147–63.
10. Maskill J, Bohay D, Anderson J. First ray injuries. Foot Ankle Clin N Am 2006;11:143–63.
11. Pearson J. Fractures of the base of the metatarsals. BMJ 1962;1:1052–4.
12. Maxwell J. Open or closed treatment of metatarsal fractures: indications and techniques. J Am Podiatry Assoc 1983;73:100–6.
13. Sánchez Alepuz E, Vicent Carsi V, Alcántara P, Llabrés AJ. Fractures of the central metatarsal. Foot Ankle Int. 1996;17(4):200–3
14. Standring S (ed.) Gray's Anatomy. The anatomical basis of clinical practice. 40th edn. Churchill Livingstone, 2009.
15. Cheung J and Au-Yong I. Anatomy of the bones of the foot. BMJ 2011; 343: d7830.
16. Rath B, Notermans HP, Franzen J, et al. The microvascular anatomy of the metatarsal bones: a plastination study. Surg Radiol Anat 2009; 31: 271–77.
17. Smith JW, Arnoczky SP and Hersh A. The intraosseous blood supply of the fifth metatarsal: implications for proximal farcture healing. Foot Ankle 1992; 13: 143–52.
18. Petersen WJ, Lankes JM, Paulsen F, Hassenpflug J. The arterial supply of the lesser metatarsal heads: a vascular injection study in human cadavers. Foot Ankle Int. 2002 Jun;23(6):491–5
19. Jaworek T. The intrinsic vascular supply to the first and lesser metatarsals: Surgical considerations. Chicago (IL): Sixth Annual Northlake Surgical Seminar; 1976.
20. Nana O. Sarpong, MD, MBA, Hasani W. Swindell, MD, Evan P. Trupia, MD, and J. Turner Vosseller, MD. Metatarsal Fractures. Foot & Ankle Orthopaedics 2018 3:3
21. Scott S, Winter D. Biomechanical model of the human foot: kinematics and kinetics during stance phase of walking. J Biomech 1993; 26: 1091–104.
22. Lundberg A. Kinematics of the ankle and foot. In vivo roentgen stereophotogrammetry. Acta Orthop Scand Suppl 1989; 233: 1–24.
23. Roy KJ. Force, pressure, and motion measurements in the foot: current concepts. Clin Podiatr Med Surg 1998; 5: 491–508.
24. Jenkyn TR, Anas K and Nichol A. Foot segment kinematics during normal walking using a multisegment model of the foot and ankle complex. J Biomech Eng 2009; 131:034504.
25. Shereff MJ. Fractures of the forefoot. Instr Course Lect. 39: 133–140, 1990.
26. Lindholm R. Operative treatment of dislocated simple fracture of the neck of the metatarsal bone. Ann Chir Gynaecol Tenn < mn 50:328–331, 1961.
27. Mert M, Unkar EA, Ozluk AV, Tuzuner T, Erdoğan S. Multiple simultaneous metatarsal stress fractures in the same foot. J Am Podiatr Med Assoc. 2015 Mar; 105(2):177–80.
28. Chuckpaiwong B, Cook C, Pietrobon R, Nunley JA. Second metatarsal stress fracture in sport: comparative risk factors between proximal and non-proximal locations. Br J Sports Med. 2007;41(8):510–4.
29. Chuckpaiwong B, Cook C, Nunley JA. Stress fractures of the second metatarsal base occur in nondancers. Clin Ortop Relat Res 461: 197, 2007.
30. Harrington, T; Crichton, KJ; Anderson, IF: Overuse ballet injury of the base of the second metatarsal. A diagnostic problem. Am. J. Sports Med. 21:591–8, 1993.
31. Micheli, LJ, Sohn, RS, Solomon, R. Stress fractures of the second metatarsal involving Lisfranc's joint in ballet dancers. A new overuse injury of the foot. J. Bone Joint Surg. 67-A:1372–5, 1985.
32. Niva MH, Sormaala MJ, Kiuru MJ, Haataja R, Ahovuo JA, Pihlajamaki HK. Bone stress injuries of the ankle and foot: an 86-month magnetic resonance imaging-based study of physically active young adults. Am J Sports Med 35: 643, 2007.

33. Korpelainen R, Orava S, Karpakka J, Siira P, Hulkko A. Risk factors for recurrent stress fractures in athletes. Am J Sports Med 29: 304, 2001.
34. Gehrmann R.M. and Renard R.L. Current concepts review: Stress fractures of the foot. Foot & Ankle International, vol. 27, no. 9, pp. 750–7, 2006.
35. O'Malley MJ, Hamilton WG, Munyak J, DeFranco MJ. Stress fractures at the base of the second metatarsal in ballet dancers. Foot Ankle Int 1996;17:89–94.
36. Aronow MS, Diaz-Doran V, Sullivan RJ, Adams DJ. The effect of triceps surae contracture force on plantar foot pressure distribution. Foot Ankle Int 2006;27:43–52.
37. Ringham R, Klump K, Kaye W, et al. Eating disorder symptomatology among ballet dancers. Int J Eat Disord 2006;39:503–8.
38. Lee DK, Mulder GD, Schwartz AK. Hallux, sesamoid, and first metatarsal injuries. Clin Podiatr Med Surg. 011;28(1):43–56.
39. Chuckpaiwong B, Queen RM, Easley ME, Nunley JA. Distinguishing Jones and proximal diaphyseal fractures of the fifth metatarsal. Clin Orthop Relat Res. 2008;466(8): 1966–70.
40. Maenpaa H, Soini I, Lehto MU, Belt EA. Insufficiency fractures in patients with chronic inflammatory joint diseases. Clin Exp Rheumatol 2002;20:77–9.
41. Arndt A, Ekenman I, Westblad P, Lundberg A. Effects of fatigue and load variation on metatarsal deformation measure in vivo during barefoot walking. J Biomech 2002;35:621–8.
42. Donahue SW, Sharkey NA. Strains in the metatarsal during the stance phase of gait implications for stress fractures. J Bone Joint Surg [Am] 1999;81:1236–44.
43. Boden BP, Osbahr DC. High-risk stress fractures: evaluation and treatment. J Am Acad Orthop Surg 2000;8:344–53.
44. Boden BP, Osbahr DC, Jimenez C. Low-risk stress fractures. Am J Sports Med 2001;29:100–11.
45. Rammelt S, Heineck J, Zwipp H. Metatarsal fractures. Injury 2004: 35(Suppl2):SB77–86
46. Zwitser EW and Breederveld RS. Fractures of the fifth metatarsal; diagnosis and treatment. Injury 2010; 41:555–62.
47. Hatch RL, Alsobrook JA, Clugston JR. Diagnosis and management of metatarsal fractures. Am Fam Physician 2007 Sep 15;76: 817–26.
48. Ross G, Cronin R, Hauzenblas J, Juliano P. Plantar ecchymosis sign: a clinical aid to diagnosis of occult Lisfranc tarsometatarsal injuries. J Orthop Trauma. 1996;10(2):119–22.
49. Pao DG, Keats TE, Dussault RG. Avulsion fracture of the base of the fifth metatarsal not seen on conventional radiography of the foot: the need for an additional projection. AJR Am J Roentgenol 2000 Aug; 175: 549–52.
50. Dameron TB Jr. Fractures and anatomical variations of the proximal portion of the fifth metatarsal. J Bone Joint Surg Am 1975 Sep; 57: 788–92.
51. Patel DS, Roth M, Kapil N. Stress fractures: diagnosis, treatment, and prevention. Am Fam Physician 2011 Jan 1; 83(1):39–46.
52. Goulart M, O'Malley MJ, Hodgkins CW, Charlton TP. Foot and ankle fractures in dancers. Clin Sports Med 2008 Apr;27(2): 295–304.
53. Banal F, Gandjbakhch F, Foltz V, et al. Sensitivity and specificity of ultrasonography in early diagnosis of metatarsal bone stress fractures: a pilot study of 37 patients. J Rheumatol 2009 Aug; 36(8): 1715–9.
54. Haapamaki V, Kiuru M, Koskinen S. Lisfranc fracture-dislocation with multiple trauma: diagnosis with mutlidetector computed tomography. Foot Ankle Int 2004; 25: 614–9.
55. Zwipp H, Baumgart F, Cronier P, et al. Integral classification of injuries (ICI) to the bones, joints, and ligaments-application to injuries of the foot. Injury 2004 Sep; 35 Suppl 2: SB3–9.
56. Hansen ST. Foot injuries. In: Browner BD, Jupiter JB, Levine AM, et al, editors. Skeletal trauma. Philadelphia: WB Saunders Company; 1998. p. 2405–38.
57. Early J. Metatarsal fractures. In: Bucholz R, Heckman J, Rockwood C, et al, editors. Rockwood and green's fractures in adults. Lippincott, Williams, & Wilkins; 2001. p. 2215.
58. Shereff M. Complex fractures of the metatarsals. Orthopedics 1990;13(8):875–82.
59. Armagan O, Shereff M. Injuries to the toes and metatarsals. Orthop Clin North Am 2001;32(1):1–10.
60. Sanders R (1999) Fractures of the midfoot and forefoot. In: Mann RA, Coughlin MJ. Surgery of the foot and ankle. St Louis: Mosby:1574–1605.
61. Raghavan P, Christofides E. Role of teriparatide in accelerating metatarsal stress fracture healing: a case series and review of the literature. Clin Med Insights Endocrinol Diabetes 2012; 5: 39–45.
62. Gray AC, Rooney BP, Ingram R. A prospective comparison of two treatment options for tuberosity fractures of the proximal fifth metatarsal. Foot (Edinb) 2008 Sep; 18(3): 156–8.
63. Sammarco GJ, Conti SF. Surgical treatment of neuroarthropathic foot deformity. Foot Ankle Int 1998;19:102–9.
64. Zenios M, Kim WY, Sampath J, Muddu BN. Functional treatment of acute metatarsal fractures. A prospective randomised comparison of management in a cast versus elasticated support bandage. Injury 2005 Jul; 36(7): 832–5.
65. Baumfeld D, Macedo BD, Nery C, Esper LE, Filho MA. Anterograde percutaneous treatment of lesser metatarsal fractures: technical description and clinical results. Rev Bras Ortop. 2015 Nov 4;47(6):760–4.
66. Kim HN, Park YW. Reduction and fixation of metatarsal neck fractures using closed antegrade intramedullary nailing: technique tip. 2011. Foot Ankle Int32(11):1098–100.
67. Kim HN. et al. Closed antegrade intramedullary pinning for reduction and fixation of metatarsal fractures. 2012. J FootAnkle Surg51(4):445–9.
68. Zarei M, Bagheri N, Nili A, Vafaei A, Ghadimi E. Closed antegrade/retrograde intramedullary fixation of central metatarsal fractures: surgical technique and clinical outcomes. Injury 2020. Mar 3.

69. Donahue MP, Manoli A, 2nd. Technical tip: transverse percutaneous pinning of metatarsal neck fractures. Foot Ankle Int. 2004 Jun;25(6):438–9.
70. Verzin EJ, Henderson SA. A new technique for the management of difficult metatarsal neck fractures. Foot & ankle international. 2000;21(10):868–9.
71. Ozer H, Oznur A. The transverse dorsal approach to displaced multi-metatarsal fractures. J Foot Ankle Surg. 2006 May-Jun;45(3):190–1.
72. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am 1976;58:453–8.
73. Sarimo J, Orava S, Alanen J. Operative treatment of stress fractures of the proximal second metatarsal. Scand J Med Sci Sports. 2007;17:383–6.
74. Murphy GA. Operative treatment of stress fractures of the metatarsals. Oper Tech Sports Med 2006; 14: 239–47.

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Review

Hypermobility of the first ray: the cinderella of the measurements conventionally assessed for correction of hallux valgus

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Summary. *Background and aim of the work:* hypermobility of the first ray (FRH) began to be considered as a pathological entity from Morton's studies and was associated as a primary cause of hallux valgus (HV). Currently, this relationship is in discussion, and various authors consider FRH as a consequence of the deformity. The purpose of this narrative review is to summarise the most influential publications relating to First Ray Mobility (FRM) to increase knowledge and promote its conventional assessment during clinical practice. *Methods:* papers of the last century were selected to obtain a homogeneous and up-to-date overview of I-MTCJ mobility and HV, as well as their relationship and management. *Results:* in recent years, FRH was studied from a biomechanical and pathophysiologic point of view. There is still not enough data regarding the aetiology of FRM. The higher rate of instability found in HV lacks an explanation of which is the cause and which is the effect. However, the Lapidus arthrodesis is still a valid method in cases of FRH and HV, even if is not rigorously indicated to treat both. When approaching FRH, radiographic or clinical findings are mandatory for the right diagnosis. *Conclusions:* FRM is an important factor that must be considered in routine clinical practice and prior and post HV surgery, as much as the conventional parameters assessed. Surgeons should consider performing I-MTCJ arthrodesis only if strictly necessary, also paying attention to soft tissue balancing. Improving the measurement of FRH could be useful to determine if it is a cause or effect of the HV deformity. (www.actabiomedica.it)

Key words: hypermobility, hypermobility of first ray, first ray mobility, hallux valgus, Lapidus procedure, foot biomechanics.

Introduction

Hypermobility of the first ray (FRH) has been described as a relatively increased arc of motion with respect to the second metatarsal bone (MB), and lacks a firm end point (1). In simple terms, it is an "*abnormal and excessive mobility in dorsi-flexion of the first metatarsal head, due to instability of the First Metatarsal-Cuneiform Joint (I-MTCJ)*" (2) not only in the sagittal plane, but also in the transverse one. Clinically, in normal conditions, applying a dorsiflexion force under the head of the first MB, its lower margin does not exceed the plane of the lesser metatarsal heads. In case of FRH, alterations of normal foot mechanics are present. While walking, for example, the vertical reaction force to the ground raises the first metatarsal head over the plane of the lesser metatarsal heads, moving the load onto the lesser metatarsals. This can lead to a collapse of the internal longitudinal arch of the foot, compromising the propulsive phase of the gait.

Historically, the first author to define the concept of I-MTCJ hypermobility was the anatomist of Columbia University, Dudley Morton (3) in 1928, who speculated that FRH may have been due to unusually free motion in the joint between the inner cuneiform and scaphoid bones, and between the inner and middle cuneiforms. He also defined a clinical method to assess FRH (Figure 1). However, hypermobility was defined as an arbitrarily excessive motion, without finding a way to quantify the examination. Then, in the 1930s, Lapidus (4–6) proposed an association between increased first ray mobility (FRM) and the development of hallux valgus (HV). However, neither Morton nor Lapidus were able to quantify the magnitude of FRM in any of their studies and based their findings on subjective clinical examination. In 1971, Courriades (7) was credited first with recognizing that FRH was a distinct clinical entity.

Rodgers and Cavanagh in 1986 (8) were the first researchers to measure dorsal motion of the first ray (FR) with a mechanical prototype device which was reengineered by Glasoe et al. in 1999. Measures of dorsal mobility with this new device have been judged valid and reliable by radiographic comparison. In 1990, Romash et al. demonstrated objective evidence of transverse hypermobility by performing a clinical squeeze test (9). Although an isolated transverse motion of the I-MTCJ is only a few degrees, the mobility can result in a large deviation of the distal metatarsal head.

In 1994, Klaue et al. introduced a non-invasive device to quantify dorsal I-MTCJ mobility with a numeric value (10). However, they were unable to selectively differentiate any of the joints of the medial column of the foot. This device has been used in several studies (11–15) and has been shown to be dependable, allowing the definition of FRH as a dorsal displacement of more than 8 to 10 mm to a lack of a firm endpoint (16). More recently, Singh et al. (17), using the same device, considered the measurement of FRM to be more adequate in a 45° dorso-medial direction (Figure 2), respecting the natural movement of the FR on the transverse plane during walking and defining it hypermobile at 10 mm displacement (Figures 3 and 4). Previously, Faber et al. (18) in 1999, observed that the relative contribution of first tarsometatarsal mobility to FRM is more pronounced in the transverse plane as opposed to the sagittal plane.

In 2006, normal dorsal mobility was reported by Glasoe and Coughlin (19) in a consensus statement to average 5 mm in normal adults, while pathologic mobility or hypermobility was defined as greater than 8 mm of sagittal translation to stress (1, 10, 12). However, in the literature there is no factual definition that exactly quantifies this overextension during walking of the FR with respect to the lesser ones. This lack of a precise definition may suggest a lack of understanding of the clinical results associated with FRM (20). Because of the intersegmental nature of foot motion, the measurement of dorsal FRM cannot be ascribed to only one specific joint as it involves more bones, and because the load imposed is not easily controlled, different methods yield different results.

In the early 2000s, many authors including Ward Glasoe (19, 21) and Thomas Michaud (22–24) suggested that this overelevation and translation of the first MB relative to the second one in a sagittal plane,

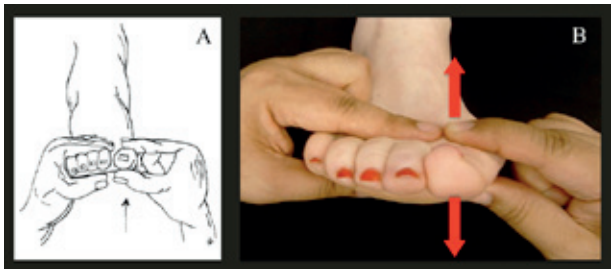

Figure 1. A and **B**: Manual examination to clinically assess FRM according to Morton. A dorsally directed forced is applied to the first ray with one hand, while other hand stabilises second to fifth metatarsals.

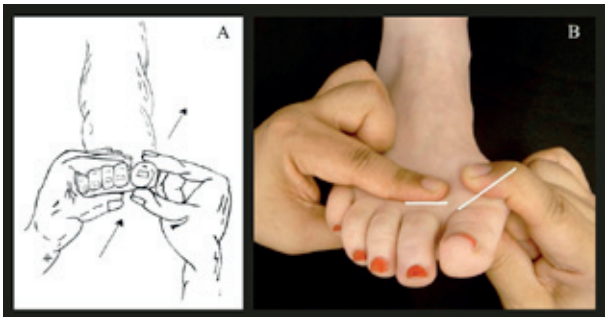

Figure 2. A and **B**: Manual examination to clinically assess FRM by displacing the first metatarsal head at an angle of 45 degrees to the transverse plane.

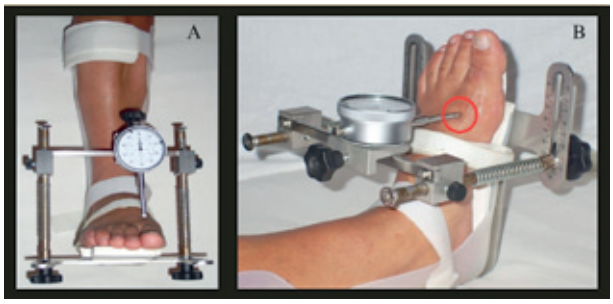

Figure 3. Correct position of foot for the measurement of FRM using the Klaue device: **A)** the foot is placed in the ankle orthosis with the ankle in neutral position and calf, ankle and midfoot are immobilised; **B)** the micrometre overlies the first metatarsal head in order to measure the mobility first in the sagittal plane.

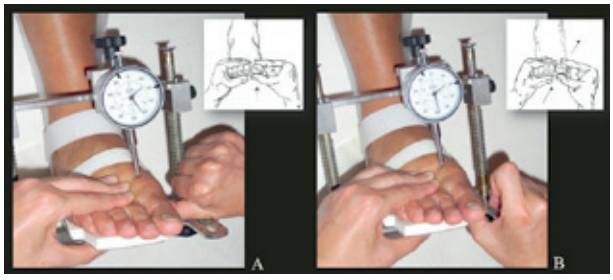

Figure 4. With one hand, the examiner immobilises second to fifth metatarsal bones, and with the other hand, exerts a force on the plantar side of the first metatarsal head, first **A)** in a purely dorsal direction; and then **B)** at a dorsomedial angle of 45 degrees to the transverse plane. Displacements were measured with the patient sitting in a non-weightbearing position, according to the method established by Klaue.

leads to overload of other MBs causing a wide range of disorders, such as HV synovitis, lesser metatarsal stress fractures, metatarsalgia and interdigital neuromas (19, 25, 26).

The clinical diagnosis of hypermobility in a sagittal plane is basically based on the drawer's sign. Although several different methods have been proposed, all describe increased dorsal excursion with a soft end point (Figures 1-5), making the quantification in a clinical setting of what constitutes hypermobility in the sagittal plane difficult. Measurement of the FRH in the transverse plane can be documented both clinically and radiographically, manifested by an increased intermetatarsal angle (IMA), as showed by Singh and Romash (9, 17).

The controversy in the English literature about the association between HV and FRH regards whether hypermobility is a real pathology, or is a consequence of a deformity. The best strategies for management of FRH and HV are in question. It has been shown that there is also a significant relationship between radiographic malreduction of sesamoids and recurrence of HV deformities (27, 28), which is why their subluxation is normally measured in the most recent studies about HV deformity correction. Perhaps FRH should be among the parameters to be corrected if present during HV treatment. Its routine assessment pre- and post-operatively at different follow-up points as the other widespread known parameters used for HV correction evaluation should seem important. The purpose of this narrative review is to summarise the most influential publications relating to FRH to increase knowledge and promote its conventional assessment during the clinical practice and the pre- and post-operative evaluations of several HV surgical procedures.

Anatomy of the First Ray

The FR is defined as a single functional foot unit, whose bone components consist of the great toe phalanges, sesamoids, first MB and medial cuneiform bone. The various bones of the FR have a moderately defined space arrangement, and a variation in their relationships in the three planes of space can be a sign of foot pathologies such as HV. One of the most characteristic signs of the alteration of the normal anatomy of the FR is the variation of the space relationship between the sesamoid bones and the first MB. This alteration could have four progressive degrees of gravity on the transverse plane, and three degrees of gravity on the coronal plane. These pathognomonic signs can be investigated using 3D methods, which manage to represent in a single figure the space alteration of the relationships between the bones of the FR (29).

There are also other joints that are involved in FRM: between the medial cuneiform and the navicular bone, between the medial cuneiform and the intermediate cuneiform and the articulation between the medial cuneiform and the second metatarsal base (30–32). An important factor of anatomical potential instability of the FR is the absence of the intermetatarsal

ligament. This structure is present among all the minor metatarsals; it is instead absent between the first and second rays (21). The absence of the intermetatarsal ligament between the first and second rays could be the reason why there can be no Morton neuroma in the first intermetatarsal space.

Anatomic structures serve as stabilisation factors of the FR. The dorsal and interosseus ligaments and above all, the plantar first MTC ligament are the most important stabilisers in the sagittal plane and in FR motion in general (26). Also the peroneus longus and flexor hallucis longus tendons contribute to minimise instability of the I-MTCJ during dorsi-flexion (33): they provide significant contribution to dorsal and medial stability with a larger role in the sagittal plane (34). Further, the role of the plantar fascia is crucial in foot stability (35), and Sarrafian specified the plantar aponeurosis as a critical component of FR stability (35). Grebing and Coughlin found an increased FRM when the ankle is plantarflexed and vice-versa when the ankle is dorsiflexed. These authors concluded that the plantar fascia is a key stabiliser of FR, but based on these findings, Doty et al. assessed that the alignment confers stability, rather than instability leading to malalignment (36, 37).

The Biomechanics of the I-MTC Joint and the First Ray

During walking, the forefoot has to be flexible to absorb ground reaction but also stiff to sustain the body weight and stressing activities (38). To support the arch of the foot, the human foot needs stability, especially at the I-MTCJ. This stability gives strength to the medial column (39), which is necessary and adapted for bipedal gait and propulsion (26, 40). Ideally, the human foot would have a rigid FR, to provide a long and rigid lever arm for the Achilles tendon during the heel rise phase of the gait cycle (26, 41).

Dullaert et al. supported the importance of peroneus longus function in maintaining medial longitudinal arch for the stability of the I-MTCJ (42). When the foot moves into the sagittal plane, the FR can spin around its axis. During the dorsiflexion of the foot, the FR inverts; during the plantarflexion of the foot, the FR everts. I-MTCJ has also mobility in the transversal plane. The biomechanical axis of the I-MTCJ motion is on a plane from 45° to 60° in a dorsomedial direction, thus allowing a movement of the first metatarsal head from a plantar-lateral to a dorso-medial position. The triplane movement of the first MB is inversion and adduction during dorsiflexion, and eversion and abduction during plantarflexion. This type of movement is commonly named "pronation of the FR" (21).

Because of these multi-plane movements, it is understandable how difficult it is to quantify FRM. Due to the number of joints which participate in the normal motion of the FR and the consequent intersegmental motion of foot, accurate measurement of hypermobility cannot be made only in the dorsal direction, considering only one joint movement and applying a load not precisely controlled (25). However, we must adopt a method to measure it in clinical sitting.

Initially Root et al. proposed that the normal FRM was 5 mm of dorsiflexion and 5 mm of plantarflexion in the sagittal plane (44), but lacked real scientific measurements. Later, various authors started to use different instruments to quantify the measurement (10, 45–47), even if not considering movement in the frontal plane of the FR. Klaue et al. reported that the dorsiflexion of the FR was normally 5.3 mm, and various authors have then used his device, obtaining diverse results from 4.4 mm to 7.2 mm (17, 36, 45, 48, 49). Dorsiflexion ranges from 3 to 8 mm in healthy adults, and one article authored in 2006 by Glasoe and Coughlin defined FRH when the value exceeds 8 mm (19).

While walking, the I-MTCJ has mobility in the sagittal plane. Some authors try to measure it ignoring the changes which take place in the frontal plane (14, 50) and have considered FRH as only a sagittal plane instability, not considering the relevance of motion in the transversal plane. The normal biomechanical axis of the I-MTCJ is a plane between 45° and 60°. For this reason, Singh et al. proposed considering FRH in the presence of a dorsal displacement more than 10 mm with FR pushed into the dorso-medial direction at an angle of 45° (17). According to these authors, the mean FRM in the 45° dorso-medial direction is 8.3 mm in patients with HV compared to a control group (Figures 2 and 4). In a recent study, gait analysis revealed a dynamic elevation of the FR

at the level of I-MTCJ in the sagittal plane, but also a pronation and adduction of the first MB is apparent (51). Hence, I-MTCJ motion in the transversal plane is important and must be considered.

According to recently published literature, the average range of the FR is of about 6 mm of dorsiflexion and about 6 mm of plantarflexion, for a total range of motion of about 12 mm (45). Geng et al. assessed that movement of I-MTCJ during weightbearing is as follows: dorsiflexion, supination and internal rotation, suggesting that FRH occurs in multiple planes in patients with HV deformity (52).

Feet with low arches and real clinical flatfoot deformity have increased measures of FRM compared to those with high arches. This supports the concept of medial column laxity as a component in the development of flatfoot deformity (53). Other authors describe medial column hypermobility in planovalgus feet with tarsometatarsal arthritis. FR instability results in a loss of ability to resist the vertical ground reaction forces, and this leads to laterally displaced forces concentrating on the second and third MBs and midfoot structures, which leads to the development of tarsometatarsal osteoarthritis (54). However, Heng et al. have described no correlation between FRM and posterior tibial tendon dysfunction in flatfoot, although this relationship is still under discussion (55).

Clinical and Radiographic Measurements of First Ray Mobility

Morton was the first to describe a clinical method to define FRH with a provocative test which is still widely used (3). One hand of the examiner applies a dorsal force to the head of the first MB while stabilizing the lateral four MBs with the other hand. The test is positive when the first metatarsal head translates dorsally relative to the second metatarsal head in a coronal plane (Figure 1). This is a highly reproducible test, but it lacks a quantifying scale of severity, and it has many interobserver errors (56). According to Grebing et al., the magnitude of FRM at clinical examination varies with the position of ankle dorsiflexion/plantarflexion; hence, the provocative test has to be done in a neutral ankle position. This is due to the key stabilising effect of plantar fascia aponeurosis, whose tension is modified by ankle position (36, 41).

In the 1970s, Root at al. introduced an alternative clinical measurement: with one hand the examiner stabilises the lesser four MBs, and with the other hand applies alternately a dorsal force and a plantar force to the head of the first metatarsal. A hypermobile FR is defined when the dorsiflexion exceeds the plantarflexion. This is the difference from Morton's manual examination. Other authors still suggest that the FR can be defined hypermobile if a dorsal stress force elevates the head of the first MB above the plane of the minor metatarsals (57).

Handheld rulers can assist in standardizing the measurement of FRM (Figure 5); three different rulers have been described in literature. The "Kilmartin Sagittal Raynger" rulers were described in 1990 by Wallace and Kilmartin. These two portable rulers are placed on the plantar surface of the foot. They are two side-to-side moving rulers that can measure the dorsal displacement of the FR, as the examiner applies a plantar force on it (58). Another type of ruler was described by Lee and Kim in 2008, naming it the "Euliji Medical Center (EMC) ruler". This tool is composed of two small pieces of a metal ruler bent at right angles, marked in 1-mm gradations. The examiner applies a

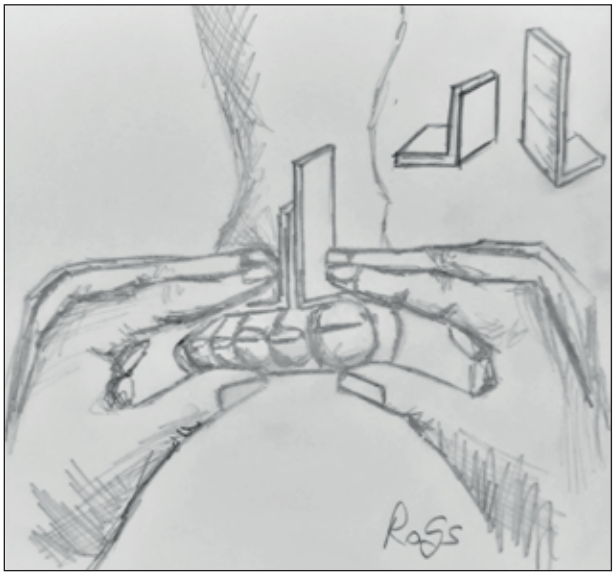

Figure 5. Manual examination to clinically assess FRM using handheld rulers.

dorsiflexion force on the FR, and measurement of the FRM is made by balancing the ruler with the shorter limb on the dorsum of the first metatarsal head, and the ruler with the longer limb on the dorsum of lesser metatarsal head (47). Greisberg et al. ideated another handheld ruler in 2010, also used for another study in 2012 (26, 59). These rulers are a modification of the EMC one, with the first ruler placed on the plantar surface of the first metatarsal head, and the other on the plantar surface of the lesser metatarsal heads. As the FR is dorsiflexed, measurements are read directly off the ruler (26). Measurement by handheld rulers is burdened by the same reproducibility errors attributed to manual examination (26) even if they have a quantified scale. Using them, Greisberg et al. quantified first MB elevation compared with the second MB rather than total metatarsal translation. According to the authors, an increased first MB elevation would tend to transfer load to the lesser metatarsals during weightbearing, causing metatarsalgia and related problems (26, 59). However, manual testing for FR instability is unreliable compared to measurements made with mechanical devices. (Table 1)

The first device described was created by Rodgers and Cavanagh in 1986. This mechanical device applied a load beneath the FR and then calculated its plantar displacement through an electronic sensor. It had a measurement error of approximately 3 mm given by the compression of the plantar fat pad during the loading process. For this reason, measurement error has been avoided by applying mechanical force on the dorsum of the FR (25, 60).

A device that most greatly influenced the method of measuring the FRH is the "Klaue device" (Figures 3 and 4). This device is composed of an ankle-foot orthosis, in which the ankle is placed in neutral position. The examiner with one hand dorsiflexes the FR until its maximum range of motion, and with the other hand blocks rays from second to fifth. A micrometre is suspended from the frame of the ankle-foot orthosis, fixed to the frame above the first metatarsal head with the ankle maintained in neutral position and in line with the FR in order to measure the mobility first in the sagittal plane. The micrometre records the full dorsiflexion range of motion of the FR. This device has variability due to the starting point of measurement and the force exerted by the examiner to dorsiflex the metatarsal head. To reduce variability, the measurement is repeated multiple times, with the average recorded for analysis (26). Additionally, since 25% of adults cannot attain a neutral ankle position with the knee extended, the knee should also be flexed (36).

The Glasoe device is similar to the one created by Klaue but has some technical expedients that reduce the variability of the measurement, having a mechanical piston able to measure the force

Table 1. Devices used to clinically assess the Hypermobility of the First Ray

Authors	Device	Description
Rodgers and Cavanagh 1986	Mechanical device with electronic sensor	This mechanical device applies a load beneath the first ray and then calculates its plantar displacement through an electronic sensor
Wallace and Kilmartin 1990	Kilmartin Sagittal Raynger	Moveable rulers to measure the displacement as an examiner dorsiflexes the first ray
Klaue et al. 1994	Klaue device	Modelled from an ankle foot orthosis with a suspended caliper on the first metatarsal that measures the dorsal displacement when the first ray is moved manually (figure 3 and 4)
Glasoe et al. 1998	Glasoe device	Similar to Klaue device. This one stabilises the hindfoot, and the first ray is moved mechanically with a load
Lee and Kim 2008	Eulji Medical Center (EMC) ruler	Two-piece plastic rulers that are placed on the dorsum of the first and second metatarsals with dorsiflexion of first ray (figure 5)
Greisberg et al. 2010	Greisberg rulers	Two similar EMC rulers, but the authors measured metatarsal elevation and not translation, which was assessed with pressure placed under the first and the lesser metatarsals simultaneously. An increased first metatarsal elevation would tend to transfer load to the lesser metatarsals

produced. The lesser MBs are blocked by a separate platform, so the starting point of measurement of the dorsiflexion of the FR is reproducible in each measurement without variations (60). The device was improved in 2005 by connecting it to a computer, allowing the storage of the data for retrieval and time-based analysis (61) . Both Klaue and Glasoe (Table 1) have a great potential in standardizing the measurement of FRH, but at present there are no commercial devices marketed on a large scale such as to allow widespread use (25).

Imaging exams can also be useful to standardize the measurement of FRM but are burdened by projection error. The modified Coleman block test is the most described x-ray exam (25). The protocol involves weightbearing lateral view radiographs of the foot. The dorsiflexion view of the FR is performed with hindfoot, midfoot and first MB stationary on a wooden block; hindfoot, midfoot and lesser metatarsals stationary on a wooden block give the plantarflexion view of the FR (62). The modified Coleman block test is widely known for measuring dorsal FRM. In 2018, Tavara-Vidalon et al. used it to measure both sagittal and frontal plane displacement on anteroposterior radiographs (45). Displacement of the FR can also be assessed in the transverse plane with the radiographic squeeze test, and measuring the FRM in 3 planes could be a valid help for surgical corrective procedure. Pressing or applying a tight bandage from first to fifth metatarsal-phalanges joints allows visualisation of significant differences in intermetatarsal angle in case of hypermobility in the transverse plane (63). Martin et al. evaluated FR dynamic motion using live fluoroscopy in 2012 taking lateral projections of radiographs during the stance phase of gait to evaluate the positional changes of the FR relative to the talus (64).

CT scan 3-dimensional (3D) evaluation of FR has also been investigated. A study of Geng and al., published in 2015, evaluated both feet of 10 females with healthy feet, and both feet of 10 females with HV. The evaluation was made with CT scan, comparing the position of the FR when the foot is in a non-weightbearing state versus when it is in a weightbearing state. Loading state was simulated by a custom-made device, that also blocked the ankle in a neutral position. The study observed that in loading conditions the I-MTCJ turns dorsiflexed, supinated, and internally rotated. These movements in multiple planes are wider in HV deformity (52).

Kimura et al. carried out a similar study in 2017. They evaluated ten feet of 10 patients with hallux valgus and 10 feet of 10 healthy volunteers with no foot disorders using CT-scans. The evaluation was made both in non-weightbearing and weightbearing state, simulated by a custom-made device. This study demonstrated that, in patients who have HV, the weightbearing state caused an increased FR mobility compared to the FR in normal feet (65).

Magnetic resonance (MR) imaging has been used to evaluate FRM. In the study of Swanson et al. in 2016, FR is scanned in a MR with the foot posed on a system of wedges to replicate the weightbearing phases of gait. Measures of hallux and FRM were made from 2D and 3D magnetic resonance scans, and the two measurement methods were compared with each other. This report found the study of FR sagittal mobility through 2D approach reliable, compared to 3D images (66).

Ultra-sound can also be used to ascertain FRH. In a study published in 2019, Stiglitz et al. asserted that ultra-sound could have good reproducibility for measures of I-MTCJ, but further studies are necessary to evaluate this procedure (67).

First Ray Hypermobility and Hallux Valgus

A complicated relationship

The aetiology of HV is complex and its connection with the instability of the FR is one of the most debated concepts in the current literature of foot and ankle disorders. Many other reports have claimed an association between increased I-MTCJ and HV valgus (10, 12, 68–70), nevertheless focusing only on mobility in the sagittal plate. Certainly, the tricky concept of the metatarsus primus varus, HV, hypermobility of the I-MTCJ and other different factors related to the HV deformity are well known, but most authors consider only a uniplanar evaluation of this multiplanar deformity (65).

Although HV deformity is estimated to be from 20 to 35% of the general population, FRH is not always and precisely assessed (65, 71, 72) often accompanied

by significant functional disability and foot pain. Despite frequent mention in a diverse body of literature, a precise estimate of the prevalence of HV is difficult to ascertain. The purpose of this systematic review was to investigate prevalence of HV in the overall population and evaluate the influence of age and gender. METHODS Electronic databases (Medline, Embase, and CINAHL). Sigh et al. found 81% FR instability in patients with HV compared to 24% of FR instability in the control normal group (17). Some categories of athletes like ballet dancers seems to have higher FRH rates probably due to dancing technical errors (pronation) and intrinsic incorrect activity (72–74), meaning that altered biomechanics of the foot can be a risk factor.

As shown previously, many methods are available to measure FRM, of which the most common is manually moving the first MB in the dorsal and plantar directions (Figure 1). Although this technique can be readily used in a clinical setting without any special equipment, the validity and reliability can be questionable (19). Glasoe et al. (21) compared the interrater reliability of this manual measurement method with that of their mechanical measuring device. Their device is similar to Klaue's in that the foot is constrained in an apparatus and the FRM is measured in a controlled environment. However, unlike the Klaue device, their device is capable of controlling the amount of pressure applied to the FR while measuring the dorsal displacement. Therefore, consistent pressure can be applied to all the subjects without relying on investigator consistency (74).

Coronal, Sagittal and Transverse: the 3 plains of Hallux Valgus Deformity

Some authors think HV is a transverse plane deformity involving HV with the sagittal plane hypermobility resulting secondarily and not acting as the primary deforming force (34, 76–79). Others claim those patients with higher motion in the sagittal plane are predisposed to the development of transverse plane malalignment and HV deformity (10, 68, 69, 80).

Recently, growing attention has been paid to the 3-dimensional changes in HV deformity (54, 65). Considering movement in multiple planes, measurement of FRH should be done in a 45° dorsomedial direction according to Singh et al. (17). In addition, it is important to consider first MB pronation in HV: by several HV surgical procedures is possible to obtain a good derotation of the first MB and a good reduction of subluxated sesamoids (54).

The association between the quantification of the HV angle (HVA) and IMA (70, 77) is well described in the current literature. Mobility of the I-MTCJ in a coronal plane causes the increase of both of these angles, but isolated sagittal plane MTC mobility has never been proven as a primary cause. With the development of HV, the dynamic restraints such as the plantar fascia, the sesamoids and the muscles around the foot become altered (70, 81). Hence, some authors propose that the increased FRM is due to loss of plantar aponeurosis alignment: it is secondary to the deformity, and the restoring of normal plantar fascia tension could resolve the instability (41).

Recently, Kimura et al. performed a comparison of intercuneiform 1-2 joint mobility between HV and normal feet using weightbearing computed tomography and 3-dimensional analysis. During their procedures, several patients with HV who had instability between the medial and middle cuneiform, in addition to the FR, were found. The results of this study showed that, relative to the medial cuneiform, the middle cuneiform was significantly displaced due to dorsiflexion and inversion under weightbearing conditions in patients with HV, suggesting that HV also involves hypermobility at the intercuneiform 1-2 joint. Because manual inspection was performed in their study, the force used might have been inconsistent among the patients. In addition, because HV deformities involve 3D factors, including rotation, and because the FRH is also 3D, it is ideal to assess the pathological condition 3-dimensionally instead of in one direction or one plane (65).

Hence, FRH in the sagittal plane is not the only indication for the Lapidus procedure because is important to consider the increased mobility in the transversal plane; I-MTCJ hypermobility occurred in both the sagittal and the transversal planes (82, 83).

Lapidus: a necessary procedure?

Lapidus was the first to propose fusing the first and second metatarsal bases with the medial cuneiforms, performing a surgical arthrodesis to reduce FRM. His technique was modified during the years

by various surgeons, and it is still used above all for severe HV deformity correction or recurrent deformity (5,84,85). The procedure has been proven by various studies and in large systematic reviews of multiple techniques, reporting an IMA correction variable from 8.5 to 14.4 mm with different fixation techniques and an overall fusion rate of 4% (85, 86). According to Lapidus, many surgeons think that by correcting excess motion at the I-MTCJ by arthrodesis, this would then normalize FRM and would address the primary cause of the HV (5,6,43,80) deformity. However, there is some disagreement with prior indications for I-MTCJ arthrodesis. Studies have shown realignment procedures at the first metatarsophalangeal joint effect vectors of soft tissue support, which serve to stabilise the medial column without arthrodesis of the I-MTCJ. Currently, few studies report FRM values during the conventional evaluation of HV deformity and the outcomes of the different surgical techniques for its correction.

Ellington et al. (80) recommended MTCJ arthrodesis in case of HV recurrence and found that 96% had preoperatively clinical signs of FRH and 52% radiographic findings of instability (Table 2). Therefore, mobility of first MB should be always assessed when considering a Lapidus procedure. On the other hand, Kim and colleagues performed a series of proximal metatarsal Chevron osteotomies and distal soft tissue procedures for HV deformity without sacrificing the I-MTCJ, concluding that FRH is multifactorial and refuting Morton's original theories (79).

Finally, procedures involving I-MTCJ fusion are technically demanding, and some investigators suggest fusion should be reserved for cases with MTCJ arthritis or more severe HV deformity cases in which the IMA cannot be improved by a metatarsal shaft osteotomy. Non-union, hardware removal and failure, metatarsalgia, and bone grafting are mentioned as factors leading to greater patient morbidity.

Hypermobility of First Ray: cause or effect of Hallux Valgus deformity?

The cause and effect between HV and FRH continue to be debated. To the clinician, it is a much more complicated matter, as the relationship between the deformity in the transverse plane and motion in the sagittal plane is more involved. It has been paralleled by some investigators to the philosophic debate: *"Which came first, the chicken or the egg?"*

Understanding the anatomic and radiographic examination of the I-MTCJ is critical to choosing an appropriate treatment algorithm for the surgical management of HV deformity. Many investigators think hypermobility arises secondarily from malalignment of the soft tissue constraints as the HV deformity progresses. Other investigators think hypermobility is a primary cause of the HV and have reported good results with surgical correction including a I-MTCJ arthrodesis.

According to a recent systematic review by Shibuya et al., there was a mean significant 3.62 mm increase of FR sagittal mobility in patients with HV compared with patients without it (75,83). Doty et al. demonstrate in a cadaveric study that dorsal motion using the Klaue device increased from 4.0 mm to 4.5 mm in specimens with mild to severe HV (48). However, it is still in discussion whether the FRM in patients with HV is the cause or the result of the deformity: in early reports, there was no consensus (41).

Regarding this dilemma, Coughlin and Jones (77) performed a prospective study on distal soft tissue reconstruction and proximal metatarsal osteotomy, showing a significant reduction of sagittal plane motion using a Klaue device. Correcting HV deformity and stabilizing sagittal plane motion without I-MTCJ arthrodesis, they concluded that FR instability is the result of the deformity and not the cause (41). The same conclusion was reached by Coughlin et al. (Table 2) using cadaver specimens, applying the identical procedure of the clinical prospective study (76).

Conclusions

From a clinical point of view, it is the belief of the authors that FRH should be assessed routinely in the clinical setting respecting both the triplane motion of FR and the 3-dimensional deformity of HV. To improve assessment, clinical practical tests without any sophisticated equipment, are necessary, even if their validity and reliability can be questionable. In the clinical context, manual tests and the use of a Klaue device or rulers are the easiest methods to implement

Table 2. Hallux Valgus and First Ray Hypermobility: the most recent literature

Authors	Procedure (if present)	Results	Device
Coughlin and Jones 2007	Proximal metatarsal osteotomy and distal soft tissue procedure alignment on hallux valgus patients (without MTC arthrodesis)	27 months of average follow up. Reduction from 7.2 mm to 4.5 mm after the procedure.	Klaue device
Kim et al. 2008	Proximal metatarsal Chevron osteotomy with distal soft tissue procedure in hallux valgus deformity correction with patient having first ray hypermobility	Mean dorsiflexion mobility of the first ray preoperatively was 6.8 mm and 1 year post-operatively was 3.2 mm.	Klaue device
Ellington et al. 2011	Lapidus procedure in feet with recurrent hallux valgus	Preoperative evaluation revealed 96% of patients with clinical hypermobility and radiological finding of instability in 52% of patients. Lapidus procedure is recommended in case of HV recurrence.	Clinical and Radiographic Coleman block test (for sagittal motion) and radiographic squeeze test (for transverse motion)
Singh et al. 2016	No intervention	First ray displacement in hallux valgus patients 11.0 in the 45° dorsal medial direction compared to 8.3 mm in control group.	Klaue device
Gent et al. 2015	No intervention	During body weight-bearing conditions, the first MTC-J in HV feet dorsiflexed an average of 2.91°, versus 1.18° in controls; supinated 2.17° versus 0.98° in controls; and internally rotated 2.65° versus 0.96° in controls. Moreover, the joint in HV feet widened significantly compared with the controls and tended to translate more in the dorsal-plantar direction.	3D models were reconstructed from CT scan in both unloaded and weight-bearing conditions
Stiglitz et al. 2019	No intervention	Both inter- and intra-observer reliability was strong for all measured parameters. Dynamic ultrasound test is simple and reproducible to assess MTC gaping distance.	Dynamic ultrasound test

FRM measures, better at 45° in the transverse plane to respect the FR biomechanics.

In relation to HV surgical correction, the original or modified Lapidus procedures are still valid to improve medial column stability. However, the historical theories seem to lack consensus in the recent literature regarding its exclusive role in correction of HV deformity and hypermobility, as also other more recent procedures seem to provide good outcomes for both.

Finally, only by implementing the measurement of FRM during clinical practice and its pre- and post-operative evaluations for the several HV techniques, will it be possible to come to the definitive conclusion whether FRH is the cause or consequence of the HV deformity. In the meantime, it remains academically controversial.

Authors' contribution

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and all authors are in agreement with the manuscript.

C.B., E.M., G.M.: study concept and design; writing/review/editing of manuscript;

E.M. and G.M.: literature research and data collection;

C.B. and J.T.: analysis, interpretation and discussion of literature research;

P.R.: final approval of the version to be published.

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References

1. Voellmicke K V, Deland JT. Manual examination technique to assess dorsal instability of the first ray. Foot ankle Int. 2002 Nov 17;23(11):1040–1.
2. Glasoe WM, Allen MK, Saltzman CL, Ludewig PM, Sublett SH. Comparison of Two Methods Used to Assess First-Ray Mobility. Foot Ankle Int. 2002 Mar 28;23(3):248–52.
3. Morton DJ. Hypermobility of the first metatarsal bone: the interlinking factor between metatarsalgia and longitudinal arch strains. JBJS. 1928;Volume 10(Issue 2):p 187–196.
4. Lapidus PW. The operative correction of the metatarsus primus varus in hallux valgus. Surg Gynecol Obs. 1934;183–91.
5. Lapidus PW. A quarter of a century of experience with the operative correction of the metatarsus varus primus in hallux valgus. Bull Hosp Joint Dis. 1956 Oct;17(2):404–21.
6. Lapidus PW. The author's bunion operation from 1931 to 1959. Clin Orthop Relat Res. 1960;16:119–35.
7. Courriades H. L' hypermobilite du premier rayon. Podologie. 1971;6:146–53.
8. Rodgers MM PC. A device for the measurement of first ray mobility. Proc North Am Congr Biomech. 1986;
9. Romash MM, Fugate D, Yanklowit B. Passive Motion of the First Metatarsal Cuneiform Joint: Preoperative Assessment. Foot Ankle. 1990 Jun 30;10(6):293–8.
10. Klaue K, Hansen ST, Masquelet AC. Clinical, Quantitative Assessment of First Tarsometatarsal Mobility in the Sagittal Plane and Its Relation to Hallux Valgus Deformity. Foot Ankle Int. 1994 Jan 17;15(1):9–13.
11. Faber FWM, Kleinrensink GJ, Mulder PGH, Verhaar JAN. Mobility of the First Tarsometatarsal Joint in Hallux Valgus Patients: A Radiographic Analysis. Foot Ankle Int. 2001 Dec 28;22(12):965–9.
12. Faber FWM, Mulder PGH, Verhaar JAN. Role of First Ray Hypermobility in the Outcome of the Hohmann and the Lapidus Procedure. J Bone Jt Surg. 2004 Mar;86(3): 486–95.
13. Fraser JJ, Koldenhoven RM, Saliba SA, Hertel J. Reliability of ankle-foot morphology, mobility, strength and motor performance measures. Int J Sports Phys Ther. 2017 Dec;12(7):1134–49.
14. Geng X, Wang C, Ma X, Wang X, Huang J, Zhang C, et al. Mobility of the first metatarsal-cuneiform joint in patients with and without hallux valgus: in vivo three-dimensional analysis using computerized tomography scan. J Orthop Surg Res. 2015 Dec 15;10(1):140.
15. Fraser JJ, Koldenhoven RM, Jaffri AH, Park JS, Saliba SF, Hart JM, et al. Foot impairments contribute to functional limitation in individuals with ankle sprain and chronic ankle instability. Knee Surgery, Sport Traumatol Arthrosc. 2020 May 6;28(5):1600–10.
16. Glasoe WM, Yack J, Saltzman CL. The Reliability and Validity of a First Ray Measurement Device. Foot Ankle Int. 2000 Mar 28;21(3):240–6.
17. Singh D, Biz C, Corradin M, Favero L. Comparison of dorsal and dorsomedial displacement in evaluation of first ray hypermobility in feet with and without hallux valgus. Foot Ankle Surg. 2016 Jun;22(2):120–4.
18. Faber FWM, Kleinrensink G-J, Verhoog MW, Vijn AH, Snijders CJ, Mulder PGH, et al. Mobility of the First Tarsometatarsal Joint in Relation to Hallux Valgus Deformity: Anatomical and Biomechanical Aspects. Foot Ankle Int. 1999 Oct 28;20(10):651–6.
19. Glasoe WM, Coughlin MJ. A Critical Analysis of Dudley Morton's Concept of Disordered Foot Function. J Foot Ankle Surg. 2006 May;45(3):147–55.
20. Roukis TS, Landsman AS. Hypermobility of the first ray: a critical review of the literature. J Foot Ankle Surg. 2003 Nov;42(6):377–90.
21. Glasoe WM, Yack HJ, Saltzman CL. Anatomy and biomechanics of the first ray. Phys Ther. 1999 Sep;79(9):854–9.
22. Michaud TC. Human locomotion : the conservative management of gait-related disorders. Newton Biomechanics; 2011. 412 p.
23. Michaud TC, Nawoczenski DA. The Influence of Two Different Types of Foot Orthoses on First Metatarsophalangeal Joint Kinematics During Gait in a Single Subject. J Manipulative Physiol Ther. 2006 Jan;29(1):60–5.
24. Michaud TC. Foot orthoses and other forms of conservative foot care. Baltimore: Williams & Wilkins; 1993. 249 p.
25. Glasoe WM, Michaud TC. Measurement of Dorsal First Ray Mobility: A Topical Historical Review and Commentary. Foot Ankle Int. 2019 May 22;40(5):603–10.
26. Greisberg J, Sperber L, Prince DE. Mobility of the First Ray in Various Foot Disorders. Foot ankle Int. 2012; 33(1).
27. Seng C, Chunyin Ho D, Chong KW. Restoring Sesamoid Position in Scarf Osteotomy: A Learning Curve. J Foot Ankle Surg. 2015 Nov;54(6):1089–92.
28. Chen JY, Rikhraj K, Gatot C, Lee JYY, Singh Rikhraj I. Tibial Sesamoid Position Influence on Functional Outcome and Satisfaction After Hallux Valgus Surgery. Foot Ankle Int. 2016 Nov 20;37(11):1178–82.
29. de Cesar Netto C, Richter M. Use of Advanced Weightbearing Imaging in Evaluation of Hallux Valgus. Foot Ankle Clin. 2020 Mar;25(1):31–45.
30. Kelso S, Richie D, Cohen I, Weed J, Root M. Direction and range of motion of the first ray. J Am Podiatr Med Assoc. 1982 Dec;72(12):600–5.
31. D'Amico JC, Schuster RO. Motion of the first ray: clarification through investigation. J Am Podiatry Assoc. 1979 Jan 1;69(1):17–23.
32. Hicks JH. The mechanics of the foot. I. The joints. J Anat. 1953 Oct;87(4):345–57.
33. Mizel MS. The role of the plantar first metatarsal first cuneiform ligament in weightbearing on the first metatarsal.

Foot Ankle. 1993 Feb 17;14(2):82–4.
34. Doty JF, Harris WT. Hallux Valgus Deformity and Treatment. Foot Ankle Clin. 2018 Jun;23(2):271–80.
36. Sarrafian SK. Functional Characteristics of the Foot and Plantar Aponeurosis under Tibiotalar Loading. Foot Ankle. 1987 Aug 30;8(1):4–18.
36. Grebing BR, Coughlin MJ. The Effect of Ankle Position on the Exam for First Ray Mobility. Foot Ankle Int. 2004 Jul 28;25(7):467–75.
37. Doty JF, Coughlin MJ. Hallux valgus and hypermobility of the first ray: facts and fiction. Int Orthop. 2013 Sep;37(9):1655–60.
38. Please change into: Alfieri Montrasio U, Corbo V, Mangiavini L, Palmucci M. Is it still current to talk about first ray hypermobility? Acta Bio Medica Atenei Parm. 2019;90(Suppl 1):32.
39. DiGiovanni CW, Greisberg J. Foot and ankle : core knowledge in orthopaedics. Elsevier Mosby; 2007. 394 p.
40. Rolian C, Lieberman DE, Hallgrímsson B. TThe Coevolution of Human Hands and Feet. Evolution (N Y). 2010 Jun 1;64(6):1558–68.
41. Van Beek C, Greisberg J. Mobility of the First Ray: Review Article. Foot Ankle Int. 2011 Sep;32(9):917–22.
42. Dullaert K, Hagen J, Klos K, Gueorguiev B, Lenz M, Richards RG, et al. The influence of the Peroneus Longus muscle on the foot under axial loading: A CT evaluated dynamic cadaveric model study. Clin Biomech (Bristol, Avon). 2016 May;34:7–11.
43. Wanivenhaus A, Pretterklieber M. First Tarsometatarsal Joint: Anatomical Biomechanical Study. Foot Ankle. 1989 Feb;9(4):153–7.
44. Merton L. Root, John H. Weed WPO. Normal and Abnormal Function of the Foot - Clinical Biomechanics Volume II -. Clinical Biomechanics Corp:Los Angeles, CA U, editor. 1977.
45. Tavara-Vidalón SP, Monge-Vera MÁ, Lafuente-Sotillos G, Domínguez-Maldonado G, Munuera-Martínez P V. Static Range of Motion of the First Metatarsal in the Sagittal and Frontal Planes. J Clin Med. 2018 Nov 21;7(11).
46. Glasoe WM, Allen MK, Saltzman CL. First Ray Dorsal Monility in Relation to Hallux Vlagus Deformity and First Intermetatarsal Angle. Foot Ankle Int. 2001 Feb 14;22(2):98–101.
47. Kim J-Y, Hwang SK, Lee KT, Young K won, Jung JS. A Simpler Device for Measuring the Mobility of the First Ray of the Foot. Foot Ankle Int. 2008 Feb;29(2):213–8.
48. Doty JF, Coughlin MJ, Hirose C, Stevens F, Schutt S, Kennedy M, et al. First Metatarsocuneiform Joint Mobility. Foot Ankle Int. 2014 May 21;35(5):504–11.
49. Coughlin MJ, Shurnas PS. Hallux Valgus in Men Part II: First Ray Mobility after Bunionectomy and Factors Associated with Hallux Valgus Deformity. Foot Ankle Int. 2003 Jan 28;24(1):73–8.
50. Roling BA, Christensen JC, Johnson CH. Biomechanics of the first ray. Part IV: The effect of selected medial column arthrodeses. A three-dimensional kinematic analysis in a cadaver model. J Foot Ankle Surg. 2002 Sep;41(5):278–85.
51. Kawakami W, Takahashi M, Iwamoto Y, Shinakoda K. Coordination Among Shank, Rearfoot, Midfoot, and Forefoot Kinematic Movement During Gait in Individuals With Hallux Valgus. J Appl Biomech. 2019 Feb;35(1):44–51.
52. Geng X, Wang C, Ma X, Wang X, Huang J, Zhang C, et al. Mobility of the first metatarsal-cuneiform joint in patients with and without hallux valgus: in vivo three-dimensional analysis using computerized tomography scan. J Orthop Surg Res. 2015 Sep 15;10(1):140.
53. Greisberg J, Assal M, Hansen ST, Sangeorzan BJ. Isolated Medial Column Stabilization Improves Alignment in Adult-acquired Flatfoot. Clin Orthop Relat Res. 2005 Jun;NA;(435):197–202.
54. Cowie S, Parsons S, Scammell B, McKenzie J. Hypermobility of the first ray in patients with planovalgus feet and tarsometatarsal osteoarthritis. Foot Ankle Surg. 2012 Dec;18(4):237–40.
55. Heng ML, Krishnasamy P, Kong PW. First ray mobility and posterior tibial tendon dysfunction (PTTD) in persons with flatfoot: A case control study. Foot. 2018 Dec;37: 57–60.
56. Cornwall MW, Fishco WD, McPoil TG, Lane CR, O'Donnell D, Hunt L. Reliability and validity of clinically assessing first-ray mobility of the foot. J Am Podiatr Med Assoc. 2004;94(5):470–6.
57. Tavara-Vidalón SP, Monge-Vera MÁ, Lafuente-Sotillos G, Domínguez-Maldonado G, Munuera-Martínez P V. Static Range of Motion of the First Metatarsal in the Sagittal and Frontal Planes. J Clin Med. 2018;7(11).
58. TE K, WA W. First metatarsal head shape in juvenile hallux abducto valgus. J Foot Surg. 1991 Sep 1;30(5):506–8.
59. Greisberg J, Prince D, Sperber L. First Ray Mobility Increase in Patients With Metatarsalgia. Foot Ankle Int. 2010 Nov;31(11):954–8.
60. Glasoe WM, Allen MK, Yack HJ. Measurement of Dorsal Mobility in the First Ray: Elimination of Fat Pad Compression as a Variable. Foot Ankle Int. 1998 Aug 17;19(8).
61. Glasoe WM, Getsoian S, Myers M, Komnick M, Kolkebeck D, Oswald W, et al. Criterion-Related Validity of a Clinical Measure of Dorsal First Ray Mobility. J Orthop Sport Phys Ther. 2005 Sep;35(9):589–93.
62. Fritz GR, Prieskorn D. First Metatarsocuneiform Motion: A Radiographic and Statistical Analysis. Foot Ankle Int. 1995 Mar 28;16(3):117–23.
63. Cruz FD. Literature Review of Hypermobile First Ray. North Ohio Foot Ankle J 3 3. 2016;
64. Martin H, Bahlke U, Dietze A, Zschorlich V, Schmitz K-P, Mittlmeier T. Investigation of first ray mobility during gait by kinematic fluoroscopic imaging-a novel method. BMC Musculoskelet Disord. 2012 Dec 9;13(1):14.
65. Kimura T, Kubota M, Suzuki N, Hattori A, Marumo K. Comparison of Intercuneiform 1-2 Joint Mobility Between Hallux Valgus and Normal Feet Using Weightbearing Computed Tomography and 3-Dimensional Analysis. Foot Ankle Int. 2018 Mar 4;39(3):355–60.
66. Swanson JE, Stoltman MG, Oyen CR, Mohrbacher JA,

Orandi A, Olson JM, et al. Comparison of 2D-3D Measurements of Hallux and First Ray Sagittal Motion in Patients With and Without Hallux Valgus. Foot Ankle Int. 2016 Feb 8;37(2):227–32.
67. Stiglitz Y, Cazeau C, Klouche S, Bauer T. Reliability of a new dynamic ultrasound test for quantifying first-ray mobility. Orthop Traumatol Surg Res. 2019 Oct;105(6): 1131–6.
68. Bednarz PA, Manoli A. Modified Lapidus Procedure for the Treatment of Hypermobile Hallux Valgus. Foot Ankle Int. 2000 Oct 26;21(10):816–21.
69. Lee KT, Young K. Measurement of first-ray mobility in normal vs. hallux valgus patients. Foot ankle Int. 2001 Dec 28;22(12):960–4.
70. Smith BW, Coughlin MJ. The first metatarsocuneiform joint, hypermobility, and hallux valgus: What does it all mean? Foot Ankle Surg. 2008 Jan;14(3):138–41.
71. Nix S, Smith M, Vicenzino B. Prevalence of hallux valgus in the general population: a systematic review and meta-analysis. J Foot Ankle Res. 2010 Dec 27;3(1):21.
72. Mansur NSB, de Souza Nery CA. Hypermobility in Hallux Valgus. Foot Ankle Clin. 2020 Mar;25(1):1–17.
73. Davenport KL, Simmel L, Kadel N. Hallux Valgus in Dancers: A Closer Look at Dance Technique and Its Impact on Dancers' Feet. J Danc Med Sci. 2014 Jun 15;18(2):86–92.
74. Biz C, Favero L, Stecco C, Aldegheri R. Hypermobility of the first ray in ballet dancer. Muscles Ligaments Tendons J. 2012 Oct;2(4):282–8.
75. Shibuya N, Roukis TS, Jupiter DC. Mobility of the First Ray in Patients With or Without Hallux Valgus Deformity: Systematic Review and Meta-Analysis. J Foot Ankle Surg. 2017 Sep;56(5).
76. Coughlin MJ, Jones CP, Viladot R, Glanó P, Grebing BR, Kennedy MJ, et al. Hallux Valgus and First Ray Mobility: A Cadaveric Study. Foot Ankle Int. 2004 Aug;25(8):537–44.
77. Coughlin MJ, Jones CP. Hallux Valgus and First Ray Mobility. A prospective study. J Bone Jt Surg. 2007 Sep;89(9):1887–98.
78. Coughlin MJ, Grebing BR, Jones CP. Arthrodesis of the First Metatarsophalangeal Joint for Idiopathic Hallux Valgus: Intermediate Results. Foot Ankle Int. 2005 Oct 28;26(10):783–92.
79. Kim J-Y, Park JS, Hwang SK, Young KW, Sung IH. Mobility changes of the first ray after hallux valgus surgery: clinical results after proximal metatarsal chevron osteotomy and distal soft tissue procedure. Foot ankle Int. 2008 May;29(5):468–72.
80. Ellington JK, Myerson MS, Coetzee JC, Stone RM. The Use of the Lapidus Procedure for Recurrent Hallux Valgus. Foot Ankle Int. 2011 Jul;32(7):674–80.
81. Rush SM, Christensen JC, Johnson CH. Biomechanics of the first ray. Part II: Metatarsus primus varus as a cause of hypermobility. A three-dimensional kinematic analysis in a cadaver model. J Foot Ankle Surg. 2000 Mar;39(2):68–77.
82. Myerson M, Kadakia AR, Preceded by: Myerson M. Reconstructive foot and ankle surgery : management of complications. 3rd edition. Elsevier, editor. 2018. 13–26 p.
83. Li S, Myerson MS. Evolution of Thinking of the Lapidus Procedure and Fixation. Foot Ankle Clin. 2020 Mar;25(1):109–26.
84. Galli MM, McAlister JE, Berlet GC, Hyer CF. Enhanced Lapidus Arthrodesis: Crossed Screw Technique With Middle Cuneiform Fixation Further Reduces Sagittal Mobility. J Foot Ankle Surg. 2015 May;54(3):437–40.
85. Blackwood S, Gossett L. Hallux Valgus/Medial Column Instability and Their Relationship with Posterior Tibial Tendon Dysfunction. Foot Ankle Clin. 2018 Jun;23(2): 297–313.
86. Willegger M, Holinka J, Ristl R, Wanivenhaus AH, Windhager R, Schuh R. Correction power and complications of first tarsometatarsal joint arthrodesis for hallux valgus deformity. Int Orthop. 2015 Mar 28;39(3):467–76.

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Review

The effectiveness of shoe modifications and orthotics in the conservative treatment of Civinini-Morton syndrome: state of art

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Summary. Civinini Morton's Syndrome (CMS), better known as Morton's Neuroma, is a benign enlargement that typically affects the third common digital branch of the plantar nerve. It is a common cause of metatarsalgia leading to debilitating pain. It prefers the female gender, with a female to male ratio of 5:1 and an average age of 50 years at time of surgery. Precise aetiology remains under debate, with four etiopathogenetic theories often cited in the literature. Clinical symptoms, physical exam and instrumental evidence are important in assessing and grading the disease. Biomechanics seem to play an important role, especially regarding the usefulness of correct footwear. The first approach in the early stages of this condition usually begins with shoe modifications and orthotics, designed to limit the nerve compression. In order to prevent or delay the development of CMS, shoes should be sufficiently long, comfortable, broad toe-boxed, should bear a flat heel and a sufficiently thick external sole which should not be excessively flexible. Most authors suggested that an insole with medial arch support and a retrocapital bar or pad, just proximal to the metatarsal heads, displaces the pressure sites and can be beneficial to relieve the pain from the pinched nerve. A threshold period of 4.5 months appears to emerge from the results of the analysed studies, indicating that, beyond this period and in neuromas larger than 5-6 mm, orthotics and/or shoes modifications do not seem to give convincing results, proving to be more a palliation for the clinical condition to allow an acceptable life with pain rather than a real treatment. (www.actabiomedica.it)

Key words: Morton neuroma; Conservative treatment; Civinini-Morton syndrome; Non-surgical treatment; Orthotics

Introduction

Civinini Morton's Syndrome (CMS), better known as Morton's Neuroma, is a benign enlargement that typically affects the third common digital branch of the plantar nerve (1).

The magnitude of the problem is still unknown, although the condition has documented predisposing factors. It affects about 30% of the population and prefers the female sex, with a female to male ratio of 5:1 (2) and an average age of 50 years at time of surgery (3).

The pathology is bilateral in 21% of cases, affects the third intermetatarsal space (IMS) in 66% of cases, the second in 32%, known as Hauser's Neuroma, and the fourth in 2%. Multiple locations are almost rare (1, 4).

It was first reported by Filippo Civinini in 1835 and later by Durlacher in 1845, who described it as a

neuralgic condition. Finally, in 1876 Thomas George Morton wrongly described the pathology as a subluxation of the fourth metatarsophalangeal (MTP) joint (5). Hoadley, in 1883, first excised an interdigital neuroma from the third IMS of a foot (6). In 1940, Betts introduced the notion of "neuroma" and compression of the plantar nerve below the intermetatarsal ligament (7).

Histology shows that it is not really a neuroma, but a perineural fibrosis with intraneural sclerohyalinosis (8); therefore, authors as Weinfield and Myerson proposed the more correct term of "interdigital neuritis" (9). Classical symptoms are a tingling and burning sensation in the forefoot with an irregular numbness in the affected toe (1). It is a common cause of metatarsalgia (10), along with hallux rigidus (11,12) and hallux valgus (13), in the overload typology.

Anatomy and pathophysiology

Neuroma consists of a bulge in the interdigital nerve just distal to the metatarsal transverse ligament and proximal to the forking of the digital nerves (Figure 1). Entrapment of the interdigital nerve between the intermetatarsal ligaments is the principal reason in the occurrence of CMS (14). Macroscopically it has a typically glossy fusiform shape, from white to yellowish appearance and a relatively soft texture (1). The common plantar digital nerves are final boughs of the medial and lateral plantar nerves passing in the IMS, under the intermetatarsal ligaments. Every common digital nerve goes through the plantar aponeurosis and splits into 2 branches supplying the plantar skin of the toes. Smaller ramifications give innervations to the adjacent metatarsals, MTP joints and plantar skin, under the metatarsal heads (15).

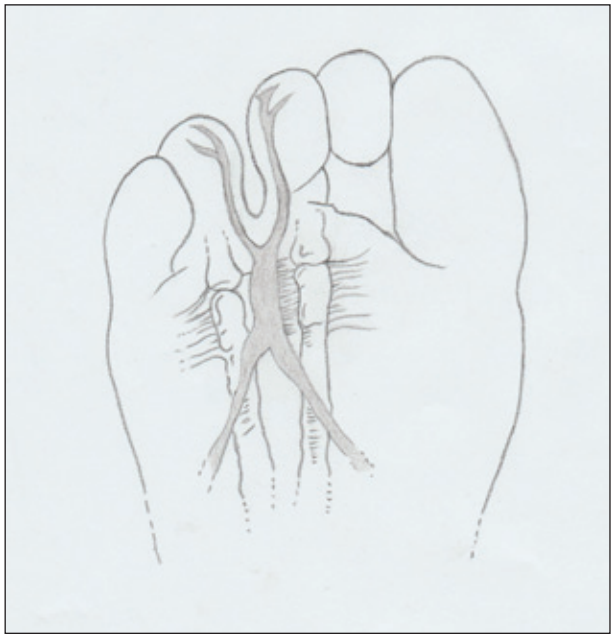

Fig.1 The schematic drawing of the neuroma in the typical third intermetatarsal space, just distal to the metatarsal transverse ligament and before the forking of the digital nerves.

Usually, the third common digital nerve, arising from the medial plantar nerve, receives a communicating bough from the lateral plantar nerve, which passes deep to the transverse metatarsal ligament. This is the narrowest space, and for that reason, the nerve there is less mobile during weight bearing. This might explain why it is a common location for the pathology (16). Female sex is usually the most affected, suggesting that the high heeled and tight footwear are contributing factors in the aetiology of this disorder (17).

The precise cause is still not clear. Until today, four etiopathogenetic theories have been propounded (18): chronic traction damage (16), inflammatory environment due to intermetatarsal bursitis (19), compression by the deep transverse intermetatarsal ligament (20) and ischemia of vasa nervorum (21).

Nevertheless, some of these biomechanical convictions are still debated. The sideboard that CMS should more commonly affected the third IMS in a more pronated foot, because of hyper mobility of the lateral column, is not supported anymore from the last studies. Even the rational hypothesis that subjects with a high body mass index (BMI) should increase pressure in the forefoot during the propulsive phase of walk, which could traumatize plantar IMS nerves, was not confirmed by recent studies on gait analysis. However, a strong association between CMS and restriction of ankle dorsiflexion was proved (22).

It was proposed that the common digital nerve of the third IMS is thicker than the others, as it is the result of an anastomosis between two nerve trunks (23). Another possible anatomical consideration is

the increased mobility of the fourth ray (moving on the cuboid), compared to the third (fixed to the cuneiform), which could predispose to inflammation. In addition, some authors affirm that the distal metatarsal transverse ligament may compress the interdigital nerve (24).

In this view, the use of high heels is another predisposing factor, as it can further increase compression on it (17). Finally, some studies also described trauma as a possible cause (25).

Signs and symptoms

When CMS is suspected, medical history and physical examination play a pivotal role in the diagnostic process. It is important to listen the patient's symptoms, often described in a very suggestive way. The foot inspection should search for the exact trigger points, distinguishing between intermetatarsal and metatarsal pain (1).

The typical symptom is a burning pain between the metatarsal heads, often radiating to the two corresponding toes, with cramps and hyperesthesia/dysesthesia (26). The pain is intense and so debilitating that the patients become afraid and anxious about walking or even putting their foot to the ground. The disorder is that of a severe, sharp, sometimes piercing pain that occurs abruptly while walking. At onset, relief of pain can be obtained by massaging the foot or manipulating the toes. In the worst cases, pain becomes debilitating and patients are timorous about walking. In other cases, patients describe milder symptoms of burning or tingling sensations (27).

Description is not always typical, and it is important to thoroughly interrogate the patient; it is to be underlined however, as a discriminating element, the disappearance of the pain at rest and the reappearance under weight-bearing. Pathognomonic of the syndrome is the so-called "sign of the shop window", a curious and picturesque expression used by some specialists (28) to indicate the urgent need to remove the shoe that covers the affected foot: the patient (frequently a woman), to be unnoticed in the manoeuvre, stops in front of a shop window pretending to observe it.

Diagnosis

Clinical evaluation

CMS evaluation is mostly clinical and requires an accurate physical examination, carried out with the patient in the supine position. On inspection, foot is apparently normal, with absence of any deformity. Rarely a diastasis of the digital fornix is not present, however it is a common sign to all pathologies that create tension in the IMS, such as bursitis and MTP capsulitis (28).

The shape of the forefoot, the sub-metatarsal plantar skin and the position of the toes are carefully assessed. The metatarsal motility, plantar and dorsal flexion of the MTP joints are gently tested. Then, the attention moves on to the palpatory exploration of the IMS, where a tenderness and a dorsal bulging with a possible enlargement of the IMS might be appreciated (1). It's very important to identify the pain, usually not located on the metatarsal heads, for a differential diagnosis (4). In these cases, it will be important to exclude other factors such as joint instabilities, forefoot conditions (first ray insufficiency, second metatarsal syndrome, bursitis), mid-hindfoot deformities (pes cavus), arthritis in the MTP joint, remote causes that act mechanically under the forefoot (retraction of gastrocnemius or Achilles tendon) or even to investigate some specific bone condition as Frieberg's disease (1).

In presence of an atypical presentations such as a localization in the second space or the presence of multiple "neuromas" on the same foot, a mechanical "overload" disorder must be ruled out (29).

To help give an accurate clinical evaluation, a full foot and ankle examination should be performed with particular attention to gait, footwear, over-pronation, sensory disturbances and soft-tissue changes (16).

Subsequently, an accurate examination of digital sensitivity should be performed, both with a pointed instrument and with a vibratory tuning fork. The vibratory sensitivity of the tip of the toe is generally the most compromised (30). A characteristic sign is the "numbness of the toes", when the opposite surfaces of the adjacent fingers show a reduced sensation (31); some authors call it "book page hypoesthesia" (28).

Various clinical tests are described in literature. The pressure can be practiced while tightening the

metatarsal heads with the other hand, and this may be associated with a painful and palpable "click" sensation (Mulder's sign) (29). This test demonstrated a 94–98% sensitivity (32). Another useful test is the "Thumb index finger squeeze" that appears to have the highest specificity and sensitivity (33).

Among provocative tests, Cloke and Greiss (34) described the "digital nerve stretch test" with 100% of sensitivity: the toes on either side of the affected IMS are passively fully extended, with the ankles in dorsiflexion and the foot on the examiner's knees. Discomfort or pain in the IMS of the affected foot indicates a positive result.

Other authors (29, 32, 35) describe a similar test, the "Lasègue sign of the toes", in which pain and hypoesthesia are evoked by forcing dorsal flexion of the toes and reduced by proximal interphalangeal joints flexion.

Imaging

As is often the case in medicine, the diagnosis of the disease is mainly clinical but rarely physical examination is considered sufficient; therefore, complementary exams are required. The most dependable method to clarify the diagnosis is a local anaesthetic injection, not always accepted by the patient (1).

X-rays appears to be essential as a first line imaging approach, to investigate other possible causes of metatarsalgia such as (36): tarsal–metatarsal joint stiffness, metatarsal hypermetria, Frieberg's disease, toe deformities and MTP instabilities. However, in order to eliminate possible doubts, sonographic (US) confirmation is usually the instrumental investigation mostly utilized (14), certainly reliable and easy to prescribe, as it is fast and inexpensive for the patient. The imaging must be carried out with plantar and back, transversal and longitudinal US scans with a 7.5 MHz high frequency probe. The neuroma appears as homogeneously hypoechoic mass, well recognizable by the adjacent hyperechoic fat and by the shadow of the metatarsal cortex. Shapiro (37) and Quinn (38) state a diagnostic reliability around 95% for lesions larger than 5 mm, being 2 mm the maximum limit of the normal nerve.

Currently, US should be performed with a dynamic technique (dynamic US), as proposed by Torriani (39) and then by Perini (40), recreating the "click" described by Mulder during the examination (29). The dynamic US would be very effective for recognizing masses larger than 3.5 mm using a 10MHz probe (40). The most recent studies appear to confirm that the high sensitivity of US (0.91) is equal to ($p = 0.88$) that of the Magnetic Resonance Imaging (MRI) (0.90) for identification of neuroma and its thickness (41). MRI offers additional advantages in the diagnosis of CMS, but it must be considered a second level investigation with the limit, as in the US, to recognize lesions smaller than 4 mm (42).

Certainly, MRI is superior in the differential diagnosis, for its sensitivity on pathologies such as stress fractures, capsulo-synovitis of the MTP, synovial articular forms, or other pathologies of the soft tissues such as lipomas, angiomas, tendon ganglia or connective malignancies of the forefoot (43). Main indications for MRI are unclear clinical assessment and cases when more than one IMS is affected (1). Finally, it must be bear in mind that a negative result does not exclude the diagnosis (false negative 17%) (44).

Shoe modifications

Shoe modifications and orthotics can play an important role in the nonsurgical management of forefoot pathology. Therapeutic footwear may improve patient gait and increase the level of ambulation; on the contrary, inadequate footwear can worsen the symptoms and be a contributing cause for the development of the pathology. (45).

Already in 1897 Bradford (46) noted alterations caused by incorrect shoes through an analysis of historical art. Nowadays, women's shoes continue to cause deformity and predispose to injury, even more so than in the past. Poorly fitting shoes are a major contributing factor to the difference in incidence of foot disorders between men and women, mostly for those over 61 years of age (47).

Traditionally, men's shoes tend to be wider and have lower heels than women's, and this could contribute to explain the different incidence of CMS in men compared to women, as described in some studies with a female-to-male ratio as high as 18 to 1 (48). As widely showed in pathophysiology, the prevalence of several musculoskeletal conditions in women are

largely the result of biomechanical changes caused by ill-fitting shoes. In particular, the altered biomechanics (associated with shoes with a narrowed toe box and high-heeled shoes) has been linked to the genesis of Freiberg disease, hallux valgus, Haglund's syndrome, hammer toe deformity, metatarsal stress fracture and, above all, CMS (17, 48).

Thus, the first approach in CMS should consist in patients' education to avoid narrow and high-heeled shoes (4). The objective of shoes modifications is to deliver the pressures uniformly over the sole of foot. Shoes should be sufficiently long, comfortable, broad toe-boxed, flat heeled and should bear a sufficiently thick external sole, not excessively flexible (Figure 2) (2). A rocker-bottom sole may be helpful (45). Some authors showed that footwear and padding may be successful in relieving symptoms in 32% of cases after a mean of 4.5 months (17, 49) but they seem to achieve lower satisfaction rates when compared with other more invasive methods such as steroid injections (50).

In most cases, clinicians will also have to educate the patient on lifestyle changes, such as losing weight and starting a regular physical activity; both being useful in most pathologies (51, 52).

Orthotics

Over the years, numerous studies have been carried out to highlight the different effects of plantar inserts for the foot comfort. Robbins and Gouw in 1991 (53) proposed that surface irregularities should be added to the insoles of running shoes to improve correct sensory inputs. In 1993,

Fig. 2 Predisposed and comfortable shoe for orthotics, with a round toe-box and slight heel.

Villeneuve (54) used a small insert to maintain postural equilibrium, by stimulating the mechanoreceptors in the plantar surface of the foot. Hayda et al. (55), the following year, found that placing a pad just proximal to the metatarsal heads provided significant reductions in forefoot plantar pressures around the first and second metatarsal heads. Burgess in 1997 (56) evaluated a series of 10 non-pathological male patients during walking, after one day wearing a pair of oxfords (hard) and running shoes (soft), containing an insert of 4 mm in height placed on a 0.8 mm EVA insole. He noted that the insert was successful in both shifting peak pressures from the medial to the lateral forefoot, whilst reducing peak pressures simultaneously. This was only evident in the hard shoe condition however, suggesting that the footbed of the running shoe was perhaps too soft to allow the insert to influence sensory input sufficiently.

More recent studies show that the perceived feel is best using wedge angles of 4 degrees and 5 degrees at a heel height of 25 mm, 10 degrees and 11 degrees at a heel height of 50 mm and 16 degrees and 18 degrees at a heel height of 75 mm (57).

Footbed shapes appear then to be essential to enhanced footwear comfort, regardless of the underlying disease. Thus, when footwear modifications alone are not enough, custom-made insoles could be designed to correct hindfoot malalignments as varus or valgus, support the medial arch, transfer the pressure just proximal to the metatarsal heads, and reduce the weights on pressure sites.

By decreasing metatarsal head loading and redeploying plantar pressures in a harmonious manner (58, 59), insoles, in selected cases, may alleviate forefoot problems (60).

In the case of CMS, some authors prefers a custom orthotics through foam impression methods, in a neutral subtalar position, with a prolonged longitudinal vault to support the first metatarsal, with a flat metatarsal support (without olive or bar), in order to favor the physiological pattern of the metatarsal weight bearing, from lateral to medial, before the pressure on the big toe (28).

Other authors suggested that a retrocapital bar or pad, just proximal to the metatarsal heads displaces the pressure sites and can be beneficial for symptoms

(Figure 3). Metatarsal padding helps to spread and cushion metatarsal heads to relieve the pain from the pinched nerve. If needed, a cup can be added beneath the painful metatarsal head or heads. Custom-made toe inserts modeled in silicone rubber can be added in patients having associated claw-toe deformity (Figure 4) (60, 61).

Bennett (17) reports that 41% of patients treated conservatively (shoes suitable for extra volume, unloading orthoses, soft metatarsal pads) demonstrate significant improvements with these non-invasive procedures. However, other authors (28) declare that these treatments, in case of CMS confirmed by "imaging" and larger than 5-6 mm, do not seem to give convincing results, proving them to be more a clinical condition to live acceptably with pain rather than a real treatment.

Figure 3. Insole with medial arch support, retrocapital bar just proximal to the metatarsal heads with targeted shock absorber insert in third intermetatarsal space.

Figure 4. Custom-made toe insert modeled in silicone rubber added in patient affected by Civinini-Morton syndrome and associated with claw deformity of the third toe.

Kilmartin (62) examined 21 patients and states that pain associated with CMS was not significantly altered by changing the position of the foot with the compressed felt orthosis (14% of cases).

Notwithstanding, this has not been confirmed by latest studies. De Oliveira (63) in his randomized, controlled, double-blind clinical trial analyzed 72 patients and proved that customized insole with metatarsal and arch support relieved pain during walking ($P = 0.048$) and improved patient-reported measures of function (in general health domains ($P < 0.001$) and physical activity ($P = 0.025$)).

In any cases, when modifications fail or if affected individuals are no longer willing to make adjustments to their lifestyle or shoe wear (64, 65), patients may always choose to undergo surgery or other non-operative treatments such as US guided percutaneous radiofrequency (66), alcohol or corticosteroids injection and percutaneous electrostimulation-guided alcoholization with phenol (67-69).

Conclusion

During the years, many therapies have been utilized to treat symptomatic CMS. Among conservative treatments, orthotics and shoes modifications have been used to off-load the forefoot and thus reduce pain from weight-bearing pressure. In order to prevent or retard the development of CMS, shoes should be sufficiently long, comfortable, broad toe-boxed, they should have a flat heel and a sufficiently thick external sole that is not excessively flexible.

A threshold period of 4.5 months appears to emerge from the results of the studies, indicating that beyond this period and in larger neuromas than 5-6 mm, orthotics and/or shoes modification do not seem to give convincing results, proving to be more a clinical condition for living acceptably with pain than a real treatment.

Despite this, use of orthotics may be considered a safe and rational treatment before more invasive interventions, without any complications. Notwithstanding a good quality of the selected articles, further studies with a longer follow-up period and high quality randomized controlled trials are needed to provide more solid and accurate proofs.

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References

1. Di Caprio F, Meringolo R, Shehab Eddine M, Ponziani L. Morton's interdigital neuroma of the foot: A literature review. Foot Ankle Surg. 2018 Apr;24(2):92–98. doi: 10.1016/j.fas.2017.01.007. Epub 2017 Feb 4.
2. Bradley N, Miller WA, Evans JP. Plantar neuroma: analysis of results following surgical excision in 145 patients. South Med J. 1976Jul;69(7):853–4.
3. Kasparek M, Schneider W. Surgical treatment of Morton's neuroma: clinical results after open excision. Int Orthop. 2013Sep;37(9):1857–61. doi: 10.1007/s00264-013-2002-6. Epub 2013 Jul 13.
4. Valisena S, Petri GJ, Ferrero A. Treatment of Morton's neuroma: A systematic review. Foot Ankle Surg. 2018 Aug;24(4):271–281. doi: 10.1016/j.fas.2017.03.010. Epub 2017 Apr 5.
5. Pisani G. Is it Morton's or Civinini's syndrome? Foot Ankle Surg. 2010 Sep;16(3):105–6. doi: 10.1016/j.fas.2009.07.006. Epub 2009 Sep 6.
6. Hoadley A. Six cases of metatarsalgia. Chicago Med Rec. 1893.5:32.
7. Delmi M. Métatarsalgies de Morton. In: Valtin B, Leemrijsee T, editors. Chirurgie de l'avant-pied. 2005. Cahiers d'enseignement de la SOFCOT. Paris: Elsevier.
8. Giannini S, Bacchini P, Ceccarelli F, Vannini F. Interdigital neuroma: clinical examination and histopathologic results in 63 cases treated with excision. Foot Ankle Int 2004 Feb;25(2):79–84.
9. Weinfeld SB, Myerson MS. Interdigital Neuritis: Diagnosis and Treatment. J Am Acad Orthop Surg. 1996 Nov;4(6):328–335.
10. Besse JL. Metatarsalgia. Orthop Traumatol Surg Res. 2017 Feb;103(1S):S29-S39. doi: 10.1016/j.otsr.2016.06.020. Epub 2017 Jan 18.
11. Colò G, Alessio-Mazzola M, Dagnino G, Felli L. Long-Term Results of Surgical Treatment of Valenti Procedures for Hallux Rigidus: A Minimum Ten-Year Follow-Up Retrospective Study. J Foot Ankle Surg. 2019 Mar; 58(2): 291–294. doi: 10.1053/j.jfas.2018.08.055.
12. Colò G, Samaila EM, Magnan B, Felli L. Valenti resection arthroplasty for hallux rigidus: A systematic review. Foot Ankle Surg. 2019 Dec 5. pii: S1268-7731(19)30209-7. doi: 10.1016/j.fas.2019.11.009. (Epub ahead of print)
13. Magnan B, Bortolazzi R, Samaila E, Pezzè L, Rossi N, Bartolozzi P. Percutaneous distal metatarsal osteotomy for correction of hallux valgus. Surgical technique. J Bone Joint Surg Am. 2006 Mar;88 Suppl 1 Pt 1:135–48.
14. Sofka CM, Adler RS, Ciavarra GA, Pavlov H. Ultrasound-guided interdigital neuroma injections: short-term clinical outcomes after a single percutaneous injection--preliminary results. HSS J 2007 Feb; 3(1):44–9. doi: 10.1007/s11420-006-9029-9.
15. Young G, Lindsey J. Etiology of symptomatic recurrent interdigital neuromas. J Am Podiatr Med Assoc. 1993 May;83(5):255–8.
16. Jain S, Mannan K. The diagnosis and management of Morton's neuroma: a literature review. Foot Ankle Spec. 2013 Aug;6(4):307–17. doi: 10.1177/1938640013493464. Epub 2013 Jun 27.
17. Bennett GL, Graham CE, Mauldin DM. Morton's interdigital neuroma: a comprehensive treatment protocol. Foot Ankle Int. 1995 Dec;16(12):760–3.
18. Hassouna H, Singh D. Morton's metatarsalgia: pathogenesis, aetiology and current management. Acta Orthop Belg. 2005 Dec;71(6):646–55.
19. Bossley CJ, Cairney PC. The intermetatarsophalangeal bursa--its significance in Morton's metatarsalgia. J Bone Joint Surg Br. 1980 May;62-B(2):184–7.
20. Gauthier G. Thomas Morton's disease: a nerve entrapment syndrome. A new surgical technique. Clin Orthop Relat Res. 1979 Jul-Aug; (142):90–2.
21. Nissen KI. Plantar digital neuritis; Morton's metatarsalgia. J Bone Joint Surg Br. 1948 Feb;30B(1):84–94.
22. Naraghi R, Bremner A, Slack-Smith L, Bryant A. The relationship between foot posture index, ankle equinus, body mass index and intermetatarsal neuroma. J Foot Ankle Res. 2016 Dec;9:46. eCollection 2016. doi: 10.1186/s13047-016-0179-9.
23. Diez EM, Mas SM, Pi JF, Aramburo F. Comparative results of two different techniques in the treatment of the Morton's neuroma. The Foot. 1999 Sep;9(3):134–7.
24. Alexander IJ, Johnson KA, Parr JW. Morton's neuroma: a review of recent concepts. Orthopedics. 1987 Jan;10(1): 103–6.
25. Litchman MH, Silver CM, Simon SD. Morton's metatarsalgia and its relationship to trauma. R I Med J. 1964 Jul;47:328–31.
26. Ruiz Santiago F, Prados Olleta N, Tomás Muñoz P, Guzmán Álvarez L, Martínez Martínez A. Short term comparison between blind and ultrasound guided injection in morton neuroma. Eur Radiol. 2019 Feb;29(2):620–627. doi: 10.1007/s00330-018-5670-1. Epub 2018 Jul 31.
27. Thomson CE, Gibson JN, Martin D. Interventions for the treatment of Morton's neuroma. Cochrane Database Syst Rev. 2004;(3):CD003118.
28. Volpe A. La sindrome di Morton. LO SCAL. 2011. 25, 60–73. doi: 10.1007/s11639-011-0098-2
29. Mulder JD. The causative mechanism in Morton's metatarsalgia. J Bone Joint Surg Br. 1951 Feb;33-B(1):94–5.
30. Jarde O. Morton's metatarsalgia. Foot Ankle Surg. 1998;4:187–191. doi: 10.1046/j.1460-9584.1998.00116.x

31. Gougoulias N, Lampridis V, Sakellariou A. Morton's interdigital neuroma: instructional review. EFORT Open Rev. 2019 Jan;4(1):14–24. doi: 10.1302/2058-5241.4.180025. eCollection 2019 Jan.
32. Pastides P, El-Sallakh S, Charalambides C. Morton's neuroma: A clinical versus radiological diagnosis. Foot Ankle Surg. 2012 Mar;18(1):22–4. doi: 10.1016/j.fas.2011.01.007. Epub 2011 Feb 16.
33. Thomas JL, Blitch EL 4th, Chaney DM, et al. Diagnosis and treatment of forefoot disorders. Section 3. Morton's intermetatarsal neuroma. J Foot Ankle Surg. 2009;48(2):251-6.
34. Cloke DJ, Greiss ME. (2006) The digital nerve stretch test: a sensitive indicator of Morton's neuroma and neuritis. Foot Ankle Surg. 2006;12:201-203. doi: 10.1016/j.fas.2006.04.002
35. Owens R, Gougoulias N, Guthrie H, Sakellariou A. (2011) Morton's neuroma: clinical testing and imaging in 76 feet, compared to a control group. Foot Ankle Surg. 2011 Sep;17(3):197–200. doi: 10.1016/j.fas.2010.07.002. Epub 2010 Sep 17.
36. Read JW, Noakes JB, Kerr D, Crichton KJ. Morton's metatarsalgia: sonographic findings and correlated histopathology. Foot Ankle Int. 1999 Mar;20(3):153–61.
37. Shapiro PP, Shapiro SL. Sonographic evaluation of interdigital neuromas. Foot Ankle Int. 1995 Oct;16(10):604–6.
38. Quinn TJ, Jacobson JA, Craig JG, van Holsbeeck MT. Sonography of Morton's neuromas. AJR Am J Roentgenol. 2000 Jun;174(6):1723–8.
39. Torriani M, Kattapuram SV. Technical innovation. Dynamic sonography of the forefoot: The sonographic Mulder sign. AJR Am J Roentgenol. 2003 Apr;180(4):1121–3.
40. Perini L, Del Borrello M, Cipriano R, Cavallo A, Volpe A. (2006) Dynamic sonography of the forefoot in Morton's syndrome: correlation with magnetic resonance and surgery. Radiol Med. 2006 Oct;111(7):897–905. Epub 2006 Oct 11.
41. Bignotti B, Signori A, Sormani MP, Molfetta L, Martinoli C, Tagliafico A. (2015) Ultrasound versus magnetic resonance imaging for Morton neuroma: systematic review and meta-analysis. Eur Radiol. 2015 Aug;25(8):2254–62. doi: 10.1007/s00330-015-3633-3. Epub 2015 Mar 26.
42. Sharp RJ, Wade CM, Hennessy MS, Saxby TS. The role of MRI and ultrasound imaging in Morton's neuroma and the effect of size of lesion on symptoms. J Bone Joint Surg Br. 2003 Sep;85(7):999–1005.
43. Zanetti M, Strehle JK, Kundert HP, Zollinger H, Hodler J. Morton neuroma: effect of MR imaging findings on diagnostic thinking and therapeutic decisions. Radiology. 1999 Nov;213(2):583–8.
44. Torres-Claramunt R, Ginés A, Pidemunt G, Puig L, De Zabala S. MRI and ultrasonography in Morton's neuroma: Diagnostic accuracy and correlation. Indian J Orthop. 2012 May;46(3):321–5. doi: 10.4103/0019-5413.96390.
45. Janisse DJ, Janisse E. Shoe modification and the use of orthoses in the treatment of foot and ankle pathology. J Am Acad Orthop Surg. 2008 Mar;16(3):152–8.
46. Bradford EH. The human foot in art. J Bone Joint Surg Am. 1897;s1- s10:148–161
47. Frey C. Foot health and shoewear for women. Clin Orthop Relat Res. 2000 Mar;(372):32–44.
48. Goud A, Khurana B, Chiodo C, Weissman BN. Women's musculoskeletal foot conditions exacerbated by shoe wear: an imaging perspective. Am J Orthop (Belle Mead NJ). 2011 Apr;40(4):183–91.
49. Saygi B, Yildirim Y, Saygi EK, Kara H, Esemenli T. Morton neuroma: comparative results of two conservative methods. Foot Ankle Int. 2005 Jul;26(7):556–9.
50. Park HJ, Kim SS, Rho MH, Hong HP, Lee SY. Sonographic appearances of Morton's neuroma: differences from other interdigital soft tissue masses. Ultrasound Med Biol. 2011 Aug;37(8):1204–9. doi: 10.1016/j.ultrasmedbio.2011.05.008. Epub 2011 Jun 16.
51. Colò G, Massarini M, Cavagnaro L, Felli L, Ferracini R. Exercise therapy indications in metastatic bone patients. Minerva Ortop e Traumatol. 2020;71: 000–000 DOI: 10.23736/S0394-3410.19.03960-2.
52. Colò G, Cavagnaro L, Alessio-Mazzola M, Zanirato A, Felli L, Formica M. Incidence, diagnosis and management of sacroiliitis after spinal surgery: a systematic review of the literature. Musculoskelet Surg. 2019 May 7. doi: 10.1007/s12306-019-00607-0. [Epub ahead of print]
53. Robbins SE, Gouw GJ. Athletic footwear: unsafe due to perceptual illusions. Med Sci Sports Exerc. 1991 Feb;23(2):217–24.
54. Villeneuve, P. Foot and posture. 1993. In 3rd European and First World Congress of Podiatry Programme, p. 14.
55. Hayda R, Tremaine MD, Tremaine K, Banco S, Teed K. Effect of metatarsal pads and their positioning: a quantitative assessment. Foot Ankle Int. 1994 Oct;15(10):561–6.
56. Burgess S, Jordan C, Bartlett R. The influence of a small insert, in the footbed of a shoe, upon plantar pressure distribution. Clin Biomech (Bristol, Avon). 1997 Apr;12(3): S5-S6.
57. Witana CP, Goonetilleke RS, Au EY, Xiong S, Lu X. Footbed shapes for enhanced footwear comfort. Ergonomics. 2009 May;52(5):617–28. doi: 10.1080/00140130802419503.
58. Chang AH, Abu-Faraj ZU, Harris GF, Nery J, Shereff MJ. Multistep measurement of plantar pressure alterations using metatarsal pads. Foot Ankle Int. 1994 Dec;15(12):654–60.
59. Holmes Jr GB, Timmerman L. A quantitative assessment of the effect of metatarsal pads on plantar pressures. Foot Ankle. 1990 Dec;11(3):141–5.
60. Kang JH, Chen MD, Chen SC, Hsi WL. Correlations between subjective treatment responses and plantar pressure parameters of metatarsal pad treatment in metatarsalgia patients: a prospective study. BMC Musculoskelet Disord. 2006 Dec 5;7:95.
61. Hinz A. Nerve disorders. In: DiGiovanni CW, Greisberg J, editors. Foot and ankle: core knowledge in orthopaedics. Philadelphia: Elsevier Mosby; 2007. p. 171–6.
62. Kilmartin TE, Wallace WA. Effect of pronation and supination orthosis on Morton's neuroma and lower extremity

function. Foot Ankle Int. 1994 May;15(5):256–62.
63. de Oliveira HAV, Natour J, Vassalli M, Rosenfeld A, Jennings F, Jones A. Effectiveness of customized insoles in patients with Morton's neuroma: a randomized, controlled, double-blind clinical trial. Clin Rehabil. 2019 Dec;33(12):1898–1907. doi: 10.1177/0269215519873949. Epub 2019 Sep 11.
64. DiPreta JA. Metatarsalgia, lesser toe deformities, and associated disorders of the forefoot. Med Clin North Am. 2014 Mar;98(2):233–51. doi: 10.1016/j.mcna.2013.10.003. Epub 2013 Dec 10.
65. Mischitz M, Zeitlinger S, Mischlinger J, Rab M. Nerve decompression according to A.L. Dellon in Morton's neuroma - A retrospective analysis. J Plast Reconstr Aesthet Surg. 2020 Jan 22. pii: S1748–6815(20)30027-9. doi: 10.1016/j.bjps.2020.01.008. [Epub ahead of print]
66. Masala S, Cuzzolino A, Morini M, Raguso M, Fiori R. Ultrasound-Guided Percutaneous Radiofrequency for the Treatment of Morton's Neuroma. Cardiovasc Intervent Radiol. 2018 Jan;41(1):137–144. doi: 10.1007/s00270-017-1786-y. Epub 2017 Sep 27.
67. Perini L, Perini C, Tagliapietra M, et al. Percutaneous alcohol injection under sonographic guidance in Morton's neuroma: follow-up in 220 treated lesions. Radiol Med. 2016 Jul;121(7):597–604. doi: 10.1007/s11547-016-0622-9. Epub 2016 Feb 16.
68. Samaila EM, Ambrosini C, Negri S, Maluta T, Valentini R, Magnan B. Can percutaneous alcoholization of Morton's neuroma with phenol by electrostimulation guidance be an alternative to surgical excision? Long-term results. Foot Ankle Surg. 2019 Apr 17. pii: S1268–7731(19)30057-8. doi: 10.1016/j.fas.2019.04.004. [Epub ahead of print]
69. Magnan B, Marangon A, Frigo A, Bartolozzi P. Local phenol injection in the treatment of interdigital neuritis of the foot (Morton's neuroma). Chir Organi Mov. 2005 Oct-Dec;90(4):371–7.

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Original article

Long head of biceps in proximal fractures of the humerus: an underestimated problem? Critical analysis and review of the literature

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Summary. *Background and aim of the work:* The long head of biceps (LHB) is one of the tendons of the rotator cuff that runs strictly close to the humeral head. In case of pathology, it can be responsible for pain and shoulder impairment: in such cases, surgical options include tenotomy or tenodesis. The management of LHB along with surgery of the rotator cuff or during shoulder prosthetic replacement has been widely discussed in the literature. Conversely, the possibility of acute impingement and incarceration of LHB in proximal humerus fractures, as well as its role in shoulder pain in outcomes of these fractures, has been poorly considered. *Methods:* The following aspects in the literature on LHB and proximal humerus fractures have been analysed: its management during fixation of fractures, the possibility of interference of the tendon with reduction of fractures or dislocations of the shoulder and its possible role in chronic pain after fixation of proximal humerus fractures. *Results:* LHB can be an obstacle in the reduction of fractures, dislocations and fracture-dislocations. Only a few papers take into account acute surgery to LHB (tenotomy or tenodesis); most of the studies on fixation of proximal humerus fractures simply ignore the problem of LHB. The tendon can be a source of pain and a cause of disability in sequelae of these fractures. *Conclusions:* LHB should be taken into consideration both in the acute phase of fractures of the proximal humerus and in the outcomes. Other studies are needed to better understand its optimal management during fracture surgery. (www.actabiomedica.it)

Key words: long head of biceps, proximal humerus fracture, tenotomy, tenodesis

Introduction

When observing the anatomy of the proximal humerus, it is possible to schematically describe four bony parts connected by two "necks", i.e. surgical and anatomical neck. The four parts are the metaphysis, the epiphysis (with the cartilage surface) and two tuberosities. The greater and the lesser tuberosities serve as an insertion of the rotator cuff and they are divided by the intertubercular groove. The long head of biceps (LHB) slides into this groove, surrounded by the synovial membrane and covered by the transverse humeral ligament (1, 2).

In 1970, based on this division, Neer made his classification of proximal humerus fractures (2), which is still used, although many new classifications have been formulated in recent decades. Neer classification divides the fracture into two, three or four parts, depending on the involvement of the surgical neck, greater and lesser tuberosity.

Proximal humerus fractures account for about 5–10% of all fractures in adults, the majority of which are attributable to osteoporosis and are caused by low-energy traumas; the incidence of such fractures is increasing worldwide as a result of an aging society, especially in females (3, 4).

Non-operative treatment, with early reprise of active movement, is a well approved solution for many of these fractures, particularly with undisplaced and

stable or even in displaced fracture patterns in low-demand patients. Complex unstable fractures, displaced fractures and fracture-dislocation very often require surgical treatment, with open reduction and internal fixation (nearly 20% of all the cases). Anatomic or reverse shoulder arthroplasty is often suggested in the elderly, while in adults and young people every effort should be made to preserve the humeral head, with open reduction and internal fixation as treatment of choice (5, 6). Despite new advances in techniques and materials, the purchase of hardware remains challenging, especially in osteoporotic and/or comminuted bones. Even with fixed-angle devices and with the improvement of "soft tissue-friendly" techniques, several complications can occur (implant loosening, cut-out or cut-through of the screws in the humeral head, etc.); moreover, the rate of unsatisfactory clinical results (limited range of movement, painful joint, etc.) remains relatively high (7, 8).

Standard X-rays and computed tomography (CT) can be used to better evaluate the fracture, especially the head-splitting component, the extent of comminution and the fracture configuration of the tuberosities (5, 9).

Minor malunion of the proximal humerus without displacement is usually well tolerated; however, in some cases, after internal fixation of a humeral fracture, chronic and recurrent pain and limited range of motion can worsen shoulder girdle function. While in some cases the reasons for these bad results are evident (head necrosis, gross tuberosities malalignment, non-union, etc.), in other cases, despite X-rays showing a perfect restoration of the anatomy of the proximal humerus, the causes of poor outcomes remain unclear (10).

LHB: anatomy, pathology and treatment

LHB originates from the upper tubercle of the glenoid, runs laterally and anteriorly above the head of the humerus in its groove, where it is stabilized by a pulley (Figure 1a-b), and then runs vertically until its myotendinous junction.

Its main role is not clearly understood. Its contribution as a shoulder lifter is very poor; a role as a humerus head depressor was hypothesized, but clinical studies have not confirmed this. More recently, its possible involvement in shoulder stability has been considered. However, its main action takes place at the level of the forearm as a supinator and flexor of the elbow (11-14).

Disorders of LHB, both inflammatory and degenerative, play an important role in shoulder pain and in limitation of glenohumeral range of motion. Pathologies of LHB are very frequent, due to its peculiar intra-articular position and to the poor blood supply in this area.

Isolate disorders of LHB account for only 5% of the total; it is more common to observe LHB pathology along with rotator cuff injury or in sequelae of proximal humerus trauma.

Diagnosis is primarily made on clinical tests. Palpation of the tendon at the level of the bicipital groove can evoke pain; in the case of tendon dislocation, it is sometimes possible to perceive a "click" of the tendon during shoulder rotations. Speed and O'Brien tests are reliable in detecting LHB pathology, although they lack absolute specificity. In the case of acute complete rupture of LHB, the patient may report the sensation of a "snap" followed by diffuse ecchymosis. The anatomical profile of the arm will often be altered by the typical Popeye sign (15-17).

Ultrasound is a useful and inexpensive tool to analyse LHB; magnetic resonance imaging (MRI) – or, potentially, MRI arthrography – is the most accurate diagnostic exam to detect LHB lesions and, generally, shoulder disorders. Arthroscopy, as a diagnostic and therapeutic tool, can directly view the tendon in its intra-articular portion and near the pulley, while it cannot follow it distally.

General indications for surgical treatment are the following:

- complete lesion of the tendon in young and high-demand patients;
- partial, symptomatic lesions that exceed 25% of the tendon section;
- instability of the tendon at the level of the pulley;
- disabling chronic tendonitis not responsive to conservative therapy for more than six months (18).

In case of surgery on LHB, the operation should address the potential shoulder pathology associated.

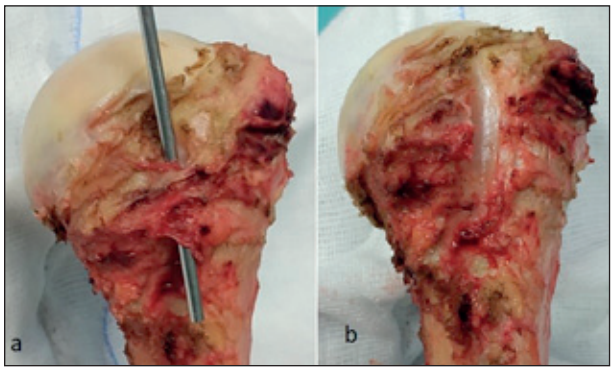

Figure 1a – 1b. Left proximal humerus of anatomical specimen. Figure a: a probe is in the bicipital groove, closed by the pulley of LHB. Figure b: the pulley has been resected, revealing the intertubercular groove

Figure 2. Patient who underwent a right proximal humerus internal fixation with tenotomy of LHB compared to his healthy left side: only a slight Popeye sign can ben noted and no diffference of shoulder function (writing authors case)

The surgical options to treat LHB pathologies are tenodesis and tenotomy. In the tenotomy procedure, the tendon is cut near its glenoid insertion and a resection of the worn tendon can be associated. This is a fast and effective procedure, although with a high incidence of Popeye sign; some studies underline the possibility of supination and flexion deficits in high-demand patients. Tenodesis, on the other hand, reduces the risk of Popeye sign and strength deficit, but it is not free from potential risks (pain or soreness in the biceps muscle, stiffness, neurologic or vascular injury, proximal humerus fracture and reflex sympathetic dystrophy). The two techniques have been studied especially in association with repair of rotator cuff: they are both effective tools in reducing pain and improving joint function. The choice between tenodesis or tenotomy is often left to the surgeon and the literature has not clearly shown a superiority of one procedure over the other (19-22) (Fig. 2).

LHB in fractures and dislocations of the shoulder

In the literature, there are case reports of axillary artery entrapment in proximal humerus fractures, but very few papers report the entrapment of LHB between fracture fragments. In some cases, the fracture was actually a fracture-dislocation of the shoulder (5).

Lucas et al. underwent a cadaveric study to investigate a potential LHB tendon impingement by a simulated proximal humeral fracture. A fracture at the level of the surgical neck of the humerus, immediately above the insertion of the pectoral, was performed. After manipulating the fracture in multiple directions, the LHB tendon did not become interposed into the fracture site at any point of the wide range of humeral motion. These findings can explain the rarity of entrapment of LHB in fractures, even in multifragmentary ones. In fracture-dislocations, the possibility of entrapment could be slightly more frequent due to a major dislocation of the fracture fragments (23).

Henderson (24) reported a case of fracture-dislocation of the shoulder in a patient treated with electro-convulsive therapy (this paper dates to 1952). LHB was entrapped between the humeral head and the greater tuberosity, thus preventing any possibility of the anatomic reduction of the tuberosity. Similar findings were reported by Pantazis in a fracture-dislocation of the shoulder (25).

Nour describes a 43-year-old male who sustained a multifragmentary fracture of the proximal humerus after a ski accident. The author performed a capsulotomy via a deltopectoral (DP) approach and he found LHB entrapped in the fracture of the humeral head (26).

The writing authors (unpublished data) observed entrapment of LHB in a fracture-dislocation of the shoulder. The humeral head was dislocated anteriorly and any attempt at its reduction with external manoeuvres was unsuccessful. The patient was operated

in a beach chair position via a DP approach: LHB lay between the humeral head and the greater tuberosity (Figure 3). After tenotomy of LHB, the dislocation was reduced and the fracture fixed with a locked plate.

Some authors discussed the problem of LHB in proximal humeral fractures in the paediatric population: they recommend open reduction after failure of one or two attempts at close reduction of the fracture.

Bahrs et al. discussed 43 cases of proximal humeral fractures in children and adolescents concluding that a failed closed reduction should be interpreted as a possible soft tissue entrapment, most likely because of LHB (27).

Similar findings were reported by Visser in physeal injuries of the proximal humerus in children (all Salter-Harris type II), who underwent open reduction and internal fixation of severely displaced fracture fragments, finding interposition of both LHB and periosteum (28). Lucas reported four cases of LHB entrapment, treated only with external manipulation for reduction of the fracture, with good radiographic and clinical results (23).

Pandya reported ten children of a mean age of 14 years with proximal humerus fractures with severe displacement/angulation, impossible to reduce in a close manner. The cause of impossible close reduction interposition of the periosteum was found to be LHB, deltoid muscle and bone fragments. For this reason, the author deemed indicated open reduction of the fractures in such cases (29).

Shoulder dislocation affects young and old people alike; in the latter case, there is frequent association with rotator cuff tears (either concomitant or previous) and, in the case of involvement of the subscapularis, the pulley can be damaged, thus leading LHB to dislocate. In the event of surgical treatment after shoulder dislocation (Bankart lesion repair, Latarjet procedure, etc.), tenodesis or tenotomy of LHB are mandatory if rotator cuff is grossly torn (30, 31).

In the literature, there are also case reports of posterior incarceration of LHB in association with anterior dislocations of the shoulder. The cases described are consequent to high-energy traumas causing anterior dislocation of the humeral head, massive lesion of the rotator cuff, destruction of the pulley and posterolateral dislocation of LHB. The authors highlight the impossibility of close reduction of shoulder dislocation: the incarceration of LHB is finally detected with MRI. The treatment of choice is open reduction via a DP approach, followed by capsule-tendon reconstruction and LHB tenodesis (32-34).

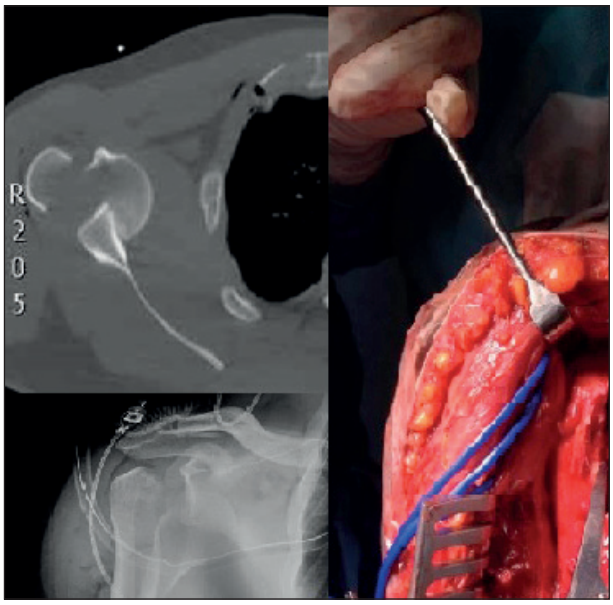

Figure 3. Fracture-dislocation of the right shoulder with interposition of LHB (white arrow) between head and Greater tuberosity

LHB in rotator cuff and shoulder prosthetic replacement surgery

In many rotator cuff tears, because of great pressure and friction on the biceps tendon, LHB is affected by inflammatory, hypertrophic and degenerative processes or tendon sheet partial lesions. On the other hand, LHB rupture is highly correlated with the presence of rotator cuff disease, with the majority of patients presenting full-thickness tears of the supraspinatus (35). As mentioned earlier, during operation for rotator cuff pathology, tenotomy and tenodesis are validated techniques for the treatment of lesions of LHB.

Partial lesion of the tendon (>25% of its diameter), hypertrophy or massive inflammation are main indications for surgical treatment of LHB in association with repair of the rotator cuff involving the supraspinatus

tendon. In the case of tear of subscapularis tendon, the involvement of the pulley is very frequent, with consequent instability of LHB, with medial dislocation. This is an absolute indication for tenodesis or tenotomy of LHB. Finally, massive rotator cuff tears are defined as tears involving the subscapularis, supra- and infraspinatus; an intact and macroscopically healthy LHB should be preserved in such cases. In case of instability of the tendon, this should be stabilized in its groove. Furthermore, LHB can provide a framework for the attachment of extrinsic musculotendinous transfers or be incorporated into intra-cuff transfers for greater strength in the repair (18, 36-39).

In elderly patients (>70 years), hemiarthroplasty (HA) or reverse shoulder arthroplasty (RSA) are well accepted options for the treatment of complex fractures of proximal humerus.

In case of HA, the anatomy of the shoulder is preserved and management of LHB must be considered. Preservation of LHB can cause residual pain and it contributes to impaired function of the shoulder, given that, by passing over the prosthetic head, it can impinge with it, especially in cases of bulky prosthetic domes. Tosounidis analysed histology and immunohistochemistry of LHB in shoulders treated with HA for humerus fracture with preservation of the tendon (fracture group). He compared the microscopic findings with tendons harvested from cadaveric shoulders (control group). Severe inflammatory and degenerative processes, even without previous LHB pathology, were noted in the fracture group. Based on the literature, there is strong indication to perform tenotomy or tenodesis of LHB along with the implant of HA of the shoulder (40-42).

RSA is gaining success for the treatment of fractures of the proximal humerus in the elderly, since it has been designed to obtain shoulder elevation even in the case of rotator cuff insufficiency. This is possible by changing the anatomy of the shoulder, which is obtained by distalisation and medialisation of the centre of rotation of the joint. Changing the anatomy of the shoulder means changing the biomechanics: for these reasons, tenodesis or tenotomy of LHB are necessary surgical steps during the operation (43-45).

LHB and approaches to proximal humerus: deltopectoral versus deltoid splitting

DP is the most common approach for plate fixation of proximal humeral fractures: it can be prolonged towards the arm when the fracture extends distally. Furthermore, this approach can be used in the case of immediate or later arthroplasty. It has been used for several years and it has always been considered the gold standard for treating these lesions. However, this approach has some limits: extensive soft tissue dissection and muscle retraction to gain adequate exposure to the lateral aspect of the humerus (especially greater tuberosity), difficulty to seat the plate in anatomic position, risk of injury to circumflex artery and consequent head necrosis. A lateral deltoid splitting (DS) approach (McKenzie and its variation) is a valid alternative to the DP approach and it is gaining more and more popularity. It allows for a direct approach to the greater tuberosity, minimising local soft tissue trauma and proper positioning of the plate (and thus of the screws) on the proximal humerus. The risk of this approach is a lesion to the axillary nerve and, with respect to the topic of the present paper, poor visualization of LHB (4, 8, 9).

With the DP approach, LHB can be easily identified just lateral to the insertion of the subscapularis and followed to its insertion on the superior tubercle of the glenoid. Identification of LHB with the DS approach is more difficult, especially with MIPO technique. However, in three- and four-part fractures of the proximal humerus, which are the most hazardous lesions for the integrity of the tendon, mobilization of the broken tuberosities allow for direct visualization and possible treatment of the tendon. Furthermore, if the incision is carried out slightly more anteriorly (McKenzie approach), then handling of LHB can be easier (4, 8, 9, 46).

In the last few years, some studies have compared the two approaches: while some papers have sustained the superiority of DP, especially for four-part fractures and because of a reduced risk of axillary nerve lesions, some others support DS as a safe and effective surgical approach to treat these fractures, with an inferior head necrosis rate and shorter operation time. However, the majority of the studies and a recent meta-analysis,

concluded that both approaches had similar results in functional outcomes, total complication, visual analogue scale and hospital stay (9, 47, 48).

LHB management in proximal humerus fracture fixation

Schai investigated arthroscopically 52 proximal humeral fractures pre-operatively, revealing a significant number of soft tissue lesions (labral, capsuloligamentous and rotator cuff). In 35% of those, there was an involvement of LHB tendon. Even though arthroscopy is not feasible in every proximal humerus fracture, the issue raised by the author is not to underestimate soft tissue lesions in such fractures (49).

In the literature, many surgical techniques to operate proximal humerus fracture are reported, with description of every step of surgery, from the approach to the final fixation (nail, plate and screws, K wire, etc.). Surprisingly, however, very few articles describe the management of LHB.

When treating proximal humerus fractures with plate and screws, some authors mention the management of LHB. Konrad and Khmelnitskaya describe how they identified the tendon of LHB and followed its course cranially using the DP approach. In the case of a fracture running in the intertubercular sulcus and/or if the tendon of LHB is damaged, a tenodesis or a tenotomy are performed after bone fixation. The authors describe their own personal surgical technique, rather than explaining the reasons for that peculiar management of LHB (6, 7).

At our knowledge, only two papers accurately describe and focus their attention on the treatment of LHB.

Kerschbaum et al. described a prospective study on 27 patients (average age 64.5 years) treated for proximal humerus fracture with locked plating. They performed the operation with a DP approach and, along with internal fixation, they pre-operatively opted for tenodesis (younger patients, with high functional and cosmetic demands) or tenotomy (older patients, with low functional and cosmetic demands) of LHB. At an average follow up of 25 months, they found no statistically significant differences between the two groups, neither in term of functionality of the joint, nor in subjective feeling and cosmetic appearance of the shoulder. It should be noted that in this study the authors did not compare the results of the two groups with a third (or a control) group, that could have included internal fixation without any treatment of LHB (50).

Greve et al. performed a retrospective study enrolling 56 patients treated with open reduction and internal fixation with locking plate, by a DP approach. Group 1 (26 patients) underwent LHB tenodesis; Group 2 (control group, 30 patients) was treated with internal fixation alone. The two groups contained similar patients regarding age, gender and fracture pattern. The average follow-up was 1.5 years; the patients were evaluated with the Munich Shoulder Questionnaire (MSQ), the Disability of Arm and Shoulder and Hand (DASH) score and the Shoulder Pain and Disability Index (SPADI). The Popeye sign and O'Brien test were also used to properly assess the status of LHB. Their results showed a better outcome when the patients had been treated with humerus fixation along with biceps tenodesis. The authors concluded that LHB tenodesis is a "promising adjunct" to ORIF of the proximal humerus (5).

LHB in outcomes of proximal humerus fractures

The involvement of the greater and, especially, of the lesser tuberosities in fractures of the proximal humerus can damage the restraints, i.e. transverse humeral ligament and expansions of the subscapularis and the supraspinatus, that stabilize LHB in the intertubercular groove. The damage to these restraints can lead to instability of LHB and, most frequently, to its medial dislocation. It should be noted that the fracture line between the tuberosities is often posterior to the bicipital groove; however, the proximity of LHB tendon to the fracture line and its possible instability can frequently compromise it even in such fractures (1, 51).

After a healed humerus fracture, even in the case of LHB perfectly seated in its groove, displacement of little fragments may cause potential disturbance of the gliding mechanism of the tendon. Thus, the tendon

sheet can become frayed and worn and, consequently, be a source of severe pain. Furthermore, in case of malunion of the tuberosities, the intertubercular groove can be severely altered and tendinopathy of LHB can be chronic and disabling (1, 52).

After proximal humerus fixation, standard X-rays are usually done: antero-posterior, internal and external rotation and axillary views can show how accurate the reduction of the fracture has been. CT is rarely needed and MRI is performed exceptionally.

In case of post-traumatic shoulder pain with persistent locking and catching, an MRI – or an MRI arthrogram – can be an option to further investigate the joint, as articular or peri-articular lesions can lead to persistent pain even after a perfect operation. Kattaghen (53) showed the results of shoulder arthroscopy in 46 shoulders after locked plating of proximal humeral fractures, before implant removal. He found that possible sources of pain include articular screw perforation, subacromial plate impingement or articular pathologies – especially of cartilage – LHB and rotator cuff tendons. Pathologies of LHB consist of full-thickness rupture, partial rupture, tendinitis, tendon capture and instability; the author treated these conditions with debridement or tenotomy. He observed that, in many cases, the pathologies of LHB were due to the perforation of the screws and direct damage to the tendon sheets, rather than to an alteration of the anatomy of the intertubercular groove.

Poroes reported a case of an intra-articular dislocation of an unusually long proximal biceps tendon stump. This was a consequence of extra-articular rupture of LHB, due to angular deformity and malunion of the proximal humerus. The patient was treated arthroscopically because of reported symptoms of pain, locking and catching (10).

Conclusions

Many papers describe how to treat – open or arthroscopically – pathologies of LHB, be they isolated or associated to rotator cuff lesions. The surgical options available are tenodesis or tenotomy of LHB, techniques that are equal in terms of clinical and functional outcomes. Even management of LHB along with prosthetic replacement of the shoulder has been described and debated, both in the case of traumatic (fracture) and non-traumatic (degenerative) conditions. Conversely, management of LHB during open reduction and internal fixation of proximal humerus fracture has not been considered in the majority of published papers; only two studies have focused on this topic so far.

Although rare, there is a possibility of acute incarceration of LHB between fragments of proximal humerus fractures or, more often, of fracture-dislocations. This possibility is relatively more frequent in children, especially in severely displaced physeal injuries. In such cases, open reduction, disengagement of the tendon and internal fixation are strongly recommended.

The treatment of LHB during internal fixation of proximal humerus fracture is scarcely debated. The management of the tendon is usually left to the surgeon's personal technique and preference, without a real analysis of which the ideal treatment (tenodesis, tenotomy or simply ignoring LHB) would be.

There seems to be agreement in treating LHB when macroscopically damaged or when the fracture line runs along the intertubercular groove. The identification of LHB is much easier with the DP approach: the tendon can be followed from extra-articular to intra-articular course, after opening the rotator cuff interval. For this reason, it can be argued that the DP approach is superior to the DS approach when treating proximal humerus fractures. However, regardless of the possible treatment of LHB, the literature has shown that clinical and radiographic results obtained with the two approaches are substantially the same and no significant differences in terms of functional scale of the shoulder have been noted.

Long-term results and outcomes after surgically treated proximal humerus fractures are another matter of debate, in relation to the possibility of LHB as a source of pain and disability. This is the reason why patients can experience shoulder pain after these fractures, even when they look perfectly reduced and fixed. This could depend on LHB-related pain, due to its degeneration, impingement or instability, especially when the fracture has interested the intertubercular groove. However, some papers outline how LHB is very often damaged by protrusion of screws, rather than disturbed by fracture fragments.

In the case of bad outcomes, other radiologic exams should be suggested: CT, MRI (even with an arthrogram) to detect pathology or abnormal course of the tendon. Arthroscopy can be an option to effectively treat these patients.

At the moment, no recommendation can be made for the treatment of LHB along with internal fixation of proximal humerus fractures. In the case of acute impingement or severe damage to the tendon sheets, tenodesis or tenotomy are options to consider. In all the other cases, that are the vast majority, the surgical management of the tendon is guided by the personal experience of the surgeon.

The lack of studies on this topic in the literature could suggest the need for prospective studies comparing patients treated with tenodesis/tenotomy and patients treated only with bone fixation.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Harrison JW, Howcroft DW, Warner JG, Hodgson SP. Internal fixation of proximal humeral fractures. Acta Orthop Belg. 2007 Feb;73(1):1–11.
2. Neer CS., 2nd Displaced proximal humeral fractures: I. Classification and evaluation. J Bone Joint Surg Am. 1970;52:1077–1089.
3. Tosounidis T, Hadjileontis C, Georgiadis M, Kafanas A, Kontakis G. The tendon of the long head of the biceps in complex proximal humerus fractures: a histological perspective. Injury. 2010 Mar;41(3):273–8.
4. Buecking B, Mohr J, Bockmann B, Zettl R, Ruchholtz S. Deltoid-split or deltopectoral approaches for the treatment of displaced proximal humeral fractures? Clin Orthop Relat Res. 2014 May;472(5):1576–85. doi: 10.1007/s11999-013-3415-7.
5. Greve F, Beirer M, Zyskowski M, Crönlein M, Müller M, Pesch S et al. Prospective outcome analysis following tenodesis of the long head of the biceps tendon along with locking plate osteosynthesis for proximal humerus fractures. Injury. 2019 Mar;50(3):681–685. doi: 10.1016/j.injury.2019.02.003.
6. Khmelnitskaya E1, Lamont LE, Taylor SA, Lorich DG, Dines DM, Dines JS. Evaluation and management of proximal humerus fractures. Adv Orthop. 2012;2012:861598. doi: 10.1155/2012/861598.
7. Konrad G, Bayer J, Hepp P, Voigt C, Oestern H, Kääb M et al. Open reduction and internal fixation of proximal humeral fractures with use of the locking proximal humerus plate. Surgical technique. J Bone Joint Surg Am. 2010 Mar;92 Suppl 1 Pt 1:85–95. doi: 10.2106/JBJS.I.01462.
8. Laux CJ, Grubhofer F, Werner CML, Simmen HP, Osterhoff G. Current concepts in locking plate fixation of proximal humerus fractures. J Orthop Surg Res. 2017 Sep 25;12(1):137. doi: 10.1186/s13018-017-0639-3.
9. Wu CH, Ma CH, Yeh JJ, Yen CY, Yu SW, Tu YK. Locked plating for proximal humeral fractures: differences between the deltopectoral and deltoid-splitting approaches. J Trauma. 2011 Nov;71(5):1364–70. doi: 10.1097/TA.0b013e31820d165d.
10. Ramos Poroes F, Desmarchelier R, Bauer S. Atypical biceps-related complication of proximal humerus fracture leading to internal shoulder impingement due to tendon stump dislocation. BMJ Case Rep. 2020 Feb 9;13(2). pii: e232124. doi: 10.1136/bcr-2019-232124.
11. Rodosky MW, Harner CD, Fu FH. The role of the long head of the biceps muscle and superior glenoid labrum in anterior stability of the shoulder. Am J Sports Med 1994;22:121–30.
12. Warner JJ, McMahon PJ. The role of the long head of the biceps brachii in superior stability of the glenohumeral joint. J Bone Joint Surg [Am] 1995;77-A:366–72.
13. Kim SH, Ka KI, Kim HS, Kim SW. Electromyographic activity of the biceps brachii muscle in shoulders with anterior instability. Arthroscopy 2001;17:864–8.
14. Ahrens PM, Boileau P. The long head of biceps and associated tendinopathy. J Bone Joint Surg [Br] VOL. 89-B, No. 8, AUGUST 2007
15. Favorito PJ, Harding WG III, Heidt RS Jr. Complete arthroscopic examination of the long head of the biceps tendon. Arthroscopy 2001;17:430–432
16. Crenshaw AH Kilgore WE. Surgical treatment of bicipital tenosynovitis. J Bone Joint Surg Am. 1966 Dec;48(8):1496–502.
17. McFarland EG Kim TK Savino RM. Clinical assessment of three common tests for superior labral anterior-posterior lesions. Am J Sports Med. 2002 Nov-Dec;30(6):810–5
18. Zhang Q, Zhou J, Ge H, Cheng B. Tenotomy or tenodesis for long head biceps lesions in shoulders with reparable rotator cuff tears: a prospective randomised trial. Knee Surg Sports Traumatol Arthrosc 2013 2015 Feb;23(2):464–9. doi: 10.1007/s00167-013-2587-8.
19. Ahmad CS, DiSipio C, Lester J, Gardner TR, Levine WN, Bigliani LU. Factors affecting dropped biceps deformity after tenotomy of the long head of the biceps tendon. Arthroscopy 23(5):537–541
20. Checchia SL, Doneux PS, Miyazaki AN, Silva LA, Fregoneze M, Ossada A et al. Biceps tenodesis associated with arthroscopic repair of rotator cuff tears. J Shoulder Elbow Surg 14(2):138–144
21. Franceschi F, Longo UG, Ruzzini L, Papalia R, Rizzello G, Denaro V. To detach the long head of the biceps tendon after tenodesis or not: outcome analysis at the 4-year follow-up of

two different techniques. Int Orthop 31(4):537–545
22. Frost A, Zafar MS, Maffulli N. Tenotomy versus tenodesis in the management of pathologic lesions of the tendon of the long head of the biceps brachii. Am J Sports Med 37(4):828–833.
23. Lucas JC, Mehlman CT, Laor T. The location of the biceps tendon in completely displaced proximal humerus fractures in children: a report of four cases with magnetic resonance imaging and cadaveric correlation. J Pediatr Orthop. 2004 May-Jun;24(3):249–53
24. Henderson SR. Fracture-dislocation of the shoulder with interposition of long head of biceps .J Bone Joint Surg Br. 1952 May;34-B(2):240–1
25. Pantazis K, Panagopoulos A, Tatani I, Daskalopoulos B, Iliopoulos I, and Minos Tyllianakis. Irreducible Anterior Shoulder Dislocation with Interposition of the Long Head of the Biceps and Greater Tuberosity Fracture: A Case Report and Review of the Literature. Open Orthop J. 2017; 11: 327–334.
26. Abdel Nour HG, Joukhadar N, Maalouly J, Ayoubi RA, Aouad DK and El Rassi GS. Entrapment of the Long Head of the Biceps in a Multi-Fragmentary Proximal Humeral Fracture: A Case Report. J Physiother Res. 2:10.
27. Bahrs C, Zipplies S, Ochs BG, Rether J, Oehm J, Eingartner C et al. Proximal humeral fractures in children and adolescents. J Pediatr Orthop. 2009 Apr-May;29(3):238–42. doi: 10.1097/BPO.0b013e31819bd9a7.
28. Visser JD, Rietberg M. Interposition of the tendon of the long head of biceps in fracture separation of the proximal humeral epiphysis. Neth J Surg. 1980;32(1):12–5.
29. Pandya NK, Behrends D, Hosalkar HS. Open reduction of proximal humerus fractures in the adolescent population.J Child Orthop. 2012 Jun;6(2):111–8. doi: 10.1007/s11832-012-0398-y. Epub 2012 Mar 29.
30. White AE, Patel NK, Hadley CJ, Dodson CC. An algorithmic approach to the management of shoulder instability. J Am Acad Orthop Surg Glob Res Rev. 2019 Dec 23;3(12).
31. Cibulas A, Leyva A, Cibulas G 2nd, Foss M, Boron A, Dennison J et al. Acute Shoulder Injury. Radiol Clin North Am. 2019 Sep;57(5):883–896.
32. Wortley P, Omar L, Robertson W, Moore D, Sims GC, Omar H. Nonreducible Shoulder Due to Acute Posterior Dislocation of the Long Head of the Biceps Tendon: A Case Report and Review of the Literature. JBJS Case Connect. 2014 Mar 12;4(1 Suppl 8):e261–4.
33. Seo JB, Yoon SH, Yang JH, Yoo JS. Irreducible posterior fracture and dislocation of shoulder with massive rotator cuff tear due to incarceration of biceps tendon: A case report. J Orthop. 2020 Feb 4;21:6–9.
34. McArthur C, Welsh F, Campbell C. Posterior dislocation of long head of biceps tendon following traumatic anterior shoulder dislocation: imaging and intra-operative findings. J Radiol Case Rep. 2013 Sep 1;7(9):19–26.
35. Vestermark GL, Van Doren BA, Connor PM, Fleischli JE, Piasecki DP, Hamid N. The prevalence of rotator cuff pathology in the setting of acute proximal biceps tendon rupture. Shoulder Elbow Surg. 2018 Jul;27(7):1258–1262. doi: 10.1016/j.jse.2018.01.006. Epub 2018 Feb 22.
36. Barber FA, Field LD, Ryu RK (2008) Biceps tendon and superior labrum injuries: decision making. Instr Course Lect 57:527–538
37. Al-Hakim W, Noorani A, Lambert S. Assessment and treatment strategies for rotator cuff tears. Shoulder Elbow. 2015 Apr;7(2):76–84. doi: 10.1177/1758573214557143. Epub 2014 Oct 31.
38. Godenèche A, Nove-Josserand L, Audebert S, Toussaint B, Denard PJ, Lädermann A. Relationship between subscapularis tears and injuries to the biceps pulley. Knee Surg Sports Traumatol Arthrosc (2017) 25:2114–2120
39. Boileau P, Baqué F, Valerio L, Ahrens P, Chuinard C, Trojani C. Isolated arthroscopic biceps tenotomy or tenodesis improves symptoms in patients with massive irreparable rotator cuff tears. J Bone Joint Surg Am. 2007 Apr;89(4):747–57.
40. Pietu G, Deluzarches P, Goin F, Letenneur J. Complex injuries of the proximal humerus treated with humeral head prosthesis: apropos of 21 cases review after a median follow-up of 4 years. Acta Orthopaedica Belgica 1992;58:159–69.
41. Moeckel BH, Dines DM, Warren RF, Altchek DW. Modular hemiarthroplasty for fractures of the proximal part of the humerus. Journal of Bone and Joint Surgery - American Volume 1992;74-A:884–9.
42. Green A, Barnard WL, Limbird RS, Providence RI. Humeral head replacement for acute, four-part proximal humerus fractures. Journal of Shoulder and Elbow Surgery 1993;2:249–54.
43. Hawkins RJ, Switlyk P. Acute prosthetic replacement for severe fractures of the proximal humerus. Clinical Orthopaedics 1993;289:156–60.
44. Goldman RT, Koval KJ, Cuomo MA, Zuckerman JD. Functional outcome after humeral head replacement for acute three- and four-part proximal humeral fractures. Journal of Shoulder and Elbow Surgery 1995;4:81–6.
45. Omar A. Soliman A, Wael MT. Proximal humeral fractures treated with hemiarthroplasty: Does tenodesis of the long head of the biceps improve results? Injury, Int. J. Care Injured 44 (2013) 461–464
46. Borer J, Schwarz J, Potthast S, Jakob M, Lenzlinger P, Zingg U. Mid-term results of minimally invasive deltoid-split versus standard open deltopectoral approach for PHILOS™ (proximal humeral internal locking system) osteosynthesis in proximal humeral fractures. Eur J Trauma Emerg Surg. 2019 Jan 14. doi: 10.1007/s00068-019-01076-7.
47. Mouraria GG, Zoppi A, Kikuta FK, Moratelli L, Cruz MA, Etchebehere M. Anterolateral approaches for proximal humeral osteosynthesis: a systematic review. Acta Ortop Bras. 2019 May-Jun;27(3):178–182. doi: 10.1590/1413-785220192703215572
48. Xie L, Zhang Y, Chen C, Zheng W, Chen H, Cai L. Deltoid-split approach versus deltopectoral approach for proximal humerus fractures: A systematic review and meta-analysis. Orthop Traumatol Surg Res. 2019 Apr;105(2):307–316.

doi: 10.1016/j.otsr.2018.12.004. Epub 2019 Mar 14.
49. Schai PA1, Hintermann B, Koris MJ. Preoperative arthroscopic assessment of fractures about the shoulder. Arthroscopy. 1999 Nov-Dec;15(8):827–35.
50. Kerschbaum M, Werth M, Gerhardt C, Scheibel M. Simultaneous surgical treatment of the long head of the biceps tendon during operative treatment of proximal humeral fractures. Unfallchirurg. 2017 Oct;120(10):865–872. doi: 10.1007/s00113-016-0279-9.
51. Ahovuo J, Paavolainen P, Björkenheim JM. Fractures of the proximal humerus involving the intertubercular groove. Acta Radiol. 1989 Jul-Aug;30(4):373–4.
52. Duparc F. Malunion of the proximal humerus. Orthop Traumatol Surg Res. 2013 Feb;99(1 Suppl):S1–11. doi: 10.1016/j.otsr.2012.11.006. Epub 2013 Jan 16
53. Katthagen JC, Hennecke D, Jensen G, Ellwein A, Voigt C, Lill H. Arthroscopy after locked plating of proximal humeral fractures: implant removal, capsular release, and intra-articular findings. Arthroscopy. 2014 Sep;30(9):1061–7. doi: 10.1016/j.arthro.2014.04.092. Epub 2014 Jun 14.

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Original article

Falls from height: orthopaedic and psychiatric evaluation

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Summary. *Background:* Fall from a height is one of the major causes of significant trauma with high morbidity and mortality rates. Traumatological damage control is often the primary treatment both for suicide attempt survivors and for accidental fall victims, but management of the hospitalization of psychiatric patients requires more resources than other patients. *Methods:* Retrospective multidisciplinary study (psychiatric and orthopaedic evaluation) and analysis of psychiatric and trauma characteristics of patients fallen from height admitted to our trauma centre. We analysed patterns of patients after suicidal jumps and accidental falls to look for possible trends that may trigger projects for further improvement of care. *Results:* 205 patients were analysed, 137 were included: 65 suicide attempt survivors and 72 accidental fall victims. Between these two groups there are no differences about the anaesthesiologic acute management or the number of damage control procedures. However, the psychiatric patients stay longer in hospital especially in intensive care unit with prolonged intubation ($p< 0.001$). Suicide attempt survivors are significant correlated with fractures of feet, but the orthopaedic lesions do not involve an increase of definitive interventions ($p< 0.05$). *Conclusion:* We showed that the suicide attempt survivors and accidental victims need the same acute management. The orthopedic definitive surgical procedures are similar between the two groups, but in spite of this patients with psychiatric disorder were associated with a statistically significant increase of care in intensive care unit and hospitalization. Our results allow to create a new multidisciplinary approach for these patients. (www.actabiomedica.it)

Key words: trauma, falls from a height, psychiatric disorder

Background

Fall from height with intentional jumping is the most common mechanism of injury in psychiatric patients (1, 2). In the UK each year, 3 - 15% of the 140,000 suicide attempts are performed through intentional jumping (3) and they represent an emerging social and economic problem in many countries (4). Surgery is often the primary treatment but management of psychiatric patients requires a multidisciplinary approach and significant resources (5-7). However, limited literature is available about those trauma patients (1, 6, 7); only few published papers studied these injuries. Ohi K. et al. investigated factors influencing hospital stays for Japanese patients attempting suicide by jumping (8), while Muhr G. et al. compared the injury patterns after suicidal jumps and accidental falls (9). Both papers underlined the peculiarity of these patients.

Aims of this study are to evaluate the patterns of patients after suicidal jumps and length of hospitalization to look for possible trends that may trigger projects for further improvement of management and care of these patients

Methods

We performed a retrospective multidisciplinary (psychiatric and orthopaedic evaluation) analysis. All

trauma patients admitted to our level I trauma centre (between January 2006 and December 2017) as a result of unintentional or intentional fallen from height were included. Our Data Platform revealed 205 records.

The orthopaedic group analysed the following parameters: age at the time of admission, gender, mechanism of injury, injury patterns, surgical interventions, complications, reinterventions, ventilator days, number of readmission, length of stay, compliance to physiotherapy, destination of discharge and mortality.

Psychiatric evaluation included: any psychiatric diagnosis (Inter-national Classification of Disease, ninth Revision, Clinical Modification (ICD-9CM)), season of event, history of attempted suicide, previous psychiatric consultation and psychiatric drug use, alcohol/drug abuse, intentional injury and the time of first physiatry evaluation.

We excluded patients falling from a height less than 3 meters, those who died prior to admission, patients without any kind of ortho-trauma lesion or surgical procedures and followed for less than 1 year. Patients were divided into two groups: suicide attempt survivors' group (group S) and accidental fall victims' group (group C) and data of the two groups were compared. Statistical analyses were performed using Stata 12.0 (Stata Corp, College Station, TX). Preliminary analyses were performed to compare injuries site, acute and post-acute surgical and not surgical management, complications and any diagnosed psychiatric disorder using Chi squared tests and analyses of variance (ANOVA). When differences were observed, analyses were completed with pairwise Chi-squared and Student's t tests. The variables "number of injuries" and "height of the fall" were simultaneously included. All data being adjusted for age and sex. We have asked the consent of patients for the use of all data.

Results

Demographic data of our population are summarised in Table 1. 205 patients were analysed; 27 patients were excluded because they were followed for less than 1 year. 41 patients were lost during the follow up. 137 were included, 65 resulting from an attempting suicide fall and 72 from an accidental fall. The

Table 1. Patient characteristics.

	N° (%)			
Total patients	205			
Patients included	137			
Patients exluded	27			
	Attempting suicide	**Accidental fall**	**Value**	**p**
Patients	65	70		
Average age	37	46	1.7	0.046*
Min age	14	14		
Max age	87	80		
>18	55 (84.62)	66 (94.28)		
<18	10 (15.38)	4 (5.71)		
Sex			2.37	0.01*
Male	36 (55.38)	60 (85.71)		
Female	29 (44.62)	10 (14.29)		
Precipitation height (m)			1.99	0.024*
<5	20 (30.77)	42 (60)		
5;10	25 (38.46)	16 (22.86)		
>10	20 (30.77)	12 (17.14)		

* p<0.05 - p<0.001

males/female's rate was higher in group C (85.71%) then group S (55.38%) (p< 0.05). The average age of group S was lesser than others (37 years old) with an increased number of minors (15.38%) (p< 0.05). There was significant correlation in the height between suicidal and accidental falls (p< 0.05): 60% of no intentional victims fell from a height lesser than 5 metres.

The specifics of attempting suicide patients are summarised in Table 2. The seasonal distribution showed a summit of attempting suicide in spring (33.85%). 26.15% of psychiatric patient had a previous suicide attempt and 10.78% died after a new attempt. 76.92% was people with psychiatric disorders already followed from psychiatrists and 44.62% had diagnosis of major depressive disorder. Psychiatrist made their first post traumatic evaluation in an average of 9 (0-31) days. A similar number of psychiatric patients 87.79% took psychiatric drugs after the trauma compared to the proportion of patients before the fall (75.38%).

There was significant correlation between the attempting suicide patients (55.38%) and fractures of feet (p< 0.001) and also vegetative complications (p<

Table 2. Intentional fall group characteristics.

	N° (%)
Patients	65
Died after subsequent	7 (10.78)
psychiatric diagnoses before attempt	50 (76.92)
Nota t first attempt	17 (26.15)
Psychiatric disorder	
MDD (Major Depressive Disorder)	29 (44.62)
BD (Bipolar Disorder)	10 (15.38)
PD (Personality Disorder)	3 (4.62)
Abuse	2 (3.08)
Schizoaffective	2 (3.08)
Psychosis	2 (3.08)
No disorders	3 (4.62)
Mean time from trauma to the first psychiatric consultation	9 (0-31)
Drugs before trauma	49 (75.38)
Antidepressants	28 (49.23)
Antipsychotics	32 (49.23)
Mood stabilizers	12 (18.46)
Benzodiazepines	35 (53.85)
Drugs after the trauma	57 (87.69)
Antidepressants	34 (52.31)
Antipsychotics	35 (53.85)
Mood stabilizers	13 (20.00)
Benzodiazepines	36 (55.38)

Table 3. Comparisons of injuries sites and complications.

	N° (%)			
Injuries site	**Attempting suicide**	**Accidental fall**	**Value**	**p**
Humerus	15 (23.08)	11 (15.71)	1.26	0.26
Forearm	17 (26.15)	22 (31.43)	0.06	0.79
Hand	8 (12.31)	8 (11.43)	0.04	0.85
Pelvis	32 (49.23)	27 (38.57)	1.73	0.18
Femour	25 (38.46)	23 (32.86)	1.75	0.41
Leg	28 (43.07)	36 (51.43)	1.11	0.29
Foot	36 (55.38)	19 (27.14)	11.54	0.00*
Spine	36 (55.38)	28 (40)	3.46	0.06
Head	18 (27.69)	18 (25.71)	0.10	0.75
Face	24 (36.92)	18 (25.71)	1.62	0.20
Thorax	28 (43.08)	20 (28.57)	3.30	0.07
Abdomen	16 (24.62)	11 (15.71)	1.77	0.18
Neurological system	9 (13.85)	6 (8.57)	1.01	0.31
Urological system	6 (9.23)	1 (1.43)	4.25	0.04
Complications				
Periferical nerve	5 (7.69)	6 (8.57)	0.026	0.87
Pulmonary	9 (13.85)	7 (10)	0.52	0.47
Urological	2 (3.08)	4 (5.71)	0.53	0.47
Abdominal	1 (1.53)	2 (2.86)	0.26	0.61
Sepsis	7 (10.77)	11 (15.71)	0.66	0.42
Cerebral	4 (6.15)	1 (1.43)	2.158	0.14
Medullary	2 (3.07)	0	2.22	0.13
Vegetative state	4 (6.15)	0	4.50	0.03*
Other	2 (3.08)	0	2.21	0.14
Infections with coltural positive	4 (6.15)	2 (2.85)	0.87	0.34
Soft tissue	4 (6.15)	2 (2.85)	2.55	0.28

0.05) (Table 3). Furthermore, patients with psychiatric disorders stayed longer in intensive care and also in hospital (respectively p< 0.001 and p< 0.05). Instead, most of who fell accidentally was discharged at home in smaller times (70%) (p< 0.05) (Table 4). We identified that the lesion of the feet did not involve an increase of orthopaedic interventions (p< 0.05), but it increased the recovery period (p< 0.05) and decreased the compliance to physiotherapy (p< 0.001) (Table 5). The patients followed by the psychiatrist before the trauma stay in hospital a shorter time than the psychiatric patients not previously followed (p< 0.05).

Discussion

Only few articles evaluated the trauma patient population with psychiatric disorder (1, 9) and showed that the psychiatric patients generate large volumes of multidisciplinary workloads (3, 14, 15) with high hospital costs (16-18).

In this study we compared the characteristics of victims in self-inflicted and unintentional falls. The attempting suicide group was composed of large number of minors with similar subdivision between males and females. The control group was mainly male, and their accident usually occurred from a height less than

Table 4. Comparison of hospitalization, treatments and discharges.

	N° (%)			
	Attempting suicide	**Accidental fall**	**Value**	**p**
Mean hospitalization	42.26	24	37.598	0.00*
Min	0	3		
Max	153	129		
Damage Control	55 (84.62)	61 (87.14)	0.11	0.19
Definitive surgical procedure (not included damage control)	12 (18.46)	13 (18.57)	0.08	0.38
Intensive care			16.12	0.05*
1-7 days	24 (36.92)	16 (22.86)		
7-15 days	7 (10.77)	13 (18.57)		
>15 days	15 (23.08)	9 (12.86)		
Orthopedic procedures			0.10	0.26
1-2 surgical procedure	34 (52.31)	52 (74.29)		
3 surgical procedure	7 (10.77)	8 (11.43)		
> 3 surgical procedure	9 (13.85)	4 (5.71)		
Non orthopedic procedures			0.01	0.87
1-2 surgical procedure	20 (30.77)	10 (14.29)		
3 surgical procedure	1 (1.54)	2 (2.86)		
> 3 surgical procedure	1 (1.54)	0		
Time from trauma for first definitive surgical procedure			0.03	0.74
1-7 days	46 (70.77)	24 (34.29)		
7-15 days	10 (15.38)	21 (30)		
>15 days	4 (6.15)	9 (12.86)		
Time from trauma for first physiatrics visit			0.13	0.12
1-7 days	30 (46.15)	29 (41.43)		
7-15 days	12 (18.46)	14 (20)		
>15 days	13 (20)	13 (18.57)		
Physiotherapy compliance	56 (86.15)	65 (92.86)	0.14	0.12
Discharge			56.78	0.00*
Home	19 (29.23)	49 (70)		
Rehabilitation center	16 (24.62)	14 (20)		
Psychiatric ward	8 (12.31)	2 (2.86)		
Other hospitals	15 (23.08)	5 (7.14)		
Other	2 (3.08)	2 (2.86)		

5 meters. The higher incidence in males may reflect the higher prevalence of males in jobs like farmers or construction worker (3, 4, 19-21).

According to another report (22), almost a quarter of the psychiatric patient had previous suicide attempt and a tenth died after a new attempt. In our study more than seventy percent of the patients was already followed by psychiatrists and took psychiatric drugs, especially antipsychotic, before the attempt.

To our knowledge, only one study compared risk factors and the pattern of injury between suicidal jumps and accidental falls (3). Our researches showed similar findings regarding the patterns of fractures (feet fractures are the most common lesions in patient with mental disorders) and the duration of staying in hospital for psychiatric patients (9-11).

Table 5. Correlations details. * p<0.05 - p<0.001

	Value	p
Foot injuries Number of ortho surgical procedure	0.07	0.45
Foot injuries Average days of stay in hospital	0.2	0.02*
Foot injuries Physiotherapy compliance	0.31	0.00*
Already known psychiatric patients Physiotherapy compliance	0.01	0.93
Already known psychiatric patients Average days of stay in hospital	0.28	0.00*

On the other hand, our data showed that intentional falls undergo a lower number of surgical procedures than unintentional falls. The latter may be explained by the low compliance of psychiatric victims to physiotherapy. Psychiatric patients also showed a longer hospital stays because they often usually cannot be discharged at home. This statement is confirmed by the lower hospitalization time in patients who were supervised by psychiatric staff before the attempt when compared to patients who were not followed.

Conclusion

Falls from a height are one of the major causes of major trauma and are burden by high morbidity and mortality rates (9, 24). One of the most common method for suicide in patients with psychiatric disorder is jumping from a height (25).

We compared suicidal jumps and accidental falls and showed that patients with psychiatric disorder were associated with a statistically significant increase of hospitalization. The latter is not supported by an increase of number of orthopaedic surgical procedures and may be justified by the poor compliance to physiotherapy.

In our opinion, our results have a clinical relevance for the creation of a specialized multidisciplinary approach after the orthopaedic acute management. We believe that a long-term standardised patient management protocol may improve the clinical outcomes of those patients and reduce hospital costs.

There is no commercial association (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

The Authors confirm that neither the manuscript nor any part of it has been published or is under consideration for publication elsewhere.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Dekker L, Heller H M, Van der Meij JE, Toor AE, Geeraedts LMG. A mixed psychiatric and somatic care unit for trauma patients: 10 years of experience in an urban level I trauma center in the Netherlands. Eur J Trauma Emerg Surg. 2019 Feb 15
2. Zatzick DF, Kang SM, Kim SY, et al. Patients with recognised psychiatric disorders in trauma surgery: incidence, inpatient length of stay, and cost. J Trauma. 2000;49(3):487–95.
3. Rocos B, Acharya M, Chesser TJS, The Pattern of Injury and Workload Associated with Managing Patients After Suicide Attempt by Jumping from a Height. *The Open Orthopaedics Journal*, 2015, *9*, 395-398 395
4. Kim do Y, Choi HJ, Park JY, Kim KH, et al. Burst Fractures as a Result of Attempted Suicide by Jumping. Korean J Neurotrauma. 2014 Oct;10(2):70-5.
5. Rocos B, Chesser TJ. Injuries in jumpers - are there any patterns? World J Orthop. 2016 Mar 18;7(3):182-7. doi: 10.5312/wjo. v7.i3.182. eCollection 2016 Mar 18.
6. Dekker L, Heller H M, Van der Meij JE, Toor AE, Geeraedts LMG. A mixed psychiatric and somatic care unit for trauma patients: 10 years of experience in an urban level I trauma center in the Netherlands. Eur J Trauma Emerg Surg. 2019 Feb 15.
7. Alberque C, Gex-Fabry M, Whitaker-Clinch B, Eytan A. The 5-year evolution of a mixed psychiatric and somatic care unit: a European experience. Psychosomatics. 2009;50(4):354–61.
8. Omi T, Ito H, Riku K, et al. Possible factors influencing the duration of hospital stay in patients with psychiatric disorders attempting suicide by jumping. BMC Psychiatry. 2017 Mar 20;17(1):99.
9. Richter D, Hahn MP, Ostermann PA, Ekkernkamp A, Muhr G. Vertical deceleration injuries: a comparative study of the injury patterns of 101 patients after accidental and intentional high falls. Injury 1996; 27(9): 655-9.
10. Fang JF, Shih LY, Lin BC, Hsu YP. Pelvic fractures due to falls from a height in people with mental disorders. Injury. 2008 Aug;39(8):881-8. Epub 2008 Jul 9.

11. Wancata J, Benda N, Windhaber J, Nowotny M. Does psychiatric comorbidity increase the length of stay in general hospitals? Gen Hosp Psychiatry. 2001 Jan-Feb;23(1):8-14.
12. Forrester JD, Yelorda K, Tennakoon L, Spain D.A., Staudenmayer K. BASE Jumping Injuries Presenting to Emergency Departments in the United States: An Assessment of Morbidity, Emergency Department, and Inpatient Costs. Epub 2019 Apr 16 Wilderness Environ Med. 2019 Jun;30(2):150-154.
13. Peyron PA, Margueritte E, Baccino E. Suicide in parachuting: A case report and review of the literature. Forensic Sci Int. 2018 May;286: e8-e13. doi: 10.1016/j.forsciint.2018.03.006.
14. Fang JF, Shih LY, Lin BC, Hsu YP. Pelvic fractures due to falls from a height in people with mental disorders. Injury. 2008 Aug;39(8):881-8.
15. Joo SH, Wang SM, Kim TW, et al. Factors associated with suicide completion: A comparison between suicide attempters and completers. Asia Pac Psychiatry. 2016 Mar;8(1):80-6.
16. Gore-Jones V, O'Callaghan J. Suicide attempts by jumping from a height: a consultation liaison experience. Australas Psychiatry. 2012 Aug;20(4):309-12.
17. Värnik A, Kõlves K, Allik J, Arensman E, Aromaa E, van Audenhove C, Bouleau JH, van der Feltz-Cornelis CM, Giupponi G, Gusmão R, Kopp M, Marusic A, Maxwell M, Oskarsson H, Palmer A, Pull C, Realo A, Reisch T, Schmidtke A, Pérez Sola V, Wittenburg L, Hegerl U. Gender issues in suicide rates, trends and methods among youths aged 15-24 in 15 European countries. J Affect Disord. 2009 Mar;113(3):216-26.
18. de Moore GM1, Robertson AR. Am J Psychiatry. Suicide attempts by firearms and by leaping from heights: a comparative study of survivors. 1999 Sep;156(9):1425-31.
19. Piazzalunga D, Rubertà F, Fugazzola P, Allievi N, Ceresoli M, Magnone S, Pisano M, Coccolini F, Tomasoni M, Montori G, Ansaloni L, Suicidal fall from heights trauma: difficult management and poor results. Eur J Trauma Emerg Surg. 2019 Mar 6.
20. ISTAT. Malattie fisiche e mentali associate al suicidio: un'analisi sulle cause multiple di morte; 2017.
21. Gore-Jones V1, O'Callaghan J. Suicide attempts by jumping from a height: a consultation liaison experience. Australas Psychiatry. 2012 Aug;20(4):309-12.
22. Oquendo MA, Kamali M, Ellis SP, Grunebaum MF, Malone KM, Brodsky BS, et al. Adequacy of antidepressant treatment after dissing- charge and the occurrence of suicidal acts in major depression: a prospective study. Am J Psychiatry 159:1746-1751, 2002
23. Murray CJ1, Lopez AD. Alternative projections of mortality and disability by cause 1990-2020: Global Burden of Disease Study. Lancet. 1997 May 24;349(9064):1498-504.
24. Mosenthal AC, Livingston DH, Elcavage J, et al. Falls: epide- miology and strategies for prevention. J Trauma 1995;38: 753-6.
25. Nakagawa M, Kawanishi C, Yamada T, et al. Comparison of characteristics of suicide attempters with family history of suicide attempt: a retrospective chart review. BMC Psychiatry. 2009 Jun 5; 9: 32.

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Original article

All-suture anchors in arthroscopic acetabular labral repair: our experience

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Summary. *Background:* Over the past years, the role of the acetabular labrum in hip joint biomechanics and its relations with joint health has been of particular interest. There is a good clinical improvement of patients in whom the acetabular labrum is preserved during arthroscopic hip surgery. The purpose of this study is to report the results of arthroscopic repair of labral tears at a medium term follow up. *Materials and methods:* We performed a retrospective review of all cases that underwent hip arthroscopy at our Institution from January 2013 until December 2018. There were 24 patients, 13 males and 11 females, and their mean age at the time of surgery was 29, 42 years (range, 19 to 43 years). All patients were treated by the same surgeon with an extracapsular OUT-IN approach. Suture was performed using a non-absorbable suture anchor all-suture. Clinical assessment was performed at December 2019 using a modified Harris hip score (mHHS), hip outcomes score activities of daily living (HOS ADL), hip outcomes score activities of sport scale (HOS SS). All patients with acetabular labrum injury had femoro-acetabular impingement. *Results:* The mean overall values in the preoperative period were 67.21 ± 10.31 for mHHS, 70.04 ± 12.11 for HOS-ADL and 60.06 ± 14.58 for HOS –SS. The results obtained in the re-evaluations of patients in December 2019 with a mean follow-up of 38, 3 months (minimum 1 year) are on average 82.17 ± 11.36 for mHHS, 83.00 ± 12.80 for HOS-ADL and 76.09 ± 18.52 for HOS-SS. *Conclusions:* The progress of knowledge and the advancement of diagnostic and therapeutic skills has led to a greater awareness of the importance of treating acetabular labrum tears. Arthroscopic treatment with suture appear to be a good option for these patients and we had encouraging results in our center. (www.actabiomedica.it)

Key words: labral, repair, arthroscopy, hip, all-suture, anchors

Introduction

Over the past years the role of the acetabular labrum in hip joint biomechanics and its relations with joint health has been of particular interest (1, 2). This is motivated by its role in the degenerative process of hip arthritis (3), and by the significant clinical improvement of patients in whom the acetabular labrum is preserved during arthroscopic hip surgery.

The acetabular labrum is a soft-tissue structure that lines the acetabular rim of the hip joint. In normal hip joint bio-mechanics, the labrum is essential for retaining a layer of intra-articular pressurized fluid for the lubrication of the hip joint and the load distribution (1). In a human cadaveric model, in a series of papers Ferguson et al. (4-6) demonstrate that with an

intact labrum a layer of pressurized fluid remains to last for several minutes in the articulation supporting load and keeping apart articular surfaces.

Its role of seal all around the femoral head contributes to hip stability (1). There is also a suction effect that creates an intrarticular low pression gradient. Indeed complete partial resection was harmful, reducing distractive force by approximately 70% mean (7, 8). It was suggested that joint instability and micro instability caused by labrum insufficiency may accelerate and exacerbate degenerative changes in the labrum and cause premature cartilage degeneration. Furthermore the labrum is also important by increasing contact area between articular surfaces reducing contact stress.

Lee at al. (9) found in their in vitro study that labral resection decreases significantly contact area and increases significantly contact pressure relative to the intact state under 700 N compression. In the same study, after reconstruction of the acetabular labrum with iliotibial band autografts and semitendinosus allografts they were able to improve contact area and reduce contact pressure comparing with the intact state.

The acetabular labrum function can be impaired by deterioration caused as a result of hip pathologies: femoro-acetabular impingement (FAI), dysplasia, capsular laxity, acute trauma, degeneration as a result of repetitive movement at extreme ranges (10-14). More specifically, in FAI caused by cam lesion, labral tears are situated at the transition zone antero-superiorly, where the labrum divorces from the cartilage because of the impingement of the pistol grip of the neck with the labrum. In pincer impingement damage is observed antero-superiorly on the labrum itself due to linear impact between the femoral head-neck junction and acetabular rim (1, 15). Often post-traumatic labral tear is a result of a trauma involving a lot of energy and causing subluxation or dislocation of the femoral head. Commonly there is an association with chondral injuries of the femoral head or of the acetabular side (10).

This damn causes pain, a restricted range of motion and finally degenerative changes of the acetabular labrum ad cartilage. In patients complaining groin pain and restriction of the range of motion of the hip labral tears are diagnosed more frequently because of the development of imaging technique like MRI, arthro-MRI and arthroscopy (16).

The hip joint may progress to osteoarthritis prematurely if the injured labrum and the underlying etiology remains untreated, indeed the treatment aims not only to treat the current pain but also to prevent the onset of a premature degenerative disease. McCarthy et al. (3) showed that there is a group of typical cartilage damage in the presence of labral tears, and they postulate that failure of the labral-chondral junction is the first event in primary degenerative arthritis of the hip. There are many therapeutic possibilities for labral tears, from a conservative treatment until surgery, nowadays arthroscopic repair is increasingly the favored option because a preserved labrum leads to a superior outcome compared with debridement and conservative treatment. (17) The aim of the study is to evaluate the short and medium term follow-up results of the acetabular labral repair.

Materials and methods

We performed a retrospective review of all cases that underwent hip arthroscopy at our Institution from January 2013 until December 2018. The same senior surgeon performed all the procedures. We included only patients with complete medical records: clinical evaluation, MRI of the affected hip, specific radiographs of the hip, pre-operation and follow-up scores.

The first visit included the anamnesis in which the patient's history, the causes of the onset of pain, the presence of trauma are deepened. The physical examination included clinical examination of the hip also with specific tests for femoro-acetabular impingement such as FADDIR, FABER, log roll test. During this visit, specific radiological scan were requested and evaluated, if already available. The radiographs required were: weight bearing pelvis in antero-posterior view, axial of the hip, frog-leg side view, false-profile view and cross-table view, and Dunn at 45° view. In addition, all patients with suspected femoro-acetabular impingement were required to have an MRI of the hip. After the evaluation of MRI, in the suspicion of an injury of the acetabular labrum, patients were asked for an arthro-MRI of the hip. One patient did the arthro-MRI and the arthro-CT (Fig.1)

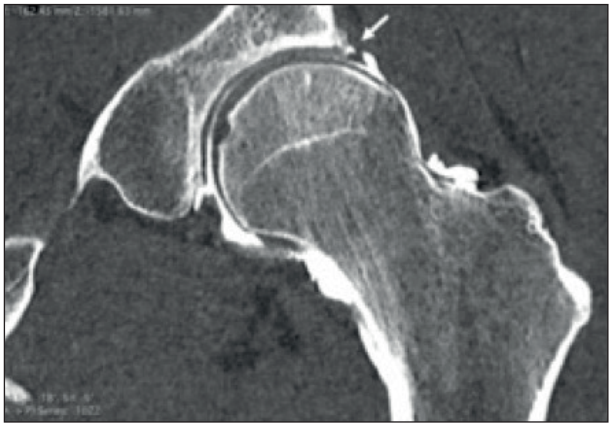


Figure 1. Arthro-CT shows the lesion of the acetabular labrum (white arrow)

Two weeks before the intervention, all patients were re-evaluated and underwent a visit with the compilation of the preoperative scores.

Hip arthroscopy was performed under general anesthesia on a traction bed. Arthroscopic findings of labral tears were classified according to the classification of Lage et al. (18). FAI was confirmed by checking impingement during hip motions in arthroscopy.

There were 24 patients, 13 males and 11 females, and their mean age at the time of surgery was 29, 42 years (range, 19 to 43 years). The lesion was located on the right side in 10 cases (42%) and the left side in 14 cases (58%). The mean body mass index was 23.8 kg/m^2(19.3-34.2 kg/m^2).

Surgical Technique

All patients were treated by the same surgeon with an extracapsular OUT-IN approach as described in a previous article by Di Benedetto P. et al. (19). Standard portals were used with the patient lying on the traction table in general anesthesia. We do not use X-ray during this procedure. Capsulotomy was performed between the anterior and antero-lateral parts of the femur neck using an arthroscopic knife. After confirming the lesion through arthroscopy, acetabular cartilage debridement was performed and suture was performer using a non-absorbable suture anchor all-suture ICONIX (Stryker, Kalamazoo, Michigan). The all suture anchors used in this series of cases can be applied with 1.4mm-2.4mm diameter holes, this allows less bone sacrifice and also repair of small-sized injuries.

Measurement of Clinical Outcomes

Clinical follow-up evaluations were performer at 2 weeks, 2, 4 and 12 months. Patients who did not attend visits regularly were contacted by telephone. All the patients were followed up in the post-operation by a physiotherapist who followed the instructions given by the surgeon during the clinical check-ups. Clinical assessment was performed at December 2019 using a modified Harris hip score (MHHS), hip outcomes score activities of daily living (HOS ADL), hip outcomes score activities of sport scale (HOS SS). The mean follow-up was 38,3 months (range 12 to 83 months). The clinical results were compared with preoperative values. Data were analyzed using STATA software, version 13 (StataCorp, College Station, TX). Continuous variables are presented through mean and standard deviation (SD); normality of distribution was evaluated by the Shapiro-Wilk test. Group comparisons were performed through paired t-test or Wilcoxon signed-rank test as appropriate. An α-level of 0.05 was assumed as guide for significance.

Results

Of the cohort of these 24 patients, 23 have practiced sports in their life, 18 at a high level up to the detection of groin pain. Among these athletes, 3 patients have not resumed the usual sporting activity after the operation and 5 patients have opted for activities that stressed the hip less. The other patients return to practice the same sport as previous after the rehabilitation period.

All patients with acetabular labrum injury had femoro-acetabular impingement. Specifically, 6 patients with cam-FAI, 7 with pincer type and 11 mixed. 5 patients had acetabular chondral lesions of grade greater than 2 according to Outerbridge classification.

The arthroscopic treatment lasted 78 minutes on average, with a minimum of 56 minutes and a maxi-

mum of 103. The surgical procedure has always included the suture of the labrum, but also the treatment of the femoro-acetabular impingement through the rim trimming of the acetabular edge and the osteochondroplasty of the femoral head-neck junction according to the specific case.

It was investigated, during the re-evaluations, even if the patients had successfully completed the rehabilitation program. In 16 cases, no further procedures were needed, in other 8 cases additional physiokinesitherapy was necessary, usually for a contracture of the iliopsoas muscle, which caused painful symptoms. 4 patients, after arthroscopic and rehabilitative treatment, continue to take NSAIDs as needed, 3 of whom were affected by cartilage injuries found during arthroscopy.

None of the patients included in this study needed a revision of the arthroscopic hip surgery or had to undergo a joint prosthesis.

The overall values of the three scores analyzed are mean in the preoperative period 67.21 ± 10.31 for mHHS, 70.04 ± 12.11 for HOS-ADL and 60.06 ± 14.58 for HOS –SS. (Tab.1)

The results obtained in the re-evaluations of patients in December 2019 with a mean follow-up of 38, 3 months are on average 82.17 ± 11.36 for mHHS, 83.00 ± 12.80 for HOS-ADL and 76.09 ± 18.52 for HOS-SS. (Tab. 2-3)

By comparing these results with those obtained from the pre-operative questionnaires, it can be seen that all patients significantly ($p < 0.001$) improved their score in the three different scales. Comparing between those of different degrees of improvement it results that 6 patients had a lesser benefit than the others from the operation, this minor improvement was not statistically significant, however 4 of the 5 patients with cartilage lesion found during arthroscopy are part of this group.

Table 1. Results of m-HSS, HOS-ADL and HOS-SS score in the preoperative period

PRE-SURGERY			
Patient	mHHS	HOS-ADL	HOS-SS
1	59.40	77.94	47.22
2	77.00	76.47	83.33
3	60.50	58.82	50.00
4	64.90	80.88	69.44
5	82.50	82.35	75.00
6	63.80	50.00	59.37
7	57.20	47.06	30.55
8	67.10	73.53	72.22
9	79.20	85.29	61.11
10	77.30	72.06	69.44
11	48.40	67.64	58.33
12	73.70	67.64	44.44
13	58.40	77.94	47.22
14	76.00	76.47	82.33
15	60.50	58.82	51.03
16	64.90	81.88	69.44
17	83.50	82.35	75.00
18	62.80	51.00	59.37
19	54.20	47.06	30.55
20	67.10	71.53	72.53
21	76.20	86.29	62.11
22	79.30	71.06	69.44
23	48.40	67.64	57.33
24	70.73	69.12	44.66
mean	*67.21*	*70.04*	*60.06*
SD	*10.31*	*12.11*	*14.58*

Discussion

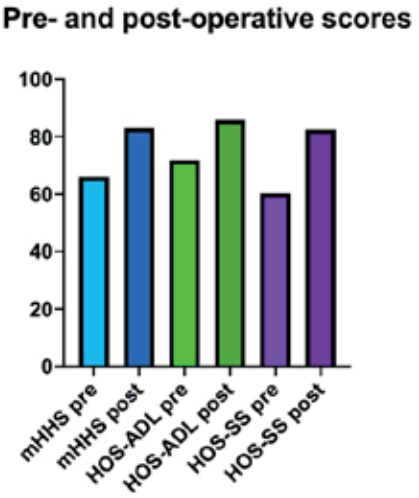
The treatment of acetabular labrum lesions is constantly evolving (17). There are several approaches, ranging from conservative treatment to debridement, or repairing the lesion, from 2010 was described also reconstructing the acetabular labrum (20). Even within the surgical options there are both open and arthroscopic approaches. Currently the tendency is to privilege arthroscopic treatment to open one, whenever possible.

Conservative treatment includes the use of NSAIDs, painkillers, intra-articular infiltrations and FKT (21). The infiltrations can be of corticosteroids, hyaluronic acid or PRP. (22) Surgical treatment with arthroscopy is reported in the literature to be superior (21, 23) however the conservative one is always acceptable for all patients who cannot undergo surgery. In our center, we reserve conservative treatment only for pa-

Table 2. Results of m-HSS, HOS-ADL and HOS-SS score in the post-operative evaluation

POST-SURGERY			
Patient	mHHS	HOS-ADL	HOS-SS
1	70,40	83,82	64,77
2	84,70	91,18	88,89
3	73,70	73,52	58,56
4	73,70	95,53	95,00
5	95,70	86,76	88,89
6	68,20	60,29	71,41
7	64,90	55,88	36,11
8	93,50	92,64	95,67
9	82,50	97,05	86,11
10	100,00	88,24	80,56
11	81,40	84,38	83,33
12	92,40	82,35	52,78
13	71,40	84,82	63,77
14	86,70	92,18	88,08
15	75,70	75,52	67,56
16	74,70	99,21	99,52
17	96,70	87,76	89,26
18	67,20	61,29	73,41
19	65,90	56,88	37,11
20	94,50	91,64	92,67
21	84,50	96,05	97,11
22	98,76	89,24	82,56
23	83,40	84,38	82,33
24	91,40	81,35	50,78
mean	*82,17*	*83,00*	*76,09*
SD	*11.36*	*12.80*	*18,52*

Table 3. Pre and post-operative results of mHHS, HOS-ADL and HOS-SS score.



tients who decide not to undergo surgery or in those in which it is contraindicated.

Debridement of the acetabular labrum was the treatment of choice before the advancement of the technique allowed suturing and reconstruction. The results reported in the literature (24-27) show that suturing is a better treatment, probably because it restores the structure and therefore the function of the labrum, thus delaying osteoarthritis. Indeed, in studies that examine patients undergoing removal of the acetabular labrum at a long follow up there is a considerable progression towards osteoarthritis and hip replacement (28). However, our follow up is not so long-term to be able to compare the results adequately. The repair by suture of the acetabular labrum lesions in arthroscopy seems to be the most successful option in literature to date (25-27), perhaps because it is associated with surgical acts that are also therapeutic for the resolution of the FAI, treating so both the lesion and one of the most frequent causes of the lesion.

As regards the reconstruction of the acetabular labrum, there is a heated debate in the literature about the indications even if the results appear encouraging both in high demand groups such as athletes (29) and in older patients (30, 31). In our cohort, no patients have been offered this treatment.

The results of our center have been compared with other works in the literature which report their own data analytically in their publications (32-35). The values found in our study are comparable with the results reported in the literature. Regarding the pre and post-operative HOS-ADL scale, results are consistent with those reported in literature, for HOS-SS, on the other hand, our findings are slightly lower than that reported by other studies both in the pre and post-operative period. Although there is a difference, this is present both in the pre and post-operative, while maintaining an improve-

ment in the score between pre and post-operative similar to the various patients and comparable to that obtained from the other studies. (32-35)

Various studies report a rate of surgical re-intervention, arthroscopic or not (31-36). In our series, no patients have undergone to a second surgery. We attribute this difference both to the low sample size compared to the other studies and to the follow up which is not particularly prolonged. However, we believe that in addition to the experience of the surgeon, the scrupulousness with which the surgical indication and the postoperative checks with close monitoring of the rehabilitation protocol is also important.

Our study has several limitations, including the fact of being a retrospective study, the number of the patients, not having considered further variables in the selection and classification of patients and finally the post-operative scores do not take into account the follow-up period which is different for the various patients.

Conclusions

In recent years, the progress of anatomical and pathophysiological knowledge and the advancement of diagnostic and therapeutic skills has led to a greater awareness of the importance of treating acetabular labrum tears.

The acetabular labrum plays an important role in the increase of the articular surface, in the best distribution of forces and thanks to its seal function, with the formation of negative pressure, improves the optimal functioning of the joint, ensuring an increase in joint longevity.

The suture of the acetabular labrum in arthroscopy is a therapy capable of significantly improving the symptomatology of the patients, being able, unlike debridement, to restore the functions of the labrum. In addition, arthroscopy often allows to resolve, together with the laceration of the labrum, also the femoroacetabular impingement, the most frequent cause of the pathology.

The results we obtained proved to be in line with the main studies reported in the literature concerning this procedure. Furthermore, it would certainly be interesting to re-evaluate patients at different times and for a longer post-operative period of time, to obtain a longer and more homogeneous follow-up, which can define more precisely the effectiveness of the treatment.

In the coming years, it is hoped that the suture of the acetabular labrum will become an increasingly common procedure, guaranteeing a more favorable prognostic evolution, thanks to an early diagnosis of these lesions that, although frequent, to date are often overlooked

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Bsat S., Frei H., Beaulé PE. The acetabular labrum: a review of its function.Bone Joint J. 2016 Jun;98-B(6):730–5.
2. Lee AJJ, Armour P, Thind D, Coates MH, Kang ACL. The prevalence of acetabular labral tears and associated pathology in a young asymptomatic population Bone Joint J May 2015, 97-B;5:623–627.
3. McCarthy JC, Noble PC, Schuck MR, Wright J, Lee J. The Otto E. Aufranc Award: the role of labral lesions to development of early degenerative hip disease. Clin Orthop Relat Res 2001;393:25–37.
4. Ferguson SJ, Bryant JT, Ganz R, Ito K. An in vitro investigation of the acetabular labral seal in hip joint mechanics. J Biomech 2003;36:171–178.
5. Ferguson SJ, Bryant JT, Ganz R, Ito K. The acetabular labrum seal: a poroelastic finite element model. Clin Biomech (Bristol, Avon) 2000;15:463–468.
6. Ferguson SJ, Bryant JT, Ganz R, Ito K. The influence of the acetabular labrum on hip joint cartilage consolidation: a poroelastic finite element model. J Biomech 2000;33:953–960.
7. Nepple JJ, Philippon MJ, Campbell KJ, et al. The hip fluid seal–Part II: The effect of an acetabular labral tear, repair, resection, and reconstruction on hip stability to distraction. Knee Surg Sports Traumatol Arthrosc 2014;22:730–736.
8. Smith MV, Panchal HB, Ruberte Thiele RA, Sekiya JK. Effect of acetabular labrum tears on hip stability and labral strain in a joint compression model. Am J Sports Med 2011;39(Suppl):103S–110S.
9. Lee S, Wuerz TH, Shewman E, et al. Labral reconstruction with iliotibial band autografts and semitendinosus allografts improves hip joint contact area and contact pressure: an in vitro analysis. Am J Sports Med 2015;43:98–104.
10. Su T, Chen GX, Yang L. Diagnosis and treatment of labral tear. Chin Med J (Engl). 2019 Jan 20;132(2):211–219.
11. Wenger D, Kendell K, Miner M, Trousdale RT. Acetabular labral tears rarely occur in the absence of bony abnormalities. Clin Orthop Relat Res 2004; 426:145–150.
12. Pogliacomi F., Costantino C., Pedrini M.F., Pourjafar S., De Filippo M., Ceccarelli F. Anterior groin pain in athlete as consequence of bone diseases: aetiopathogenensis, diagnosis

and principles of treatment. Medicina dello Sport, 2014, 67(1), 1–27.
13. Pogliacomi F., Costantino C., Pedrini M.F., Pourjafar S., De Filippo M., Ceccarelli F. Anterior groin pain in athletes as a consequence of intra-articular diseases: aetiopathogenensis, diagnosis and principles of treatment. Medicina dello Sport, 2014, 67(3), 341–68.
14. Pogliacomi F., Pedrini M.F., Pourjafar S., Pellegrini A., Paraskevopoulos A., Costantino C., Ceccarelli F. Pubalgia and soccer: real problem or overestimated? Medicina dello Sport, 2015; 68(4): 651–62.
15. Groh MM, Herrera J. A comprehensive review of hip labral tears. Curr Rev Musculoskelet Med 2009;2:105–117.
16. Reiman MP, Mather RC, Hash TW, Cook CE. Examination of acetabular labral tear: a continued diagnostic challenge. Br J Sports Med. 2014 Feb;48(4):311–9.
17. Woyski D., Mather RC. Surgical Treatment of Labral Tears: Debridement, Repair, Reconstruction. Curr Rev Musculoskelet Med. 2019 Sep;12(3):291-299.
18. Lage LA1, Patel JV, Villar RN. The acetabular labral tear: an arthroscopic classification. Arthroscopy. 1996 Jun;12(3):269–72.
19. Di Benedetto P1, Barbattini P, Povegliano L, Beltrame A, Gisonni R, Cainero V, Causero A. Extracapsular vs standard approach in hip arthroscopy. Acta Biomed. 2016 Apr 15;87 Suppl 1:41–5.
20. Philippon MJ, Briggs KK, Hay CJ, Kuppersmith DA, Dewing CB, Huang MJ. Arthroscopic labral reconstruction in the hip using iliotibial band autograft: technique and early outcomes. Arthroscopy. 2010;6:750–6.
21. Griffin DR, Dickenson EJ, Wall PDH, UK FASHIoN group. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome: a multicenter randomized controlled trial. Lancet. 2018;10136:2225–35
22. Chandrasekaran S, Lodhia P, Suarez-Ahedo C, Vemula SP, Martin TJ, Domb BG. Symposium: evidence for the use of intra-articular cortisone or hyaluronic acid injection in the hip. J Hip Preserv Surg. 2015;(1):5–15
23. Palmer AJR, Ayyar Gupta V, Fernquest S, FAIT Study Group. Arthroscopic hip surgery compared with physiotherapy and activity modification for the treatment of symptomatic femoroacetabular impingement: multicenter randomized controlled trial. BMJ. 2019;364:I185
24. Krych AJ, Thompson M, Knutson Z, Scoon J, Coleman SH. Arthroscopic labral repair versus selective labral debridement in female patients with femoroacetabular impingement: a prospective randomized study. Arthroscopy. 2013;1:46–53
25. Menge TJ, Briggs KK, Dornan GJ, McNamara SC, Philippon MJ. Survivorship and outcomes 10 years following hip arthroscopy for femoroacetabular impingement: labral debridement compared with labral repair. J Bone Joint Surg Am. 2017;12:997–1004
26. Larson CM, Giveans MR, Stone RM. Arthroscopic debridement versus refixation of the acetabular labrum associated with femoroacetabular impingement: mean 3.5-year follow-up. Am J Sports Med. 2012;40(5):1015–21.
27. Larson CM, Giveans MR. Arthroscopic debridement versus refixation of the acetabular labrum associated with femoroacetabular impingement. Arthroscopy. 2009;25(4): 369–376.
28. Byrd JW, Jones KS. Hip arthroscopy for labral pathology: prospective analysis with 10-year follow-up. Arthroscopy. 2009;25(4): 365–8.
29. Maldonado DR, Chen SL, Yelton MJ, Rosinsky PJ, Walker-Santiago R, Shapira J, Lall AC, Domb BG. Return to Sport and Athletic Function in an Active Population After Primary arthroscopic Labral Reconstruction of the Hip. Orthop J Sports Med. 2020 Feb 5;8(2):2325967119900767.
30. Rahl MD, LaPorte C, Steinl GK, O'Connor M, Lynch TS, Menge TJ. Outcomes After Arthroscopic Hip Labral Reconstruction: A Systematic Review and Meta-analysis. Am J Sports Med. 2019 Oct 21:363546519878147.
31. Scanaliato JP, Christensen DL, Salfiti C, Herzog MM, Wolff AB. Primary circumferential acetabular labral reconstruction: achieving outcomes similar to primary labral repair despite more challenging patient characteristics. Am J Sports Med. 2018;9:2079–88
32. Domb BG, Yuen LC, Ortiz-Declet V, Litrenta J, Perets I, Chen AW. Arthroscopic Labral Base Repair in the Hip: 5-Year Minimum Clinical Outcomes. Am J Sports Med. 2017 Oct;45(12):2882–2890.
33. Sawyer GA, Briggs KK, Dornan GJ, Ommen ND, Philippon MJ. Clinical Outcomes After Arthroscopic Hip Labral Repair Using Looped Versus Pierced Suture Techniques. Am J Sports Med. 2015 Jul;43(7):1683–8.
34. Jackson TJ, Hanypsiak B, Stake CE, Lindner D, El Bitar YF, Domb BG. Arthroscopic labral base repair in the hip: clinical results of a described technique. Arthroscopy. 2014 Feb;30(2):208–13.
35. Lee JW, Hwang DS, Kang C, Hwang JM, Chung HJ. Arthroscopic Repair of Acetabular Labral Tears Associated with Femoroacetabular Impingement: 7-10 Years of Long-Term Follow-up Results. Clin Orthop Surg. 2019 Mar;11(1):28-35.
36. Mehta N, Chamberlin P, Marx RG, Hidaka C, Ge Y, Nawabi DH, et al. Defining the learning curve for hip arthroscopy: a threshold analysis of the volume-outcomes relationship. Am J Sports Med. 2018;6:1284–93

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Original article

Capsular closure after hip arthroscopy: our experience

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Summary. *Background and aim of the work:* In the last decade, arthroscopic treatment of hip diseases has significantly spread and evolved and currently it represents the gold standard for the treatment of femoral-acetabular impingement. In the recent years, the function of the joint capsule (and therefore the results of an arthroscopic capsulotomy) has been hugely developed, opening a heated debate. The Literature is still torn about the need for a capsular suture, but more recent studies are more oriented in its execution at the end of the surgical procedure. According to these recent studies, the joint capsule performs an essential function of primary stability, and its closure is therefore necessary to restore the native anatomy and physiology. Nevertheless, capsular management remains a controversial topic. This is a retrospective study with the aim of assessing the influence of capsular suture on the patient's functional outcome in a cohort of patients with femoral-acetabular impingement arthroscopically treated. *Hypothesis:* Our hypothesis is that an adequate capsular suture positively influences the patient's functional outcome. *Methods and Results:* 50 patients treated with hip arthroscopy for femoral-acetabular impingement have been retrospectively enrolled at the Orthopaedic Clinic of Academic Hospital of Udine during a period of two-years (2017-2018); collected data have been analysed and compared with a retrospective model. Patients have been divided into two equivalent groups, 25 treated with capsular suture, 25 without performing the suture. Patient's post-operative functional outcome has been analysed using the modified Harris Hip Score (mHHS), the Non-Arthritic Hip Score (NAHS) and the Hip Outcome Score-Sport Scale (HOS-SS). The functional outcome in patients where capsular sutures were performed was better than in non-sutured patients, in all three analysed scales. *Conclusions:* Capsular suture with a single side-to-side stitch at the end of the procedure can positively influence the patient's functional outcome. (www.actabiomedica.it)

Key words: Hip arthroscopy, capsular suture, capsulotomy, femoral-acetabular impingement

Introduction

In recent decades, hip arthroscopy has considerably grown as a treatment of diseases affecting the coxo-femoral joint and its surrounding structures. This increase is likely related to the improvement of surgical techniques, the raised surgeons' interests about this approach and, finally, the evolution of the diagnostic techniques and dedicated tools. Currently, hip arthroscopy represents the gold standard for the treatment of femoral-acetabular impingement (FAI).

Hip arthroscopy for the treatment of FAI requires some precautions: firstly, mini-accesses for specific portals (the most used are the Antero-Lateral and the Mid-Lateral); secondly, a minimally invasive management of extra-articular tissues to be less demolitive as possible, but also to obtain an adequate view of the joint capsule. Moreover, the best possible capsulotomy must be performed to obtain a good manoeuvrability of the instruments, a better exposition of the intra-articular structures (including the acetabular labrum) and an acceptable workspace for the treatment of impingement.

If the utility of an adequate capsulotomy is well known, the Literature is not univocal on the impact of the capsulotomy and its possible repair at the end of the procedure, in terms of possible complications and restoration of the biomechanical stability (1, 2).

Some previous studies (some of which dated), did not find significant differences comparing suture and non-capsular suture strategy (3)

Whereas, several recent studies have reopened the debate which in the last years has been considerably inflamed. In fact, recent authors have demonstrated how capsular suture at the end of the operation determines biomechanical and functional benefits to the joint, positively influencing the patient's post-operative outcome, including range of motion, quality of life, satisfaction, pain and minor complications and hence reintervention. (4, 5). These are the main reasons why capsular repair has increasingly spread despite the lack of high-level evidence. Unfortunately, is not yet clear whether capsular suture should be performed as a routine procedure or not.

Joint capsule anatomy: The joint capsule consists of three external and one internal ligaments whose interconnections provide biomechanical constraints during movement through modifying forces about the hip. (6) The Iliofemoral ligament is the thickest and represents the primary limit to hip hyperextension and external-rotation. This ligament is made up of two portions, one lateral more vertical, and one medial more oblique. The primary function of the second external ligament, the Pubofemoral, is to limit abduction and external-rotation. The Ischio-femoral ligament finally effectively limits hyperextension (7). The internal ligament is the Zona orbicularis, a synovium-lined composed of circumferentially oriented fibres, which aid in resisting hip distraction, thereby stabilizing the femoral head and neck (8). Although the three external ligaments constitute a single capsular structure, the greatest mechanical influence is given by the Ileo-femoral ligament, which represents a critical component for the biomechanics of the hip, determining stability and limiting distraction or joint translation beyond the physiological range of motion. The joint capsule determines a non-dynamic primary stability of the joint (9-11). Further functions are joint sealing, proprioception and pain sensitivity (12). These features have been studied for a long time, especially in pathological pictures such as congenital hip dysplasia, with its pathogenesis of laxity and capsular instability (13).

Operating technique: Our operating technique involves the patient under General anaesthesia placed on an orthopaedic traction bed with the foot intrarotated about 15°. An extra-articular approach without traction as described in a previous paper by Di Benedetto et al. (14) is preferred. Two accesses are performed, the Antero-Lateral and Mid-Lateral Access. Besides, A mini-toilet of extra-articular tissues is executed.

After the long use by the surgeon of the interportal capsulotomy and T shape capsulotomy, our current technique involves a single incision centred on the femoral neck following the course of the capsular fibers up to the limit of the acetabular labrum (Fig.1-2); this new manoeuvre determines a less invasive effect on the Iliofemoral ligament, a lesser need to touch the extracapsular tissues, a lower risk of injury to the intra-articular structures and particularly of the acetabular

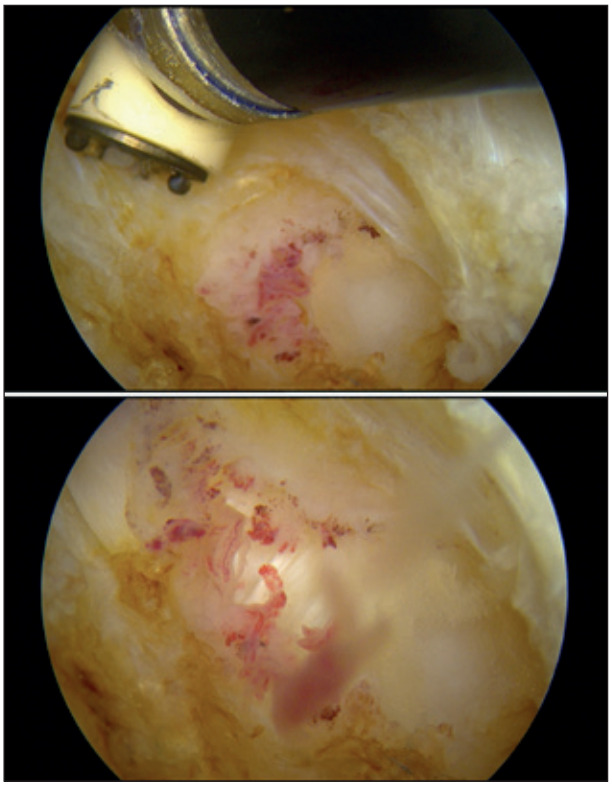

Figure 1–2. Capsulotomy with a single longitudinal incision from distal to proximal up to the acetabular labrum

lip. At the end of the surgery, a suture with a single side-to-side stitch with high resistance wire (14-15) is made to obtain a complete closure (fig. 3-4). The treatment lasts about 60 minutes with a maximum of 15 minutes in legs' traction. The aim of the study is to evaluate the clinical and the functional benefit of capsular closure after hip arthroscopy.

Methods

The retrospective study was performed on a group of 50 patients treated with hip arthroscopy in the period between February 2017 and October 2018. All the operations were performed by the same expert surgeon. Inclusion criteria were: clinically confirmed FAI diagnosis with dedicated radiographs and MRI study, age between 15 and 35 years, pre-operative pain for at least 6 months not regressed with physical, physiotherapic and analgesic therapies. Exclusion criteria included: evidence of hip dysplasia, coxa profunda or coxa protrusa, signs of advanced osteoarthritis, results of traumatic events such as fractures, previous local surgery, severe acetabular deformity, concomitant presence of other joint and extra-articular disorders, any intra-operative complications, arthroscopic surgery on the contralateral limb within the year.

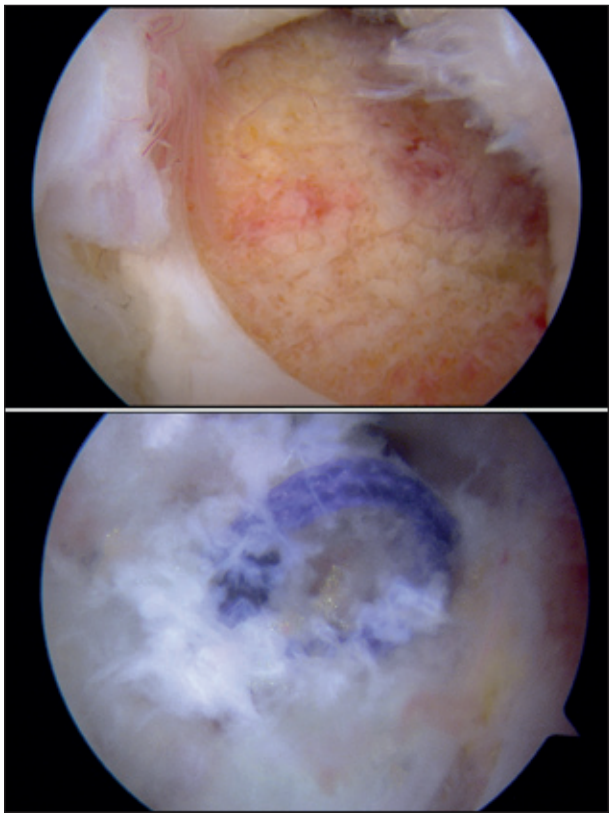

Figure 3–4. Suture of the capsule with a single side-to-side stitch

Among the 50 patients considered in the study, joint capsule closure procedure was not performed at the end of surgery in 25 of them; the second group included 25 patients who were treated with capsular suture with a side-to-side stitch, as previously described.

All patients underwent usual follow up at 2 weeks from the index procedure, at 45 days, at 3 months, at 6 months and at 1 year. Data have been collected 1 year after the surgery through a face-to-face interview filling in the modified Harris Hip Score (mHHS), Non-Arthritic Hip Score (NAHS) and Hip Outcome Score-Sport Scale (HOS-SS).

Continuous variables are presented through mean and standard deviation (SD); variables' distribution was assessed by the Shapiro-Wilk test. Group comparisons (non capsular closure group vs capsular closure group) were performed through Wilcoxon rank-sum (Mann-Whitney) test or two sample t-test as appropriate. Intra-group comparisons (before and after surgery) were based on paired t-test or Wilcoxon signed-rank test as appropriate. An α-level equal to 0.05 was assumed as guide for significance. All analysis were perfomed using STATA software version 13 (StataCorp, College Station, TX).

Results

All patients enrolled in the study (50 hip arthroscopy procedures) were examined for the treatment of the FAI. Both groups included 13 females and 12 males, the average age was 26 years (age range 15-35). The mean time for surgery was 55 minutes (range 40-72 minutes) for the non-capsular closure groups and 62 minutes (52-80 minutes) for the capsular closure group. The functional outcomes were evaluated 1 year after the operation with the mHHS, NAHS and HOS-SS. No patients needed additional procedures and no complications occurred in both groups.

The increase in the functional results, from pre-operative to post-operative (1 years FU), occurred in all patients of both groups and for all scales (Tab. 1-2). In both groups all scores at 1 year evaluation showed an increase statistically significant compared to pre-surgery evaluation.

As regards the analysis of the variation between pre and post surgery in the two groups, only in the mHHS score the "Capsular closure" group showed statistically significant increases on average higher than the comparison group. (α-level 0.05).

Tab.1 Mean of m-HHS, NAHS and HOS-SS pre-surgery and at 1 year after surgery for each group. NS (non capsular closure group); S (capsular closure group)

Discussion

During the last decade, the frequency of arthroscopic hip operations has increased exponentially; this procedure has become the standard technique for the treatment of non-arthritic intra and extra-articular pathologies of the hip, in particular of the femoral-acetabular impingement. In conjunction with the improvement of the surgical technique, a heated debate has opened regarding the instability of the joint capsule following the procedure. The pivotal questions of the debate are whether the capsulotomy determines an instability of the joint or not and whether a possible capsular suture restores the pre-intervention anatomy

Table 1. Mean and standard deviation of m-HHS, NAHS and HOS-SS for each group. NS (non capsular closure group); S (capsular closure group)

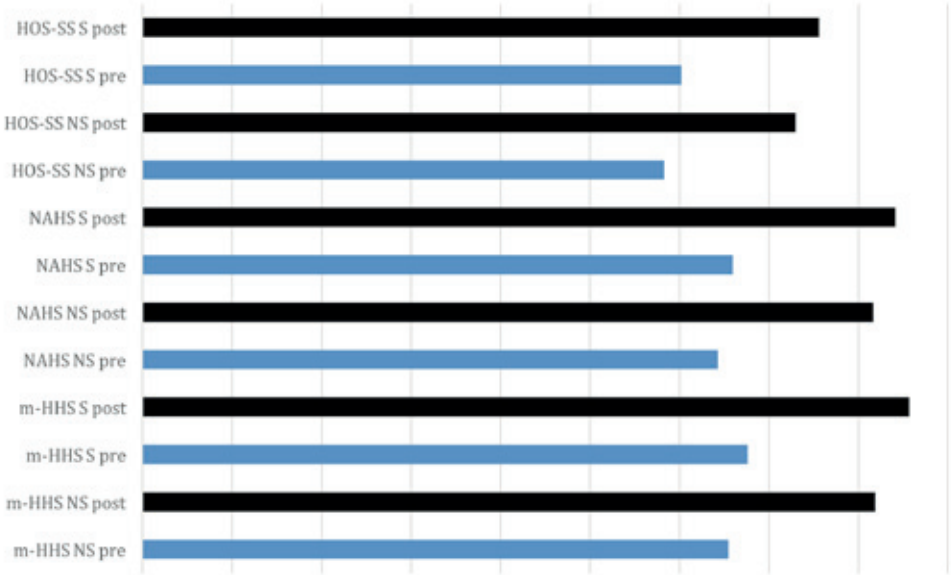

Table 2. Mean and standard deviation of m-HHS, NAHS and HOS-SS for each group. NS (non capsular closure group); S (capsular closure group)

	m-HHS NS pre	m-HHS NS post	NAHS NS pre	NAHS NS post	HOS-SS NS pre	HOS-SS NS post
Mean	65,48	81,88	64,24	81,64	58,32	73
Std. Deviation	2,786	2,027	2,976	1,8	4,516	5,115
	m-HHS S pre	m-HHS S post	NAHS S pre	NAHS S post	HOS-SS S pre	HOS-SS S post
Mean	67,6	85,68	65,96	84,12	60,2	75,6
Std. Deviation	1,555	3,198	2,371	2,789	3,571	3,958

and physiology, thus promoting the patient's post-operative outcome.

The issue is still open; the complexity and diversity of the variables in the field do not allow the use of univocal criteria to obtain homogeneous and comparable results (16,17). Currently the execution of the capsular suture is subject to the surgeon's ability and discretion, and there are no standard criteria (pathological and personal of the patient) that suggest the execution of this practice.

As anticipated, the Literature is not yet in agreement.

In some studies, the clinical benefits of capsular suture are not proven and do not demonstrate significant outcome differences between if the suture is performed (18). Ekhtiari et al (12) concludes that there is no evidence that capsular suture has long-term influences on joint stability.

Recent studies highlight how capsular suture promotes the well-being of soft tissues, prevents postoperative dislocations or dislocations, limits the development of heterotopic ossifications and increases functional outcome (19-20). Thaunat et al. this year he performed a retrospective study on functional outcome, demonstrating how capsular suture has clear positive effects. Abrams et al (19), studying the effects of capsulotomy on joint ROM, showed how repair restores the physiological rotational profile.

Myers et al (20), performed a study in cadavers, demonstrating that the joint capsule plays an important role in stability and that injury to the Iliofemoral ligament leads to an increase in anterior translation. Khair et al (21), again with studies in cadavers, concluded that joint stability depends on the size of the capsulotomy and on the possible post-surgery suture.

Nho et al (6) considers complete capsular suture an essential part of arthroscopic surgery to obtain an adequate functional outcome. Baha et al. (4) concludes that adequate repair restores range of motion and joint translation close to native levels, thus suggesting the execution of the capsular suture.

Our study is certainly in line with the most recent works (5). Our study has several limitations, including the fact of being a retrospective study, the number of patients, not having considered further variables in the selection and classification of patients. Moreover, the data obtained are not statistically significant except for the m-HHS score, but it could be a first step to deepen the subject. In any case further studies and analyses are necessary with more data to obtain an adequate result.

Conclusions

In conclusion, considering the limitations of our study, despite the conflicting opinions and the lack of clarity in the Literature, we still recommend the execution of the capsular suture at the end of the procedure, and we act to encourage this practice to become routine.

As it has been shown in surgery on other joints (22), minimizing soft tissue trauma and restoring native anatomy and physiology are principles that must also guide this surgery.

It is our opinion that, since it is a quick, easy, painless and minimally invasive procedure, it should be routinely adopted.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Thaunat M., Sarr S., Georgeokostas T., Azeem A., Murphy C. G., Kacem S (2020). Femoroacetabular impingement treatment using the arthroscopic extracapsular outside-in approach: Does capsular suture affect functional outcome?. Orthopaedics & Traumatology: Surgery & Research.
2. Ran Atzmon, Zachary T Sharfman, Barak Haviv, Michal Frankl, Gilad Rotem, Eyal Amar, Michael Drexler, Ehud Rath, Does capsular closure influence patient-reported outcomes in hip arthroscopy for femoroacetabular impingement and labral tear?, Journal of Hip Preservation Surgery, Volume 6, Issue 3, August 2019,
3. Benjamin G. Domb, Christine E. Stake, Zachary J. Finley, Tian Chen, Brian D. Giordano, Influence of capsular repair versus unrepaired capsulotomy on 2-year clinical outcomes after arthroscopic hip preservation surgery. Arthroscopy. 2015 Apr; 31(4): 643–650.
4. Baha P, Burkhart TA, Getgood A, Degen RM. Complete capsular repair restores native kinematics after interportal and T-capsulotomy. Am J Sports Med. 2019 May;47(6):1451–8. Epub 2019 Apr 4.

5. Westermann, R. W., Bessette, M. C., Lynch, T. S., & Rosneck, J. (2018). Does Closure of the Capsule Impact Outcomes in Hip Arthroscopy? A Systematic Review of Comparative Studies. The Iowa orthopaedic journal, 38, 93–99.
6. Nho, S.J., Beck, E.C., Kunze, K.N. et al. Contemporary Management of the Hip Capsule During Arthroscopic Hip Preservation Surgery. Curr Rev Musculoskelet Med 12, 260–270 (2019).
7. Nam D, Osbahr DC, Choi D, Ranawat AS, Kelly BT, Coleman SH. Defining the origins of the iliofemoral, ischiofemoral, and pubofemoral ligaments of the hip capsuloligamentous complex utilizing computer navigation. HSS J. 2011;7(3):239–43.
8. Ito H, Song Y, Lindsey DP, SafranMR, Giori NJ. The proximal hip joint capsule and the zona orbicularis contribute to hip joint stability in distraction. J Orthop Res. 2009;27(8):989–95.
9. Domb BG, Philippon MJ, Giordano BD. Arthroscopic capsulotomy, capsular repair, and capsular plication of the hip: relation to atraumatic instability. Arthroscopy 2013; 29: 162–73.
10. Kuhns BD, Weber AE, Levy DM et al. Capsular management in hip arthroscopy: an anatomic, biomechanical, and technical review. Front Surg 2016; 3: 13.
11. Martin HD, Savage A, Braly BA et al. The function of the hip capsular ligaments: a quantitative report. Arthroscopy 2008; 24: 188–95.
12. Alzaharani A, Bali K, Gudena R et al. The innervation of the human acetabular labrum and hip joint: an anatomic study. BMC Musculoskelet Disord 2014; 15: 41.
13. Ekhtiari S, de Sa D, Haldane CE et al. Hip arthroscopic capsulotomy techniques and capsular management strategies: a systematic review. Knee Surg Sports Traumatol Arthrosc 2017; 25: 9–23.
14. Di Benedetto P, Barbattini P, Povegliano L, et al. Extracapsular vs standard approach in hip arthroscopy. Acta Biomed. 2016;87(suppl 1):41-45.
15. Pierannunzii L., Di Benedetto P., Carulli C., Fiorentino G., Munegato D., Panascì M, Santori N. (2019). Mid-term outcome after arthroscopic treatment of femoroacetabular impingement: development of a predictive score. HIP International, 29(3), 303–309.
16. Rachel M. Frank, Simon Lee, Charles A. Bush-Joseph, Bryan T. Kelly, Michael J. Salata, Shane J. Nho, Improved outcomes after hip arthroscopic surgery in patients undergoing T-capsulotomy with complete repair versus partial repair for femoroacetabular impingement: a comparative matched-pair analysis. Am J Sports Med. 2014 Nov; 42(11): 2634–2642.
17. Eyal Amar, Yaniv Warschawski, Thomas G. Sampson, Ehud Atoun, Ely L. Steinberg, Ehud Rath, Capsular closure does not affect development of heterotopic ossification after hip arthroscopy. Arthroscopy. 2015 Feb; 31(2): 225–230.
18. Asheesh Gupta, Carlos Suarez-Ahedo, John M. Redmond, Michael B. Gerhardt, Bryan Hanypsiak, Christine E. Stake, Nathan A. Finch, Benjamin G. Domb, Best Practices During Hip Arthroscopy: Aggregate Recommendations of High-Volume Surgeons. Arthroscopy. 2015 Sep; 31(9): 1722–1727
19. Abrams GD, Hart MA, Takami K et al. Biomechanical evaluation of capsulotomy, capsulectomy, and capsular repair on hip rotation. Arthroscopy 2015; 31: 1511–7.
20. Myers CA, et al. Role of the acetabular labrum and the iliofemoral ligament in hip stability: an in vitro biplane fluoroscopy study.AmJ Sports Med. 2011;39 (Suppl): 85S–91S
21. Khair MM, et al. The effect of capsulotomy and capsular repair on hip distraction: a cadaveric investigation. Arthroscopy. 2017;33(3): 559–65
22. Ryan J.A., Meyers K.N., DiBenedetto P., Wright T.M. and Haas S.B. (2010) Failure of the Patellar Tendon with the Patella Everted Versus Noneverted in a Matched-Pair Cadaver, Model. HSS Journal , 6, 134–137.

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Original article

Direct anterior total hip arthroplasty: a retrospective study

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Abstract. *Background:* The quest for less invasive surgical approaches for total hip arthroplasty has gained much attention recently. There is very little information regarding differences about the main surgical access. The purpose of this study was to collect data regarding patients' subjective perceptions of the direct anterior hip arthroplasty, heterotopic ossification degrees, range of movement and complication and comparing these satisfaction results with the other surgical techniques. *Methods:* The study involved 51 patients operated in our Orthopedic clinic with direct anterior total hip arthroplasty between 2016 and 2017. We recorded and compared clinical and radiographic data at 1 year with anterolateral hip arthroplasty. *Result:* Only one patient described less than an 8/10 satisfaction; 5.45% of the patients restored the physiological ROM and 21.82 % lost only 5° of range of motion. According to Brooker Classification 58.33 % did not develop any Heterotopic Ossification. *Conclusion:* All standard approaches to the hip have been shown to be safe and efficacious, with particular advantages and disadvantages for each approach. DAA has some short term advantages like a faster recovery, less blood loss and less heterotopic ossification. Long term studies are required to demonstrate a cost benefit or quality of care advantage to other hip approaches. (www.actabiomedica.it)

Key words: THA, Direct Anterior, Approach

Introduction

Total hip arthroplasty (THA) is considered one of most successful orthopedic treatments for improving quality of life in patients with osteoarthritis (1,2). Improvement in THA has led to faster functional recovery, short hospitalization and higher patient satisfaction (3). Among these factors, different surgical approaches, can also affect the clinical outcomes after THA. The Direct Anterior Approach (DAA) was first described in 1881 by German surgeon Carl Hueter (4). It represents an increasingly popular surgical approach for total hip arthroplasty (THA). It is considered a less invasive technique as it exploits an intermuscular and nervous space. The aim of our study is to demonstrate the advantages of this approach.

Surgical technique

The oblique skin incision is marked approximately from 2 to 4 cm distally and laterally to the ASIS and is directed along the TFL belly for 7-9 cm. A reported complication of this approach is the proximity to the Lateral Femoral Cutaneous Nerve. Blunt dissection through the subcutaneous fat is recommended to further minimize risk of nerve injury, which can result in paresthesia. (5) The interval between the TFL and Sartorius is entered by incision of the fascia over the medial TFL muscle belly, retaining an adequate sleeve of tissue for closure and offering protection to the LCFN. Care should be taken to ensure the appropriate interval, as dissection through the lateral TFL and not in the intramuscular portal, may result in damage to the motor branch of the superior Gluteal Nerve. If the exposure is too posterior, blood vessels should be seen entering the fascia. The fascia becomes denser as it overlies the Gluteus Medius, which should prompt recognition of the improper interval. Conversely, if the plane is developed too medially, dissection into the femoral triangle will occur, risking injury to the femoral neurovascular bundle. Blunt dissection separates

the TFL muscle belly from the fascia and facilitates entry into the interval for proper exposure of the hip capsule. A self-retraining retractor is positioned between the Vastus lateralis and the Rectus Femoralis. By blunt dissection, the ascending branch of the LFCA is isolated and closed. The retractor in now positioned deeper to expose the capsule. The portion of Ileopsoas adherent to the capsule is detached and then the capsule is incised with a triangular shape (with the apex pointing to the cranial portion of the acetabular edge). The strip of capsule is preserved for the closure. The leg is then extra-rotated so the osteothomy of the femoral neck is performed. Femoral head is removed by corkscrew. Chanley retractor is positioned to expose the acetabulum. The acetabulum is reamed with increasing size. The reamer head is positioned first and then is connected to the engine. A press fit acetabular cup may be inserted with a target abduction angle of 35-45° and anteversion angle 10-20°. Acetabular liner is then inserted. The medial and cranial portion of the great trochanter is exposed by a ligamentous and capsular release until an extra-rotation of 150-180° and then the leg is extended. During this movement the femur is elevated and the great trochanter is stayed in the acetabulum, avoiding acetabular edge lesion. The femoral canal is prepared until the achievement of correct fit. The lateral proximal portion of the intramedullary canal is enlarged using Luer tongs. X-Rays of the pelvis are useful to control the correct positioning of the stem. The definitive stem is implanted and external movements are performed to test the stability of the implant. Drains are positioned and soft tissue is sutured in order. Attention should be paid in order to avoid nervous injuries.

Material and methods

Between August, 2016 to November, 2016 156 patients were treated for THA by anterior approach. We enrolled 51 patients in this retrospective study due to our inclusion and exclusion criteria. There were 24 male and 27 female patients, with a mean age of 68 year (49 – 85 years). The operation was executed by the same surgical team, using the same technique (Hueter anterior approach) and same instrumentation and prosthesis (Medacta Switzerland, and Biolox delta fourth generation ceramic head, CeramTec, Stuttgart, Germany, ceramic or polyethylene liner). 21 patients were excluded and 84 did not answer our request. At 1 year of follow-up (mean 1,33 years, 0,51 – 1,56 years) we performed hip radiography (AP and Lateral projections) to measure correct positioning of prosthesis and for calcification (classificated by Brooker index); we scored patients by Harris Hips Score, rated satisfaction scores and measured ROM. We considered complications and failures of the implant. Microsoft Excel was used for statistical analysis and linear regressions were performed for all factors collected at follow-up.

Results

The mean age of 51 patients (47% men and 53% women) was 68 years (min 49 years, max 85 yeas). The clinical and radiological mean follow-up was 16 months (min 6 months, max 19 months). Only 4 patients received blood transfusion after surgery (7,84%), and one of these patients was a bilateral implant. Average length of hospital stay was 5,5 (5,1 for men and 5,8 for women). Using a Brooker Index we discovered 42% of patients did not have calcifications, 31% had a first grade, 6% a second grade, 2% a third grade and 2% a fourth grade when analyzing X-Rays. All the prosthesis were correctly positioned with a 45° acetabular inclination and 15° of anteversion. None of the monobloc stem radiographs showed evidence of asceptic loosening. We did not have any breakages of implants. Regarding clinical appearance, on a scale from 0 to 10 (with 10 being the most satisfied), patients reported an 8 to 10 of satisfaction with the implant except for one patient. The only patient that did not report a high rate of satisfaction was the patient with the grade four calcification index. The mean Harris Hip Score (HHS) was 91 (94 men and 88 women), 73% excellent (90-100), 16% good, 7% fair, 3% poor. Mean Range of Motion (ROM) was 36° (5-50) of extrarotation, 28° (5-35) of intrarotation, 117° (70-135) of flexion, 36° (5-25) of extension, 30° (10-35) of adduction and 39° (5-45) of abduction; these values are near normal limits. It should be noted that 21% of patients actually had a physiological ROM value of the hip.

Complications were found in only 2,4% of patients: one case of infection, which was healed with antibiotics, VAC therapy and finally by spacer and revision surgery; a case of peri-prosthetic fracture, classified as Vancouver C that underwent osteosynthesis by plate and cerclage; one case of post-operative hematoma healed spontaneously; and one case of cup aseptic loosening treated with revision surgery. We performed linear regressions between HHS and ROMs (R^2=0,02; significance of F = 0,15), HHS and perceived satisfaction (R^2 = 0,001; significance of F = 0,78); there was no correlation or significance between these values. Therefore, HHS is not correlated with function of the arthroplasty.

Discussion

Total Hip replacement has undergone many technical improvements since its introduction in orthopedic surgery. Six different approaches have been described and used: the anterior (12), antero-lateral (13), posterior (14), posterolateral (15), lateral (16), and the double incision with fluoroscopy (17). Every approach has some advantages and disadvantages. So, how to decide? There are many factors to take into account. First, some surgical technical considerations. The DAA approach has lower wound complication rates in comparison to the Lateral approach (6). Also the prosthesis component positioning could be influenced by the surgical approach. Implant alignment is the key to stability and long term retention. The Lewinnek Safe Zone is defined by an inclination of 40°+- 10° and an antiversion of 15°+- 10°. Positioning the acetabular cup between this range of degrees is associated with a lower rate of dislocation. Higgins et. al suggested that DAA is associated with higher rates of acetabular cup positioned in the safe zone compared to the lateral and posterolateral access. (7) The DAA performed with leg traction has even greater percentage of correct acetabular cup positioning thanks to better X-ray projections and better visualization of the acetabulum (10). In our study all of the acetabular cups were positioned with 45° of inclination and 15° of anteversion. A comparison of visually inspected muscle damage to cadaveric specimens undergoing anterior or posterior approaches showed less damage to the gluteus medius and minimus with the anterior approach. 31% of the anterior hips showed evidence of tensor fascia lata (TFL) damage and 12% had damage to the direct head of the rectus femoris. The greatest difference was in damage to the gluteus minimus. All external rotators were released as part of the posterior approach, whereas 50% of anterior hip procedures required release for mobilization (8). A study of 421 DAA hips estimated that increasing TFL damage was related to the male sex and increasing body mass index (BMI)(9). The incidence of heterotopic ossification (HO), possibly related to retraction damage to the TFL or rectus femoris, has also been evaluated in anterior hips. According to the Brooker classification and X-ray analysis we discovered only 2% of patients had a grade 4 of calcification Brooker index: 58,33 % didn't had calcifications, 31% had a grade 1, 6% a grade 2, 2% a grade 3 and 2% a grade 4. The direct anterior approach could be performed using a standard table with a manual leg control or with a leg positioner. There are many comparative study between the two approaches that show a decreased surgical time in traction DAA with a positive learning curve. (10) In this study we chose to always use a medacta leg traction. In our surgical approach the protection of the TFL with a strip of capsule and the release of the lateral capsule avoided to damage the extrarotator muscles could be the explaining of the lower heterotopic calcification compared to the lateral access and to the anterior approach in literature. A retrospective comparison of 100 minimal-incision DAA and 100 transgluteal lateral approaches showed decreased hospital length of stay, decreased pain on post-operative day zero and one, and decreased time to reach defined range of motion for the anterior approach. (11) In our study Mean Range of Motion (ROM) were 36° (5-50) of extrarotation, 28° (5-35) of intrarotation, 117° (70-135) of flexion, 36° (5-25) of extension, 30° (10-35) of adduction and 39° (5-45) of abduction; these value are near normal ones. It's to be notice that 21% of patients had exactly physiological value of hip ROM. Hip joint kinetics and kinematics are influenced by the surgical approach in the short term follow up. In comparing DAA to ALA approach, DAA showed faster recovery with a peak during the first three months. In

a study of Queen et al., the ALA group exhibited a higher adduction movement compared with the unoperated hip, while a decreased hip adduction moment was observed in the DAA group compared with the unoperated hip. (18) Such outcomes are probably due to the relative increase in adductor movement at the operative hip in patients included in the ALA group, which may have corresponded with pelvic drop during the propulsion phase. It may be attributed to weak abductor mechanism. The internal rotation of hip joint and internal rotation of foot progression angle correlated with reduced abductor function. Abductor momentum arm is compensated by internal rotation of hip in patients with reduced abductor function. Regardless, one year after operation the functional outcome was similar between groups. We performed linear regressions between HHS and ROMs, HHS and rated satisfaction ($R^2 = 0{,}001$; significance of $F = 0{,}78$); there was no correlation or significance between these values. Therefore, HHS is not correlated with function of the arthroplasty. The time of recovery, the emetic loss and complications are other parameters of comparison between the surgical approaches. Review of comparative studies indicates DAA tends toward shorter hospital stays and high rates of patients discharged home. However, rates of intraoperative femur fracture, operative time and blood loss are notably higher for those developing familiarity with this approach. However, when surgeons have performed a modest number of procedures, the complication rates tend to markedly decrease in most studies to levels comparable to other approaches and the learning curve seems to be faster with a leg positioner. In our study, complications were found in only 2,4% of patients: one case of infection, healed with antibiotics, VACtherapy, and finally by spacer and revision surgery; a case of peri-prosthetic fracture, classified as Vancouver C that underwent osteosynthesis by plate and cerclage; one case of postoperative hematoma which healed spontaneously; and, one case of cup aseptic loosening treated with revision surgery. Additionally, only 4 patients received blood transfusions after surgery (7,84%), one of them who was a bilateral implant. The days of hospitalization were 5,5 (5,1 for men and 5,8 for women).

Conclusion

All standard approaches to the hip have been shown to be safe and efficaciuos, with particular advantages and disadvantages for each approach. DAA has been associated with a steep learning curve. The leg traction allows for a more repeatable operation with a faster learning curve. The rates of complication decrease with the growth of the surgeon's experience. The advantages of this tecnique are less invasion, a better visualization of the acetabulum, less heterotopic ossification, faster recovery time, and less blood loss. Long term studies of a larger number of patients are still required to demonstrate a cost benefit or quality of care advantage to other hip approaches.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1 Hojer Karlse AP, Geisler A, Petersen PL, Mathiesen O, Dahl JB,. Postoperative pain, treatment after total hip arthroplasty ; a systematic review. Pain. 2015;156(1):8–30
2 Marques EM, Jones HE, Elsever KT, Pyke M, Blom AW, Beswick AD. Local anaesthetic infiltration for peri-operative pain control in total hip and knee replacement: systematic review and meta-analyses of short and long-term effectiveness. BMC Muskoloskelet Disord 2014; 15:220
3 Kaunaratne S, Duan M, Pappas E, Fritsch B, Boyle R, Gupta S, Stalley P, Horsley M, Steffens D. The effectiveness of robotic hip and knee arthroplasty on patient-reported outcomes: a systematic review and meta-analysis. Int Orthop. 2018.(Epub ahead of print)
4 Rachbauer F, Kain MS, Leunig M. The history of the anterior approach to the hip Orthop Clin North Am 2009;
5 Bender B, Nogler M, Hozack WJ. Direct anterior approach for total hip arthroplasty. Orthop Clin North Am 2009
6 Poehling-Monaghan KL, Kamath AF, Taunton MJ, Pagnano MW. Direct anterior versus miniposterior THA with the same advanced perioperative protocols: surprising early clinical results. Clin Orthop Relat Res 2015; 473: 623–631 (PMID: 25082624 DOI: 10.1007/s11999-014-3827-z)
7 Higgins BT, Barlow DR, Heagerty NE, Lin TJ. Anterior vs. posterior approach for total hip arthroplasty, a systematic review and meta-analysis. J Arthroplasty 2015; 30: 419–434 (PMID: 25453632 DOI: 10.1016/j.arth.2014.10.020)
8 Meneghini RM, Pagnano MW, Trousdale RT, Hozack WJ. Muscle damage during MIS total hip arthroplasty: Smith-

Petersen versus posterior approach. Clin Orthop Relat Res 2006; 453: 293–298 (PMID: 17006366 DOI: 10.1097/01.blo.0000238859.46615.34)
9 Frye BM, Berend KR, Lombardi AV, Morris MJ, Adams JB. Do sex and BMI predict or does stem design prevent muscle damage in anterior supine minimally invasive THA? Clin Orthop Relat Res 2015; 473: 632–638 (PMID: 25337974 DOI: 10.1007/s11999-014- 3991-1)
10 Junich Nakamura, Shigeo Hagiwara, Sumihisa Orita. Direct asnterior approach for total hip arthrhoplasty with a novel mobile traction table - a prospective cohort study. Muscoloskeletal disorder 2017 DOI 10.1186/s12891-017-1427–2
11 Goebel S, Steinert AF, Schillinger J, Eulert J, Broscheit J, Rudert M, Nöth U. Reduced postoperative pain in total hip arthroplasty after minimal-invasive anterior approach. Int Orthop 2012; 36: 491–498 (PMID: 21611823 DOI: 10.1007/s00264-011-1280-0)
12 Kennon R, Keggi J, Zatorski LE, Keggi KJ (2004) Anterior approach for total hip arthroplasty: beyond the minimally invasive technique. J Bone Joint Surg Am 86-A (Suppl 2): 91–97
13 Bertin KC, Rottinger H (2004) Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res 429:248–255
14 Goldstein WM, Branson JJ, Berland KA, Gordon AC (2003) Minimal-incision total hip arthroplasty. J Bone Joint Surg Am 85-A(Suppl 4):33–38
15 Moore AT (1959) The Moore self-locking vitallium prothesis in fresh femoral neck fractures: a new low posterior approach (the southern exposure). AAOS Instr Course Lect 16:309
16 Berger RA (2004) Mini-incision total hip replacement using an anterolateral approach: technique and results. Orthop Clin North Am 35(2):143–151. doi:10.1016/S0030-5898(03)00111-1
17 Berger RA, Duwelius PJ (2004) The two-incision minimally invasive total hip arthroplasty: technique and results. Orthop Clin North Am 35(2):163–172. doi:10.1016/S0030-5898(03)00110-X

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Original article

Facing complications of direct anterior approach in total hip arthroplasty during the learning curve

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Summary. *Background:* This study aims to evaluate complications and early postoperative clinical outcomes of direct anterior approach (DAA) in total hip arthroplasty (THA). *Methods:* Ninety-one consecutive patients who underwent primary elective unilateral THA between January 2013 and December 2019 were identified. Collected data included age of patient, BMI, ASA score, EBL (estimated blood loss), LOS (length of stay), operating time, and intra/postoperative complications. The recorded complications included prolonged wound drainage without infection, superficial and deep infection, dislocation, periprosthetic fracture, aseptic loosening or failure of osteointegration and nervous damage. Any reoperation, with or without prosthetic component revision, was recorded. *Results:* Fourteen complications (15,4%) and 12 (13,18%) postoperative anemizations were observed in this series. No deep infection was reported. Most common complications were nerve damage (3/91; 3,29%), greater trochanter fracture (3/91; 3,29%), and wound trouble (3/91; 3,29%). Two (2,19%) dislocations were reported. One (1,09%) intraoperative periprosthetic fracture was treated with cerclage wiring. One (1,09%) revision was needed for an acetabular mobilization. One patient (1,09%) had severe periprosthetic ectopic ossifications (Brooker 4), needing reintervention because of severe limitations of the range of motion (ROM). *Conclusions:* Complications rate in this study with THA by DAA is comparable to those reported in literature. DAA is a safe, efficient procedure but it needs a steep learning curve. (www.actabiomedica.it)

Key words: DAA (Direct anterior approach), THA

Introduction

The number of primary total hip arthroplasty (THA) performed through a direct anterior approach (DAA) is increasing (1, 2). This approach utilizes an internervous and intermuscular plane between the tensor fascia latae and the sartorius muscles (3).

Proponents of the DAA believe this technique to be associated with less muscle damage, faster patient recovery and lower risk of postoperative hip dislocation (2, 4, 5).

However, it is important for surgeons adopting this approach to understand the potential complications and pitfalls in order to decrease the risk of failure and potential harm for patient.

In this study the results observed in a series of 91 cases were compared with those reported in the Literature in order to evaluate the risk of complication of DAA.

Methods

A retrospective cohort study was performed. Ninety-one consecutive patients who underwent primary unilateral THA through DAA between January 2013 and December 2019 were identified. All operations were performed by the same senior surgeon since the beginning of his learning curve with DAA.

Collected data included the age of the patient, Body Mass Index (BMI), ASA score (6), EBL (estimated blood loss [preop Haemoglobin - postop Haemoglobin, g/dl]), length of stay (LOS), operating time, and intra/postoperative complications. Complications to be recorded included prolonged wound drainage without infection, superficial and deep infection, dislocation, periprosthetic fracture, aseptic loosening or failure of osteointegration and nervous damage. Any reoperation, with or without prosthetic component revision, was recorded. Prolonged drainage was defined as that which continues for more than ten days postoperatively requiring negative pressure therapy, compression dressings or changes in anticoagulation regimen. Superficial infection was defined as local infection without drainage that required and improved with antibiotics and without further surgery. Deep infection was defined according to MSIS (Musculoskeletal Infection Society) criteria (7, 8).

A standard institution protocol for all patients undergoing THA regardless of surgical approach was used for all patients during the study period. Primary cementless THA components were used (MicroPort Orthopedics™, Shanghai, China), without traction surgical table.

Short-term intraoperative antibiotic prophylaxis was administered within 60 minutes of the incision; all patients received routine thromboembolic prophylaxis using low-molecular-weight-heparin in addition to compression devices while they stayed in hospital, unless medical conditions, comorbidities or allergies necessitated the use other prophylactic agents. All patients got prophylactic therapy for ectopic ossification in the same day of surgery with Indomethacin 150 mg/die for 6 days, excluding patients who suffer from gastrointestinal and cardiovascular diseases.

Results

Demographics showed a mean age of 69 ± 10,3 years (range 26-87); the mean BMI was 27,79 ± 4,3 (range 17,6-39,7).

The mean ASA score was 2 (71 patients classified as 2, 19 as 3 and 1 patient as 1 ASA score) and the mean operating time was 75 ± 16,63 minutes (range 61-130 minutes).

Only 12 patients needed blood transfusions (mean blood loss was 4,02 ± 1,26 g/dl; range 1,2-6,7 g/dl); the mean LOS was 6,24 ± 2,25 days (range 3-18 days). The patients were always discharged to an acute rehabilitation facility.

There were 14 complications, with an incidence of 15,4% (Table I).

Of these complications, 2/91 (2,19%) were due to superficial infection, 1/91 (1,09%) were due to prolonged wound drainage. No deep infections were reported. 1 (1,09%) periprosthetic fracture, 3 (3,29%) greater trochanter fracture and 2 (2,19%) dislocation during the early postoperative rehabilitation.

One patient (1,09%) had severe periprosthetic ectopic ossifications (Brooker 4) (9), and needed reintervention because of severe limitations of the ROM.

One (1,09%) aseptic loosening (due to failure of osteointegration) was treated with revision of the acetabular component, with good postoperative results.

Two dislocations found in our series healed without further complications.

Finally, another complication in our series was the damage of lateral femoral cutaneous nerve (LFCN), with an incidence of 3/91 (3,29%). Most of cases were transient numbness/dysesthesia in the anterolateral region of the thigh. No lesions to the superior gluteal nerve were reported. Only one case (1,09%) referred long lasting numbness, without any functional limitation.

Discussion and conclusion

The most common complications reported for DAA are:

1 - Nerve Damage: The DAA has evolved since its original description by Carl Heuter in 1870 with modifications by Smith-Peterson and Judet (10). The continuing evolution of the approach makes difficult interpreting the literature on lateral femoral cutaneous nerve (LFCN) injury reported rates as there are wide discrepancies, from 0,1 to 8,1% (11, 12). This is probably related to the variability in skin incision and deep dissection described for the anterior approach (13).

The LFCN is purely a sensory nerve, and injury generally manifests as numbness in the anterolateral region of the tight; some patients report burning or

Table 1. Incidence of complications

Incidence	Cases	Complication
2,19%	2/91	Superficial infection
1,09%	1/91	Polonged wound drainage
1,09%	1/91	Periprosthetic fracture
3,29%	3/91	Greater trochanter fracture
2,19%	2/91	Dislocation
1,09%	1/91	Periprosthetic ectopic ossification
1,09%	1/91	Aseptic loosening
3,29%	3/91	Nerve damage

dysesthesia. LFCN neuropraxia rates range from 67% to 91% in some series (14) with no functional limitations reported by the patients and as measured by the SF-12, WOMAC, UCLA PROM scores.

Avoidance of this complication is possible with blunt dissection between the sartorius and tensor fasciae latae, by using a more lateral incision away from the lateral border of the sartorius muscle, careful dissection, and confining the DAA to the area inferior and lateral to the anterior superior iliac spine.

The terminal branches of the inferior branch of the superior gluteal nerve innervates the tensor fasciae latae being at potential risk during DAA (15).

Grob et al. performed an anatomical study with cadaveric dissection of the course of the nerve branch and found that that the nerve is at risk during the placement of retractors and coagulation of the ascending branch of the lateral femoral circumflex femoral artery (16).

Care must be taken during broaching: insufficient exposure may lead to direct damage to the fibres of the tensor fasciae latae muscle, including the motor nerve branches (17, 18).

In present study, only three patients report this complication; in two cases, the paraesthesia was transient and resolve within three months after surgery. Only one case present a persistent numbness, without any functional limitation due to purely sensitive nature of the LFCN.

2 - Fracture Risk: modified fractures traction table are commonly used in DAA for THA with a mobile foot attachment for rotation of the leg; the use of these devices must be done with care, as fractures attributable to their unsafe use have been reported. Intraoperative fractures of the femoral shaft (0,8%) and greater trochanter (5,7%) are reported in some series (19-21).

The incidence of postoperative periprosthetic femoral fracture for primary cementless THA ranges from 0,47 to 7,1% (22). Advanced age, female sex, and BMI have been reported as risk factors; no significant associations where found among the different surgical approaches (23, 24).

Only one (1,09%) periprosthetic fracture was found in this series; a young woman sustain an intraoperative fracture, treated with cerclage wiring (Figure 1). No weightbearing was allowed in this case for the first month after surgery, but passive mobilization was carried on. The functional outcome at 6 months was excellent despite the intraoperative complication.

Prompt recognition during the primary surgery permit a better management and treatment of these complications.

In this series 3 (3,29%) greater trochanter fractures among the first cases of the learning curve were recorded, which didn't require any treatment. They had only local pain for one month resolved at the follow-up.

3 - Revision risk: in the last decade there is a concerning trend of increasing early THA failures rates within 5 years of the primary procedure (25).

The literature is unclear about how that relates to the increase in DAA for THA (26); some series (27, 28) report early femoral failure as more common in patients operated by DAA. However, the same authors also found revision for acetabular component failure more common in patients with a posterior approach.

A study published in 2015 (29) evaluating a total of 42 438 primary THA's found no differences in risk of septic or aseptic revision between the DAA, anterolateral, or posterior approach for THA. They also report a lower risk of hip dislocation for the anterolateral and direct anterior approach when compared to posterior approach.

We reported 2 (2,19%) cases of dislocation. One, a young female, sustained an early dislocation during the immediate postoperative rehabilitation protocol. After reduction, a hip abduction brace was worn for

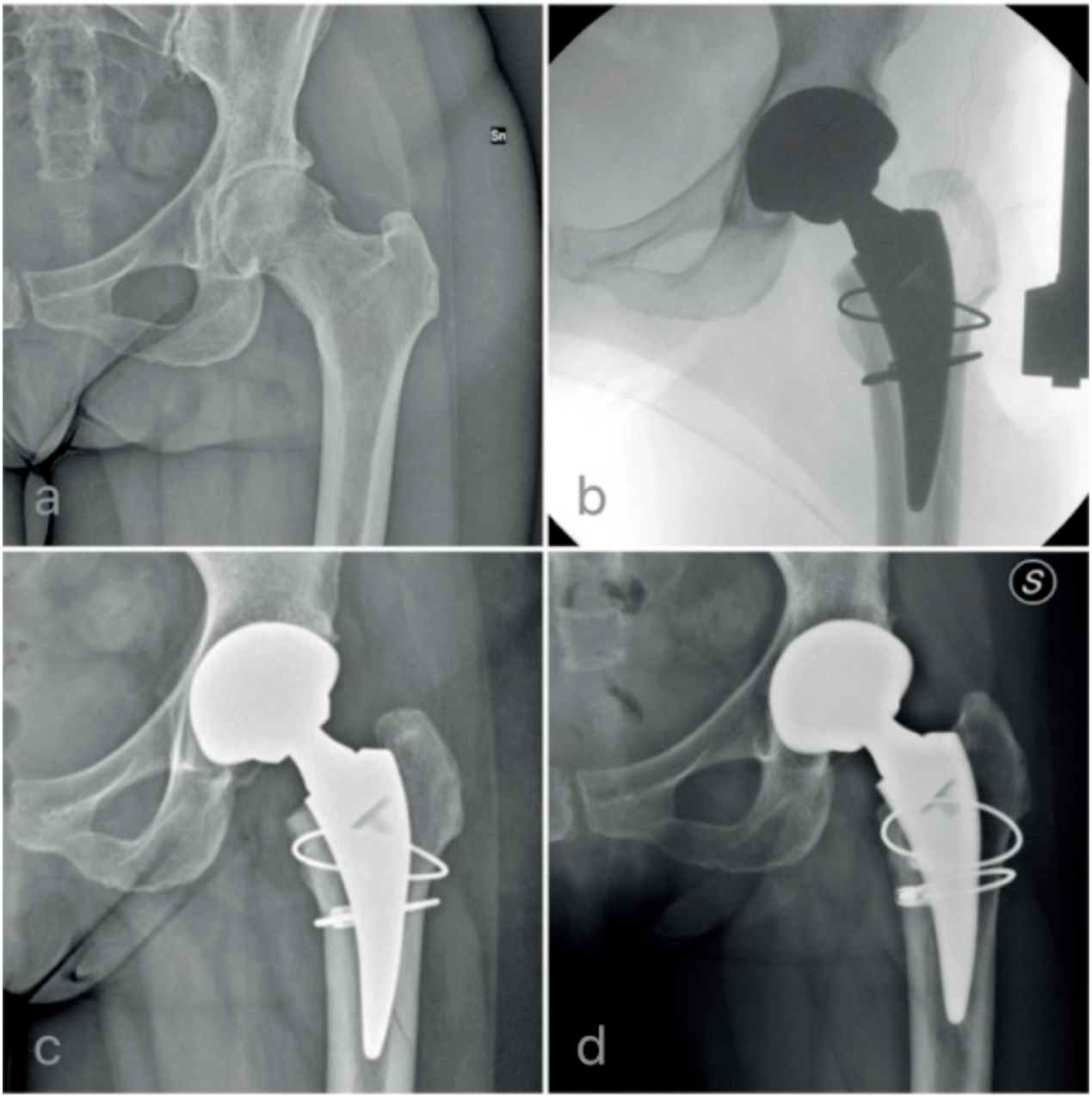

Figure 1. Clinical case of periprosthetic intraoperative fracture with DAA. (a) Preoperative x-ray; (b) intraoperative x-ray showing the fracture treated with cerclage wiring; (c, d) postoperative x-ray images at 1 and 6 months in which healing of the periprosthetic fracture is showed

three weeks. No recurrent dislocations were reported later, with a good functional result at 6 months. Another patient, a 75 yo male, sustained 2 dislocations. In both cases, surgical revision was not necessary.

Revision surgery was deemed necessary in only one (1,09%) case. It was an aseptic loosening of the acetabular component, due to failure of osteointegration. Revision surgery with implantation of acetabular cemented cup was necessary. The patient report satisfactory outcomes, despite a minimal limitation in hip flexion (95°).

4 - Blood Loss: the blood loss after THA may be evaluated in various way (surgeon estimation of intraoperative blood loss (EBL); post-operative drain

output; number or necessity of transfusion; change in serum haemoglobin or haematocrit levels). This heterogeneity in evaluation makes literature conflicting to be interpreted. It's difficult, given the available literature, to draw any conclusion about blood loss in DAA; some series found no differences in operative blood loss/transfusion/Hb-Hct levels between DAA compared to posterior approach (30, 31).

The source of bleeding could be the ascending branch of the lateral circumflex artery, that can be damaged during the preparation of the femoral canal or improperly ligated/coagulated (32).

The mean blood loss in our series was estimated to be 1258 ± 402,6 ml; only 12/91 (13,18%) needed blood transfusions postoperatively. The mean age was 69; the older the patients, the higher was the risk for blood transfusion, probably due to comorbidities.

5 - Wound complications and infection: reducing wound complication and deep surgical site infection is paramount in every THA procedure. The literature report conflicting data about the rates of wound complication in DAA; two series report a reoperation rate for wound infection/wound necrosis of 1,6% and 1,4%, respectively for DAA and posterior approach. (33, 34). However, the deep infection rate was comparable to series of alternatives approach (0,8%).

Another study (35) evaluated obesity as a risk factor for wound complication. Obesity has been shown to be a risk factor for wound complication and surgical site infection in THA regardless of approach (36, 37); the proximity of the anterior skin incision to the inguinal skin crease with overlying abdominal pannus in obese individuals may explain a high rates of reoperation for wound complication in obese patients (BMI > 40) (38, 39).

In our series, wound complications were reported in 3/91 patients (3,29%). All the patients heal with dressing and a brief administration of oral antibiotics. No deep infection was reported.

6 – Ectopic ossifications: onset of ectopic ossification is a common complication following THA. The incidence is up to 30% according to Łęgosz et al. (40).

Anyway, there is no agreement in the literature on the real incidence of this pathology, even if the prevalence is probably underestimated because only the severe cases are reported. In our study we reported 1 case (1,09%). There are several risk factors that predispose the population to develop ossifications. These are listed in the study from Zhu: male gender, cemented arthroplasty, bilateral procedure rheumatoid, arthritis, ankylosing spondylitis (41). Attention must be paid to

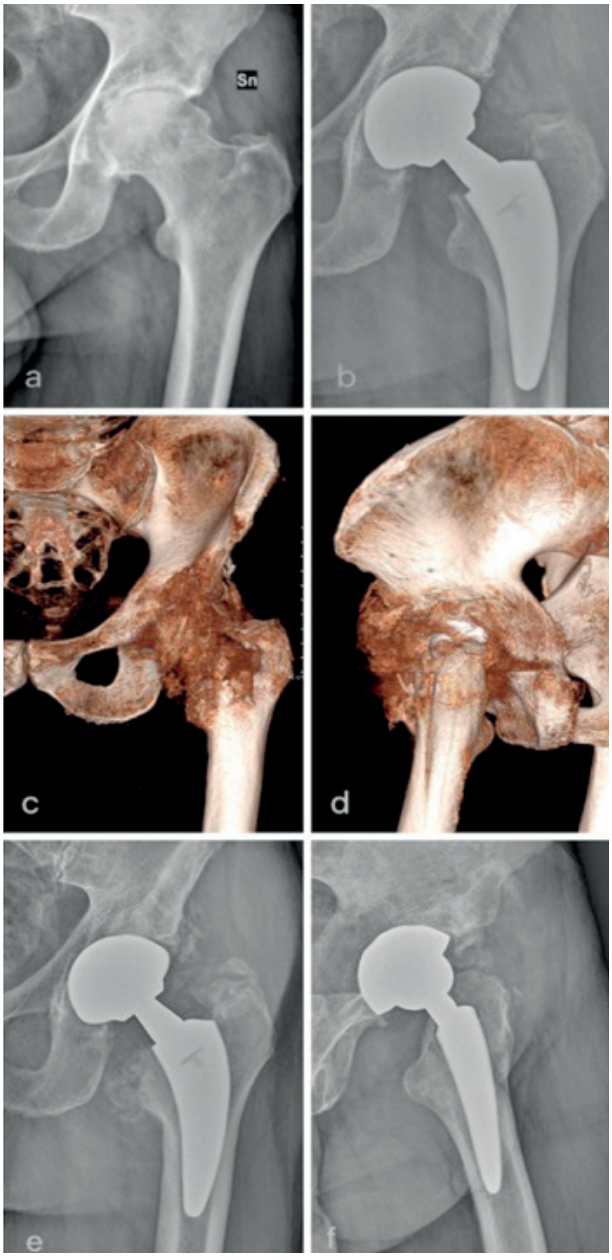

Figure 2. Clinical case with severe periprosthetic ectopic ossifications which required revision surgery: (a) preoperative x-ray; (b) postoperative x-ray at 1 month after THA; (c, d) 3D CT scan, anterior and posterior views respectively, of Brooker's grade 4 ectopic ossifications; (e, f) post-operative x-ray image after surgical removal of ectopic bone formations.

patients who suffered from these medical conditions because they are at high risk of develop ectopic ossifications and prophylactic postoperative therapy should be commenced. In our series all patients got prophylactic therapy in the same day of surgery with Indomethacin 150 mg/die for 6 days, excluding patients who suffer from GI and CV diseases. Just in 1 case (1,09%), as abovementioned, the complication was reported, and it was classified as 4 in Brooker's classification (Figure 2 a, b, c, d). The patient was affected by limited ROM due to pain (0-80° of flexion) and it was decided to candidate patient for surgical removal of heterotopic bone formations (Figure 2 e, f). Post-operative course was characterized by femoral nerve stupor that caused extension knee deficit and numbness at the level of thigh and saphenous nerve territory. At 1 month after discharge patient was able to walk with one crutch aid, pain was disappeared, and full movement of the hip was achieved.

Complications recorded in this study are similar to those commonly reported in the literature.

Understanding the potential complications of DAA is important and can help decrease risks for patients. The surgeon should be familiar with the procedure and carefully trained specifically for DAA, especially during the learning curve (42).

The most common complications reported are nerve damage; careful planning of incision and dissection should be made to avoid the risk of injury to the LFCN.

Conflicting evidence in the literature makes it difficult to draw conclusions about the long-term superiority of DAA for THA; a growing body of evidence otherwise points towards superiority in early recovery and functional outcomes with DAA in experienced hands compared to posterior and lateral based approaches.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Berry DJ, Bozic KJ. Current practice patterns in primary hip and knee arthroplasty among members of the American Association of Hip and Knee Surgeons. J Arthroplasty 2010; 25(6 Suppl.):2.
2. Post ZD, Orozco F, Diaz-Ledezma C, Hozack WJ, Ong A. Direct anterior approach for total hip arthroplasty: indications, technique, and results. J Am Acad Orthop Surg 2014; 22(9):595.
3. Malik AK, Chou DT, Witt JD. Anterior approaches to the hip for the treatment of femoro-acetabular impingement: a cadaveric approach. Hip Int 2010;20(4):482.
4. Moskal JT. Anterior approach in THA improves outcomes: affirms. Orthopedics 2011; 34(9):e456.
5. Pogliacomi F, De Filippo M, Paraskevopoulos A, Alesci M, Marenghi P, Ceccarelli F. Mini-incision direct lateral approach versus anterior mini-invasive approach in total hip replacement: results 1 year after surgery. Acta Biomedica 2012; 83(2): 114-21.
6. Saklad M. Grading of patients for surgical procedures. Anestesiol 1941;2:281–4
7. Parvizi J, Zmistowski B, Berbari EF, Bauer TW, Springer BD, Della Valle CJ, Garvin KL, Mont MA, Wongworawat MD, Zalavras CG. New definition for periprosthetic joint infection: from the workgroup of the musculoskeletal infection society. Clin Orthop Relat Res. 2011;469(11): 2992–4.
8. Purcell RL, Parks NL, Gargiulo JM, Hamilton WG. Severely Obese Patients Have a Higher Risk of Infection After Direct Anterior Approach Total Hip Arthroplasty. J Arthroplasty 2016; 31:162–5
9. Brooker AF, Bowerman JW, Robinson RA, Riley RH Jr. Ectopic ossification following total hip replacement. Incidence and a method of classification. J Bone Joint Surg Am 1973;55(8):1629–1632.
10. Rachbauer F, Kain MS, Leunig M. The history of the anterior approach to the hip. Orthop Clin North Am 2009;40:311–20.)
11. Restrepo C, Parvizi J, Pour AE, Hozack WJ. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplasty 2010;25:671–9.e1.
12. Homma Y, Baba T, Sano K, Ochi H, Matsumoto M, Kobayashi H, Yuasa T, Maruyama Y, Kaneko K. Lateral femoral cutaneous nerve injury with the direct anterior approach for total hip arthroplasty. Int Orthop 2016;40:1587–93.
13. Rudin D, Manestar M, Ullrich O, Erhardt J, Grob K. The Anatomical Course of the Lateral Femoral Cutaneous Nerve with Special Attention to the Anterior Approach to the Hip Joint. J Bone Joint Surg Am 2016;98:561–7.
14. Goulding K, Beaulé PE, Kim PR, Fazekas A. Incidence of lateral femoral cutaneous nerve neuropraxia after anterior approach hip arthroplasty. Clin Orthop Relat Res 2010;468:2397–404
15. Eksioglu F, Uslu M, Gudemez E, Atik OS, Tekdemir I. Reliability of the safe area for the superior gluteal nerve. Clin Orthop Relat Res 2003:111–6.
16. Grob K, Manestar M, Ackland T, Filgueira L, Kuster MS. Potential Risk to the Superior Gluteal Nerve During the Anterior Approach to the Hip Joint: An Anatomical Study. J Bone Joint Surg Am 2015;97:1426–31.

17. Meneghini RM, Pagnano MW, Trousdale RT, Hozack WJ. Muscle damage during MIS total hip arthroplasty: Smith-Petersen versus posterior approach. Clin Orthop Relat Res 2006;453:293–8.
18. Pfirrmann CWA, Notzli HP, Dora C, Hodler J, Zanetti M. Abductor tendons and muscles assessed at MR imaging after total hip arthroplasty in asymptomatic and symptomatic patients. Radiology 2005;235:969–76.
19. Woolson ST, Pouliot MA, Huddleston JI. Primary total hip arthroplasty using an anterior approach and a fracture table: short-term results from a community hospital. J Arthroplasty 2009;24:999–1005.
20. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res 2005;441:115–24.
21. De Geest T, Vansintjan P, De Loore G. Direct anterior total hip arthroplasty: complications and early outcome in a series of 300 cases. Acta Orthop Belg 2013;79:166–73.
22. Sidler-Maier CC, Waddell JP. Incidence and predisposing factors of periprosthetic proximal femoral fractures: a literature review. Int Orthop 2015;39:1673–82.
23. Berend KR, Mirza AJ, Morris MJ, Lombardi AV Jr. Risk of Periprosthetic Fractures With Direct Anterior Primary Total Hip Arthroplasty. J Arthroplasty 2016;31:2295–8.
24. Franklin J, Malchau H. Risk factors for periprosthetic femoral fracture. Injury 2007;38:655–60.
25. Ulrich SD, Seyler TM, Bennett D, Delanois RE, Saleh KJ, Thongtrangan I, Kuskowski M, Cheng EY, Sharkey PF, Parvizi J, Stiehl JB, Mont MA. Total hip arthroplasties: what are the reasons for revision? Int Orthop 2008;32:597–604.
26. Dall'Oca C, Trivellin G, D'Orazio L, Sambugaro E, Mezzari S, Zanetti G, Corbo VR, Magnan B. Hip arthroscopy in osteoarthritis consequent to FAI Acta Biomed. 2016 Apr 15;87 Suppl 1:46–52.
27. Meneghini RM, Elston AS, Chen AF, Kheir MM, Fehring TK, Springer BD. Direct Anterior Approach: Risk Factor for Early Femoral Failure of Cementless Total Hip Arthroplasty: A Multicenter Study. J Bone Joint Surg Am 2017;99:99–105.
28. Eto S, Hwang K, Huddleston JI, Amanatullah DF, Maloney WJ, Goodman SB. The Direct Anterior Approach is Associated With Early Revision Total Hip Arthroplasty. J Arthroplasty 2017;32:1001–5.
29. Sheth D, Cafri G, Inacio MCS, Paxton EW, Namba RS. Anterior and Anterolateral Approaches for THA Are Associated With Lower Dislocation Risk Without Higher Revision Risk. Clin Orthop Relat Res 2015;473:3401–8.
30. Bergin PF, Doppelt JD, Kephart CJ, Benke MT, Graeter JH, Holmes AS, Haleem-Smith H, Tuan RS, Unger AS. Comparison of minimally invasive direct anterior versus posterior total hip arthroplasty based on inflammation and muscle damage markers. J Bone Joint Surg Am 2011;93: 1392–8.
31. Martin CT, Pugely AJ, Gao Y, Clark CR. A comparison of hospital length of stay and short-term morbidity between the anterior and the posterior approaches to total hip arthroplasty. J Arthroplasty 2013;28:849–54.
32. Scaglia M, Ditta A, Magnan B, Navarro U, Cassini M Late bleeding during anterior approach to the hip: case report. Acta Biomed. 2019 Dec 5;90(12-S):184–186
33. Jewett BA, Collis DK. High complication rate with anterior total hip arthroplasties on a fracture table. Clin Orthop Relat Res 2011;469:503–7.
34. Christensen CP, Karthikeyan T, Jacobs CA. Greater prevalence of wound complications requiring reoperation with direct anterior approach total hip arthroplasty. J Arthroplasty 2014;29:1839–41.
35. Watts CD, Houdek MT, Wagner ER, Sculco PK, Chalmers BP, Taunton MJ. High Risk of Wound Complications Following Direct Anterior Total Hip Arthroplasty in Obese Patients. J Arthroplasty 2015;30:2296–8.
36. Pugely AJ, Martin CT, Gao Y, Schweizer ML, Callaghan JJ. The Incidence of and Risk Factors for 30-Day Surgical Site Infections Following Primary and Revision Total Joint Arthroplasty. J Arthroplasty 2015;30:47–50.
37. Patel VP, Walsh M, Sehgal B, Preston C, DeWal H, Di Cesare PE. Factors associated with prolonged wound drainage after primary total hip and knee arthroplasty. J Bone Joint Surg Am 2007;89:33–8.
38. Jahng KH, Bas MA, Rodriguez JA, Cooper HJ. Risk Factors for Wound Complications After Direct Anterior Approach Hip Arthroplasty. J Arthroplasty 2016;31: 2583–7.
39. Purcell RL, Parks NL, Gargiulo JM, Hamilton WG. Severely Obese Patients Have a Higher Risk of Infection After Direct Anterior Approach Total Hip Arthroplasty. J Arthroplasty 2016;31:162–5
40. Łęgosz P, Otworowski M, Sibilska A, Starszak K, Kotrych D, Kwapisz A, Synder M. "Heterotopic Ossification: A Challenging Complication of Total Hip Arthroplasty: Risk Factors, Diagnosis, Prophylaxis, and Treatment." BioMed research international vol. 2019 3860142.
41. Zhu Y, Zhang F, Chen W, Zhang Q, Liu S, Zhang Y. Incidence and risk factors for heterotopic ossification after total hip arthroplasty: a meta-analysis. Arch Orthop Trauma Surg 135, 1307–1314 (2015).
42. Pogliacomi F, Paraskevopoulos A, Costantino C, Marenghi P, Ceccarelli F. Influence of surgical experience in the learning curve of a new approach in hip replacement: anterior mini-invasive vs standard lateral. Hip International 2012; 22(5): 555–61.

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Original article

Acetabular de-escalation in hip revision

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Summary. *Background:* The idea of "de-escalation" (DE) indicates an arthroplasty revision performed by changing a revision component by a primary component. Aim of this study is to verify if this technique can represent an option in case of cage or ring failure. *Methods:* We observed five cases of revision hip cage loosening with complete allograft consolidation. This group of patients were revised with use of a primary cup and were specifically followed in ours institutions offices. Patients were clinically and radiologically followed every 6 months for the next two years and then annually *Results:* At final follow-up (15-2 years, mean 6 years) four patients (80%) showed a good recovery of their levels of activity. The mean Harris hip score improved from 20 points (range,7-38 points) preoperatively to 48 points (range, 16-88 points). At final radiological follow-up acetabular components were radiographically stable at the last follow-up. One patient (20%) at two years follow-up, was unable to walk without crutchies due to hip pain. X-rays showed cup loosening in all three zones. Patient was dissatisfied. Primary cup was revised with a Burch Schneider cage. *Conclusions:* De-escalation technique is a surgical option to consider in case of young patients, limited number of previous revisions and more than three years survivorship of loosened acetabular cage. (www.actabiomedica.it)

Key words: hip revision, de-escalation technique, Burch Schneider cage

Introduction

The idea of "de-escalation" (DE) indicates an arthroplasty revision performed by changing a revision component by a primary component. This technique was introduced with use of distal locked stem as temporary femoral revision implant to be following by a standard primary component replacement (1,2). On the acetabular side, bone reconstruction after impaction grafting and ring or cage revision may allow a further revision by using a primary cup. In our experience DE technique was applied in five cases of acetabular ring loosening. Aim of this study is to verify if this technique can represent an option in case of cage or ring failure.

Materials and Methods

From January 2000 to December 2014, 116 failed total hip arthroplasty with complex acetabular deficiency reconstruction *via* antiprotrusio Burch Schneider cage and structural allografts were performed at our institutions. Twenty-four (20.6%) cages were revised. The causes of failed cages were infection in 4 hip, non-healing allograft with cage loosening in 10 cases, polyethylene loosening in 2 cases, recurrent dislocations in 3 cases and cage loosening with complete allograft consolidation in 5 hips. The sub group of failed Burch Schneider cage with complete allograft consolidation were revised with use of a primary cup. These patients were specifically followed in ours institutions offices. Patients were clinically and radiologically fol-

lowed every 6 months for the next two years and then annually. The Harris hip scores (3) were calculated preoperatively and on follow up and the patients expressed their subjective impression of the result as very satisfied, satisfied, or dissatisfied. At the same time, radiographic analysis was carried out to identify the presence of any radiolucent lines, osteolysis and sclerosis, according to the three zones defined by DeLee and Charnley (4). Radiographic examination included views, such as antero-posterior (AP) of the pelvis and lateral of the affected hip, according to a standard protocol for imaging reproducibility. A single observer made all measurements.

Results

From January 2006 to December 2014 we performed 5 revisions of acetabular ring by standard cup. 4 patients was female, 1 patient was male. Average age was 60,8 years (51-68). Survivorship of de-escalated acetabular ring was respectively 15,8,3,2,2 years. Number of previous revisions before DE surgery was: 3 in one case, 2 in two cases and 1 in two cases. During de-escalation surgery all hips were exposed using a postero-lateral approach (Table 1). Good quality of bone reconstruction after cage removal was intraoperatively evaluated. A primary press-fit cup with 2 or 3 screws were implanted in all cases. At final follow-up (15-2 years, mean 6 years) four patients showed a good recovery of their levels of activity. The mean Harris hip score improved from 20 points (range,7-38 points) preoperatively to 48 points (range, 16-88 points) at the time of the latest examination. Two patients were very satisfied and two patients were satisfied with their outcome. At final radiological follow-up acetabular components were radiographically stable at the last follow-up, showing evident signs of bone remodelling and integration, without any radiolucent lines, sclerotic areas or periprosthetic osteolysis in all four cases.

One patient (20%) at two years follow-up, was unable to walk without crutchies due to hip pain. X-rays showed cup loosening in all three zones. Patient was dissatisfied. Primary cup was revised with a Burch Schneider cage.

Discussion

The aim of the "reconstruction ring" approach is to replenish lost bone stock for future revisions, place the acetabulum at the correct anatomic position, and allow progressive weight bearing earlier, because the ring is attached directly to the pelvis, protecting the consolidating bone graft (5-7). Chance to revise a ring cup by using a primary cup depends on residual bone stock after ring removal. In turn, residual bone stock depends on previous graft incorporation. At time of ring implant, bone defects of the acetabulum can be treated by morcelized or massive bone grafting. Some authors considered the Burch Schneider cage to bridge the ilium and ischium and protect the bone grafts from resorption by excessive mechanical forces (6-8). Investigators have reported favorable results with both morselized autografts or allografts (9,10). Buma et al (11) studied morcelized bone graft incorporation and showed the histological data concerning 9 biopsies taken from 8 grafted acetabula, 1-72 months after revision. During previous surgery femoral heads received from the local bone bank were morsellized with a into chips of about 1/2 cm^3. The quantity of graft used varied from 1 to 3 femoral heads per patient. Histological study revealed different stages of graft incorporation. In the specimen 1 month post-revision, no signs of graft incorporation were found. At 8 and 9 months,

Table 1. Pre DE surgery and outcome data

Case N°	N° previous revisions	Acetabular defect at time of ring surgery (Paprosky class)	Ring implant survival (years)	Age at DE surgery (years)	Reason of DE revision	F.U
1	1	IIIa	8	67	Aseptic loosening	15 years
2	2	IIIb	6	68	Aseptic loosening	2 year
3	3	IIIa	3	51	Aseptic loosening	2 years loosening
4	2	IIIb	5	51	Aseptic loosening	8 years
5	1	IIIb	15	67	Aseptic loosening	3 years

various amounts of graft remnants were embedded in a new trabecular structure. The bone in the specimens, with a follow-up of 15 months or longer, closely resembled normal trabecular bone, with only very few remnants of graft. They concluded that impacted morsellized chip graft completely incorporates into a new trabecular structure. A very similar original bone structure restoration can allow a primary cup implant.

The idea of DE tecnique indicates an arthroplasty revision performed by changing a revision component by a primary component. This technique was introduced and developed by Vives in 1987 (12) with use of distal locked stem, called "interlocking rod" as temporary femoral revision implant to be following by a standard primary component replacement before bone restoration. Use of interlocking stem has been widespread in France in the nineties but DE revision by primary stem was not routinely applied because locked

Figure 1. Case 4. Preoperative DE x-ray. Loosening of Burch Shneider revision cage

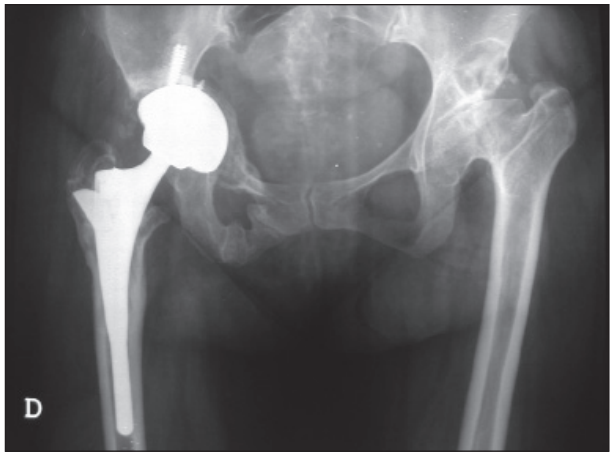

Figure 2. Case 4. Revision using a press-fit primary cup. No need for new bone graft or structural support. 8 years follow up

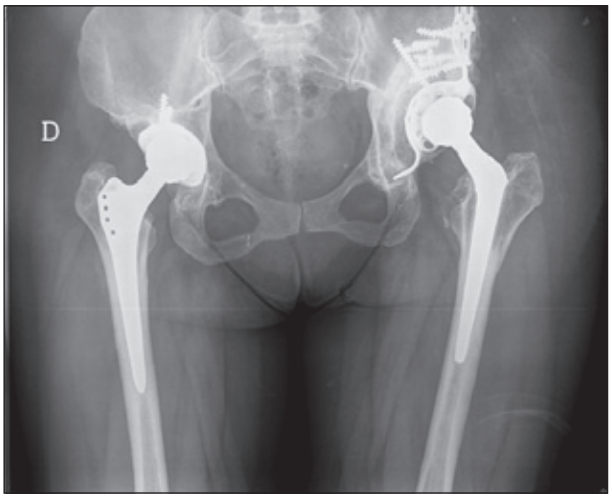

Figure 3. Case 3. Preoperative DE x-ray. Loosening of Burch Shneider revision cage three years before third hip revision

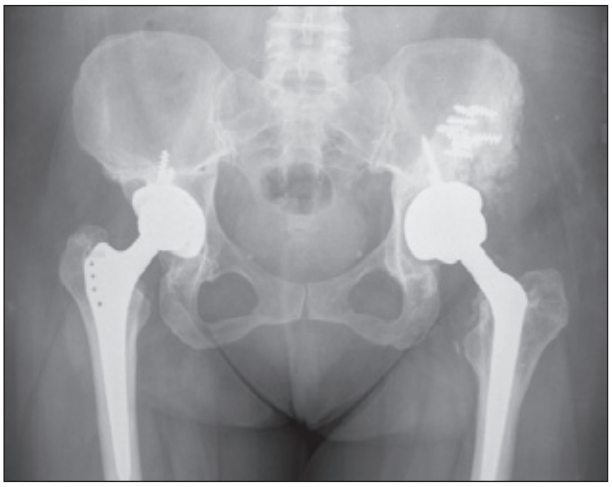

Figure 4. Case 3. Revision using a press-fit primary cup. 2 years follow up, loosening of the primary cup

stems have produced satisfactory and long lasting results (1,2).

Miletic et al.(1) reported good results of stem DE technique studying a group of 15 patients. In their experience DE technique was applied in case of loosened locked revision stem. There were no difficulties extracting the locked stem and a standard length primary stem was inserted with no associated procedures or bone complications in any of the cases.

Contrary to French experience, DE acetabular revision is not a two stage scheduled technique but it is allowed by graft incorporation and bone reconstruction protected by ring or cage implant.

Acetabular reinforcement rings or cages (Ganz rings and Burch-Schneider cages) are commonly used for reconstruction of severe bone defects in complex hip arthroplasty (13-16). They are widely implanted in revision hip arthroplasty with periprosthetic acetabular bone resorption but DE acetabular technique is rarely reported in literature.

Abolghasemian et Al (17) retrospectively reviewed 44 consecutive patients (50 hips) who underwent acetabular re-revision after a failed previous revision that had been performed using structural or morcellised allograft bone, with a cage or ring for uncontained defects. In 17 hips (34%), re-revision was possible using a cemented (n=2) or uncemented (n=15) primary acetabular component. No data concerning results of this sub group where available in the study. The mean follow-up of the entire group of study was 70.2 months (6 to 146) for 47 available patients. There were 18 (38.3%) radiological failures due to aseptic loosening, at a mean of 65 months (6 to 146) after the re-revision. In addition, four hips failed (8.5%) due to infection.

Hsu et al (16) retrospectively evaluated clinical outcomes and complications of using the Burch Schneider cage and structural allografts for complex acetabular reconstruction in 31 hips with a a mean follow up of 5.5 years (range, 3.0e10.5 years). Using re-revision surgery as the endpoint, the cage had a survival rate of 76% at 5 years and 57% at 10 years. At the time of re-review, three hips had a failed reconstruction cage and small contained defect after partial consolidation of the previous structural allograft; they were treated with a noncemented primary acetabular component and morselized allografts. Regarding to this sub group, at the follow up at 14 months, 16 months, and 28 months (average follow up of 19.3 months), the radiographs of the three hips confirmed that no hip had any measurable migration or displacement of the acetabular component

In our experience, in all five cases, we used morselized allograft bone from the tissue bank. In our opinion cadaver allografts offer advantages over autologous bone because they are available at any amount and thus enable us to avoid extensive damage to the iliac crest by autologous tissue harvesting. The size of 7 to 10 mm is optimal because it permits the grafts to maintain both structure and strength (18). The strict procedure of sample collection and examination minimizes the risk of infection transfer. As usual the progress of graft bone ingrowth was in our experience evaluated on radiographs that showed incorporation of allograft into the surrounding bone.

Only one patient out of five was revised due to de-escalation failure. Revised patient showed the highest number of previous revisions (n=3) and the lowest survivorship of de-escalation (3 years). Despite our results cannot considered statistically significant, age, functional requests, previous number of hip revisions should be data to be considered in case of DE technique planning. Quality of bone reconstruction after cage implant needs an intraoperatively evaluation.

Conclusions

Our little experience, according to clinical and histological reported studies confirms that impacted morsellized chip graft during revision by acetabular ring are completely incorporated into a new trabecular structure. This structure is able to integrate a standard cup in case of ring failure. De-escalation technique is a surgical option to consider in case of young patients, limited number of previous revisions and more than three years survivorship of loosened acetabular cage.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Miletic B, May O, Krantz N, Girard J, Pasquier G, Migaud H. De-escalation exchange of loosened locked revision stems to a primary stem design: complications, stem fixation and bone reconstruction in 15 cases. Orthop Traumatol Surg Res. 2012;98(2):138-43.
2. Mencière ML, Wissocq N, Krief E, Elkoun D, Taviaux J, Mertl P. Mid-term outcomes after distally locked-to-standard primary stem exchange in 29 hip-prosthesis patients. Orthop Traumatol Surg Res. 2014;100(1):135-40.
3. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969;51:737-75.
4. Morscher E, Dick W, Seelig W. Revision arthroplasty of the hip joint with autologous and homologous cancellous bone. Orthopäde 1989;18:428-37.
5. Goodman S, Sastamoinen H, Shasha N. Complications of ilio-ischial reconstructions rings in revision total hip arthroplasty. J Arthroplasty 2004; 19:436–46.
6. Gill TJ, Sledge JB, Mueller ME. The Burch–Schneider anti-protrusio cage in revision hip arthroplasty. Indications, principles and long-term results. J Bone Joint Surg 1998; 80:946–953.
7. Saleh KJ, Jaroszynski G, Woodgate I. Revision total hip arthroplasty with the use of structural acetabular allograft and reconstruction ring. A case series with a 10 year average follow-up. J Arthroplasty 2000; 15:951–958.
8. Eggli S, Muller C, Ganz R. Revision surgery in pelvic discontinuity. An analysis of seven patients. Clin Orthop 2002; 398:136–145.
9. Gross AE, Goodman SB. Rebuilding the skeleton. The intraoperative use of trabecular metal in revision total hip arthroplasty. J Arthroplasty 2005; 20:91–93.
10. Dennis DA Management of massive acetabular defects in revision total hip arthroplasty. J Arthroplasty 2003; 18:121–125.
11. Buma P, Lamerigts N, Schreurs BW, Gardeniers J, Versleyen D, Slooff TJ. Impacted graft incorporation after cemented acetabular revision. Acta Orthop Scand 1996 Dec;67(6):536-40.
12. Vivès P, Plaquet JL, Leclair A, Blejwas D, Filloux JF. Revision of interlocking rod for loosening of THP. Concept–preliminary results. Acta Orthop Belg 1992;58:28—35.
13. Gill TJ, Siebenrock K, Oberholzer R, Ganz R. Acetabular reconstruction in developmental dysplasia of the hip results of the acetabular reinforcement ring with hook. J Arthroplasty 1999;14(2):131–7.
14. Gurtner P, Aebi M, Ganz R. The acetabular roof cup in revision arthroplasty of the hip. Z Orthop Ihre Grenzgeb 1993;131(6):594–600.
15. Schlegel UJ, Bitsch RG, Pritsch M, Aldinger PR, Mau H, Breusch SJ. Acetabular reinforcement rings in revision total hip arthroplasty midterm results in 298 cases. Orthopade 2008;37(9):904–906-13.
16. Hsu CC, Hsu CH, Yen SH, Wang JW. Use of the Burche-Schneider cage and structuralallografts in complex acetabular deficiency: 3- to10-year follow up Kaohsiung J Med Sci.2015;31(10):540-7
17. Abolghasemian M, Drexler M, Abdelbary H, Sayedi H, Backstein D, Kuzyk P, Safir O, Gross AE. Reconstruction of massive uncontained acetabular defects using allograft with cage or ring reinforcement Bone Joint J. 2013;95-B(6):777-81.
18. Maruyama M, Wakabayashi S, Ota H, Tensho K. Use of the Burch-Schneider cage and structural allografts in complex acetabular deficiency: 3- to 10-year follow up. Clin Orthop Relat Res. 2017;475(2):387-395

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Original article

Epidemiology and risk factors for contralateral proximal femur fracture: a single center retrospective cohort study on 1022 patients

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Summary. *Background and aim of the work:* Given the high impact of proximal femur fractures (PFFs) on elderly patients and healthcare systems, the burden of contralateral PFFs might be overlooked. Aim of the study is to analyze the epidemiology and risk factors of contralateral proximal femur fractures. Secondary aim is to detect mortality rate differences in first and contralateral PPF. *Methods:* A population of 1022 patients admitted for proximal femur fractures in a single center was studied. Prevalence at admission as well as incidence of contralateral PFF during a 18 to 36 months follow-up was recorded. Epidemiology of contralateral PFF was studied recording number of events, time to second fracture and fracture type. Mortality at 1-year was recorded for all patients and compared between first and second PFF patients. Comorbidities, pharmacotherapy, BMI, MNA and SPMSQ were studied as possible risk factors. *Results:* Prevalence and incidence of contralateral PFFs were 9.4% and 6.5% respectively. Median time to second fracture was 12 months. One-year mortality of contralateral PFFs was significantly lower (20.5% vs 25.1%, p 0.003) than first PFF. Contralateral fracture patients had a significantly lower BMI and a significantly lower proportion of malnourished patients. *Conclusions:* The incidence and prevalence of contralateral PFFs is relevant. Mortality of contralateral PFFs results to be lower than first PFF. Patients with higher BMI and malnourished patients have a lower risk of contralateral PFF. (www.actabiomedica.it)

Key words: proximal femur fracture, hip fracture, contralateral, bilateral, risk factors

Background and aim of the work

Proximal femoral fractures (PFFs) are a relevant problem in developed countries. The high impact of these fractures on patients' quality of life, social independence and mortality is well known, as well as the relevant social and economic burden. The incidence of PFFs increases every year due to overall aging of the population and prevalence of osteoporosis. In Italy, the incidence of hip fracture for patients > 65 years old was of 77.8 per 10.000 in 2009, showing an increase of 29.8% between 2000 and 2009 (1). These fractures are still the main indication for hospitalization and surgical treatment in the elderly (2-3).

The number of PFFs is rising despite the huge efforts of global and local healthcare systems to identify risk factors and to develop new prevention and treatment strategies. Besides high morbidity and mortality rates, patients who suffer from a PFF have an increased risk of undergoing a second fragility fracture, including a contralateral PFF (4). The incidence of contralateral PFF has been reported to be 2-5% within 12 months in some literature reports (4,5,6). Risk factors for contralateral PFF still have to be clearly determined, possibly including dementia, cardiac disease, institutionalization, vision impairment and respiratory disease (7, 8).

Aim of the study is to analyze the epidemiology and risk factors of contralateral proximal femur fractures

on a large cohort of PFF patients treated in a single center. Secondary aim of the study is to detect mortality rate differences in first PPF and contralateral PPF.

Patients and method

The study population counts 1022 patients admitted for PPF to the Orthopaedics and Traumatology Unit of Cattinara University Hospital in Trieste (Italy) between January 2016 and December 2017. Exclusion criteria were the following: patients aged < 65 years old, periprosthetic fractures, ipsilateral second fracture, pathologic fractures.

Patients data were retrospectively analyzed through institutional medical records and registry data between January and June 2019.

For all patients, demographic data (age, sex) were registered. Prevalence of previous contralateral fracture at admittance was recorded. The incidence of contralateral fractures occurring during a period of 18 to 36 months of follow-up in patients who sustained the first PFF within the January 2016-December 2017 interval was also registered, together with the time interval occurring from first and second fracture. Data regarding fracture type (medial or lateral PFF) were registered in all contralateral fracture patients to assess whether the second fracture was of the same type as the first fracture.

Patients admitted with a contralateral fracture (Group A) or who underwent a contralateral fracture during follow-up (Group B) were grouped and data compared with unilateral fracture patients (Group C) to evaluate differences in mortality rate between unilateral and contralateral fractures at one month and 1 year.

For Group B and C more data were registered and compared in order to detect possible risk factors for contralateral fracture. Comorbidities were registered grouped into the following categories: hypertension and cardiac diseases (cardiac insufficiency, myocardial infarction, angina pectoris, arrythmia), respiratory diseases (chronic obstructive pulmonary disease, chronic respiratory insufficiency), diabetes mellitus, renal and liver insufficiency, visual impairment, balance disorders, alcohol consumption, smoking. Regarding pharmacotherapy, previous long term or high dosage systemic corticosteroid therapy was recorded, as well as pharmacological therapies for osteoporosis (Vitamin D and/or antiresorptive drugs) in use at admission. Patients were also divided according to body mass index (BMI), into three groups: underweight (BMI < 18.5), normal weight (BMI 18.5-25) and overweight/obese patients (BMI > 25). Data regarding nutritional and mental status, respectively evaluated with the Mini Nutritional Assessment (MNA) and the Short Portable Mental Status Questionnaire (SPMSQ) at admittance, were recorded as well. According to MNA values patients were divided into three groups: malnourished (score < 17), at risk of malnutrition (score between 17 and 23.5) and well-nourished (score ≥ 23.5).

Statistical analysis

The statistical analysis was performed using the SPSS software. The dichotomous variables were compared using the Fischer's exact test. Categorical variables were compared using the chi-squared test. Quantitative variables were analyzed using the Mann-Whitney U test. *P* values of < 0.05 were considered statistically significant.

Results

The study population counted 1022 patients, 795 (77,8%) female and 227 (22,2%) male, median age 85 yrs (range 65-107 yrs) (Table 1).

The prevalence of contralateral fractures at admittance was 9.4% (96/1022 patients, Group A). The incidence of contralateral fractures occurring during follow-up was 6.5% (60/926 patients, Group B).

The 866 patients who neither presented a contralateral fracture at admittance nor developed a contralateral fracture at follow up constituted Group C.

The median (IQR) interval between the first and second fracture in Group B was 12 months. In detail, the second fracture occurred within 12 months in 28 patients (47%) and in 54 patients (85%) within 24 months.

Most contralateral PFFs were of the same type as the first fracture (73.1%, 114/156). In detail, 61 out of 79 (77.2%) were lateral fractures, while 53 out of 77 (68,8%) were medial fractures.

Table 1. Demographic data of 1022 patients (age > 65 years) admitted for proximal femur fracture in 2016-2017

	Whole population *(n = 1022)*	Group A *(n = 96)*	Group B *(n = 60)*	Group A + Group B *(n = 156)*	Group C *(n = 866)*
Age (mean)	85	85,8	84,5	85,6	83,8
Sex (M/F)	227/795	15/81	9/51	24/127	203/663

Table 2. Mortality rate among groups at 30-days and at 1 year after surgery

Mortality	Group A + B (n = 156)	Group C (866)	*P value*
At 30 days	5 (3.2%)	37 (4.2%)	*1.000*
At 1 year	32 (20.5%)	217 (25.1%)	***0.031***

Mortality of the whole study population was 4.1% (42 patients) at 30 days and 24.4% (249 patients) at 1 year. Comparing first and contralateral fractures (Table 2), mortality in Group C was 4.2% (37 out of 866) at 30 days and 25.1% (217 out of 866) at 1 year, while mortality in Group A + B was 3.2% (5 patients out of 156) at 30 days and 20.5% (32 of 156) at 1 year. Mortality rate at 1 year resulted to be significantly higher in Group C (p-value 0.03).

Data regarding comorbidities, pharmacotherapy, BMI, MNA and SPMSQ, and for group B and C are resumed in Table 3.

There was no significant difference between Group B vs C regarding age, gender, comorbidities, pharmacotherapy and SPMSQ. Conversely, significant differences were found for BMI and MNA.

In detail, BMI resulted to be significantly higher in Group C both considering quantitative (*p* value = 0.035) and categorical values (*p* value = 0.025) distribution (Table 3). According to MNA, the mean score of group B and C are similar, respectively 22.7 and 22.3, but categorizing the two population in the three groups (malnourished, at risk of malnutrition and well-nourished) in Group C there was a significantly higher proportion of malnourished patients (*p* value = 0.048) (Table 3). Mortality at 1 year in malnourished patients was 47%.

Table 3. Analysis of variables between groups

	Group B *(n = 60)*	Group C *(n = 866)*	P value
Cardiologic diseases	33	526	*0.581*
Respiratory diseases	9	103	*0.406*
Diabetus mellitus	8	154	*0.592*
Renal/liver insufficiency	10	138	*0.853*
Visual impairments	19	339	*0.404*
Balance disorders	18	314	*0.481*
Alcohol consumption	12	240	*0.288*
Smoking	6	97	*1.000*
Corticosteroid therapy	3	22	*0.203*
Osteoporosis Treatment:			
Vit D	8	67	*0.132*
Bisphosphonates	1	18	*1.000*
BMI (Body Mass Index):			
mean value	22,94 (16-33)	24,16 (12-39)	***0.035***
< 18.5	4	78	
18.5-25	47	528	***0.025***
> 25	9	260	
MNA (Mini Nutritional Assessment):			
mean score	22,7(13-29,5)	22,3(5,5-30)	*0.976*
< 17	3	127	
17-23.5	31	334	***0.048***
≥ 23.5	26	405	
SPMSQ (Short Portable Mental Status Questionnaire):			
mean score	4,3 (0-10)	3,7 (0-10)	*0.115*
0-2 errors	21	415	
3-4 errors	16	148	*0.183*
5-7 errors	9	126	
8-10 errors	14	177	

Discussion

There is a lack of evidence about epidemiology, risk factors and outcome of contralateral PFFs. In the present study, the cumulative incidence of contralateral PFF at final follow-up was 6.5%. However, the slightly higher prevalence registered in the present study

(9.4%) might suggest the incidence to raise with longer follow-up. Indeed, the incidence of contralateral PFF raised consistently during follow-up, from 3.2% at one year to 6.5% at final follow-up. In the meta-analysis performed by Zhu et al. in the 23 studies analyzed the overall incidence of contralateral PFF was found to be 8,5% in a period ranged from 9 months to 22 years (9). More recently, Muller et al. found an overall incidence of 10,4% in a cohort of 2296 patients at 10 years of follow up (10). However, there is no clear evidence on the ideal follow-up length required to detect a more reliable incidence value, which actually seems to vary between 5 and 11% (4, 11-21).

Nevertheless, a contralateral PFF was more likely to occur in the early period in many studies, reporting a higher incidence in the first 2 years (4,15,16). The present study data are in line with these findings, with more than 80% of cases occurred during the first 24 months.

In the present study most contralateral PFFs were of the same type as the first fracture, especially in lateral fracture pattern. These data are consistent with other literature reports (5,13,16,17,20, 22-29), suggesting that factors related to specific anatomic and gait aspects could more probably lead to a medial or a lateral fracture in different patients (25, 27, 29, 30).

Given the high impact of PFF on patients and healthcare systems, the burden of contralateral PFF might be overlooked. However, literature data about outcome seem not to differ significantly between first and second PFFs. Mortality is reported to be comparable after the first and second fracture in many studies, with some authors reporting lower mortality rates for contralateral fractures (21,22,31,32).The present study data are in line with this finding, with a significantly lower mortality rate in contralateral PFFs at 1 year (20.5% vs 25.1%, p-value 0.03). The reasons for this result might reside in the higher mortality rate after the first fracture in patients with severe comorbid conditions. Several studies have reported a high 1-year mortality rate in these patients (33,34). This might lead patients in better conditions who survive the first event to have higher chances to survive the second event as well. Nevertheless, the impact of each single comorbidity on mortality has not been evaluated in the present study. A better functional status in contralateral fracture patients compared with first fracture patients is similarly reported in literature (31,35-37).

Gender is debated to be a possible risk factor for contralateral PFF, based on the clearly demonstrated higher risk of PFF in elderly women (8,38). The results of the literature on this topic are conflicting. A metaanalysis performed by Liu et al. (7) seem to confirm this hypothesis. However, in the present study no difference in contralateral PFF incidence was found according to gender. This result is consistent with many other studies (39-42). These conflicting findings are also reported for age and comorbidities. In detail, comorbid conditions were not found to be related with contralateral PFF in the present and in other studies (18,41,42). However, Chang et al. (8) revealed a significant association for both dementia and respiratory diseases with contralateral PFF. Mitani et al. (40) identified postoperative delirium, visual impairment and respiratory diseases as risk factors. Concerning mental status, SPMSQ score has been previously used to value the influence of cognitive status on outcome and mortality rate after a hip fracture (43,44), but not as risk factor for secondary PFF. Nonetheless, it was not significantly associated to contralateral PFF in the present study.

The association between high doses of corticosteroids and PFF is well known, due to reduction of bone mineral density (45,46). Likely, Shan et al reported use of steroids as a significant predictor also for second hip fracture (47). Data retrieved in the present study could not confirm this statement, possibly due to the very low number of patients constituting the corticosteroid therapy group. Antiresorptive medications for osteoporosis treatment are an efficient preventative strategy for patients with high risk for controlateral fractures (47-49). In the present study, no significant differences in osteoporosis treatment was noted between single or bilateral fracture patients. However, only treatment in use at admission was registered. Nonetheless, in literature the effective role of bisphosphonates in tertiary prevention of osteoporosis remains unclear. In fact, some papers reported that bisphosphonates therapy may be protective against a secondary hip fracture (46,50), while others did not find any statistically significant correlation (28,51,52).

Conversely, a higher BMI appears to be protective for hip fractures in many studies (53-55). Many theories have been proposed to explain this protective role of higher BMI. More sedentary subjects could be less likely to fall and sustain a fracture (56). The fat tissue covering the hip could have a cushioning effect (57,58). The higher levels of calcitonin and the greater production of estrogens by the adipocytes (59) may also play a role. Interestingly, higher BMI has been also recognized to be associated to a lower incidence of contralateral PFF by Berry et al. (35), probably for the same reasons. The results of the present study seem to confirm this finding, with contralateral fracture patients having significantly lower BMI values. Similarly, contralateral PFF risk might be related to malnutrition. At our knowledge, MNA was not previously analyzed as possible risk factor for contralateral PFF. In the present study, MNA values demonstrated a significantly higher proportion of malnourished patients in Group C. Beside the considerations already discussed for BMI that might probably apply to nutritional status, mortality rate should also be taken into account. In the present study, mortality rate at one year in malnourished patients was 47%. This is consistent with data found by Bell et al. and Zanetti et al. who found a poor nutritional status to be an independent predictor of mortality at 1 year after PFF (33,59). The high mortality rate of malnourished patients could have effectively affected the proportion of patients in which contralateral PFF could occur.

Conclusions

Independent risk factors for contralateral PFF still have to be clearly determined. A higher BMI seems to be protective for contralateral PFF while malnutrition is negatively associated to contralateral PFF, probably due to high mortality rates after first fracture. Mortality in contralateral PFF results to be significantly lower with respect to first PFF at 1 year.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

References

1. Piscitelli P, Feola M, Rao C, et al.Ten years of hip fractures in Italy: For the first time a decreasing trend in elderly women. World J Orthop 2014; 5(3):386–391
2. Ratti C, Vulcano E, La Barbera G, Canton G, Murena L, Cherubino P. The incidence of fragility fractures in Italy. Aging Clin. Exp Res 2013; 25(Suppl 1):S13–S14
3. Zurlo A, Bellelli G. Orthogeriatrics in Italy: the Gruppo Italiano di Ortogeriatria (GIOG) audit on hip fractures in the elderly. Geriatric Care 2018;4(2):33–35
4. Vochteloo AJH, Van Der Burg BLSB, Röling MA, et al. Contralateral hip fractures and other osteoporosis-related fractures in hip fracture patients: Incidence and risk factors. An observational cohort study of 1,229 patients. Arch Orthop Trauma Surg 2012;132(8):1191–1197
5. Boston DA. Bilateral fractures of the femoral neck. Injury 1982;14:207–210
6. Dretakis E, Kritsikis N, Economou K, Christodoulou N. Bilateral non-contemporary fractures of the proximal femur. Acta Orthop 1981; 52:227–229
7. Liu, S., Zhu, Y., Chen, W. et al. Risk factors for the second contralateral hip fracture in elderly patients: A systematic review and meta-analysis**.** Clin Rehabil 2015; 29: 285–294
8. Chang Jh, Yoo JH, Reddy P, Lee SS, Hwang JH, Kim TY. Risk factors for contra-lateral hip fracture in elderly patients with previous hip fracture. Injury 2013;44(12):1930–1933
9. Zhu Y, Chen W, Sun T, Zhang Q, Liu S, Zhang Y. Epidemiological characteristics and outcome in elderly patients sustaining non-simultaneous bilateral hip fracture: a systematic review and meta-analysis. Geriatr Gerontol Int 2015;15(1):11–18.
10. Müller F, Galler M, Zellner M, Bäuml C, Roll C, Füchtmeier B. Comparative analysis of non-simultaneous bilateral fractures of the proximal femur. Eur J Trauma Emerg Surg 2019;45(6):1053–1057
11. Finsen V, Benum P (1986) The second hip fracture an epidemiologic study. An epidemiologic study. Acta Orthop Scand 1986;57(5)431–433
12. Van Der Steenhoven TJ, Staffhorst B, Van De Velde SK, Nelissen RGHH, Verhofstad MHJ. Complications and institutionalization are almost doubled after second hip fracture surgery in the elderly patient. J Orthop Trauma 2015;29(3):e103-e108
13. Aurégan JC, Frison A, Bégué T, et al. Contra-lateral hip fracture in the elderly: are decreased body mass index and skin thickness predictive factors? Int Orthop 2017;41(2) 247–252
14. Shabat S, Gepstein R, Mann G, Kish B, Fredman B, Nyska M. The second hip fracture - An analysis of 84 elderly patients. J Orthop Trauma 2003;17(9):613–617
15. Pearse EO, Redfern DJ, Sinha M, Edge AJ. Outcome following a second hip fracture. Injury 2003;34(7):518–521
16. Fukushima T, Sudo A, Uchida A. Bilateral hip fractures. J Orthop Sci. 2006;11(5)435–438
17. Lönnroos E, Kautiainen H, Karppi P, Hartikainen S,

Kiviranta I, Sulkava R. Incidence of second hip fractures. A population-based study. Osteoporos Int 2007;18(9):1279–1285
18. Gaumetou E, Zilber S, Hernigou P. Non-simultaneous bilateral hip fracture: Epidemiologic study of 241 hip fractures. Orthop Traumatol Surg Res 2011;97(1):22–27
19. Kaukonen JP, Lüthje P, Nurmi-Lüthje I, Kataja M, Naboulsi H. Second hip fracture and patients' medication after the first hip fracture: A follow-up of 221 hip fracture patients in Finland. Arch Gerontol Geriatr 2011;52(2)185–189
20. Khan SK, Rushton SP, Dosani A, Gray AC, Deehan DJ. Factors influencing length of stay and mortality after first and second hip fractures: an event modeling analysis. J Orthop Trauma. 2013;27(2):82–86.
21. Harvey L, Toson B, Mitchell R, Brodaty H, Draper B, Close J. Incidence, timing and impact of comorbidity on second hip fracture: a population-based study. ANZ J Surg. 2018;88(6):577–581.
23 Yamanashi A, Yamazaki K, Kanamori M, et al. Assessment of risk factors for second hip fractures in Japanese elderly. Osteoporos Int. 2005;16(10):1239–1246.
24. Saxena P, Shankar J. Contralateral hip fractures - can predisposing factors be determined?. Injury. 2000;31(6): 421–424
25. Kok LM, van der Steenhoven TJ, Nelissen RG. A retrospective analysis of bilateral fractures over sixteen years: localisation and variation in treatment of second hip fractures. Int Orthop. 2011;35(10):1545–1551.
26. Lawrence TM, Wenn R, Boulton CT, Moran CG. Age-specific incidence of first and second fractures of the hip. J Bone Joint Surg Br. 2010;92(2):258–261
27. Sawalha S, Parker MJ. Characteristics and outcome in patients sustaining a second contralateral fracture of the hip. J Bone Joint Surg Br. 2012;94(1):102–106.
28. Hagino H, Sawaguchi T, Endo N, Ito Y, Nakano T, Watanabe Y. The risk of a second hip fracture in patients after their first hip fracture. Calcif Tissue Int. 2012;90(1):14–21.
29. Chapurlat RD, Bauer DC, Nevitt M, Stone K, Cummings SR. Incidence and risk factors for a second hip fracture in elderly women. The Study of Osteoporotic Fractures. Osteoporos Int. 2003;14(2):130–136
30. Pellegrini A, Tacci F, Leigheb M, Costantino C, Pedrazzini A, Pedrazzi G, Vaienti E, Ceccarelli F, Pogliacomi F. Injuries of the trochanteric region: can analysis of radiographic indices help in prediction of recurrent osteoporotic hip fractures? Acta Biomed. 2017 Oct 18;88(4 -S):43–9.
31. Ryg J, Rejnmark L, Overgaard S, Brixen K, Vestergaard P. Hip fracture patients at risk of second hip fracture: a nationwide population-based cohort study of 169,145 cases during 1977–2001. J Bone Miner Res. 2009;24(7):1299–1307
32. Skála-Rosenbaum J, Džupa V, Bartoška R, Říha D, Waldauf P, Báča V. Subsequent contralateral hip fractures: can at-risk patients be identified? An observational study of 5,102 patients. Int Orthop. 2015;39(4):755–760.
33. Bell JJ, Pulle RC, Crouch AM, Kuys SS, Ferrier RL, Whitehouse SL. Impact of malnutrition on 12-month mortality following acute hip fracture. ANZ J Surg. 2016;86(3):157–161.
34. Hindmarsh D, Loh M, Finch CF, Hayen A, Close JC. Effect of comorbidity on relative survival following hospitalisation for fall-related hip fracture in older people. Australas J Ageing. 2014;33(3):E1–E7.
35. Berry SD, Samelson EJ, Hannan MT, et al. Second hip fracture in older men and women: the Framingham Study. Arch Intern Med. 2007;167(18):1971–1976
36. Kim SM, Moon YW, Lim SJ, et al. Prediction of survival, second fracture, and functional recovery following the first hip fracture surgery in elderly patients. Bone. 2012;50(6):1343–1350
37. Holt G, Smith R, Duncan K, Hutchison JD, Gregori A, Reid D. Outcome after sequential hip fracture in the elderly. J Bone Joint Surg Am. 2012;94(19):1801–1808
38. Johnell O, Gullberg B, Allander E, Kanis JA; MEDOS Study Group. The apparent incidence of hip fracture in Europe: a study of national register sources. Osteoporos Int. 1992;2(6):298–302
39. Melton LJ 3rd, Kearns AE, Atkinson EJ, et al. Secular trends in hip fracture incidence and recurrence. Osteoporos Int. 2009;20(5):687–694.
40. Mitani S, Shimizu M, Abo M, Hagino H, Kurozawa Y. Risk factors for second hip fractures among elderly patients. J Orthop Sci. 2010;15(2):192–197
41. Batin S, Ozan F, Gurbuz K, Koyuncu S, Vatansever F, Uzun E. Evaluation of Risk Factors for Second Hip Fractures in Elderly Patients. J Clin Med Res. 2018;10(3):217–220
42. Pogliacomi F, Pellegrini A, Tacci F, Pedrini MF, Costantino C, Pedrazzini A, Pedrazzi G, Lauretani F, Vaienti E, Ceccarelli F. Risks of subsequent contralateral fractures of the trochanteric region in elderly. Acta Biomed. 2016; 87(3): 275–81.
43. Sheikh HQ, Hossain FS, Khan S, Usman M, Kapoor H, Aqil A. Short-term risk factors for a second hip fracture in a UK population. Eur J Orthop Surg Traumatol. 2019;29(5):1055–1060.
44. Mukka S, Knutsson B, Krupic F, Sayed-Noor AS. The influence of cognitive status on outcome and walking ability after hemiarthroplasty for femoral neck fracture: a prospective cohort study. Eur J Orthop Surg Traumatol. 2017; 27(5):653–658.
45. Söderqvist A, Ekström W, Ponzer S, et al. Prediction of mortality in elderly patients with hip fractures: a two-year prospective study of 1,944 patients. Gerontology. 2009;55(5):496–504.
46. van Staa TP, Leufkens HG, Abenhaim L, Zhang B, Cooper C. Oral corticosteroids and fracture risk: relationship to daily and cumulative doses. Rheumatology (Oxford). 2000; 39(12):1383–1389.
47. Shen SH, Huang KC, Tsai YH, et al. Risk analysis for second hip fracture in patients after hip fracture surgery: a nationwide population-based study. J Am Med Dir Assoc. 2014;15(10):725–731.

48. Morin S, Rahme E, Behlouli H, Tenenhouse A, Goltzman D, Pilote L. Effectiveness of antiresorptive agents in the prevention of recurrent hip fractures. Osteoporos Int. 2007;18(12):1625–1632.
49. Lyles KW, Colón-Emeric CS, Magaziner JS, et al. Zoledronic acid and clinical fractures and mortality after hip fracture. N Engl J Med. 2007;357(18):1799–1809.
50. Osaki M, Tatsuki K, Hashikawa T, et al. Beneficial effect of risedronate for preventing recurrent hip fracture in the elderly Japanese women. Osteoporos Int. 2012;23(2): 695–703
51. Lee YK, Ha YC, Yoon BH, Koo KH. Incidence of second hip fracture and compliant use of bisphosphonate (published correction appears in Osteoporos Int. 2014 Sep;25(9):2327). Osteoporos Int. 2013;24(7):2099–2104.
52. Besalduch M, Carrera I, Gómez-Masdeu M, De Caso J. Antiresorptive treatment, when initiated after a first hip fracture, may not protect of a second contralateral episode in elderly population: A study with 685 patients. Injury. 2016;47(4):877–880.
53. Suzuki N, Arai K, Kon S, et al. Challenges to prevent secondary fractures in patients with hip fractures in Joetsu Myoko, Japan through the increased use of osteoporosis treatment and collaboration with family doctors. J Bone Miner Metab. 2017;35(3):315–323
54. Young Y, Myers AH, Provenzano G. Factors associated with time to first hip fracture. J Aging Health. 2001;13(4): 511–526
55. De Laet C, Kanis JA, Odén A, et al. Body mass index as a predictor of fracture risk: a meta-analysis. Osteoporos Int. 2005;16(11):1330–1338.
56. Court-Brown CM, Duckworth AD, Ralston S, McQueen MM. The relationship between obesity and fractures. Injury. 2019;50(8):1423–1428.
57. Kiel DP, Felson DT, Anderson JJ, Wilson PW, Moskowitz MA. Hip fracture and the use of estrogens in postmenopausal women. The Framingham Study. N Engl J Med. 1987;317(19):1169–1174.
58. Cummings SR, Nevitt MC. A hypothesis: the causes of hip fractures. J Gerontol. 1989;44(4):M107–M111
59. Perez Cano R, Galan Galan F, Dilsen G. Risk factors for hip fracture in Spanish and Turkish women. Bone. 1993; 14 Suppl 1: S69–S72.
60. Zanetti M, Gortan Cappellari G, Ratti C, et al. Poor nutritional status but not cognitive or functional impairment per se independently predict 1-year mortality in elderly patients with hip-fracture. Clin Nutr. 2019;38(4):1607–1612

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Original article

A preliminary experience with a new intramedullary nail for trochanteric fractures

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Summary. *Background and aim of the work:* The worldwide incidence of fractures of the proximal end of the femur is increasing as the average age of the population rises. The current surgical gold treatment standard is intramedullary nail fixation. The Authors present their experience with the D-Nail system for intertrochanteric femur fractures. *Methods:* From January 1st to February 21st 2020 (breakout of COVID-19 pandemic) 34 patients were treated with the D-Nail system: 11 with basicervical fractures, 16 with intertrochanteric stable fractures and 7 with intertrochanteric unstable fractures. In 11 cases, a single cephalic screw was used; in 23 cases, two of them were used. Distal locking was executed in 7 patients. Follow-up time ranged from 2 to 3 months. *Results:* None of the reported intra- or post-operative complication was linked to the fixation device or the surgical technique. Patients were monitored with clinical and radiological checkups using modified Harris Hip Score to accurately evaluate the fluctuations in the rehabilitation period. *Conclusion:* The main advantages of this synthesis device are the proximal hole's peculiar shape, which allows the possibility to position one or two cephalic screws on the same nail, and the silicon coating, which provides numerous biological advantages. Distal locking was executed in selected cases only, based on fracture type. Optimum treatment involves rapid execution of surgery, minimal trauma during surgery, maximum mechanical stability, and rapid weight-bearing. Although our case number is small and follow-up time brief, our results are encouraging. (www.actabiomedica.it)

Key words: Pertrochaneric fractures, Intramedullary nail, Silicon coating, D-Nail , COVID-19

Introduction

Femoral fracture is the predominant reason for surgical procedure in the orthopaedic field (1). As the Italian population gets progressively older, we are witnessing a consequent increase in femoral fractures, to the extent that the current values are expected to triple as of 2050, constituting an ever-growing cause of mortality and morbidity (2,3). Proximal femur fractures are more common in the elderly populace because they are often due to accidental falls, while they can occur in younger people because of high-energy traumas (i.e. traffic accidents) (4,5). Old-age-related issues like osteoporosis, malnutrition, scarce to no physical activities, neurological impairments, imbalance or asthenia elevate the risk of potential falling, thus increasing fracture risk (2,6,7).

The most important classifications of proximal femur fractures is that of the AO Foundation/Orthopaedic Trauma Association (AO/OTA) fracture classification (8) (Table 1).

To better describe fracture of the trochanteric region, we also have to use the Evans-Jensen classification (9), which divides fractures into two groups:

stable and unstable. Stable fractures are in turn split into undisplaced 2 part fractures (type IA) and displaced 2 part fractures (type IB). Unstable fractures are split into displaced 3 part fractures with posterolateral comminution (type IIA), displaced 3 part fractures with large posteromedial comminuted fragment (type IIB) and 4 part fractures (type III).

It has been demonstrated that, especially for an elderly patient with a precarious physical condition, it is crucial to swiftly intervene surgically (within 48 hours of the main trauma), thus allowing a quick functional recovery and minimising bedridden time (10-12). This way, the patient benefits with regard to both survival and quality of life, and it is also more cost-effective.

Table 1. AO Foundation/Orthopaedic Trauma Association (AO/OTA) fracture classification

Trochanteric region fractures (31A): o Simple pertrochanteric (31A1), subsequently divided into isolated single trochanter (31A1.1), 2-part (31A1.2), lateral wall intact (>20.5mm) (31A1.3) o Multifragmentary pertrochanteric lateral wall incompetent (≤20.5mm) (31A2), subsequently divided, provided each of them has 1 intermediate fragment (31A2.2) or 2 or more intermediate fragments (31A2.3) o Intertrochanteric reverse obliquity (31A3), subsequently divided into simple oblique (31A3.1), simple transverse (31A3.2) and wedge or multifragmentary (31A3.3)
Neck fractures (31B): o Subcapital (31B1), subsequently divided into valgus impacted (31B1.1), non-displaced (31B1.2) and displaced (31B1.3) o Transcervical (31B2), subsequently divided into simple (31B2.1), multifragmentary (31B2.2) and shear 31B2.3) o Basicervical (31B3)
Head fractures (31C): o Split (31C1), subsequently divided into avulsion of ligamentum teres (31C1.1), intrafoveal (31C1.2) and suprafoveal (31C1.3) o Depression (31C2), subsequently divided into chondral lesion (31C2.1), depression impaction (31C2.2) and split depression (31C2.3)

Currently, intramedullary nailing is the most employed synthesis method in this type of fracture (13,14). Over time, there has been an ongoing evolution of surgical techniques and tool collections, which have brought about a reduction in complication and mortality rates (15-17).

The authors present their experience with the D-Nail system for intertrochanteric femur fractures. This particular synthesis device differs from others currently on the market for two main reasons: it has a particular silicon coating, and it gives the possibility to place one or two cephalic screws on the same nail (Figure 1).

Methods

We analyzed 34 lateral femoral fracture cases that were treated at the Orthopedics and Traumatology Department of the Guglielmo da Saliceto Hospital in Piacenza from January 1st to February 21st 2020. The series is comprised of 19 females (55.9%) and 15 males (44.1%), with an average age of 78.1 ± 7.9 (range, 67 –87) years, females averaging 78.5 years, males averaging 77.5 years. The fractures were basicervical in 11 cases, stable pertrochanteric in 16 cases and unstable pertrocantheric in 7 cases.

Figure 1. D Nail

Twenty-one patients (61.8%) were operated within 48 hours from the main trauma. For the other 13 patients (38.2%), we had to wait longer because of antiaggregating treatment (2 patients in treatment with Clopidogrel, 5.9% of total patients, 15.4% of delay) or anticoagulating treatment (18) (4 patients in treatment with Warfarin, 11.8% of total patients, 30.8% of delay; 1 patient with Acenocumarol, 2.9% of total patients, 7.7% of delay), trauma close to the weekend (4 cases, 11.8% of total patients, 30.8% of delay), and full operating room (2 cases, 5.9% of total patients, 15.4% of delay).

In all cases, the fracture was treated using D-Nail (Medgal Sp. Z o.o., Ksiezyno Polonia). This is a 170mm long, 130° wide intramedullary nail, made of silicon coating (Si-DLC) titanium alloy. Its main feature is its peculiar versatility, thanks to its three-circled hole situated in the proximal part, which can host a 10mm cephalic screw or two 6mm cephalic screws. Distal locking can be static or dynamic, depending on the screw's positioning inside of the single hole present on the nail's extremity.

We locked the nail with two cephalic screws in the 11 basicervical fractures. In 23 cases, we used a lone cephalic screw to treat both stable and unstable pertrochanteric fractures. A distal locking screw was positioned in 7 pertrocantheric fractures, because of comminution of the great trochanter, presence of a large posteromedial fragment which crossed the small trochanter's line or wide intramedullary canal (Figures 2,3,4).

After surgery, all patients underwent x rays control and began their customized rehabilitation protocol. From the first day after surgery, muscle strengthening

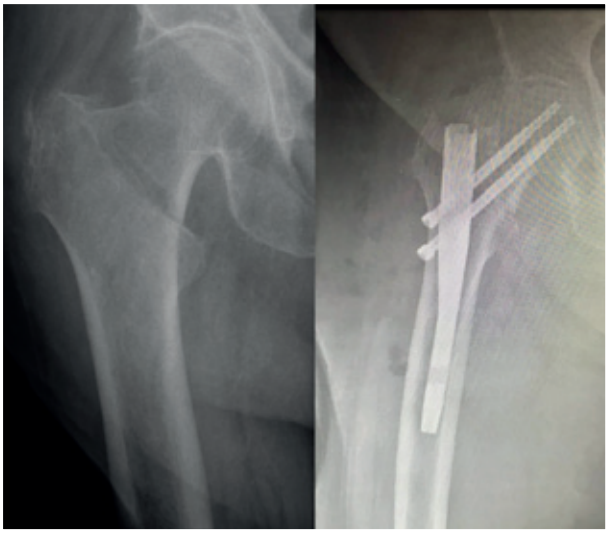

Figure 2. Basicervical fracture, two cephalic screws fixation without distal locking

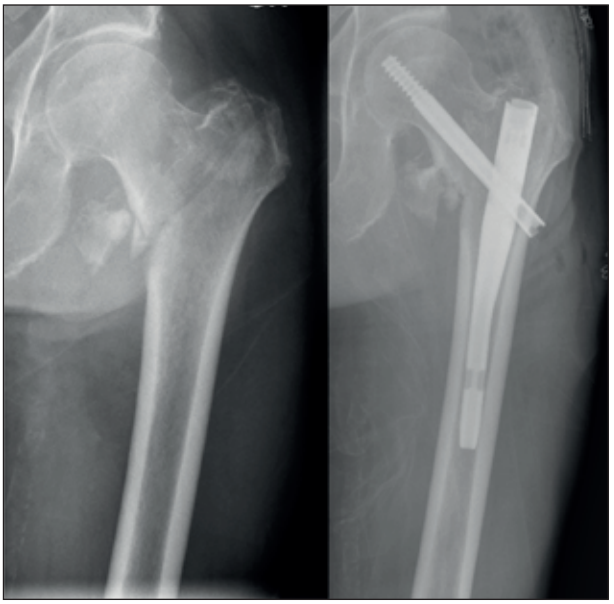

Figure 3. Stable pertrochanteric fracture, one cephalic screw fixation without distal locking

Figure 4. Unstable pertochanteric fracture, one cephalic screw fixation with distal locking

exercises and range of motion (ROM) recovery exercises were performed, both actively and passively. Starting from day two or three (depending on the patient's condition), full load and crutch walking were allowed.

Patients were clinically and radiological followed at15, 30 and 60 days from surgery. Stitches were removed during the first post operative month,. To monitor the evolution of post-operative rehabilitation, we calculated the modified Harris Hip Score (mHHS) for every patient duringfollow up .

Results

Despite the limited number of cases and the absence of a complete follow-up, the initial results are very encouraging. None of the reported intra- or post-operative complication was linked to the fixation device or the surgical technique Quali complicanze? . Patients were monitored with clinical and radiological checkups, using the modified Harris Hip Score to evaluate the fluctuations in the rehabilitation period even more accurately. No patients in the cohort reported intraoperative complication. Mean surgery duration was 43.6 minutes (range, 35–53). Blood loss during surgery procedure was 130ml on average, so no drainage application was needed. All patients began rehab on the following day, starting with active/passive on the first day to an orthostatic state on the second/third day. In 6 cases, the patient needed a blood transfusion due to post-haemorrhagic anaemia. Mean post-operative hospitalization time was 6.8 days (range, 5 – 9). After their stay, 21 patients (61.8%) were transferred to a long-term hospitalization ward, while 13 patients (38.2%) went home. Due to the outbreak of the COVID-19 pandemic, the long-term hospitalization ward stopped the access, and consequently the patients who were still hospitalized in our department (9 patients, 26.5%) were sent home.

All patients arrived at their 15-day post-surgery follow up in a stretcher or a wheelchair. Wounds showed no signs of inflammation, and stitches were removed right away in all cases. Patients showed ROM improvement compared to the hospitalization period. No complications were found. The mean mHHS was 31.7 (range, 15 - 49).

At the 30-day post-surgery checkup, 26 patients (76.5%) were walking autonomously, although needing specific aids (elbow crutches), while 8 patients (23.5%) were not walking autonomously yet. Radiography showed that fractures were completely consolidated. Surgical wounds were all satisfactorily healed, with no signs of inflammation. Regarding joint functionality, 23 patients (67.6%) recovered a good amount of ROM, almost equalling pre-op values, while 11 patients (32.3%) had a worse ROM than before suffering the trauma. No complications were found. Mean mHHS was 45.8 (range, 37 - 57).

At the 60 days post-op checkup, 9 patients (26.4%) were walking without crutches, 2 of whom (5.8%) were walking aided by an elbow crutch or a walking stick. Radiographic images did not detect any significant variations since the latest checkup. Surgical wounds were free from inflammation. Joint functionality was good, with ROM equaling pre-trauma values in the majority of patients. Only 3 patients (8.8%) still have a slower recovery and struggled to obtain maximum degrees of movement. No complications were found. The mean mHHS was 67.2 (range, 59 - 89).

Discussion

These fractures have a very high incidence in the elderly population, and they often result in negative consequences on these patients' daily activities: 20% of them completely lose motor autonomy, and only 30-40% of them manage to recover previous functionality (19).

Although the sliding hip screw and plate has been the gold standard for many years, intramedullary nailing is becoming the preferred solution for most orthopaedic surgeons (14).

The choice of putting our trust in this new type of osteosynthesis device was based on two factors: the nail's shape and the innovative material with which it is manufactured.

As to its shape, the main peculiarity is the proximal hole, comprised of three circles, to host a 10mm screw or two 6mm screws. This allows surgeons to decide whether to fixate the nail with one or two screws

even during the operation, so it is possible to edit preoperative planning without needing intramedullary nail removal.

The Authors suggest the use of two screws in basicervical fractures: one in pertrochanteric stable whitout distal locking, one in pertrochanteric unstable whit distal locking. In the case of subtrochanteric fractures, we prefer to use a long nail.

As to coating, the incorporation of other elements into the DLC matrix can provide important enhancement of the biological properties of the device (20,21,22) and can be applied for any orthopaedic implants that substitute bones (20). Specifically, silicon brings some important benefits: it reduces the surface energy of DLC, preventing bacterial adhesion and, as a result, reduces the chances of having a post-operative infection (23); it increases hemocompatibility (24-26) and biocompatibility (27-29), decreasing the risk of adverse tissue reactions (inflammation, irritation, allergy); it improves the interaction of DLC with bone cells, promoting adhesion and proliferation of osteoblasts (30) (increasing osteointegration and consequently the bone healing process); it corrects surface energy by favouring the attachment of endothelial cells (27); and finally, it's not cytotoxic (27).

We decided to employ distal locking in only 7 cases where there was lateral wall comminution, presence of a large posteromedial fragment which crossed the small trochanter's line, or the intramedullary canal was wide. The choice to proceed with distal locking only in these cases is in line with many articles in the scope of present literature (31-33).

By evaluating post-operative tendencies of patients operated with this method of synthesis, we can confirm the benefits of the nail's mechanical and biological characteristics; we observed that the fractures consolidated as soon as 30 days after surgery in all cases and that the intramedullary nail integrates perfectly. Moreover, no post-op complications, infections or inflammatory episodes were detected in the surgical wound. For the evaluation of the post-operative course, we used the modified Harris Hip Score, which proved useful in lateral femur fractures (34). Mean mHHS progressively increased, from 31.7 fifteen days after surgery, to 45.8 thirty days after surgery, and finally settling to 67.2 sixty days after surgery.

Conclusions

The treatment of choice for osteosynthesis of fractures of the trochanteric region is the second generation of intramedullary nail. Based on the data in our possession, employment of the intramedullary D-Nail for lateral femoral fracture treatment is safe and reliable. We did not detect any post-operative complication in any of the examined cases. The analyzed timespan is brief, and it would be useful for this study to go further, to increase the number of properly analyzed cases and to extend clinical and radiological imaging follow-up. There could be an assessment of whether or not the silicon coating affects biological integration and mechanical nail sealing. Unique advantage of a intertrochanteric fixation by a 10mm screw or two 6mm screws offers to surgeon a better approach to different types of fractures. For this reason and thanks to encouraging primary results we believe that D-Nail can be considered a good solution for this type of fractures.

Conflicts of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

References

1. Parker M, Johansen A. Hip fracture. BMJ 2006; 333: 27–30.
2. Maniscalco P, Rivera F, Bertone C, Urgelli S, Bocchi L. Compression hip screw nail-plate system for intertrochanteric fractures. Panminerva Med. 2002. Jun;44(2):135–9. PubMed PMID: 12032432
3. Frandsen PA, T Kruse T. Hip fractures in the county of Funen, Denmark. Implications of demographic aging and changes in incidence rates. Acta Orthop Scand 1983; 54: 681–6.
4. Paganini-Hill A, Chao A, Ross RK, Henderson BE. Exercise and other factors in the prevention of hip fracture: the Leisure World study. Epidemiology 1991; 2: 16–25.
5. Oldani D, Maniscalco P. Preliminary experience with MEDGAL DHS for treatment of proximal femoral fractures. Acta Biomed 2019; 90: 82–85.
6. Rebuzzi E, Pannone A, S Schiavetti S, et al. IMHS clinical experience in the treatment of peritrochanteric fractures. The results of a multicentric Italian study of 981 cases. Injury 2002; 33: 407–12.
7. Kenzora JE, McCarthy RE, Lowell JD, Sledge CB. Hip fracture mortality. Relation to age, treatment, preoperative

illness, time of surgery, and complications. Clin Orthop Relat Res 1984; 186: 45–56.
8. Muller ME, Nazarian S., Koch P, Schatzker J. The comprehensive classification of fractures of long bones; Springer, Berlin. 1990.
9. Jensen JS. Classification of trochanteric fractures. Acta Orthop Scand 1980; 51: 803–810
10. Lee DJ, Elfar JC. Timing of hip fracture surgery in the elderly. Geriatric orthopaedic surgery & rehabilitation 2014; 5: 138–40.
11. Shiga T, Wajima Z, Ohe Y. Is operative delay associated with increased mortality of hip fracture patients? Systematic review, meta-analysis, and meta-regression. Can J Anaesth 2008; 55: 146–54.
12. Moja L, Piatti A, Pecoraro V, et al. Timing matters in hip fracture surgery: patients operated within 48 hours have better outcomes. A meta-analysis and meta-regression of over 190,000 patients. PLoS One 2012; 7: e46175.
13. Uzer G, Elmadag NM, Yıldız F, Bilsel K, Erden T, Toprak H. Comparison of two types of proximal femoral hails in the treatment of intertrochanteric femur fractures. Ulus Travma Acil Cerrahi Derg 2015; 21: 385–91.
14. Makridis KG, Georgaklis V, Georgoussis M, Mandalos V, Kontogeorgakos V, Badras L. Comparing two intramedullary devices for treating trochanteric fractures: A prospective study. J Orthop Surg Res 2010; 5: 9.
15. Haidukewych GJ, Israel TA, Berry DJ. Reverse obliquity fractures of the intertrochanteric region of the femur. J Bone Joint Surg Am 2001;83:643–650.
16. Hardy DC, Drossos K. Slotted intramedullary hip screw nails reduce proximal mechanical unloading. Clin Orthop Relat Res 2003; 406: 176–84.
17. Rantanen J, Aro HT. Intramedullary fixation of high subtrochanteric femoral fractures: A study comparing two implant designs, the Gamma nail and the intramedullary hip screw. J Orthop Trauma 1998; 12: 249–52.
18. Maniscalco P, Caforio M, Imberti D, Porcellini G, Benedetti R. Apixaban versus enoxaparin in elective major orthopedic surgery: a clinical review. Clin Appl Thromb Hemost 2015; 21: 115–9.
19. Ministero della Salute, CCM. Indagine multicentrica sugli esiti delle fratture degli arti inferiori negli anziani a seguito di incidente domestico, 2007.
20. Swiatek L, Olejnik A, Grabarczyk J. The influence of the DLC and DLC-Si coatings on the changes occurring on the implants surface during the implant-bone contact. Eng Biomaterials 2016; 19: 2–12.
21. Koryszewski K, Bociąga D, Skowroński R. Results of peritrochanteric fracture treatment with carbon (DLC) and silicon-carbon (Si-DLC) coated Gamma nail – preliminary report. Chir Narzadow Ruchu Ortop Pol 2015; 80: 171–5.
22. Olejnik A, Świątek L, Bociąga D. Biological evaluation of modified DLC coatings - a review. World Sci News 2017; 73: 61–71.
23. Ren DW, Zhao Q, Bendavid A. Anti-bacterial property of Si and F doped diamond-like carbon coatings. Surf Coat Tech 2013; 226: 1–6.
24. Okpalugo TIT, Ogwu AA, Maguire PD, McLaughlin JAD, Hirst DG. In-vitro blood compatibility of a-C:H:Si and a-C:H thin films. Diam Relat Mater 2004; 13: 1088–92.
25. Ong SE, Zhang S, Du H, Too HC, Aung KN. Influence of silicon concentration on the haemocompatibility of amorphous carbon. Biomater 2007; 28: 4033–8.
26. Randeniya LK, Bendavid A, Martin PJ, et al. Incorporation of Si and SiOx into diamond-like carbon films: Impact on surface properties and osteoblast adhesion. Acta Biomater 2009; 5: 1791–7.
27. Ogwu AA, Okpalugo TI, Ali N, Maguire PD, McLaughlin JA. Endothelial cell growth on silicon modified hydrogenated amorphous carbon thin films. J Biomed Mater Res 2008; 85: 105–13.
28. Okpalugo TI, McKenna E, Magee AC, McLaughlin J, Brown NM. The MTT assays of bovine retinal pericytes and human microvascular endothelial cells on DLC and Si-DLC-coated TCPS. J Biomed Mater Res A 2004; 71: 201–8.
29. Okpalugo TI1, Murphy H, Ogwu AA, Abbas G, Ray SC, Maguire PD, McLaughlin J, McCullough RW. Human microvascular endothelial cellular interaction with atomic n-doped DLC compared with Si-doped DLC thin films. J Biomed Mater Res B Appl Biomater 2006; 78: 222–9.
30. G. Thorwarth, B. Saldamli, Schwarz, F, et al. Biocompatibility of doped diamond-like carbon coatings for medical implants. Plasma Process Polym 2007; 4: 364–8.
31. Li X, Zhang L, Hou Z, et al. Distal Locked and unlocked nailing for perthrochanteric fractures – A prospective comparative randomized study. Int Orthop 2015; 39: 1645–52.
32. Ciaffa V, Vicenti G, Mori CM. Unlocked versus dynamic and static distal locked femoral nails in stable and unstable intertrochanteric fractures. A prospective study. Injury 2018; 49: 19–25.
33. Oldani D, Maniscalco P. Preliminary experience with EBA ONE intramedullary nail for the treatment of pertrochanteric fractures. Acta Biomed 2019; 90: 86–90.
34. Vishwanathan K, Akbari K, Patel AJ. Is the modified Harris hip score valid and responsive instrument for outcome assessment in the Indian population with pertrochanteric fractures? J Orthop 2018; 15: 40–6.

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Review

MPFL reconstruction: indications and results

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Summary. *Background and aim:* The medial patellofemoral ligament (MPFL) is the most important structure commonly injured during lateral patellar dislocation and its rupture accounts for 3% of total knee injuries. MPFL reconstruction (MPFLR) is a reliable procedure with good results but variable rates of recurrent instability. The aim of this study is to underline the proper indications for the MPFLR reconstruction and to explain all the pearls and pitfalls regarding the MPFLR both in our experience and found in the latest literature. *Methods:* A comprehensive search in the latest literature using various combinations of the keywords MPFL, MPFLR, dislocation, treatment was performed. The following data were extracted: diagnosis methods, indications and contraindications for isolated MPFLR, type of management, recurrence of instability, outcomes and complications. *Results:* History of multiple patellar dislocations is the most relevant indication for ligament reconstruction especially after a failed course of conservative treatment in presence of persistent patello-femoral instability. Gold standard technique for MPFLR has not been clearly defined yet. *Conclusions:* There is still poor literature about outcome comparisons, therefore it is challenging to decide which technique is the most appropriate as surgical procedures are continuously developing. The ideal candidates for MPFLR have to be decided after a throughout evaluation and careful planning and, with nowadays knowledge, it is possible to put indication for a reconstruction exposing the patient to minimal risks. (www.actabiomedica.it)

Key word: MPFL; MPFLR; patello-femoral instability; patellar dislocation; MPFL reconstruction

Introduction

The MPFL is the most important structure commonly injured during lateral patellar dislocation. The typical injury pattern that leads to a patellar dislocation consists in a trauma without direct contact, with the knee performing a movement in flexion, internal rotation and with application of a valgus force.

MPFL lesions account for 3% of total knee injuries. It is commonly found in young females between 10-17 years old, probably due to a major ligamentous laxity and a minor support from the muscular mass compared to the male gender (1). Other predisposing factors for patellar dislocation may include patella alta, lateral patellar tilt, trochlear dysplasia, increased Q-angle, genu valgum, vastus medialis muscle hypoplasia, ligament hyperlaxity, external tibial torsion, subtalar joint pronation and increased femoral anteversion (2).

Rupture of the MPFL typically occurs at the femoral origin. Associated tearing of the vastus medialis oblique (VMO) and the medial retinaculum may also occur with dislocation of the patella, as the MPFL and VMO share common meshing fibers. Additionally, osteochondral fractures may be seen with dislocation as the patella impacts the femur (1,3).

Up to 10 years ago, there was not a reliable surgical treatment for patellar luxation. In the recent years MPFLR configures as the best option, for suitable patients, to regain the pre-lesion activity. Along with the MPFL there are other neighboring structures that prevent lateral displacement of the patella. For instance, the VMO is a patellar dynamic stabilizer; Its contraction aids the proper patellar tracking in the trochlea groove (3). Multiple anatomic and biomechanical studies have proved the MPFL performs its restraining action in the range of movements from full

knee extension (0°) until the patella engages the trochlear groove (at roughly 30°) which corresponds to the "Screw Home Mechanism" (1,4).

More recently the roles of the other medial soft tissue restraints have been highlighted. The medial quadriceps tendon-femoral ligament (MQTFL), the medial patella-tibial ligament (MPTL), the medial patella-meniscal ligament (MPML), and the VMO have distinct yet closely related functions to MPFL that contribute to medial patella support, and many new reconstruction techniques have emerged that use the isolated or combined reconstruction of the different knee medial ligamentous structures (5).

The aim of this study is to underline the proper indications for the MPFLR since there are many conditions that are not suitable for this specific procedure. Moreover, our purpose is to explain all the pearls and pitfalls regarding the MPFLR both in our experience and found in the latest literature.

Methods

We performed a comprehensive search of the latest literature using various combinations of the keywords MPFL, MPFLR, patellar dislocation and patellar dislocation treatment. We then extracted the following data to underline the proper indications and explain all the pearls and pitfalls regarding the MPFLR. In addition, we included a small chapter on the anatomy of the interested area to give a better understanding of the MPFL and the surrounding structures.

Anatomy

Nomura et al. (6), in a study on a total of 20 knee specimens, reported a description of the MPFL. The length was 58.8 ± 4.7 mm, while the width and thickness were respectively 12 ± 3.1 mm and 0.44 ± 0.19 mm at the middle point. Two functional bundles were described: an inferior-straight and a superior oblique one, with the latter closely associated to the VMO. (6) The structures of the MPFL originate from the medial femoral condyle, just distal to the adductor tubercle and proximal to the attachment of the medial collateral ligament (MCL) and insert on the medial and superior margin of the patella. The superior fibers merge with the patellar tendon and the VMO (Figure 1) (1,3,6-8).

The medial patellar stabilizers, as already stated, are composed of the medial retinaculum the MPFL, the MQTFL, the MPTL, the MPML, and the VMO.

MQTFL is a separate independent anatomic structure which extends from the distal deep quadriceps tendon to the adductor tubercle region, just proximal to the MPFL insertion, which ensures a static connection between the medial femur and the extensor mechanism of the anterior knee throughout the ROM. (9) The proximal medial patello-femoral complex (MPFC) consists of the MPFL and the MQTFL (10).

In the coronal plane there are 6 degrees of valgus between femur and tibia, and a similar angle is present between the trochlear groove and the anterior tibial tubercle. Due to these, there is a lateral force vector acting on the patella while the quadriceps contracts. The MPFL is the main medial stabilizer of the patella, providing about 50-60% of the counteracting mechanism (3,6,11-13).

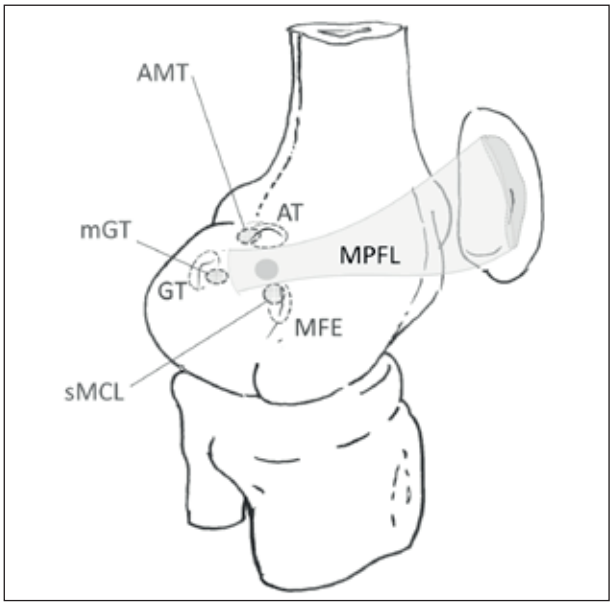

Figure 1. MPFL attachment areas in darker shading; AT Adductor Tubercle; AMT Adductor Magnus Tendon; GT Gastrocnemius Tubercle; mGT medial Gastrocnemius Tendon; sMCL superficial Medial Collateral Ligament; MFE Medial Femoral Condyle.

Dejour and Lecoutre (14) first described the condition known as trochlear dysplasia, which is a congenital condition consisting in a progressive filling of the trochlear groove and leads to displacement of the patella even during the normal mobility of the knee. Trochlear dysplasia presents with MPFL laxity and subsequent multiple patellar dislocations.

Diagnosis

Clinical examination is essential, and it is the first step to take to formulate a diagnosis. In case there is a dislocated patella it is necessary to reduce it by fully extending the affected knee and medializing a lateralized patella. In case this is an inaugural trauma it is likely for the patient to experience hemarthrosis which can be drained; by drawing blood we relieve the pain and facilitate the following clinical and radiological examinations (1).

Physical examination consists in evaluation of range of motion, apprehension sign and pain with patellar compression. If we divide the patella in 4 areas longitudinally on the coronal plane and have more than 2 of lateralization it is a positive sign of patellar instability (1,3,6,10).

In the acute setting, patients with MPFL rupture will present with pain and tenderness along the medial retinaculum. There may also be a block to motion due to an osteochondral fragment displacement. The presence of apprehension with lateralization of the patella and the absence of a firm end point to lateral translation suggests previous dislocation and damage to MPFL.

A classic antero-posterior (AP) view x-ray can be useful to evaluate the bone quality and correct alignment but not a direct correlation with patello-femoral instability. A true lateral, on the other hand, shows radiographic signs of trochlea dysplasia, such as: the crossing sign and the double contour (16). The Merchant view (weight bearing with knees at 45° of flexion) grants the possibility to evaluate the patello-femoral alignment and can also reveal bone avulsion from the medial side of the patella (3).

In order to confirm the diagnosis, it is necessary an MRI to directly study the MPFL and the remaining medial stabilizers of the knee (Figure 2-3) (1).

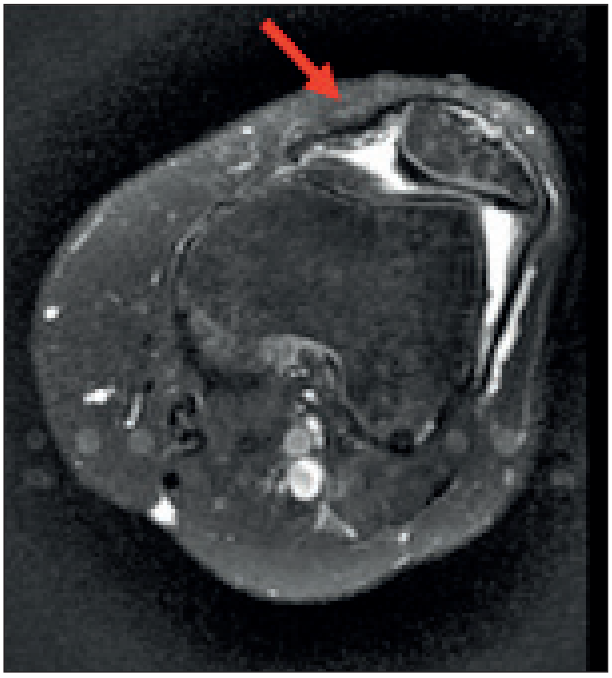

Figure 2. Left Knee MPFL injury of a 34years old man. A transverse T2-FSE MR image of the knee shows attenuation of signal of the MPFL.

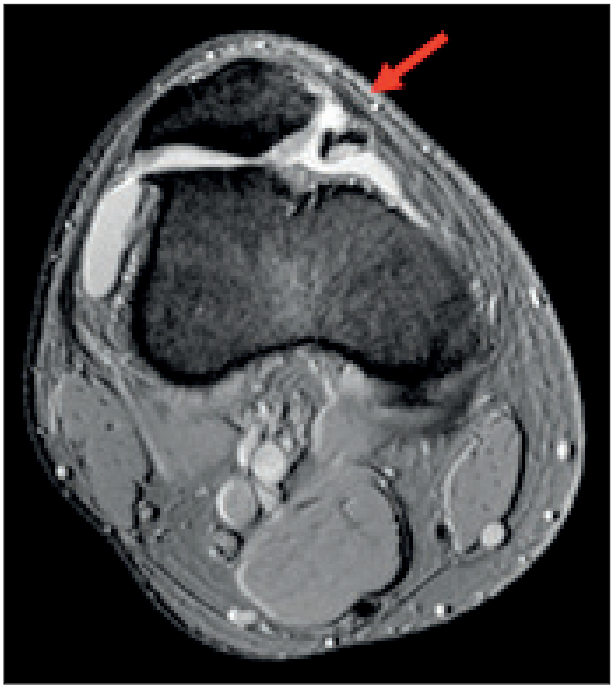

Figure 3. Right Knee MPLF injury of a 41years old woman. A transverse T2 MR image of the knee obtained at the level of the MPFL patellar insertion shows complete avulsion of the MPFL from its patellar insertion.

In case we suspect underlying knee conditions closely related to the injury that are identified as contraindications for MPFL reconstruction, such as trochlea dysplasia or tibial tubercle misalignment, the CT scan following the Lyon protocol can facilitate the diagnosis.

Classification

MPFL injuries have been classified into four categories based on location either at the level of the MPFL patellar insertion, within the mid-substance of the ligament, at the femoral origin, or in more than one location. Patellar insertion MPFL injuries can be further subdivided into three categories: type P_0 with purely ligamentous disruption, type P_1 with a bony avulsion fragment, and type P_2 with bony avulsion involving the articular surface of the medial facet of the patella. A schematic representation of the latter classification is reported in Figure 4 (2).

Patellar MPFL avulsion injury comprised two different types of osteochondral avulsion fractures: P_1 without articular cartilage involvement (only bone from medial patellar margin) and P_2 with articular cartilage involvement (medial patellar facet articular surface). In chronic instability cases, medial patellar ossicles can occasionally be observed as a sign of previous patellar MPFL avulsion fracture.

Between 40 and 90 % of MPFL injuries are located in the femoral attachment, whereas some studies have reported figures up to 50 to 60 % at the patellar insertion (17-19).

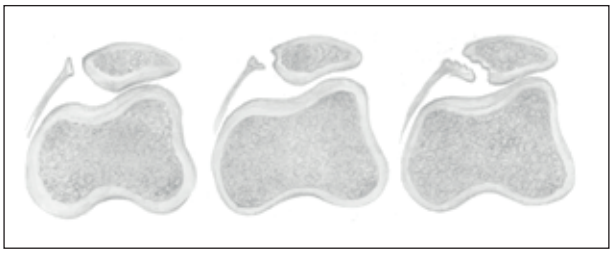

Figure 4. Three types of patellar MPFL injuries: **a type P_0** with ligamentous disruption at the patellar attachment; **b type P_1** with bony avulsion fracture from medial margin of the patella; **c type P_2** with bony avulsion involving articular cartilage from the medial facet of the patella.

Indications

According to the latest literature the most common indication for isolated Medial Patellar-Femoral Ligament Reconstruction is recurrent patello-femoral instability (20-22), while common reasons for not performing it include bony malalignment, trochlear dysplasia and patella alta.

MPFLR in presence of patello-femoral instability is usually indicated after 2 or more episodes of patellar dislocation; while MPFLR after the first episode of dislocation is sometimes considered, depending on the authors, in presence of ongoing symptoms of instability (as lateral subluxation), osteochondral fracture or failure of conservative management, such as bracing and physiotherapy.

Many authors set many other indications for isolated MPFLR (Table 1), such as symptomatic patellar-femoral instability associated with pain, positive physical examination findings, positive imaging, and participation in sport (22-25).

Gold standard treatment for MPFLR have not been clearly defined yet. Surgical techniques are continuously developing, and the relative credits versus non-operative management will become clear as more data become available. In the meantime, there are certain principles to which the orthopedic surgeon should adhere to perform an MPFLR:

1 Evaluate each patient for factors that predispose to patellar instability;
2 The location of injury to the MPFL should be identified and the repair should be focused on this site if possible;
3 Based on the available literature, open techniques seem to outperform arthroscopic ones. Proper tensioning of the MPFL is critical. Overtightening of the MPFL should be avoided.
4 Suture repairs should be stout, and anchors used to further strengthen the repair when feasible. In a bio-mechanical evaluation, MPFL repairs using suture anchors in addition to sutures failed at 142 N, whereas suture repair alone failed at 37 N (15).

The ideal candidate for an isolated MPFLR should fit the following profile (15), with regards to potential risk factors for recurrent patellar dislocation:
- Trochlear morphology: normal or type A dysplasia

Table 1. Indications for isolated MPFLR

Recurrent patellar instability
Failed conservative measures
Primary patellar dislocation
Patellar instability— positive clinical examination
Patellar dislocations
- With ongoing instability symptoms
- Associated osteochondral fracture
Painful subluxation
- Excessive lateral mobility/laxity on examination
- Positive patellar apprehension
Patellar instability—Imaging positive CT-MRI
Loose osteochondral lesion
Participation in sports

Table 2. Reasons to not perform an isolated MPFLR

Bony malalignment
- Excessive femoral anteversion
- Increased knee valgus angle
- Increased Q-angle
- Excessive tibial torsion
- Increased TT-TG distance
- Abnormal pelvic geometry
- Abnormal hind foot position
Dysplasias
- Trochlear dysplasia
- Patellar dysplasia
Patella alta
Neurogenic abnormality
General ligamentous laxity
Contralateral patellar instability
Obesity
Patellofemoral arthrosis
Severe osteochondral lesion
Patellofemoral arthritis
Other ligamentous or meniscal injury
Patellofemoral crepitus
Associated fractures
Inability to comply to treatment protocol
Joint infection

- Tibial tuberosity–trochlear sulcus angle of 0 to 5° valgus or a tibial tuberosity-trochlear groove distance less than 20 mm with the knee at 0° of flexion
- No excessive increase in the patellar height ratio (Caton-Deschamps index <1.2 or Insall-Salvati index <1.4)
- Patellar tilt less than 20° when measured on an axial image, using the posterior femoral condyles as a reference line, or some tilt but no lateral tightness on physical examination with the patella reduced

In presence of underlying causes, isolated MPFLR is not recommended because without the resolution of the underlying condition, there would not be benefit for the patient (Table 2).

In this perspective, bony malalignment is the most common reason for not performing an isolated MPFLR. There is no agreement between authors for the specific Q angle, according to different authors the cut-off spans from a minimum of 15° to 25° (23,26-27). In presence of an increased tibial tubercle-trochlear groove (TT-TG) distance there is no indication to perform an isolated MPFLR. Even in this case there is no agreement in literature for a specific distance threshold since multiple cut-offs are reported: 22mm (28), 20mm (29), and 15mm (22).

Other malalignments are stated as reasons to avoid an isolated MPFLR, among these we find increased knee valgus, excessive femoral anteversion (EFA) and excessive tibial torsion (ETT). Even for these there is not a univocal threshold, in fact different cutoffs are considered for the knee valgus, (greater than 10, 7 or 5° (22, 25, 30)), and for EFA (greater than 35 or 20°) (22, 31).

Patella alta is often considered as a contraindication for isolated MPFLR, and as before, different cut-offs are set by different authors: accounting the Insall-Salviati ratio, there is a threshold that varies from 1.2 to 1.3 mm (25,32). Whereas the Caton-Deschamps index presented cut-offs from 1.2 to 1.35 mm (33,34).

Dysplasia of both the trochlea and patella are described as a contraindication to perform an isolated MPFLR, and the Authors do not agree with the specific amount of dysplasia. In case of trochlear dysplasia, a trochlear-sulcus angle greater than 150° (23) or 145° (32) can be considered viable for surgery.

Discussion

An injury to the MPFL occurs with a rate between 94-100% following a patellar dislocation (3,6,11). Traumatic lesions to this ligament, if not treated, can lead to recurring dislocation in 14-44% of cases, osteochondral lesions and, eventually, to early osteoarthritis (35). In order to avoid any future complication, a surgical procedure to re-establish the normal anatomy, is mandatory due to the high chances to experience more recurrent episodes of dislocation compared to conservative treatments of any sort (11).

According to a 2015 Cochrane review, the difference between non-operative and operative treatment it is not in the functional scores, which are similar, but in a lower risk of recurrent dislocations with surgery at the price of surgical complications (36). As already stated, it is strong opinion for patients who experience multiple patellar dislocations, to undergo MPFL reconstruction. This might be the most relevant indication for ligament reconstruction (20,23,36) especially after a failed course of conservative treatment. Usually only elite athletes undergo MPFLR after only one dislocation.

Patella alta, trochlear dysplasia or increased TT-TG distance are predisposing factors which can definitely spike the risk of traumatic first events but at the same time their recurrency (3,4,12,29). All the aforementioned conditions preclude the possibility of a simple MPFL reconstruction due to a high risk of re-rupture of the graft. Therefore, associated procedures must be performed to decrease the likelihood of re-injury. It is not in the purpose of this paper to discuss trochleoplasty or tibial tubercle transposition, but persistent instability beyond 30° of knee flexion suggests bony malalignment (29,37).

Around 130 surgical techniques have been proposed since 1915, the year of the first ever published manuscript about this topic (21,38-39), and there is no universal consensus yet about the best procedure. In fact, multiple variations in graft sources have been suggested in literature, including semitendinous, gracilis, partial quadriceps, partial patellar tendon, allograft or artificial tendons (40-41), and none of them proved to have better results over the others. Moreover, there are variations in both patellar and femoral fixation and angle of knee flexion during fixation. Because of the many variables, it is still an endeavor to find the best surgical treatment, even though the technique has been refined thanks to a better understanding of the origin and insertion of the ligament.

Fortunately, the surgical procedures are more reproducible because there is consensus about the necessity to recreate an accurate and isometric ligament through an anatomical placement, especially, of the femoral bone tunnel (15,43). The Schöttle point, this is the exact area where to place the femoral tunnel during the reconstruction procedure in order to restore the isometry of the ligament (44).

As stated, every technique has its complications. In literature, sutures for MPFL are considered easier to be performed but are not as stable as trans-patellar bone tunnels (24% vs 8.6% of hypermobility respectively). On the other hand, bone tunnels carry the risk of iatrogenic fractures (0,9-3.6%) and highest complication rate (21.6%) (11,45-46).

Overall the cumulative rate of complications following reconstruction is 26.1% according to Shah et al. (46) which might be affected by possible misdiagnosed predisposing conditions and, especially, by technical errors that account for 50% of graft failures.

Re-dislocations following a reconstruction have a low and variable rate. In the cohort of 209 patients evaluated by Howells et al. (21) the re-dislocation rate was a surprising 0% with a single patellar tunnel technique and the use of a suspensory button. Mayer et al. (45) had only 3 cases out of 104 (2,9%) using an implant-free V-shaped patellar tunnel. While Enderlein et al. (40) experienced a 4.5% in a pool of 240 cases with a particular type of transpatellar tunnel and no graft fixation.

Conclusion

In conclusion there is still sparse literature about outcome comparisons, therefore it is challenging to decide which technique is the most appropriate. At the same time the ideal candidates for MPFL reconstruction have to be decided after a throughout evaluation and careful planning. In the past predisposing pathologies were overlooked but, with nowadays knowledge, it is possible to put indication for a reconstruction exposing the patient to minimal risks.

Diclosures: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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References

1. Rosinski A, Chakrabarti M, Gwosdz J, McGahan PJ, Chen JL. Double-Bundle Medial Patellofemoral Ligament Reconstruction With Allograft. Arthrosc Tech. 2019 May;8(5):e513–e520
2. Sillanpaa PJ, First-time patellar dislocation: surgery or conservative treatment? Sport Med Arthrosc. 2012;20(3): 128–135
3. Duthon VB. Acute traumatic patellar dislocation. Orthop Traumatol Surg Res. 2015 Feb;101
4. Sanchis-Alfonso V. How to Deal With Chronic Patellar Instability: What Does the Literature Tell Us?. Sports Health. 2016 Jan-Feb;8(1):86–90
5. LaPrade MD, Kallenbach SL, Aman ZS, et al. Biomechanical evaluation of the medial stabilizers of the patella. Am J Sports Med 2018;46:1575–1582
6. Nomura E, Inoue M, Osada N. Anatomical analysis of the medial patellofemoral ligament of the knee, especially the femoral attachment. Knee Surg Sports Traumatol Arthrosc. 2005 Oct;13(7):510–5
7. Kang HJ, Wang F, Chen BC, Su YL, Zhang ZC, Yan CB. Functional bundles of the medial patellofemoral ligament._Knee Surg Sports Traumatol Arthrosc. 2010 Nov;18(11):1511–6
8. Fujino K, Tajima G, Yan J, Kamei Y, Maruyama M, Takeda S, Kikuchi S, Shimamura T.Morphology of the femoral insertion site of the medial patellofemoral ligament. Knee Surg Sports Traumatol Arthrosc. 2015 Apr;23(4):998–1003
9. John P. Fulkerson, M.D Medial Quadriceps Tendon Femoral Ligament: Surgical Anatomy and Reconstruction Technique to Prevent Patella Instability Arth Tech 2013;2(2):125–128
10. Espregueira-Mendes J, Andrade R Combined Soft Tissue Reconstruction of the Medial Patellofemoral Ligament and Medial Quadriceps TendoneFemoral Ligament . Arthroscopy Techniques, in press.
11. Hendawi T, Godshaw B, Flowers C, Stephens I, Haber L, Waldron S. Autograft vs Allograft Comparison in Pediatric Medial Patellofemoral Ligament Reconstruction.Ochsner J. 2019 Summer;19(2):96–101
12. Yeung M, Leblanc MC, Ayeni OR, Khan M, Hiemstra LA, Kerslake S, Peterson D. Indications for Medial Patellofemoral Ligament Reconstruction: A Systematic Review.J Knee Surg. 2016 Oct;29(7):543–554
13. Krebs C, The medial patellofemoral ligament: Review of the literature, J Ortho 15 (2018) 596–599
14. Dejour DRP, Lecoultre B. Douleur et instabilité rotulienne: essai de classification. Med Hyg 1998;5:1466–70.
15. Wang CH, Ma LF, Zhou JW, Ji G, Wang HY, Wang F, Wang J. Double-bundle anatomical versus single-bundle isometric medial patellofemoral ligament reconstruction for patellar dislocation. Int Orthop. 2013 Apr;37(4):617–24
16. W.N.Scott et al. Insall & Scott. Surgery of the knee. Sixth edition (2018)
17. Guerrero P, Medial patellofemoral ligament injury patterns and associated pathology in lateral patella dislocation: an MRI study. Sports Med Arthrosc Rehabil Ther Technol 2009, 1:17
18. Kepler CK, Zone of injury of the medial patellofemoral ligament after acute patellar dislocation in children and adoles- cents. Am J Sports Med 2011, 39:1444–1449
19. Weber-Spickschen TS, The relationship between trochlear dysplasia and medial patellofemoral ligament rupture location after patellar dislocation: an MRI evaluation. Knee 2011, 18(3):185–188
20. Csintalan RP, Latt LD, Fornalski S, Raiszadeh K, Inacio MC, Fithian DC. Medial patellofemoral ligament (MPFL) reconstruction for the treatment of patellofemoral instability. J Knee Surg. 2014 Apr;27(2):139–46
21. Howells NR, Barnett AJ, Ahearn N, Ansari A, Eldridge JD. Medial patellofemoral ligament reconstruction: a prospective outcome assessment of a large single centre series. J Bone Joint Surg Br. 2012 Sep;94(9):1202–8
22. Ma LF, Wang F, Chen BC, Wang CH, Zhou JW, Wang HY. Medial retinaculum plasty versus medial patellofemoral ligament recon- struction for recurrent patellar instability in adults: a randomized controlled trial. Arthroscopy 2013;29(5):891–897
23. Mehta VM, Inoue M, Nomura E, Fithian DC. An algorithm guiding the evaluation and treatment of acute primary patellar dislocations. Sports Med Arthrosc Rev 2007;15(2):78–8
24. Ronga M, Oliva F, Longo UG, Testa V, Capasso G, Maffulli N. Isolated medial patellofemoral ligament reconstruction for recurrent patellar dislocation. Am J Sports Med 2009;37(9):1735–1742
25. Hiemstra LA, Kerslake S, Kupfer N, Lafave M. Patellofemoral Stabilization: Postoperative Redislocation and Risk Factors Following Surgery. Orthop J Sports Med.2019 Jun;7(6):2325967119852627
26. Hiemstra LA, Kerslake S, Kupfer N, Lafave M. Patellofemoral Stabilization: Postoperative Redislocation and Risk Factors Following Surgery. Orthop J Sports Med.2019 Jun;7(6):2325967119852627
27. Drez D Jr, Edwards TB, Williams CS. Results of medial patellofe- moral ligament reconstruction in the treatment of patellar dislo- cation. Arthroscopy 2001;17(3):298–306
28. Lippacher S, Dreyhaupt J, Williams SR, Reichel H, Nelitz M. Reconstruction of the medial patellofemoral ligament:

Clinical outcomes and return to sports. Am J Sports Med 2014;42(7): 1661–1668
29. Zhou JW, Wang CH, Ji G, Ma LF, Wang J, Zhang F, Dong JT, Wang F. A minimally invasive medial patellofemoral ligament arthroscopic reconstruction. Eur J Orthop Surg Traumatol. 2014 Feb;24(2):225–30
30. Ellera Gomes JL, Stigler Marczyk LR, César de César P, Jungblut CF. Medial patellofemoral ligament reconstruction with semitendi- nosus autograft for chronic patellar instability: a follow-up study. Arthroscopy 2004;20(2):147–151
31. Hinterwimmer S, Imhoff AB, Minzlaff P, et al. Anatomical two- bundle medial patellofemoral ligament reconstruction with hard- ware-free patellar graft fixation: technical note and preliminary results. Knee Surg Sports Traumatol Arthrosc 2013;21(9): 2147–2154
32. Panni AS, Alam M, Cerciello S, Vasso M, Maffulli N. Medial patellofemoral ligament reconstruction with a divergent patellar transverse 2-tunnel technique. Am J Sports Med 2011;39(12): 2647–2655
33. Raghuveer RK, Mishra CB. Reconstruction of medial patellofe- moral ligament for chronic patellar instability. Indian J Orthop 2012;46(4):447–454
34. Arendt EA, Dahm DL, Dejour D, Fithian DC, Patellofemoral joint: from instability to arthritis. Instr Course Lect. 2014; 63:355–368
35. Schöttle PB, Fucentese SF, Romero J. Clinical and radiological outcome of medial patellofemoral ligament reconstruction with a semitendinosus autograft for patella instability. Knee Surg Sports Traumatol Arthrosc. 2005 Oct;13(7):516–21
36. Smith TO, Donell S, Song F, Hing CB. Surgical versus non-surgical interventions for treating patellar dislocation. Cochrane Database Syst Rev. 2015 Feb 26;(2):CD008106
37. Fujino K, Tajima G, Yan J, Kamei Y, Maruyama M, Takeda S, Kikuchi S, Shimamura T.Morphology of the femoral insertion site of the medial patellofemoral ligament. Knee Surg Sports Traumatol Arthrosc. 2015 Apr;23(4):998–1003
38. Buckens CF, Saris DB. Reconstruction of the medial patellofemoral ligament for treatment of patellofemoral instability: a systematic review. Am J Sports Med. 2010 Jan;38(1):181–8
39. Jibri Z, Jamieson P, Rakhra KS, Sampaio ML, Dervin G. Patellar maltracking: an update on the diagnosis and treatment strategies. Insights Imaging. 2019 Jun 14;10(1):65. doi: 10.1186/s13244-019-0755-1
40. Enderlein D, Nielsen T, Christiansen SE, Faunø P, Lind M. Clinical outcome after reconstruction of the medial patellofemoral ligament in patients with recurrent patella instability. Knee Surg Sports Traumatol Arthrosc. 2014 Oct;22(10):2458–64
41. Schottle PB, Hensler D, Imhoff AB (2010) Anatomical double bundle MPFL reconstruction with an aperture fixation. Knee Surg Sports Traumatol Arthrosc 18:147–151
42. Aframian A, Smith TO, Tennent TD, Cobb JP, Hing CB. Origin and insertion of the medial patellofemoral ligament: a systematic review of anatomy. Knee Surg Sports Traumatol Arthrosc. 2017 Dec;25(12):3755–3772
43. Fujino K, Tajima G, Yan J, Kamei Y, Maruyama M, Takeda S, Kikuchi S, Shimamura T.Morphology of the femoral insertion site of the medial patellofemoral ligament. Knee Surg Sports Traumatol Arthrosc. 2015 Apr;23(4):998–1003
44. Schöttle PB, Schmeling A, Rosenstiel N, Weiler A. Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction. Am J Sports Med.2007 May;35(5):801–4
45. Mayer P, Schuster P, Schlumberger M, Eichinger M, Pfaff M, Immendörfer M, Richter J. Midterm Results after Implant-Free Patellar Fixation Technique for Medial Patellofemoral Ligament Reconstruction. J Knee Surg. 2019 Jul 3
46. Shah JN, Howard JS, Flanigan DC, Brophy RH, Carey JL, Lattermann C. A systematic review of complications and failures associated with medial patellofemoral ligament reconstruction for recurrent patellar dislocation. Am J Sports Med. 2012 Aug;40(8):1916–23

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Original article

Histological analysis of ACL reconstruction failures due to synthetic-ACL (LARS) ruptures

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Summary. *Introduction:* Anterior Cruciate Ligament (ACL) reconstruction is an established surgical procedure. Synthetic ligaments represent an option for ACL reconstruction. Their popularity declined for the raising concerns due to re-ruptures, knee synovitis and early arthritis related to I and II generation artificial ligaments. The introduction of a III generation synthetic ligament (Ligament Advanced Reinforcement System-LARS) permitted renewed interest in the adoption of this kind of graft. Main purpose of our study was to describe the histological findings on samples obtained from a consecutive series of ACL revision surgeries due to LARS ACL reconstruction failures. Secondary aim was to determine the reason for LARS rupture. *Methods:* In a period between 2016 and 2018 eleven patients underwent ACL revision surgery due to LARS ACL reconstruction failure. At the time of the arthroscopic procedure, samples of synovial membrane and remnants of the torn LARS were sent to the Pathological-Anatomy Institute of our Hospital for a histological analysis. *Results:* Histological analysis of the synovial tissues confirmed the arthroscopic evidence of synovitis mainly characterized by chronic inflammation with predominance of multinucleated giant cells. The adoption of polarized light microscopy revealed the presence of brightly bi-refractive material (LARS wear particles) in the synovial tissue; at higher magnification wear debris were detected inside the cytoplasma of multi nucleated cells. The histological analysis of the removed LARS revealed a surrounding typical foreign body reaction with poor signs of fibrovascular ingrowth of the synthetic ligament. *Conclusions:* Our findings could not clearly advocate a unique mechanism of LARS-ACL reconstruction failure: biologic issues (poor tissue ingrowth) and mechanical issues (fibers properties and tunnel position) probably concur in a multi factorial manner. ACL reconstruction using artificial ligaments can not be considered a simple surgery. Artificial augments require some expertise and could therefore achieve better results if used by skilled sport surgeons other than trainees or low volume surgeons. The Authors believe that ACL reconstruction with synthetic devices still have restricted indications for selected patients (e.g. elderly patients who require a fast recovery, professional athlete, autologous tendons not available and/or refusing donor tendons). Our study arises additional suspicion on the unresponsiveness of synthetic fibers and claim some concern in the implantation of synthetic devices. (www.actabiomedica.it)

Key words: anterior cruciate ligament, synthetic ligament, reconstruction, histology, failure

Introduction

Anterior Cruciate Ligament (ACL) reconstruction is an established surgical procedure performed to restore knee stability that can achieve optimal results in terms of both patients related outcomes (symptoms, return to pre-injury level) and objective clinical assessment (knee stability assessed by instrumentations) (23).

Several surgical techniques have been described and it has been postulated that the best option should be tailored on patients' characteristics and expectations (22).

A crucial aspect regarding ACL reconstruction is the selection of the graft since each of the different possibilities have relative advantages and disadvantages. Autologous tendons harvested from a donor site (hamstring, patellar, quadriceps tendons) represent the graft of choice for many authors and the gold standard for younger patients (<40 years) (24). Allograft tendons (quadriceps, Achilles tendon, hamstring, patellar, anterior and posterior tibialis tendons and the fascia lata) represent an option in primary ACL reconstruction for older patients and in revision ACL surgery (21,24).

A third graft option for ACL reconstruction are synthetic ligaments. Supporters of artificial grafts advocate relative advantages compared to autografts and allografts: a quicker surgery in absence of donor site morbidity and a faster rehabilitation compared to autograft and the absence of potential disease transmission compared to allograft (21). Furthermore, the sterilization process and irradiation may contribute to the weakening of the allograft (26).

Despite the above assumptions, several failures in the early 80's and 90's - re-ruptures of the ligament, knee synovitis, clinical instability and early arthritis (1,2) - with I and II generation synthetic ligaments (1) lead to a progressive concern and their popularity declined.

The introduction on the market of a 3rd generation synthetic ligament (Ligament Advanced Reinforcement System-LARS) made of Polyethylene Terephtalate (PET) permitted renewed interest in the choice of this graft for primary (and revision) ACL reconstruction. The microscopic structure of the LARS and a particular purification mechanism of the fibers should lead to a better soft tissue ingrowth and reduce the risk of synovitis (3). Furthermore, the fibers of the synthetic ligament present two different arrangement: in the intraarticular portion, the ligament consists of longitudinal fibers that are twisted at 90° angles without transverse fibers while in the extra articular part the LARS is waved by longitudinal and transverse fibers (21). These peculiar issues of the LARS should minimize the shear stress to the device thus leading to a better ingrowth of tissues with an inferior risk of wearing, less spreading debris particles and, therefore, a minor risk of synovitis and other complications advocated to older synthetic devices (1,14).

Despite very satisfying results on short to mid-term follow-up (15,16,21) a recent study by Tulloch et al (20), reported a LARS-ACL reconstruction failure rate of 33.3% at a minimum of 6 year of follow-up and concluded that the LARS should not be considered as a graft option for primary ACL reconstruction.

Main purpose of our study was to describe the histological findings on samples obtained from a consecutive series of ACL revision surgeries due to synthetic (LARS) ACL reconstruction failures.

Secondary aim was to determine the cause of failure of LARS ACL reconstructions.

Materials and methods

In a period between 2016 and 2018 eleven patients (10 male, 1 female), mean age of 41 years-old (ranging from 24 to 49), presented at our Institution complaining for knee instability after ACL reconstruction performed with a synthetic ligament (LARS). All the patients had the primary ACL reconstruction in other hospitals and came at our clinics at a mean of 3 years (minimum 9 months, maximum 5 years) after the index surgery. All the patients were clinically tested (anterior drawer, Lachman and pivot shift test) and imaging investigations (X-Rays and MRI) were evaluated (Figure A-B-C).

All the eleven patients were treated due to the failure (rupture) of the LARS-ACL reconstruction determining clinical instability; none of the patients were treated due other symptoms potentially related to the artificial ligament (e.g. swelling or synovitis) or

associated lesions (e.g. meniscal tears, cartilage lesions, associated ligamentous injuries).

ACL revision surgeries were guided by the REVISE ACL classification (25) and in all the eleven patients we were able to perform a one-stage ACL revision surgery since previous tunnels well acceptable (7/11 revisions) or grossly malpositioned (4/11 revisions) such that they could be avoided during the drilling of new tunnels (26). In accordance with Di Benedetto et al (27), our preference in ACL revision surgery was towards allograft tendons – cryopreserved gracilis and semitendinosus - associated with a transtibial technique. In all the patients we utilized a femoral suspension system (Top Traction System-TTS) (28) (Figure D). At the time of the arthroscopic procedure, we withdrawed samples of periarticular tissues (synovial membrane) and remnants of the torn LARS (Figure E-F); when possible, the LARS stump was removed "en bloc". Both the samples were sent to the Pathological-Anatomy Institute of our Hospital where the specimens were prepared on tissue slide sections and processed on Hematoxylin-Eosin staining. A histological analysis was performed on optical and polarized light microscopy at different magnification.

Results

At the time of the ACL revision surgery we documented the arthroscopic findings in all the patients.

In eleven revision surgery (100% of the patients) the clinical diagnosis of rupture of the synthetic ACL reconstruction was confirmed intra operatively and in seven of the eleven patients we were able to remove "en

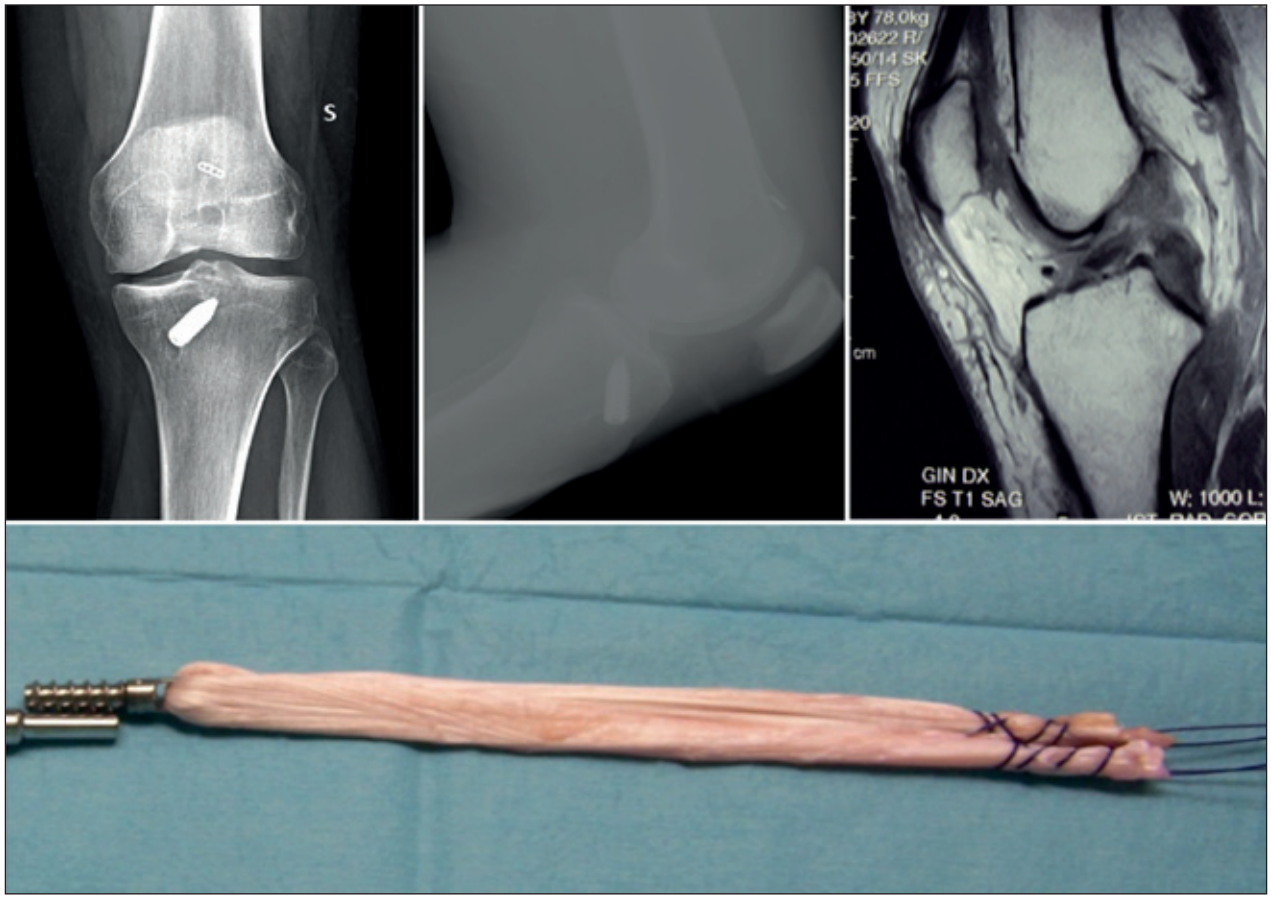

Figure A-B-C-D. X-Rays showing fixation methods in primary ACL reconstruction **(A-B)**. MRI demonstrating the rupture of the ACL **(C)**. Allograft hamstring tendons quadruplicated and prepared with a TTS screw **(D)**.

bloc" one of the two stumps of the LARS, usually on the proximal (femoral) side (Figure G-H).

As expected, the removal of the LARS remnant showed the absence of macroscopic integration of the ligament at the bone-ligament interface; according to other authors (20,21), in all the eleven revision surgeries we have not found signs of osteolysis and/or widening of the tibial or femoral tunnels. Furthermore, in six of the eleven patients (54.5%) we found a wrong position of the tunnel and in 5 of them, according to Samitier et al and recent literature (26,29,30), the misplaced tunnel was more often on the femoral side and usually in a too vertical and anterior position. The roughly malposition of the tunnel led us to drill a new tunnel without a coalescence or weakening of the bone (Figure X-Y). In all the 11 revision surgeries we were able to perform a one-stage procedure without the need of staged procedure.

In all the patients we found severe widespread villonodular synovitis to every compartment of the knee joint. The synovitis was macroscopically characterized by evident hyperemic and redundant intra-articular tissue (Figure I-J).

During the ACL revision surgeries we removed arthroscopically the failed LARS and we took samples of synovial tissue; both the specimens were preserved in formalin and sent to the pathological-anatomy institute for the analysis.

In all the patients a partial synovectomy rather than a radical synovectomy was performed in order to limit post-operative bleeding and swelling of the knees thus to facilitate an early rehabilitation protocol.

Histological analysis of the synovial tissue confirmed the arthroscopic evidence of synovitis; confocal microscopy revealed at different magnification the

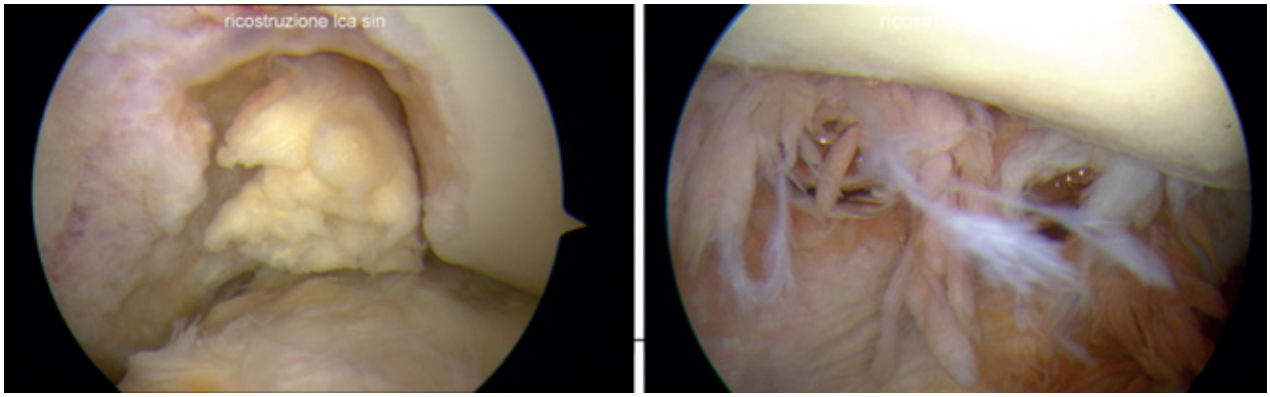

Figure E-F. Arthroscopic findings. Femoral-side LARS stump with intercondylar and medial condyle signs of cartilage damage **(E)**. Intra-articular tissues demonstrating villonodular synovitis **(F)**.

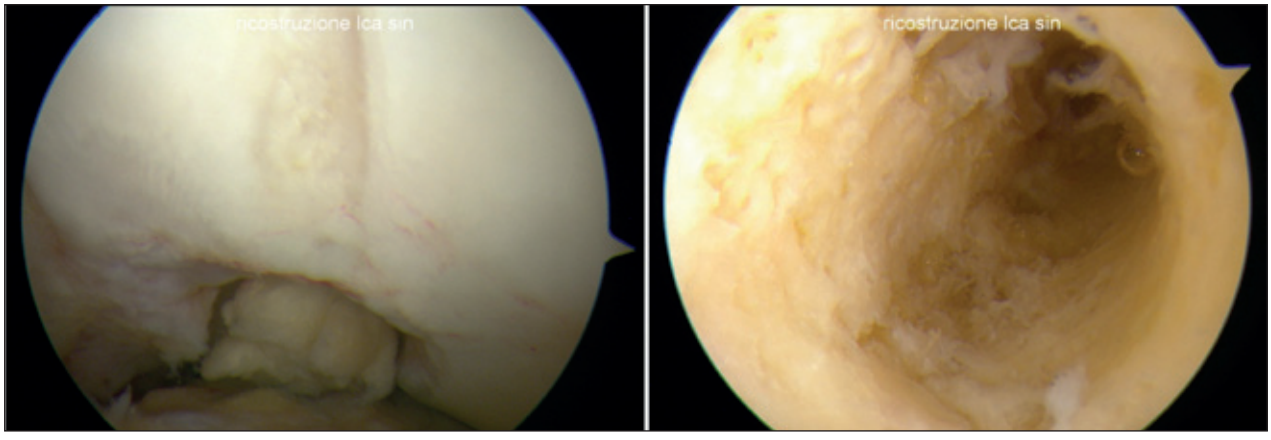

Figure G-H. Rupture of the LARS at the opening of the femoral tunnel (G). (H) Femoral Tunnel after the removal of the LARS. Figure H demonstrates the absence of macroscopic signs of ligament bone ingrowth

hyperplasia and the hypertrophy of the synovial tissue characterized by a typical cellularity of chronic inflammation with predominance of multinucleated giant cells typical of foreign body reaction (Figure K-L).

The adoption of polarized light microscopy - on the same histological slide - revealed at 2X magnification microscopy the presence of brightly polarizable - bi-refractive – material spread in the synovial tissue; at higher magnification (40X) polarized light microscopy detected the bi-refractive material inside the cytoplasm of multi nucleated cells (Figure M-N).

Assuming that bi-refractivity under polarized light is a characteristic of the synthetic fibers - poly ethylene terephthalate (PET) - we were able to —demonstrate the widespread diffusion of wear particles in the synovial tissue and the consequent reaction of the organism.

None of the synovial tissue samples presented signs of malignancy or local aggressivity.The same histological analysis was performed on sections of the stump or sections of the remnant of the ligament prepared on hematoxylin-eosin staining.

Light microscopy at different magnification well documented the arrangement of synthetic fibers disposed in a parallel and regular layout surrounded by a poor, dense fibrous - scar-like -tissue with multinucleated giant cell interposed (Figure N-O). Furthermore, the histological description made on the LARS revealed a typical foreign body reaction with poor signs of fibrovascular ingrowth of the synthetic ligament.

Polarized light microscopy applied on LARS sections (Figure P-Q) confirmed the brightly polarizable aspect of the synthetic PET fibers thus to confirm the

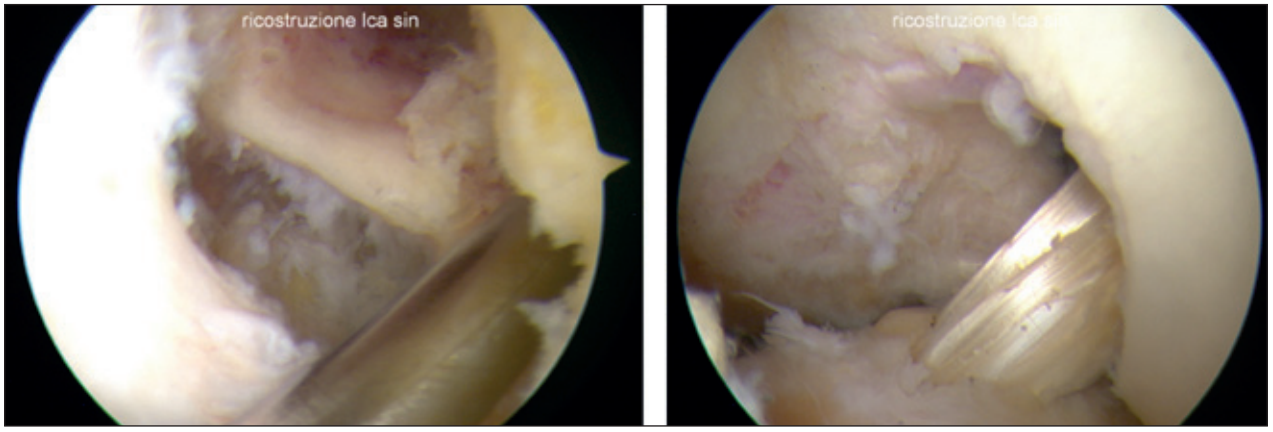

Figure X-Y. The examination tool show the direction of the new femoral tunnel without interfering with the previous anterior tunnel (**X**). Allograft hamstring ACL reconstruction in situ. The previous tunnel is still visible (**Y**).

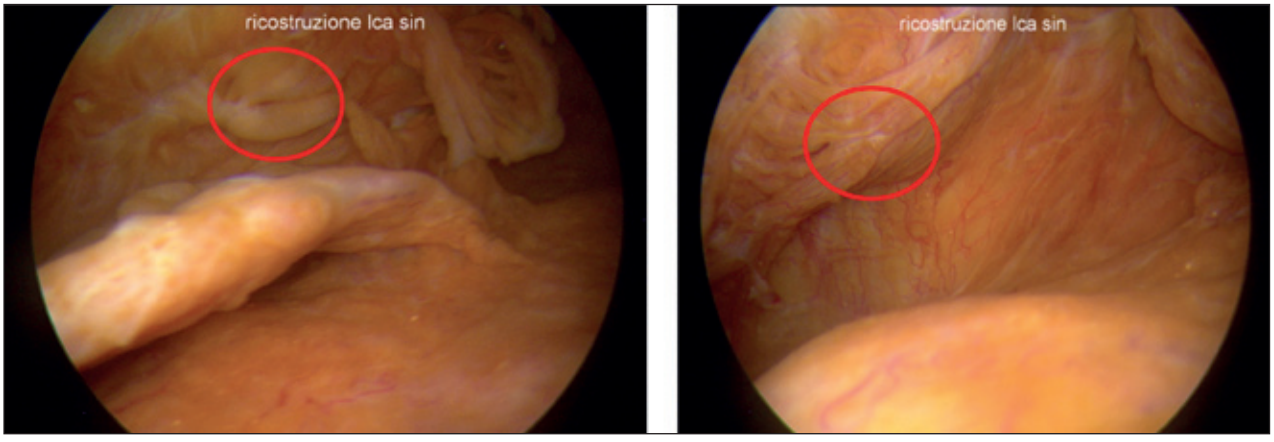

Figure I-J. Severe widespread synovitis with hyperemic and hypertrophic tissues of the knee. Roughly PET debris are visible (red circles).

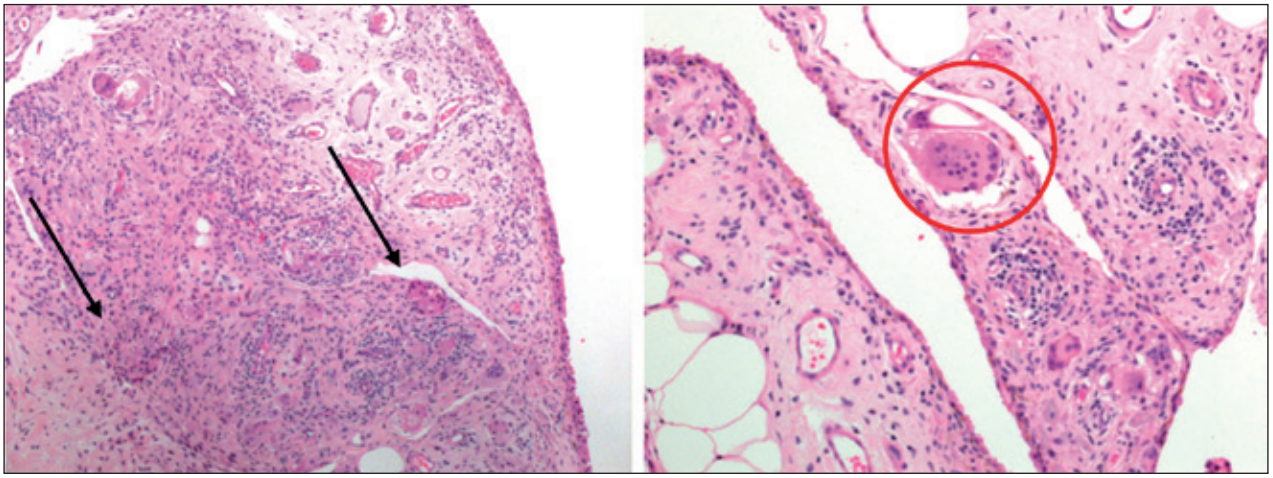

Figure K-L. Hematoxylin-Eosin staining of Synovial Tissue. 2X magnification microscopy demonstrate multiple multi-nucleated giant cells (black arrows) (**H**). 40X magnification shows a macrophage cell close to a foreign body (red circle) (**I**).

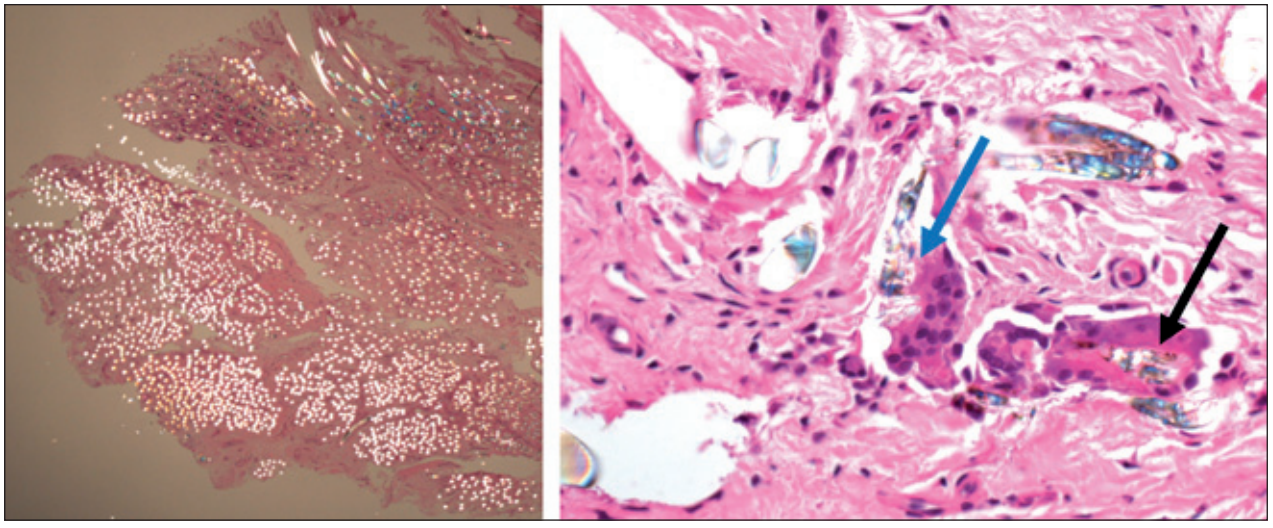

Figure L-M. Polarized light microscopy. 2X magnification showing spread debris in the synovial tissue (**J**). 40X magnification keeping a minimal polarization: black arrows on the right shows PET debris of the LARS inside the cytoplasm of a multinucleated cell. Blue arrow indicates a macrophage in the act of phagocyting a PET particle (**K**).

nature of the wear particles demonstrated in the synovial tissue and inside the cytoplasm of multi nucleated cells.

Histological analysis performed both on the synovial tissues and on the synthetic ligament did not show any suspect cellularity for knee infection.

Discussion

ACL reconstruction is the gold standard to treat knee instability and to prevent meniscal tears and cartilage damage after an ACL injury: autograft tendons appear the graft of choice especially in young patients (4, 5).

Early artificial ligaments yielded poor results in terms of clinical outcomes and incidence of complications including mechanical failures, synovitis and early arthritis thus the majority of the orthopedic community ceased this graft option till the early 90's (12).

The introduction of LARS as a possible device for ACL reconstruction gained renewed interest among synthetic devices. Bianchi et al compared the LARS to

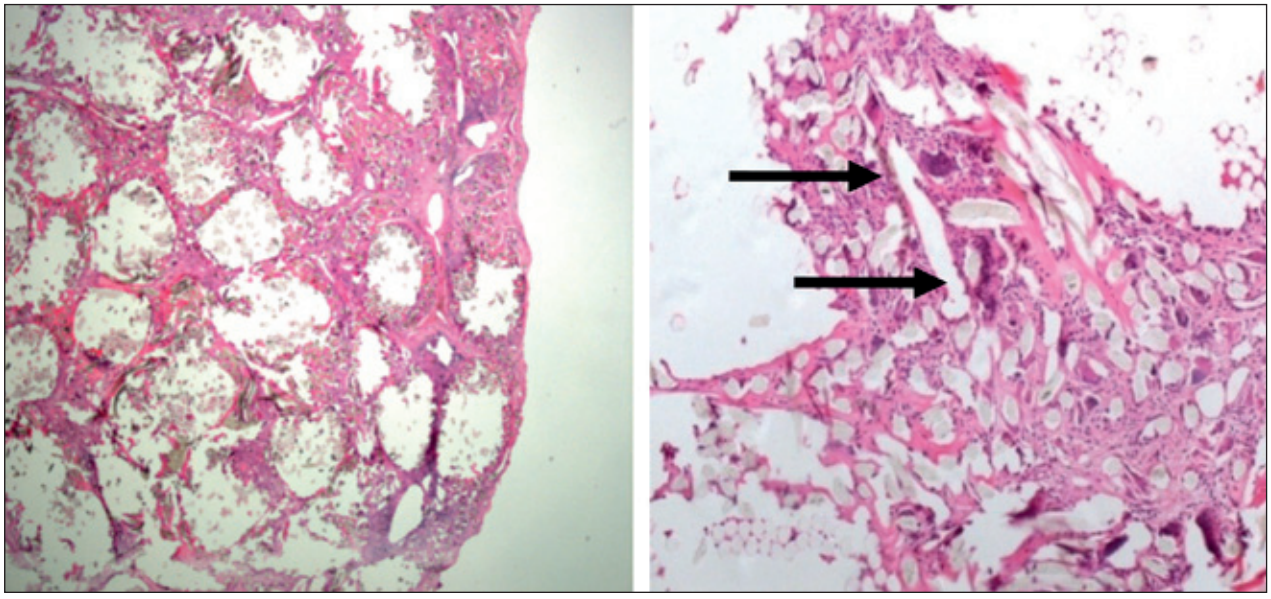

Figure N-O. Section of the LARS specimen demonstrates the regular arrangement of the fibers of the ligament with multinucleated giant cells (arrows) interposed between the fibers.

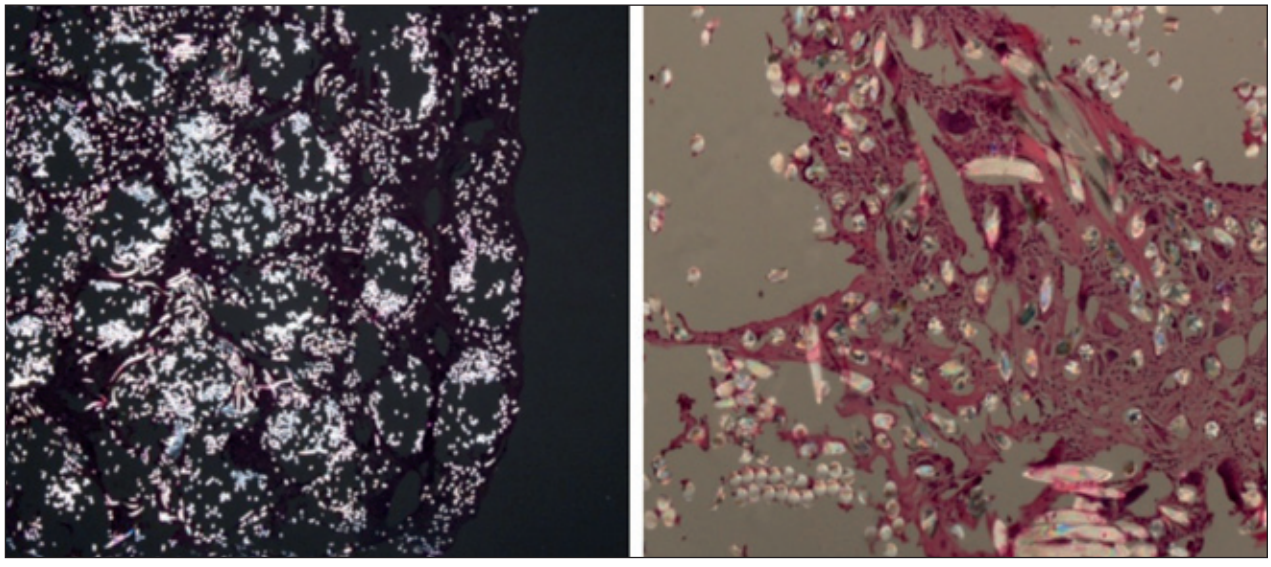

Figure P-Q. same sections of picture L and M on polarizable light microscopy. LARS fibers show the typical bi refractivity.

hamstring tendon autograft in a 8 years follow-up concluding that both the grafts dramatically improved the knee functional outcome with LARS being superior in terms of achieved joint stability (14). In contrast Jia et al compared the LARS and autograft ACL reconstruction in a large meta-analysis and concluded that the two grafts are not different in terms of patient-oriented outcomes and complications but instrumented knee laxity was more evident after synthetic ligaments, especially for early generation devices (14).

Jia demonstrated a low failure rate at a mid-term follow-up (seven years) with an incidence of 4.4% confirming an overall failure incidence of 4.75% in all the studies whit a mean follow-up longer than 3 years (15).

Despite good mid-term results in the cited studies (12-15), no authors postulated LARS as the graft

of choice and still recommended caution in its use: some surgeons advocated the LARS as a suitable option for faster recovery after ACL reconstruction (15), others indicate LARS as an alternative for carefully selected cases, especially in older patients (12-16).

Tiefenbok, in contrast, after a minimum follow-up of 10 years, concluded that LARS system should not be currently suggested as a potential graft for primary ACL reconstruction due to a re-rupture failure rate of 27.8% and a low percentage of patient satisfaction (55.6%)(17). Furthermore, Li et al reported the case of a 26 years-old patient with rare severe knee synovitis 3 years after the operation (18); some concerns arise from the young age of the patient, probably not respecting the correct indications for ACL reconstruction previously mentioned. Same author during revision arthroscopy observed a large amount of synovial hyperplasia in the knee joint and found the femoral tunnel placed too anteriorly. Moreover, the author performed a histological analysis of the LARS and detached a thick fibrous scar tissue around the graft and a poorly organized fibrous scar tissue infiltrated into the graft fibers (18).

Although these results came from a single patient case report, the histological analysis completely agree with our findings on eleven consecutive patients thus to supporting the hypothesis that without an appropriate tissue ingrowth, the LARS could progressively lose its structural integrity with an eventual graft fatigue failure.

Similar findings were reported by Norsworthy: the author during "second-look" surgeries after LARS ACL reconstruction demonstrated variable fibrous tissue incorporation with the LARS device (only 1 of the 21 patients) and frequent chronic synovitis with giant cell foreign body reaction (9 of the 21 patients) (1).

Recently Tulloch et al (19) took 12 second-look arthroscopies after primary LARS-ACL reconstruction due to mechanical symptoms (meniscal tears, cyclops lesions, cartilage damage) and/or knee instability: as described in our series, none of the patients underwent surgery for symptomatic synovitis. Interestingly the Author histologically demonstrated the presence of a hypertrophic synovial tissue more often than the arthroscopic appearance of synovitis among patient with a ruptured LARS; moreover, the author demonstrated the presence of synovitis also in one of the six patients with an entire LARS and this is in accordance also with previous studies (7). The population enrolled in our study consisted only of patient with a rupture LARS and could therefore represent a bias: the confirmation of synovial tissue inflammation with an entire LARS or even in patients with normal arthroscopic intra-articular tissue aspect, reinforce the importance of our findings.

Tulloch et al in another paper (20) reported an elevated LARS ACL reconstruction failure rate of 33.3% at a median of 3.9 years after reconstruction: the reported data is high end unexpected for the Author himself. Several key points are in common between our findings and this study: the failure of the LARS mainly on the opening of the femoral tunnel, the absence of evidence of tunnel widening and the detection of frequent synovitis.

Whilst our results cannot conclude on a direct relation between LARS failure and the development of synovitis, our study supports previous research about the risk to expose the knee to synthetic material due to the risk of developing a foreign body reaction.

Although these objective considerations, our study has several limitations.

First, a low number of enrolled patients.

We don't use synthetic ligaments neither for primary and revision ACL surgery; all the patients had primary ACL reconstruction in other hospitals and the use of synthetic ligaments still has few indications compared to autologous and heterologous tendons.

Second, the lack of a control group.

Our study only had a descriptive purpose of the histological findings on cases of LARS-ACL reconstruction failure (rupture of the ligament); in the period of the study we did not have any patients who underwent to a second-look arthroscopy in presence of an intact LARS neo-ACL so it was not possible to provide a control group.

Third, all the primary ACL reconstruction were performed in other hospitals.

Preoperative (X-Rays) and intraoperative findings demonstrated in several patients a wrong position of the synthetic ligament as shown in Figure R-S: this issue is detrimental for the synthetic ligament (8,9) due to the impingement in the intercondylar notch

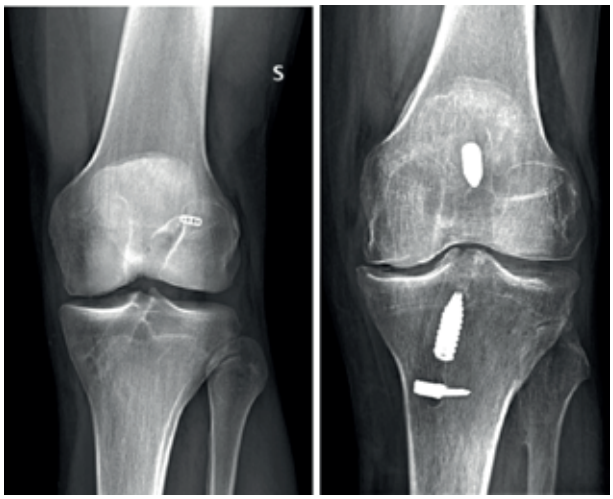

Figure R-S. Pre operative X-Rays show two cases of failed ACL reconstructions using the LARS: both cases demonstrate a vertical ligament in the intercondylar notch.

and the consequent weakening of the fibers (mechanical failure?). Furthermore, some essential key point (8,9) in the use of the LARS at the time of the primary reconstruction (e.g. ACL stumps preserve) could not be evaluated.

Fourth, the histhological analysis were performed only on patients with a rupture LARS.

Although we demonstrated a poor ingrowth inside the LARS, the isthopathological findings could be influenced by the spreading of the synthetic particles inside the knee joint (6) due to the rupture of the ligament and so our results are not definitive to advocate a biological failure of the graft.

Conclusions

Despite objective results of our study (histologic analysis) we cannot clearly advocate a unique mechanism of LARS-ACL reconstruction failures: biologic issues (poor tissue ingrowth) and mechanical issues (fibers properties and tunnel position) probably concur in a multi factorial manner.

Although synthetic devices have some advantages compared to other grafts, ACL reconstruction using artificial ligaments cannot be considered a straightforward surgery. Artificial augments require some expertise in ligament reconstruction surgery and is therefore a demanding procedure that can achieve better results in skilled sport surgeon hands other than trainees or low volume surgeon.

The Authors continue not to use synthetic ligaments for primary (or revision) ACL reconstruction and believe that ACL reconstruction with synthetic devices still have restricted indications in selected patients (e.g. elderly patients who require a fast recovery, professional athlete, autologous tendons not available and/or refusing donor tendons).

Our study arises additional suspicion on the unresponsiveness of synthetic fibers and even if the results cannot support a definitive relation between LARS failure and synovitis, we claim some concerns to expose the knee to artificial ligament implantation.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Cameron J Norsworthy, MB.BS., FRACS (Australia). My experience with the LARS ACL device at minimum 5 year follow up. 2017 ISAKOS Congress.
2. Ventura A, Terzaghi C, Legnani C, Borgo E, Albisetti W. Synthetic grafts for anterior cruciate ligament rupture: 19-year outcome study. The Knee 2010;17–2:108–13.
3. Newman SD, Atkinson HD, Willis-Owen CA. Anterior cruciate ligament reconstruction with the ligament augmentation and reconstruction system: a systematic review. Int Orthop. 2013 Feb;37(2):321–6. doi: 10.1007/s00264-012-1654-y. Epub 2012 Sep 14. Review.
4. Roe J, Pincewski L, Russell V et al. A 7-Year Follow-up of Patellar Tendon and Hamstring Tendon Grafts for Arthroscopic Anterior Cruciate Ligament Reconstruction. AJSM 2005; 33 (9): 1337–1345
5. Yasen S, Borton Z, Eyre-Brook A et al. Clinical outcomes of anatomic, all inside, anterior cruciate ligament (ACL) reconstruction. The Knee 2017; (24): 55–62
6. Glezos CM[1], Waller A, Bourke HE, Salmon LJ, Pinczewski LA. Disabling synovitis associated with LARS artificial ligament use in anterior cruciate ligament reconstruction: a case report.
   Am J Sports Med. 2012 May;40(5):1167–71. doi: 10.1177/0363546512438510. Epub 2012 Mar 9.
7. Li H, Yao Z, Jiang J, Hua Y, Chen J, Li Y, Gao K, Chen S. Biologic failure of a ligament advanced reinforcement system artificial ligament in anterior cruciate ligament re-

construction: a report of serious knee synovitis. Arthroscopy. 2012 Apr;28(4):583–6. doi: 10.1016/j.arthro.2011.12.008. Epub 2012 Feb 22.
8. Guidoin MF[1], Marois Y, Bejui J, Poddevin N, King MW, Analysis of retrieved polymer fiber based replacements for the ACL. Biomaterials. 2000 Dec;21(23):2461–74.
9. Bugelli et al, LARS in ACL reconstruction: evaluation of 60 cases with 5-year minimum follow-up (2017) Musculoskeletal Surg DOI 10.1007//s12306-017-0499-3
10. Viateau V[1], Manassero M, Anagnostou F, Guérard S, Mitton D, Migonney V. Biological and biomechanical evaluation of the ligament advanced reinforcement system (LARS AC) in a sheep model of anterior cruciate ligament replacement: a 3-month and 12-month study.
11. Zhenyu J, Chenchen X, Wei W et al. Clinical outcomes of anterior cruciate ligament reconstruction using LARS artificial graft with an at least 7-year follow-up. Medicine Open (2017) 96:14 (e6568)
12. Parchi P.D et al, Anteriori Cruciate Ligament reconstruction with LARS Artificial Ligament-Clinical results after long-term follow-up Joints 2018;6:75–79
13. Jia et al, Comparison of artificial graft versus autograft in anterior cruciate ligament reconstruction: a meta-analysis, BMC Musculoskeletal Disorders (2017) 18:309
14. Bianchi et al, LARS versus hamstring tendon autograft in anterior cruciate ligament reconstruction: a single-centre, single surgeon retrospective study with 8 years of follow-up European Journal of Orthopaedic Surgery & Traumatology https://doi.org/10.1007/s00590-018-2304-x
15. Jia et al, Clinical outcomes aof anterior cruciate ligament reconstruction using LARS artificial graft with at least 7-year follow-up Medicine 2017 96:14 (e6568) http://dx.doi.org/10.1097/MD.0000000000006568
16. Bugelli et al, LARS in ACL reconstruction: evaluation of 60 cases with 5-year minimum follw-up Musculoskeletal Surg 2017 DOI 10.1007/s12306-017-0499-3
17. Tiefenboeck et al, Clinical and functional outcome after anterior cruciate ligament reconstruction using the LARS system at a minimum follow-up of 10 years Knee 2015 22(6):565–568
18. Li et al, Biologic failure of a ligament advanced reinforcement system artificial ligament in anterior cruciate ligament reconstruction: a report of serious knee synovitis Arthroscopy 2012;28:583–6
19. Tulloch et al, Synovitis following anterior cruciate ligament reconstruction using the LARS device Knee Surg Sports Traumatol Arthrosc 27 (8), 2592–2598 Aug 2019
20. Tulloch et al, Primary ACL reconstruction using the LARS device is associated with a high failure rate at minimum of 6-year follow-up European Society of Sports Traumatology, Knee Surgery, Arthroscopy https://doi.org/10.1007/s00167-019-05478-3
21. Satora et al, Synthetic grafts in the treatment of ruptured anterior cruciate ligament of the knee joint, Polym Med. 2017;47(1):55–59
22. Filbay et al, Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture Best Pract Res Clin Rheumatol. 2019 Feb; 33(1): 33–47.
23. Mall et al, Results After Anterior Cruciate Ligament Reconstruction in Patients Older Than 40 Years: How Do They Compare With Younger Patients? A Systematic Review and Comparison With Younger Populations. Sports Health. 2016 Mar-Apr;8(2):177–81. doi: 10.1177/1941738115622138.
24. Kan et al, Autograft Versus Allograft in Anterior Cruciate Ligament Reconstruction: A Meta-Analysis With Trial Sequential Analysis, Medicine (Baltimore) , 95 (38), e4936 Sep 2016
25. De SA et al, The REVision using imaging to guide staging and evaluation (REVISE) in ACL reconstruction classification, J Knee Surg. 2019 Sep 30. doi: 10.1055/s-0039-1697902.
26. Wilde et al, Revision anterior cruciate ligament reconstruction, Sports Health: a multidisciplinary approach 2014 6:504
27. Di Benedetto P. et al, Causes of failure of anterior cruciate ligament reconstruction and revision surgical strategies, Knee Surg Relat Res 2016;28(4):319–324
28. Di Benedetto P. et al, New System for femoral fixation (TTS) in anterior cruciate ligament reconstruction with hamstring tendons-5 year follow-up, Orthopaedic Proceedings 2009 91-B:SUPP_I, 86–86
29. Dini et al, Multiple ACL revision: failure analysis and clinical outcome, The Journal of Knee Surgery DOI https://doi.org/10.1055/s-0039-3400741
30. Samitier et al, Failure of anterior cruciate ligament reconstruction Arch Bone Jt Surg 2015; 3(4):220–240

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Original article

Total knee revision arthroplasty: comparison between tibial tubercle osteotomy and quadriceps snip approach. Complication rate

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Summary. *Background and aim of the work:* The total knee arthroplasty (TKA) revision is not a second time of primary implant surgery but is a very complex issue for orthopedic surgeon. When local conditions make necessary a greater visualization, medial para-patellar access with *quadriceps snip (QS)* or the osteotomy of the tibial tuberosity (TTO) can be the solutions. This work aims to compare the *quadriceps snip* and the detachment of the tibial tubercle, focusing on possible complications. *Materials and Methods:* At our institution, between January 2017 and February 2019 52 TKA revision for periprosthetic joint infection (PJI) or aseptic mobilization were performed. In 43 cases an extensive surgical approach was required: for patients with range of movement (ROM) < 60° was chosen TTO, while with ROM > 60° a QS was performed. Clinical and radiological follow-up was available for all the 43 cases. *Results:* The data about clinical outcome in our study show that both groups have a positive trend in KSS score over time with similar ROM results. Two partial avulsions of patellar tendon during revision surgery were reported. Clinical outcome in both groups has shown good results at the end of follow-up with no post-operative incidence of complications. *Conclusion:* We can assert that both QS and TTO are good approach for TKA revision. Future studies will be needed to understand if preparatory ROM is a good way to decide which surgical approach to use. (www.actabiomedica.it)

Key words: Arthroplasty, Revision, Knee, Tibial Tuberosity Osteotomy, Quadriceps Snip, Complication.

Introduction

The implant of a total knee arthroplasty (TKA) is an extremely common surgery nowadays. In Italy, according to RIAP data (1), the number of implants of TKA is approximately 25,000 per year. The results are satisfactory but there are complications that sometimes can lead to the need for revision surgery (2).

The TKA revision is not a second time of primary implant surgery, but is a very complex issue for orthopaedic surgeon (3-5). Of course, the pre-operative planning is mandatory: among the various aspects to be analyzed is very important the surgical approach. Surgical approach to the knee must ensure a wide view of the operating field and the capability to view all anatomical structures and protect the integrity of these, guarantee a complete soft tissue cover and favors an early mobilization and rehabilitation (6). This is not always possible: it is not uncommon to find a stiff knee, hypertrophic scar tissue or even less than non-optimal skin conditions. The usual approach used in our institution for primary knee arthroplasty is the medial para-patellar approach. When local conditions make necessary a greater visualization of the operative field or an easier eversion of the patella (7) an extended approach must be used: in literature are present many papers about this topic.

Coonse and Adams described a quadriceps turn-down (8) subsequently modified with the addition of a medial para-patellar incision, the femoral peel (9), but we must not forget about the extensile medial para-patellar approach, which can be useful in the simplest cases.

In our institution the preferred approach is the medial para-patellar one with *quadriceps snip (QS)* (10) or the osteotomy of the tibial tuberosity (TTO) (11) when an extended approach is required. Both approaches have advantages and disadvantages. This work aims to compare the *quadriceps snip* and the detachment of the tibial tubercle, focusing on possible complications.

Material and Methods

This is prospective evaluation of a case series of 52 TKA revisions for periprosthetic joint infection (PJI) or aseptic mobilization performed at our institution, between January 2017 and February 2019. In 43 cases an extensive surgical approach was required to ensure correct visualization of the anatomical structures: TTO was performed in 23 cases and a QS in 20 cases.

The choice between the 2 extensive approach was based on the pre-operative range-of-motion (ROM) of the knee: for patients with ROM < 60° TTO was chosen, while QS was preferred with ROM > 60°. Surgical approach was performed in all cases by a single expert surgeon. After surgery, the rehabilitation protocol was the same in two groups: the only difference was the use of a post-operative hinged knee brace in TTO group and the prohibition of active extension for the first 2 weeks. The protocol allowed passive and active ROM (as tolerated) from first post-operative day. From second post-operative day assisted partial weight-bearing was allowed with crutches.

The following targets at 4 week were active ROM 0-90° and full weight-bearing with one crutch. From the 4th up to the 12th week, exercises aimed to recovery of muscle tropism and complete range-of-motion were recommended. In the TTO group, brace removal was allowed after radiological evaluation of bony union at 45 days.

All the 43 cases were re-evaluated by clinical assessments about 45 days after surgery, and subsequently at 3 months, 6 months and one year after surgery. Outcome were evaluated at 45 days, 6 months and one year after surgery by submitting the Knee Society Score (KSS) to all patients. Control radiographs (included full length weightbearing x-ray) were performed at each outpatient access: in particular, any changes in femoro-tibial alignment and pre and post-operative height of patella were assessed.

Complications, such as wound-related problems, mal-union or non-union, PJI, loss of hardware stability, fibrosis and joint stiffness were also assessed.

Surgical Technique

Quadriceps Snip: the technique is similar to a standard medial para-patellar with an anterior skin incision slightly extended proximally. The arthrotomy is performed through the medial part of quadriceps tendon with distal extension through medial patellar retinaculum and medial third o patellar tendon. Proximally the arthrotomy is extended to the apex of quadriceps tendon. At this point an oblique incision, in line with vastus lateralis fibers, is made through the quadriceps tendon. This allows a decrease of tension of tibial tubercle making possible, with tibial external rotation, patellar eversion.

Tibial Tubercule Osteotomy: this technique provides an anterior skin incision prolonged distally by 6-8 cm above the tibial tubercle. The arthrotomy is similarly extended distally trough the tibial tubercle and tibial anterior crest. The osteotomy is performed with an oscillating saw initially and then completed with an osteotome: a 8 cm long, 2 cm wide and 1,5 cm thick bony fragment is detached including the patellar tendon insertion. There are two methods for osteosynthesis: fixation with screws or with AO laces. We prefer fixation with AO laces, taking care to prepare the holes and to accommodate the necessary laces before implanting the tibial component. If you choose screws fixation, a tip may be pre-drilling 2 holes for screws before performing the osteotomy for the subsequent osteosynthesis. If it is necessary to raise patella in case of *patella baja* screws fixation is out treatment of choice.

Statistical analysis

Mean, SD and distribution of values were determined for each group. An independent-samples t-test was performed for comparison of the continuous variables between the QS and TTO groups. Proportions of categorical data were compared using chi-square tests. The level of significance was set at p-Value of < 0.05.

Results

Patients mean age was 70.6 years in the TTO group and 69.4 in the QS group. There where 9 male subjects in the TTO group and 7 males in the QS group.

In the TTO group, at the first control (45 post-operative day) only 1 patient not has achieved partial bone union. That patient has achieved complete bone healing at 90th post-operative day.

About post-operative clinical examination, at first assessment (45 day) the mean ROM in QS group were 76.2 ± 16.9 degree and in TTO group were 58.1 ± 9.7 degree. At subsequent assessment mean ROM in QS were 95.2 ± 16.8 degree at 3 months, 96.2 ± 16.9 degree at 6 months and 98.3 ± 17.3 degree at 1 year, meanwhile in TTO group were 84.1 ± 9.7 degree at 3 months, 96.3 ± 9.7 degree at 6 months and 99.1 ± 9.9 degree at 1 year. The KSS at 45 days in QS group were 64.4 ± 2.8, at 6 months were 81.3 ± 2.9 and at 1 year were 86.5 ± 2.8; instead in the TTO group the KSS at 45 days were 60.2 ± 3.2, at 6 months were 80.3 ± 3.5 and at 1 year were 86.4 ± 3.6.

Demographic data and clinical results are reported in Table 1.

The mean surgical time (from skin incision to skin suture) in TTO group was 192 min and in the QS was 167 min.

In all cases the mechanical alignment was respected into the range ± 3° varus-valgus measured on full length weightbearing x-ray. In the TTO group, in 7 cases, a *patella baja correction* with an elevation of TTO during fixation was necessary. One case of re-infection was reported at 10 months after surgery and treated with DAIR (debridement, antibiotics and implant retention) (12).

In QS group 2 partial avulsion of the patellar tendon were reported during revision surgery.

Discussion

A wide-vision approach to the knee for TKA revision is the first step for a successful outcome (6,13). A great number of papers are present in literature about surgical approach in TKA revision (6, 14, 15).

The QS, described by Insall (10), is technically easy because provides a good exposure of the knee without specific instruments. An important characteristic of QS is that it do not need a specific rehabilitation protocol (16). Some studies shown similar outcome between QS and the more used medial para-patellar approach (10) but is mandatory to remind that the load in the extensor mechanism is higher proximally in the quadriceps tendon rather distally in the patellar tendon (17).

The TTO were described by Dolin (11) and afterword modified by Whiteside and Ohl (18). These technique have some advantages like the preservation of extensor mechanism and avoidance of patellar

Table 1. Comparison pre- and post-operative data between two-groups (Mean±SD)

	Qadriceps snip (n 20)				Tibial tuberccle osteotomy				p-value			
Gender	7 14				9 14				0.50			
Age (year)	69.5 ± 6.1				70.6 ± 6.4				0.55			
BMI	25.5 ± 2.3				25.8 ± 2.3				0.65			
	45 d	90 d	180 d	270 d	45 d	90 d	180 d	270 d	45 d	90 d	180 d	270 d
ROM	76.1 ± 16.9	95.1 ± 16.8	96.2 ± 16.9	98.3 ± 17.7	58.1 ± 9.7	84.1 ± 9.7	96.3 ± 9.8	99.1 ± 9.9	0.002	0.001	0.42	0.72
KSS	64.4 ± 2.8		81.3 ± 2.9	86.5 ± 2.8	60.2 ± 3.2		80.3 ± 3.5	86.4 ± 3.6	0.001		0.34	0.91
Follow-up	22.1± 12.4				21.5± 11.4				0.89			

Table 2. Range of Motion in QS group and TTO group (Mean ± SD)

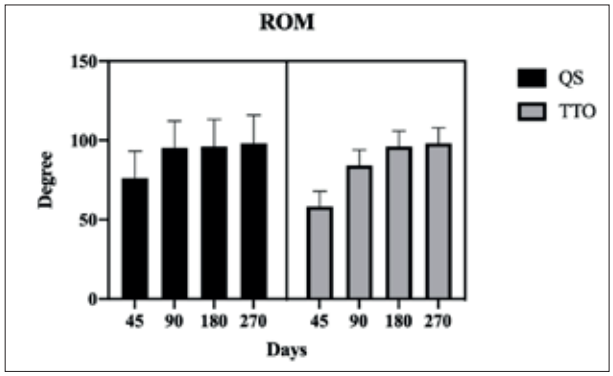


Table 3. KSS in QS group and TTO group (Mean ± SD)

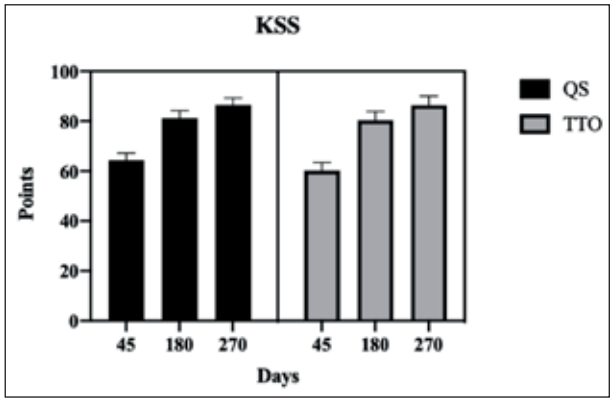
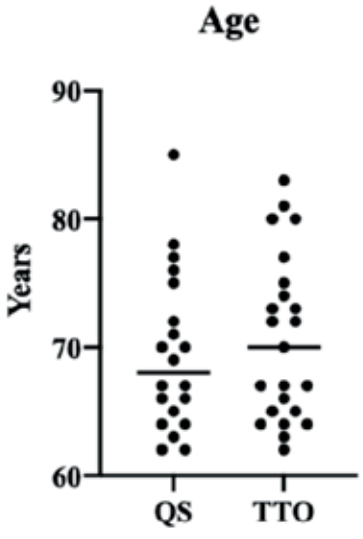


Table 4. Age distribution and mean in QS group and TTO group



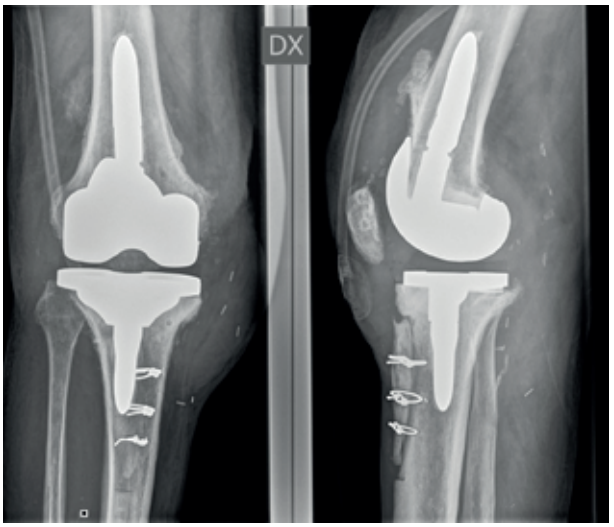


Figure 1. TKA revision with TTO approach and AO laces fixation.

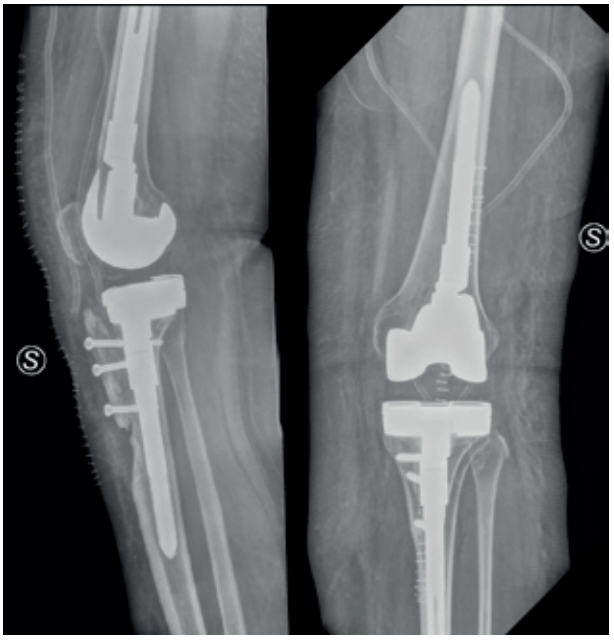


Figure 2. TKA revision with TTO approach and screws fixation.

tendon avulsion (15) but the most important is the possibility to modify tibial tuberosity height and to perform realignment of extensor mechanism (19). According to literature, screws are the best method for bone fixation (20).

From our results it seems that, when an extensive surgical approach is needed, there are no significant

differences in terms of operating time between the QS and the TTO groups. The 25-minutes difference between the two groups is due to the fact that in the TTO group requires the osteotomy fixation. In addition, analyzing the data emerges as the most complex surgeries have been carried out through an approach with TTO. Comparing the operations that are temporally lasted less, it is clear that the operative time difference is more restricted, however always in favor of QS group.

The data about clinical outcome in our study show that both groups have a positive trend in KSS score over time that is comparable to previous studies (10). The initial gap in KSS in favor of QS group seen at 45 days is progressively reduced until the last assessment. Also the ROM shows a similar trend: at 45 days the ROM are 76.2 ± 16.9 degree and only 58.1 ± 9.7 degree for the QS and TTO group respectively, while after one year they are comparable (98.3 ± 17.7 degree and 99.1 ± 9.9 degree for the QS and TTO group respectively). The 45-days gaps are statistically significant either for KSS and ROM (also at 90-days), probably for the difference in the initial rehabilitation procotol with the TTO patients using a brace with a forbidden active extension for the first 2 weeks. (14). The only cases of intra-operative partial patellar tendon avulsion were reported in the QS group, thus highlighting that TTO approach is effective in reducing the risk for this complication in stiff knees (21).

Conclusion

Our study has many limitations: foremost is a retrospective study. All data were extrapolated from clinical records of our patients. The comparison between two groups not keep in mind difference in surgical cases complication: obviously the TTO approach were performed in most hard cases, with very important stiffness or after multiple surgeries. Conversely the QS approach were performed in mild difficult cases. Clinical outcome in both groups has shown good results at the end of follow-up with no incidence of complications. We can assert that both QS and TTO are good approach for TKA revision. Future studies will be needed to understand if pre-operative ROM may be the best factor to take into consideration to decide the more suitable surgical approach.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Registro Italiano ArtroProtesi - Annual Report. 2018, Istituto Superirore di Sanità.
2. Fehring, T.K., et al., Early failures in total knee arthroplasty. Clin Orthop Relat Res, 2001(392): p. 315–8.
3. Delanois, R.E., et al., Current Epidemiology of Revision Total Knee Arthroplasty in the United States. J Arthroplasty, 2017. 32(9): p. 2663–2668.
4. Di Benedetto, P., et al., Two-stage revision after total knee arthroplasty. Acta Biomed, 2017. 88(2S): p. 92–97.
5. Mancuso, F., et al., Management of metaphyseal bone loss in revision knee arthroplasty. Acta Biomed, 2017. 88(2S): p. 98–111.
6. Della Valle, C.J., R.A. Berger, and A.G. Rosenberg, Surgical exposures in revision total knee arthroplasty. Clin Orthop Relat Res, 2006. 446: p. 59–68.
7. Ryan, J.A., et al., Failure of the Patellar Tendon with the Patella Everted versus Noneverted in a Matched-Pair Cadaver Model. HSS J, 2010. 6(2): p. 134–7.
8. Coonse KD, A.J., A new operative approach to the knee joint. Surg Gynecol Obstet, 1943. 77: p. 344.
9. Lavernia, C., J.S. Contreras, and J.C. Alcerro, The peel in total knee revision: exposure in the difficult knee. Clin Orthop Relat Res, 2011. 469(1): p. 146–53.
10. Garvin, K.L., G. Scuderi, and J.N. Insall, Evolution of the quadriceps snip. Clin Orthop Relat Res, 1995(321): p. 131–7.
11. Dolin, M.G., Osteotomy of the tibial tubercle in total knee replacement. A technical note. J Bone Joint Surg Am, 1983. 65(5): p. 704–6.
12. Di Benedetto, P., et al., Acute periprosthetic knee infection: is there still a role for DAIR? Acta Biomed, 2017. 88(2S): p. 84–91.
13. Vaienti E., Scita G., Ceccarelli F., Pogliacomi F. Understanding the human knee and its relationship to total knee replacement. Acta Biomed. 2017 Jun 7; 88(2 -S): 6–16.
14. Barrack, R.L., Specialized surgical exposure for revision total knee: quadriceps snip and patellar turndown. Instr Course Lect, 1999. 48: p. 149–52.
15. Mendes, M.W., P. Caldwell, and W.A. Jiranek, The results of tibial tubercle osteotomy for revision total knee arthroplasty. J Arthroplasty, 2004. 19(2): p. 167–74.
16. Rand, J.A., et al., Intraoperative assessment in revision total knee arthroplasty. J Bone Joint Surg Am, 2003. 85-A Suppl 1: p. S26–37.
17. Denham, R.A. and R.E. Bishop, Mechanics of the knee and problems in reconstructive surgery. J Bone Joint Surg Br, 1978. 60-B(3): p. 345–52.
18. Whiteside, L.A. and M.D. Ohl, Tibial tubercle osteotomy

for exposure of the difficult total knee arthroplasty. Clin Orthop Relat Res, 1990(260): p. 6–9.
19. Bruni, D., et al., Tibial tubercle osteotomy or quadriceps snip in two-stage revision for prosthetic knee infection? A randomized prospective study. Clin Orthop Relat Res, 2013. 471(4): p. 1305–18.
20. Caldwell, P.E., et al., Dynamic confirmation of fixation techniques of the tibial tubercle osteotomy. Clin Orthop Relat Res, 2004(424): p. 173–9.
21. Anand, S., et al., Management of Patellar Tendon Rupture after Total Knee Arthroplasty using Hamstring graft: A Case Report. J Orthop Case Rep, 2018. 8(2): p. 57–60.

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Original Article

Arthroscopically-assisted Reduction and Internal Fixation (ARIF) of tibial plateau fractures: clinical and radiographic medium-term follow-up

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Summary. *Background and Aim of the work:* Tibial plateau fractures include a wide spectrum of lesions with potentially disabling sequelae. Arthroscopically-assisted Reduction and Internal Fixation (ARIF) is an alternative to traditional ORIF. The aim of this retrospective single centre study is to evaluate medium-term clinical and radiographic outcomes achieved in a consecutive series of patients treated with ARIF. *Methods:* 21 patients, with a mean age of 52.2 ± 13.4 years at surgery, were included. According to Schatzker classification, there were 9 type II, 10 type III, 2 type IV fractures. Associated intra-articular injuries (meniscal tears, tibial spine fractures, chondral lesions) were detected in 8 patients. At follow up, patients were clinically and radiographically evaluated according to knee ROM, KOOS, OKS and Rasmussen Clinical and Radiological Scores. *Results:* At an average follow-up of 84 ± 22.5 months, 18 patients were evaluated. Mean values recorded were the following: knee ROM 1° - 135°, OKS 41.6 / 48 ± 8.18, subscale KOOS scores ranged from 75% ± 25.4 (Quality of Life) to 91.1% ± 11.2 (Pain), Rasmussen Clinical e Radiological 27.2 ± 2.64 (14 excellent, 3 good, 1 fair) and 9.1 ± 0.64 (15 excellent, 3 good), respectively. Worse results were observed in 5 patients with pre-existing degenerative chondropathy. *Conclusions:* ARIF revealed to be an effective technique for surgical treatment of unicondylar tibial plateau fractures. Our findings support the favourable results reported by other authors. ARIF is not a simple technique and requires specific experience in knee arthroscopy and a steep learning curve. (www.actabiomedica.it)

Key words: tibial plateau fractures, arthroscopy, internal fixation, joint trauma, post-traumatic osteoarthritis

Introduction

Tibial plateau fractures are articular injuries commonly caused by high-energy traumas in young patients and low-energy traumas in old osteoporotic patients (1-3). They represent approximately 1% of all fractures (4), with an incidence of 10.3 per 100'000 person-year (5). The management of these fractures might be challenging: the goal is to achieve anatomical reduction and stable fixation, in order to allow early knee mobilization and complete ROM recovery. These are the assumptions to achieve an optimal clinical and functional outcome (6, 7). For this reason, if not appropriately treated, tibial plateau fractures can lead to severe disability with a significant social impact.

Fracture treatment depends on several factors such as fracture configuration, soft tissue condition, bone quality, patient's age and lifestyle (8). Due to the injury mechanism, these fractures are often associated with intra-articular lesions such as chondral damage, meniscal tear and ligament rupture (9, 10).

Arthroscopically-assisted Reduction and Internal Fixation (ARIF), initially described by Caspari et al. (11) and Jennings (12), has gained popularity as an

alternative treatment to Open Reduction and Internal Fixation (ORIF) particularly for unicondylar tibial plateau fractures (13, 14). The minimally invasive ARIF technique allows direct visualization of the joint space, providing a better control of articular surface reduction and the possibility of both evaluating and treating associated intra-articular lesions (9).

The purpose of this study is to report the medium-term clinical and radiographic outcome achieved in a series of patients, who underwent ARIF for tibial plateau fractures.

Materials and methods

This retrospective, single-center study was performed on a consecutive series of 21 patients, who underwent ARIF for tibial plateau fracture in the Orthopaedics and Traumatology Unit of the "Maggiore della Carità" University Hospital in Novara (Italy), between August 2009 and February 2017. All data were collected from divisional digital registries (database "AcceWeb", Hi.Tech Software Engineering, Bagno a Ripoli - FI, Italy; database "Ormaweb", Dedalus Italia, Firenze – FI, Italy) and from patients' medical records.

Data collection allowed to identify 24 patients treated with ARIF for tibial plateau fractures, but 3 patients were excluded because the initial arthroscopic procedure required the conversion to ORIF. Thus, the study included 21 patients (10 males and 11 females), with a mean age of 52.2 ± 13.4 years.

The most frequent mechanism of injury was a traffic-road accident, accounting for 11 cases (52.4%), 5 pedestrian accidents, 5 car or motorbike crashes and 1 bicycle accident. The remaining patients reported falls from a height in 8 cases (38.2%) and sports injuries in 2 cases (9.5 %).

All patients were preoperatively evaluated with radiographs and CT scans. According to Schatzker classification (15), there were 9 type II, 10 type III and 2 type IV tibial plateau fractures. The fracture involved the posterior portion of the tibial plateau in 8 patients (44.4%), 7 in the lateral and 1 in the medial condyle.

Eight patients presented concomitant traumatic intra-articular injuries: 3 meniscal tears (1 medial, 2 lateral), 3 tibial spine fractures and 2 chondral lesions of the femoral condyles. Seven patients showed preexisting chronic lesions: 5 degenerative chondropathy, 2 degenerative meniscopathy, 1 ACL rupture and 1 PCL partial lesion.

All the operations were performed by two surgeons experienced in knee arthroscopy, with the aid of fluoroscopy.

Fracture fixation was achieved with one screw in 2 patients, with two screws in 15 patients and with three screws in 2 patients; plate osteosynthesis was performed in 2 cases. Allogenic cancellous bone graft was used to fill a metaphyseal bone defect in one patient, while xenogenic bone chips were used in another one.

The tibial spine fractures were all treated with ARIF, using wire cerclage in 1 case and suture cerclage in 2 cases. Among patients with meniscal tears, selective meniscectomy was performed in three of them and meniscal suture in one.

All patients received a standardized post-operative rehabilitation protocol. Active knee motion started within 10 days after surgery and was gradually increased to reach 90° of flexion after 4 weeks. Progressive weight bearing with the aid of two crutches was allowed 8 weeks after surgery and full weight bearing without any aid after 12 weeks. X-rays were taken at 1, 3 and 6 months to check fracture healing.

At the time of this study, patients were clinically and radiographically evaluated. ROM measurement, Rasmussen Clinical Score (RCS) (16), Knee Injury and Osteoarthritis Outcome Score (KOOS) (17, 18) and Oxford Knee Score (OKS) (19, 20) were used for the clinical and functional assessment. Patients were also interviewed about their self-perception of therapeutic outcome, using a Likert scale with 5 levels of satisfaction, ranging from 1 (poor) to 5 (excellent).

Antero-posterior and latero-lateral radiographs were taken and compared to previous radiograms to calculate the Rasmussen Radiological Score (RRS) (16).

Continuous variables were described as mean ± SD, and their distribution within analysed subassemblies has been described using univariate linear regression. Student's t test was used for statistical analysis. For all analyses, a confidence interval level of 95% was selected (statistical significance set at p values of < 0.05). All the analyses were performed using the software "Stata 15".

Results

At an average follow-up of 84 ± 22.5 months (range, 33 - 119), 18 patients were available for evaluation. The remaining 3 patients from the study group were not evaluated: 1 patient was deceased and 2 were unreachable. All the enrolled patients agreed to attend this study and signed an informed consent for the anonymous collection of their data.

Mean age at surgery was 53.8 ± 13.7 years. Fractures included 7 Schatzker type II, 9 type III (Figure 1) and 2 type IV (Figure 2). The posterior portion of the tibial plateau was involved in 7/18 patients. Detailed data of these patients are reported in Table 1.

Average interval between trauma and surgery was 5.6 ± 3.6 days; mean surgical time was 95.6 ± 30.7 minutes and mean hospitalization after surgery was 2.9 ± 3.2 days.

Only one patient, a 45-year old woman also treated for a concomitant tibial spine fracture, did not fulfil the rehabilitation protocol because of joint stiffness. This was the only complication that occurred in the postoperative period and required releases after 5 and 10 months from ARIF (Figure 1).

During follow-up period, 3 patients underwent surgical removal of the hardware due to local tenderness (Figure 2).

Clinical evaluation at follow up revealed a mean knee ROM of 1° - 135°. The average values recorded for the KOOS, OKS and Rasmussen scoring systems are reported in Table 2. According to the Rasmussen scoring system, results were graded as excellent in 14 patients, good in 3 and fair in 1 patient for the Clinical assessment, while the Radiological assessment showed 15 excellent and 3 good scores.

No statistically significant differences were found among our population groups divided by gender, laterality or traumatic mechanism, in any scoring system. At the statistical analysis, the 7 patients with posterior portion involvement as well as the 8 patients with fracture-associated intra-articular lesions didn't show any significant difference compared to the rest of the sample in any score.

5 patients (27.8%), with pre-existing degenerative chondropathy, got lower scores than the rest of the sample resulting in statistically significant differences in KOOS, specifically for the subscale "Quality of life" (56.2% versus 82.2%, -26%, p=0.045), in OKS (35 vs 44.1, -9%, p=0.030), and in the RCS (25 vs 28, -3%, p=0.026) (Table 3). No statistically significant differences were found in RRS.

Patients reported an average subjective satisfaction degree of 4.56/5 ± 1 points (range, 2 to 5) on the Likert scale; 15/18 patients were satisfied or very satisfied (4 or 5 points).

Discussion

Tibial plateau fractures include a wide spectrum of lesions, ranging from simple patterns to very severe and complex injuries. Any treatment is aimed to anatomically reduce the articular surface, restore correct limb alignment and firmly fix fracture fragments, in order to allow early knee mobilization and reduce the risk of post-traumatic sequelae, especially knee osteoarthritis (8, 10).

These goals were traditionally pursued with ORIF, but during the last decades several authors reported good clinical and radiographic results with ARIF (8, 11, 12, 21-23), not only in the treatment of lateral tibial plateau fractures, but also for unicondylar medial fractures (13,14).

This retrospective study was performed on a consecutive series of patients treated with ARIF for Schatzker fracture types II, III and IV. At surgery time, arthroscopy was found to be very helpful in restoring the articular surface, particularly when depression was present. Moreover, it was useful to identify and treat associated intra-articular injuries, such as meniscal tears or tibial spine fractures. It has been reported that associated joint injuries occur in 30% to 71% of patients with tibial plateau fractures (9, 24); in our experience, they were found in 8/21 of the cases (38%).

One of the main concern with ARIF is the increased risk of postoperative compartment syndrome (23), particularly in case of fractures with diaphyseal involvement. However, a recent systematic review showed lower overall morbidity, better functional outcomes, and fewer perioperative complications with ARIF in comparison with open techniques (25). We did not observe any case of compartment syndrome,

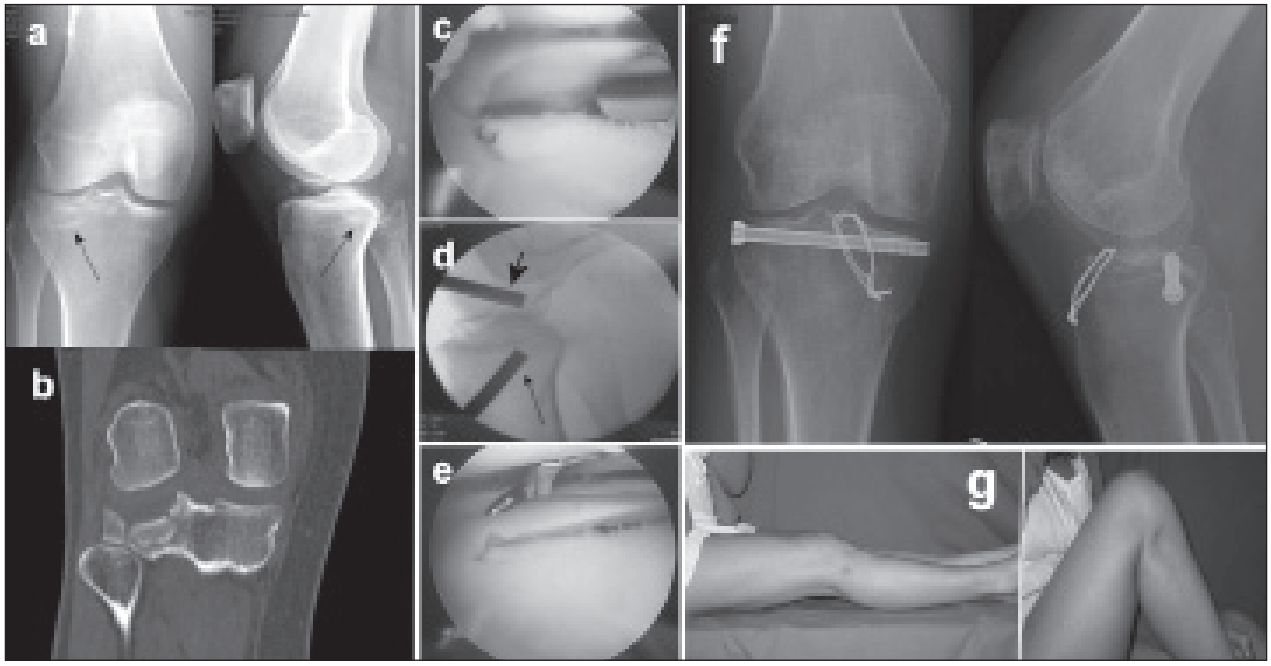

Figure 1. a) Schatzker type 3 fracture with a concomitant tibial spine fracture in a 45-year old woman. Arrows indicate the inferiorly displaced articular fragment. b) Coronal CT scan highlighting the depression of the articular surface. c) Arthroscopic view of the lateral knee compartment before ARIF. d) Intraoperative fluoroscopy to check the correct position of the impactor in elevating the depressed bone fragment. The thin arrow indicates the impactor and the large one points the arthroscope. e) Arthroscopic view showing restoration of the articular surface of the lateral tibial condyle after ARIF. f) Radiographic control 3 months after surgery showing the good anatomical result. Wire cerclages were used to treat the tibial spine fracture. The patient suffered joint stiffness and underwent two subsequent arthroscopic arthrolysis. g) Final knee ROM one year after index procedure: extension was not fully recovered.

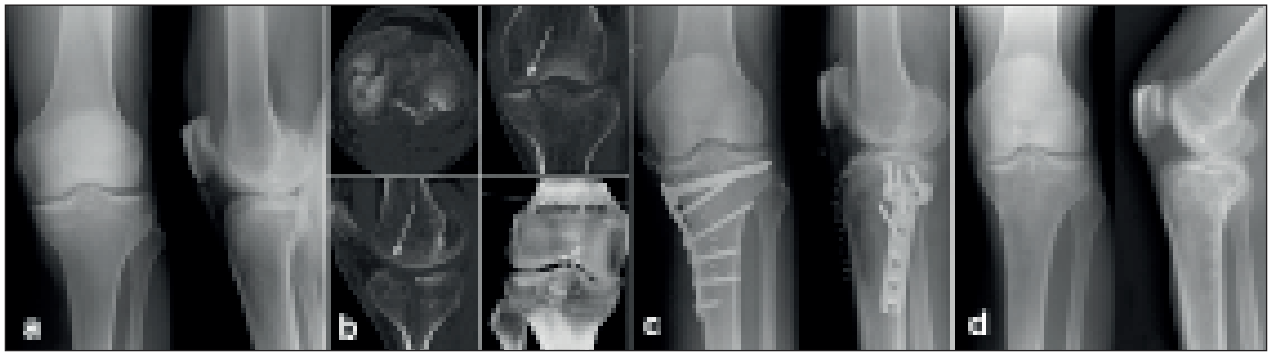

Figure 2. a) Schatzker type 4 fracture in a 52-year old man with chronic ACL tear. b) CT scan images show an associated chondral lesion of the medial femoral condyle in the coronal and sagittal views (white arrows). c) Postoperative radiograms after ARIF with plate. d) Radiographic control 8 years after ARIF: mild degenerative changes are evident in the medial compartment. Plate and screws were removed 2 years after index procedure because of local tenderness.

but this risk should not be underestimated. ARIF surgical time tends to be prolonged, especially with non-experienced surgeons, and fluid extravasation in the muscle compartments might occur and be relevant, also when treating simple fracture patterns.

The only postoperative complication in our series was joint stiffness, that was observed in a middle-aged woman with a concomitant tibial spine fracture. Delayed knee mobilization was the main cause of this condition and the patient eventually recovered after two arthroscopic releases.

At an average follow up of 7 years, the clinical

Table 1 - Demographic and anatomo-clinical data of patients evaluated at follow up

	Age / Gender	Follow-up *(months)*	Schatzker type	PPI	Associated knee injuries	Pre-existing knee lesions	Surgical treatment
1	45/ F	114	III	✓	Tibial spine fracture (*)	-	1 screw + WC
2	35/F	119	III	-	-	-	1 screw
3	35/M	114	II	-	Lateral meniscal tear (*)	-	2 screws + MS
4	64/F	101	III	-	Chondral lesion (lateral femoral condyle)	-	2 screws
5	52/M	93	IV	✓	Chondral lesion (medial femoral condyle)	Lateral DC, ACL rupture	Plate
6	75/F	80	II	-	-	Lateral DC	2 screws
7	54/M	33	III	-	-	-	2 screws
8	48/M	60	III	✓	Tibial spine fracture (*)	-	2 screws + SC
9	55/F	81	III	✓	-	-	3 screws
10	65/M	90	II	-	Lateral meniscal tear	-	2 screws
11	58/M	79	III	✓	-	-	2 screws
12	74/F	49	III	✓	-	Medial DC	2 screws
13	59/F	77	II	-		-	2 screws
14	49/M	89	II	-	Medial meniscal tear (*)	-	2 screws + SM
15	71/F	99	II	-	-	Med / Lat DC, medial DM (*)	2 screws + SM
16	43/M	71	II	-	-	Previous medial meniscectomy	3 screws
17	26/F	94	IV	-	-	-	2 screws
18	61/F	70	III	✓	-	Med DC, Lat DM PCL partial tear	2 screws + SM

Legenda: PPI = posterior plateau involvement; DC = degenerative condropathy; DM = degenerative meniscopathy; WC = wire cerclage; SC = suture cerclage; MS = meniscal suture; SM = selective meniscectomy; (*) = treated surgically during ARIF.

Table 2 - Outcomes at an average follow up of 84 months (range, 33 to 199)

		Mean ± DS	Range
Knee ROM		1° – 135°	Extension: 0-10° Flexion: 80°-150°
KOOS	*Pain*	91.1% ± 11.2	58.3% - 100%
	Symptoms	86.3% ± 15	53.6% - 100%
	Daily Activity	89.7% ± 16.3	30.9% - 100%
	Sport Activity (*)	78.5% ± 18.9	50% - 100%
	Life Quality	75% ± 25.4	25% - 100%
OKS		41.6 */ 48* ± 8.1	21 - 48
Rasmussen Scores	*Clinical*	27.2 */ 30* ± 2.6	19 - 30
Radiological		9.1 */ 10* ± 0.6	8 - 10
Satisfaction degree		4.56 */ 5* ± 1	2 - 5

(*) measured on 13/18 patients, because 5 patients didn't practice any sport

Table 3 - Scores comparison between patients with and without degenerative condropathy

		Patients WITH condropathy (*n* = 5)	Patients WITHOUT condropathy (*n* = 13)	*p value*
KOOS	*Pain*	83.3% ± 15	94% ± 8.3	*0.068*
	Symptoms	82,1% ± 19	87.9% ± 13.8	*0.484*
	Daily Activity	77.9% ± 27.6	94.2%± 6.6	*0.055*
	Sport Activity (*)	70%± 28.3	80%± 18.2	*0.514*
	Life Quality	56.2% ± 29.3	82.2%± 20.7	**0.045** *
OKS		35 ± 10.2	44.1 ± 5.9	**0.030** *
Rasmussen Scores	*Clinical*	25 ± 3.4	28 ± 1.8	**0.026** *
Radiological		8.8 ± 0.4	9.15 ± 0.7	*0.307*

Table 4 - Comparison between ARIF clinical series with similar samples and outcome measures

	n	Average age *(years)*	Schatzker type	Hospitalization *(days)*	Follow-up *(months)*	RCS	ROM *(ext – flex)*
Dall'Oca et al.	50	51 ± n.r.	I - VI	n.r.	73 ± n.r.	27.6 ± 2.6	n.r.
Duan et al.	39	35.9 ± 11.2	I - V	n.r.	34 ± 18	26 ± 3	1° - 130°
Gill et al.	25	45.2 ± n.r.	I - IV	1.6 ± n.r.	24 ± n.r.	27.5 ± n.r.	1° - 95°
Rossi et al.	46	48 ± 13.6	II - III	2.5 ± 1.1	60 ± n.r.	28.2 ± 1.4	n.r.
Siegler et al.	21	45 ± n.r.	I - III	5 ± N/A	59.5 ± n.r.	25.5 ± n.r.	1° - 131°
Verona et al.	19	45.5 ± 17.1	I - III	3.95 ± 1.3	41.9 ± 28.8	n.r.	n.r.- 128°
Present study	18	53.8 ± 13.7	II - IV	2.9 ± 3.2	84 ± 22.5	27.2 ± 2.6	1° - 135°

Legenda: RCS = Rasmussen Clinical Score; n.r. = not reported.

and functional status of most of the patients was excellent, with complete knee ROM recovery and very high scores in three different evaluating scales (KOOS, OKS and RCS). Less satisfactory results were achieved in 5 patients with pre-existing degenerative chondropathy. These changes by themselves might impair knee function, with the fracture being an additional detrimental factor for the joint. Other authors reported that pre-existing degenerative joint changes can negatively affect the outcome, regardless of the good reduction and fixation of the fracture (8). Nevertheless, no patients required total knee replacement that is commonly more demanding in posttraumatic cases previously synthesized with plating (26).

Radiographic evaluation with the RRS showed satisfactory results in most of the patients. However, a certain discrepancy between clinical and radiographic assessment was noticed: good radiographic results were observed in some patients who didn't achieve optimal clinical outcomes; likewise, excellent clinical results were sometime associated to less brilliant radiographic findings.

Patients' satisfaction for the therapeutic outcome was high: only 2 patients were somewhat disappointed by their final status. This finding correlates well with the high scores achieved with the KOOS and OKS scale, indicating a good life quality with maintenance of normal daily activities for most of the patients.

It's difficult to compare our results with the different series reported in literature, mainly because the evaluation methods are quite heterogeneous. Among the scoring systems used in the present study, the RCS was the most suitable for comparing our data to published studies with samples similar to ours (8, 13, 21, 22, 27,28). As shown in Table 4, our RCS is comparable to the scores reported by all the other authors. Among studies reporting also knee ROM, the average values are very similar, with the exception of one series, in which average flexion was limited to 95° (26). A statistical comparison with these results didn't show any significant difference.

Conclusions

Based on our experience, ARIF revealed to be a valid and reliable technique for unicondylar tibial plateau fractures treatment. Our findings are in accordance and support the favourable results reported by other authors. Worse outcomes seem to be related to pre-existing chronic knee lesions, namely degenerative chondropathy, and not to concomitant traumatic injuries.

ARIF is less invasive than ORIF and offers significant advantages, that include direct joint visualization during reduction of articular fracture fragments, easy recognition of concomitant intra-articular injuries and their possible treatment. It is not a simple surgical technique: it requires specific experience in knee arthroscopy and a steep learning curve.

Anatomical reduction and stable fixation are the ultimate goals in surgical treatment of tibial plateau fractures. If they cannot be accomplished with ARIF, it's advisable to convert the procedure to ORIF for not delaying the rehabilitation program and prevent post-traumatic sequelae.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury 2006; 37:691-7.
2. He Q fang, Sun H, Shu L yuan, Zhan Y, He C yan, Zhu Y, et al. Tibial plateau fractures in elderly people: an institutional retrospective study. J Orthop Surg Res 2018; 13:1–8.
3. Frattini M, Vaienti E, Soncini G, Pogliacomi F. Tibial plateau fractures in elderly patients. Chir Organi Mov 2009; 93:109–14.
4. Van Dreumel RLM, Van Wunnik BPW, Janssen L, Simons PCG, Janzing HMJ. Mid- to long-term functional outcome after open reduction and internal fixation of tibial plateau fractures. Injury 2015; 46:1608–12.
5. Elsoe, R., Larsen, P., Nielsen N et al., Elsoe R, Larsen P, Nielsen NPH, Swenne J, Rasmussen S, et al. Population-Based Epidemiology of Tibial Plateau Fractures. Orthopedics 2015; 38:e780–e786.
6. Cassard X, Beaufils P, Blin JL, Hardy P. Arthroscopic treatment of tibial plateau fractures. Report on 26 cases. Rev Chir Orthop Reparatrice Appar Mot 1999; 85:257–66.
7. Guanche CA, Markman AW. Arthroscopic management of tibial plateau fractures. Arthroscopy. 1993; 9:467–71.
8. Siegler J, Galissier B, Marcheix PS, Charissoux JL, Mabit C, Arnaud JP. Percutaneous fixation of tibial plateau fractures under arthroscopy: A medium term perspective. Orthop Traumatol Surg Res 2011; 97:44–50.
9. Stahl D, Serrano-Riera R, Collin K, Griffing R, Defenbaugh B, Sagi HC, et al. Operatively treated meniscal tears associated with tibial plateau fractures: A report on 661 patients. J Orthop Trauma 2015; 29:322–4.
10. Prat-Fabregat S, Camacho-Carrasco P. Treatment strategy for tibial plateau fractures: an update. EFORT Open Rev. 2016; 1:225–32.
11. Caspari RB, Hutton PM, Whipple TL, Meyers JF. The role of arthroscopy in the management of tibial plateau fractures. Arthroscopy 1985; 1:76–82.
12. Jennings J. Arthroscopic management of tibial plateau fractures. Arthroscopy 1985; 1:160–8.
13. Duan XJ, Yang L, Guo L, Chen GX, Dai G. Arthroscopically assisted treatment for Schatzker type I-V tibial plateau fractures. Chinese J Traumatol (Eng.) 2008; 11:288–92.
14. Pogliacomi F, Verdano MA, Frattini M, Costantino C, Vaienti E, Soncini G. Combined arthroscopic and radioscopic management of tibial plateau fractures: Report of 18 clinical cases. Acta Biomed 2005; 76:107–14.
15. Schatzker J, McBroom R, Bruce D. The tibial plateau fracture. The Toronto experience 1968-1975. Clin Orthop Relat Res 1979; 138:94–104.
16. Rasmussen PS. Tibial condylar fractures. Impairment of knee joint stability as an indication for surgical treatment. J Bone Joint Surg Am 1973; 55-A:1331-50.
17. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS) - Development of a self-administered outcome measure. J Orthop Sports Phys Ther 1998; 28:88-96.
18. Monticone M, Ferrante S, Salvaderi S, et al. Development of the Italian version of the knee injury and osteoarthritis outcome score for patients with knee injuries: Cross-cultural adaptation, dimensionality, reliability, and validity. Osteoarthr Cartil 2012; 20:330–5.
19. Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br 1998; 80-B:63–9.
20. Padua R, Zanoli G, Ceccarelli E, Romanini E, Bondì R, Campi A. The Italian version of the Oxford 12-item knee questionnaire - Cross-cultural adaptation and validation. Int Orthop. 2003; 27:214–6.
21. Rossi R, Bonasia DE, Blonna D, Assom M, Castoldi F. Prospective follow-up of a simple arthroscopic-assisted technique for lateral tibial plateau fractures: Results at 5 years. Knee 2008; 15:378–83.
22. Dall'Oca C, Maluta T, Lavini F, Bondi M, Micheloni GM, Bartolozzi P. Tibial plateau fractures: Compared outcomes between ARIF and ORIF. Strateg Trauma Limb Reconstr. 2012; 7:163–75.
23. Burdin G. Arthroscopic management of tibial plateau frac-

tures: surgical technique. Orthop Traumatol Surg Res 2013; 99(1 Suppl):S208-18.
24. Abdel-Hamid MZ, Chang CH, Chan YS, Lo YP, Huang JW, Hsu KY, et al. Arthroscopic Evaluation of Soft Tissue Injuries in Tibial Plateau Fractures: Retrospective Analysis of 98 Cases. Arthroscopy 2006; 22:669–75.
25. Chen XZ, Liu CG, Chen Y, Wang LQ, Zhu QZ LP, Chen XZ, Liu CG, Chen Y, Wang LQ, Zhu QZ, et al. Arthroscopy-assisted surgery for tibial plateau fractures. Arthroscopy. 2015; 31:143–53.
26. Vaienti E, Scita G, Ceccarelli F, Pogliacomi F. Understanding the human knee and its relationship to total knee replacement. Acta Biomed. 2017 Jun 7; 88(2 -S): 6-16.
27. Gill TJ, Moezzi DM, Oates KM, Sterett WI. Arthroscopic reduction and internal fixation of tibial plateau fractures in skiing. Clin Orthop Relat Res. 2001; 383:243–9
28. Verona M, Marongiu G, Cardoni G, Piras N, Frigau L, Capone A. Arthroscopically assisted reduction and internal fixation (ARIF) versus open reduction and internal fixation (ORIF) for lateral tibial plateau fractures: A comparative retrospective study. J Orthop Surg Res. 2019; 14:155.

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Original article

Translation, cross-cultural adaptation, reliability, and validation of the italian version of the Foot and Ankle Disability Index (FADI)

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Summary. *Background and Aim of the work:* Foot-and-Ankle-Disability-Index (FADI) is one of the most widely used evaluation questionnaires for this anatomical district, but an italian validated version lacks and is necessary to properly evaluate italian people. In fact a correct interpretation of the items by patients is essential to obtain a precise subjective response, making the questionnaire valid to evaluate patients' satisfaction and wellness. Our purpose was to translate and culturally adapt into Italian the FADI questionnaire, and to check its reproducibility and validity. *Materials and Methods:* The original english version of FADI questionnaire was translated into Italian and checked for medical part coherence. It was submitted to 10 italian randomized patients to verify a correct cultural adaptation, and then to other 50 randomized patients operated at their ankle or hallux to assess intra- and inter-observer reproducibility by the Pearson's-Correlation-Coefficient (PCC) and the Intra-Class-Correlation (ICC) coefficient. Moreover, Short-Form-36 (SF36) questionnaire for Quality-of-Life and Visual-Analogue-Scale (VAS) for pain were also administered to the same 60 people and compared to italian-FADI to perform validation analysis by PCC and ICC coefficient. *Results:* Cultural adaptation of the translated version of the scale resulted good in terms of understandability by patients. An optimal correlation of the inter- and intra-observer reproducibility was obtained. The correlation obtained between FADI and SF-36 as well as between FADI and VAS indicates success in the validation process. *Conclusions:* Validation of the FADI italian version has been performed successfully, its use can be considered appropriate and is indicated in italian clinical practice. (www.actabiomedica.it)

Key words: evaluation scale, validation, cultural adaptation, foot, ankle, disability, Quality of Life, questionnaire, FADI, Italian.

Introduction

The importance of patient's perspective is recognized to be central for judging the effectiveness of a treatment in health care (1). Particularly for musculoskeletal disorders the response in terms of Quality of Life (QoL) of patients is important to obtain indication on functional limitation and disability before and after surgery (2). To this purpose several questionnaires were born to analyse patient's individual outcome. These tools can be divided into two groups: one dedicated to generic measures investigating overall health and wellness, designed to be applied to several diseases and body parts and to be widely used across

various population, whilst another group of questionnaires is dedicated to specific measures related to well defined anatomical regions (3).

Many specialistic questionnaires have been designed to investigate different orthopaedic conditions, encountering wide consent among doctors and healthcare professionals, because they can well investigate the impact of a specific disease and the direct consequence of therapeutic intervention on QoL and wellness state of patients (4).

One of the most widely used questionnaires for foot and ankle disorders is the Foot and Ankle Disability Index (FADI), first described in 1999 by Martin et al.: it consists of 22 activity related items and 4 pain related items (5).

The clinimetric qualities are extensively documented for the FADI, and in particular it has been considered a reliable and sensitive, patient-assessed tool to quantify functional disability in patients with chronic ankle instability (3).

A great advantage of FADI compared to other rating scales lies in the possibility of remote patient compilation.

However, its appropriate utilization is strongly limited by the english language in which it has been offered to scientific world. In fact, the validity of this tool in reporting the effective subjective response by patients cannot be separated from an adequate comprehension of the text of the items proposed inside the questionnaire. Moreover, the intervention of healthcare personnel to mediate or explain the questionnaire may generate interpretative bias causing loss of sincerity or misunderstanding, with consequent poor reproducibility invalidating the use of the questionnaire (6).

Therefore, the use of the questionnaire in the non-english language of the country where is administered, needs the translation for a full comprehension necessary for an adequate use. However it has been claimed that a simple translation cannot adequately respect the proper sense of the items, and a cross-cultural adaptation should be performed. The need to apply a scheduled procedure in which the questionnaire is not simply translated, but also culturally adapted to the language to maintain the same evaluation properties, was proposed by Guillemin et al. in 1993 (7).

Objective

In the present work we aimed to perform a translation of the FADI questionnaire into the italian language, to ascertain its cross-cultural adaptation and to verify its reliability and validity.

Materials and Methods

Characteristics of FADI questionnaire

The FADI specific questionnaire for foot and ankle consists in a total of 26 items, grouped into three different categories of questions: 16 items (1-16) related to walking, 6 items (17-22) to daily activity and 4 (23-26) to pain. Each item can be scored on a 5-points Likert scale (from zero to four), with a maximum total score of 104 points; the score can be transformed into percentage if a comparison with other questionnaires is needed.

The best possible score (104) corresponds to a complete absence of any difficulty in daily activities and no pain; the minimum score of zero (0) corresponds to the worst possible condition i.e. severe limitation in walking and daily activities as well as pain presence.

Exclusion of existence of previous Italian validated FADI

To assure that an italian translation of FADI was not already available for valid use, a Medline database search was performed typing in the PubMed service (National Center for Biotechnology Information - NCBI, National Library of Medicine - NLM, National Institutes of Health - NIH, USA) the keywords "Italian FADI" and the search didn't find any previous italian validated version. The same result was obtained by the Scopus (Elsevier) and Web of Science databases.

Translation and cultural adaptation

Translation and cultural adaptation were performed according to the different stages process proposed by Guillemin (7, 8), and already used for AOFAS Italian validation (9, 10).

1) First Stage: a primary *translation* of the FADI questionnaire from English into Italian was made by two translators aware of the study, namely an orthopaedic surgeon (M.L.), and a university student in-

volved in non-medical disciplines (A.C.); both translations were compared and discussed to obtain a unique version.

2) Second Stage: the first italian version was submitted to a native English translator who was unaware of the study and of the original english version of the questionnaire; the translator had to *back-translate* the FADI questionnaire from Italian to English. We gained a new english version from the native translator and we compared this one to the original to define a second correct italian version: this step is important to verify eventual change or shift of significance related to linguistic expression during translation procedure (6).

3) Third Stage for *cultural adaptation* of the translated questionnaire: we randomly enlisted 10 patients with regular informed consent who had undergone a surgical procedure at our institution for the treatment of hallux valgus or limitus, or bimalleolar fracture from 1-1-2016 to 31-12-2017, retrieved from the hospital database "AcceWeb" (Hi.Tech S.p.A. Software Engineering, Firenze, Italy), typing the ICD-9 codes (International Classification of Diseases, 9th edition) 735.0 for Hallux valgus, 735.2 for Hallux rigidus/limitus, 824.4 for Bimalleolar-closed fracture and 824.5 Bimalleolar-open fracture. These pathologies were chosen as their outcomes are among the most representative situations for the use of FADI.

To those who tested the second italian version of FADI questionnaire was added the question "difficult to understand?" to each sentence. We posed the limit of 90% of patients understanding the italian questionnaire to indicate a good translation; otherwise we should have to restart from the first step of the process to try to improve the cultural adaptation.

We also submitted the FADI questionnaire to 10 healthcare professionals (3 orthopaedists, 2 physiotherapists, 2 medical residents, 3 nurses) to check the comprehension of the items and professional approval of the indication used in the several items as appropriate in analysing foot and ankle disability. The comprehension and acceptance of the text by healthcare professionals had to be, as for patients, with a positive feedback of at least 90% to continue with the following steps, otherwise, even in these cases, we should have to restart from first stage for searching a translation improvement.

4) Assessment of reproducibility and validity of the Italian version of the FADI questionnaire. The definitive italian FADI questionnaire (Tab.1) was administered to a randomized group of 60 patients including, and with the same criteria as, the 10 patients previously recruited to assess the cultural adaptation of the evaluation scale. Each patient of the group underwent three interviews made by two previously trained and independent interviewers (interviewers A and B). The first interview was made from A and the same day after 30 minutes it was made from B: this step was necessary to check the inter-observer reproducibility. Within 15 days, interviewer A (A bis) reassessed all the patients with the Italian FADI questionnaires to check the intra-observer reproducibility. At the moment of the first interview, interviewer A also submitted the Short Form 36 (SF-36) questionnaire for QoL and the Visual Analogue Scale (VAS) to measure pain, in order to gain data to proceed to FADI scale validation.

Statistical Analysis

Demographic and clinical data of the assessed patients were characterized.

Data scores and statistics indices related to the FADI items are reported grouped in three domains, characterizing the FADI questionnaire: walking (items 1-16), daily activity (items 17-22), pain (items 23-26).

The Pearson's Correlation Coefficient (PCC) and the Intra-Class Correlation (ICC) coefficient were calculated to check the inter and intra-observer reproducibility for validation.

PCC evaluation results will be read as follows: $0 < PCC < 0.3$: weak correlation; $0.3 < PCC < 0.7$: moderate correlation, $0.7 < PCC < 1.0$: good correlation.

All statistical procedures were performed by STATA 13.0 statistical program.

Results

Translation and cultural adaptation

During the dispensing of the questionnaire for checking the cultural adaptation, five patients out of the ten, found difficulties to understand the ninth item related to the term "rollata", while three out of ten in-

Table 1. Italian version of the Foot and Ankle Questionnaire (FADI)
Indice di disabilità di piede e caviglia (FADI)
Prego risponda ad ogni domanda con una risposta che descriva più appropriatamente la sua condizione nell'ultima settimana. Se l'attività in questione è limitata da qualcos'altro oltre al suo piede o caviglia, segni 0.

	Difficoltà in attività	**Nessuna difficoltà 4**	**Leggera difficoltà 3**	**Moderata difficoltà 2**	**Estrema difficoltà 1**	**Incapace ad eseguire 0**
1	Stare in piedi					
2	Camminare su superficie regolare					
3	Camminare su superficie regolare senza scarpe					
4	Camminare in salita					
5	Camminare in discesa					
6	Salire le scale					
7	Scendere le scale					
8	Camminare su superficie irregolare/disconnessa					
9	Fare il passo completo con appoggio e spinta					
10	Accovacciarsi					
11	Dormire					
12	Salire in punta di piedi					
13	Iniziare a camminare					
14	Camminare 5 minuti o meno					
15	Camminare circa 10 minuti					
16	Camminare 15 minuti o più					
17	Lavori domestici					
18	Attività di vita quotidiana					
19	Igiene personale					
20	Lavoro da leggero a moderato (stare in piedi, camminare)					
21	Lavoro pesante (spingere/tirare, arrampicarsi, portare pesi)					
22	Attività ricreative					
	Dolore	Nessun dolore 4	Lieve 3	Moderato 2	Severo 1	Insostenibile 0
23	Livello generale di dolore					
24	Dolore a riposo					
25	Dolore durante la sua normale attività					
26	Dolore appena sveglio					
Cognome e Nome:		**Data:**			**Totale: …/104**	

dicated as confounding the same term, for which they required explanations.

Therefore, this item of the scale did invalidate the proposal of good comprehension level settled at 90% of patients. Because in any other item the patients showed to have difficulty to understand and no improper translation was revealed, only the item number 9 was subject to re-evaluation in its cultural adaptation and this process brought to delete the term indicated as not adequately comprehensible (Table 2). Any observation emerged by healthcare professionals interviewed for checking the medical part comprehension.

Statistical reproducibility and validity of the italian version of the FADI questionnaire

The 60 patients randomly enlisted to assess the validity of the questionnaire, were represented by: 77% (N=46) females and 23% (N=14) males, with average

Table 2. Different translation of the ninth item to better perform the cultural adaptation of the item

First translation of the voice "Stepping up and down curves" of the FADI questionnaire						
	Difficoltà in attività	Nessuna difficoltà 4	Leggera difficoltà 3	Moderata difficoltà 2	Estrema difficoltà 1	Incapace ad eseguire 0
9	Fare il passo completo con appoggio e spinta (rollata)					
Second translation culturally adapted of the voice "Stepping up and down curves" of the FADI questionnaire						
	Difficoltà in attività	Nessuna difficoltà 4	Leggera difficoltà 3	Moderata difficoltà 2	Estrema difficoltà 1	Incapace ad eseguire 0
9	Fare il passo completo con appoggio e spinta					

age 62 ±12 years, ranging from 38 to 80 years; 50% (N=30) with previous diagnoses of hallux valgus, 17% (N=10) hallux limitus and 33% (N=20) bimalleolar fracture, of which 17 closed and 3 open.

The time elapsed between the two interviews performed by the interviewer A was not the same for each patient, but all were interviewed after a minimum interval of 7 days and a maximum of 15 days.

The data for every item of the FADI questionnaire, collected by interviewer at first interview, are detailed in Table 3; whereas the comparison of the total scores collected by the interviewer A in the first and in the second time and by the interviewer B are resumed in Table 4.

The analysis related to the reproducibility of scale outcomes, concerning inter- and intra-interviewer variability is resumed in Table 5.

The reproducibility evaluated by PCC shows an optimal correlation for the several items of FADI questionnaire as evidenced by the domains. The intra-interviewer and inter-interviewer coefficients are very similar evidencing a very high coherence of response obtainable with the scale (Table 5). The ICC coefficient used to assess the reproducibility was compared with the PCC (Table 6); the analysis confirms the occurrence of a strong link among the different scores detected by interviewer A vs. Abis and A vs. B, allowing us to judge optimal the correlation in terms of in-

Table 3. FADI scores at the first interview.

FADI Questions/Items	Mean	SD	Minimum detected	Maximum detected
Walking (items 1 – 16)	3.7	0.6	0	4
Daily activity (items 17 – 22)	3.8	0.5	0	4
Pain (items 23 – 26)	3.7	0.6	0	4

Table 4. FADI total scores detected following the different interview performed on patients.

INTERVIEWER	Mean ± SD	CL 95%
A	96.0 ± 14.5	92.3 – 99.7
A bis	95.8 ± 14.2	92.2 – 96.4
B	98.9 ± 14.3	92.3 – 99.5

Table 5. Assessment of intra and inter-interviewer reproducibility of FADI questionnaire with Pearson correlation coefficient.

FADI Questions/Items	Pearson Correlation Coefficient	
	Intra-Interviewer	Inter-Interviewer
Walking (items 1 – 16)	0.9962	0.9983
Daily activity (items 17 – 22)	0.9863	0.9957
Pain (items 23 – 26)	0.9907	0.9958

Table 6. Analysis of the reproducibility by means of the Pearson's Correlation Coefficient (PCC) and of the Intra-Class Correlation coefficient (ICCc) values for the total score of the FADI assessment scale.

	Intra-Interviewer	CL 95%	Inter-Interviewer	CL 95%
PCC	0.9972		0.9988	
ICCc, individual	0.99868	0.99780 – 0.99921	0.99868	0.99780 – 0.99921
ICCc, average	0.99934	0.99890 – 0.99960	0.99934	0.99890 – 0.99960

ter and intra- interviewer variability. In conclusion the analysis evidences an optimal level of reproducibility, indicating the italian version of FADI questionnaire as adequate for the use by different interviewers.

The validation of the italian version of FADI questionnaire was performed comparing the total FADI score to the 8 domains of SF-36 health quality survey by the PCC (Table 7).

The PCC coefficients show a prevalence of a moderate correlation in the single domains in which is subdivided the SF-36 scale; they are rather similar (mean PCC = 0.503 ± 0.071) showing the occurrence of a limited internal variability of FADI questionnaire values.

For further control, we compared the FADI questionnaire total value of the interviewer A with the VAS scale; similarly, we compared the items related to pain of the italian version of FADI questionnaire (items 23-26) with VAS scale, being these items related to the same concept of the VAS i.e. the pain; the results are resumed in Table 8.

In both cases we obtained a good correlation, indicative of a strong influence of pain status in determining the values of the response.

Table 7. Correlation through Pearson's coefficient, of the FADI total score with the 8 domains and the total of the SF-36 results, obtained by observer A at the first interview.

SF-36 domains	Pearson's coefficient
Physical functions	0.4693
Role physical	0.4366
Bodily pain	0.4145
General health	0.5748
Vitality	0.4880
Social function	0.5103
Role emotion	0.6318
Mental health	0.4986
SF-36 TOTAL	0.6043

Table 8. Correlation with Pearson's coefficient of the VAS scale for FADI-total score and FADI-pain results obtained from interviewer A the first time.

FADI scores, interviewer A	Pearson's coefficient
Total	- 0.7399
Pain (items 23 – 26)	-0.7034

The negative sign in the PCC coefficient indicates that the value sequence of the two evaluation scales are displayed in opposite direction.

Discussion

In order to better understand and treat our patients, it is essential to evaluate effectively the impact of a disease and the effect of therapy on patient's well-being and Quality of Life. Every medical intervention has its real efficacy in the amelioration of patients' condition to reach satisfaction and wellness (11).

In this contest numerous questionnaires investigating patients' wellness were born. The increasing spread of specific questionnaires facilitates physicians to investigate specific diseases and related therapeutic interventions (12).

These questionnaires are gaining wide success and use, and thus need a proper cultural adaptation into the current language of the country in which it is applied, and a proper analysis for reproducibility and scientific validation (9, 10).

In our case the Italian culturally adapted FADI questionnaire has revealed a high level of reproducibility as assessed by the correlation indexes (Pearson CC and Intra-Class CC) of the statistical analysis. This finding brings us to introduce the use of the adapted FADI questionnaire as a reliable tool that can be used in clinical practice.

Moreover, the validity of the adapted FADI questionnaire has been assessed by the correlation analysis, with PCC, with the 8 domains characterizing the items of the SF36 health survey questionnaire which has been found to be reliable, valid, and responsive for a variety of medical diagnoses (13), and is eligible for our validity analysis (9, 10).

However, this comparison procedure, even if widely adopted, has a limit due to the different architecture of the evaluation scales born to investigate different topics. Therefore, the moderate values obtained in our PCC analysis can be anyway considered a good result that supports the validity of the italian adapted FADI questionnaire.

A further PCC analysis was performed with VAS scale which is one of the most eligible scales for pain

assessment in patients' subjective outcome. It is an evaluation index less rigorous than results of SF-36 questionnaire, but equally valid. Correlation analysis of italian FADI with VAS scale is used to confirm validity by an adequate PCC index, resulted even higher in our study than the one obtained in relation with SF-36. From this double check we obtained a further confirm of validity of our italian adapted FADI questionnaire.

The comparison with VAS scale is also used to detect the influence that pain has on the psychological state of patients and then their response (14, 15). The good level of values detected by PCC analysis, also in relationships to pain specific items of FADI, evidences that patients' pain is an important determinant in orienting the spontaneous response of patients.

In **conclusion**, validation and cross-cultural adaptation of the italian version of FADI questionnaire has been performed successfully and its use can be considered appropriate and suggested in Italian clinical practice.

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References

1. Eechaute C, Vaes P, Van Aerschot L, Asman S and Duquet W. The clinimetric qualities of patient-assessed instruments for measuring chronic ankle instability: a systematic review. BMC Musculoskelet Disord 2007; 8: 6.
2. Parker J, Nester CJ, Long AF, Barrie J. The problem with measuring patient perceptions of outcome with existing outcome measures in foot and ankle surgery. Foot Ankle Int 2003; 24: 56-60.
3. Hale SH and Hertel J. Reliability and sensitivity of the Foot and Ankle Disability Index in subjects with chronic ankle instability. J Athl Train 2005; 40: 35-40.
4. Pinsker E, Daniels TR, Inrig T, Warmington K, Beaton DE. The ability of outcome questionnaires to capture patient concerns following ankle reconstruction. Foot Ankle Int 2013; 34: 65-74.
5. Martin RL, Burdett RG, Irrgang JJ. Development of the Foot and Ankle Disability Index (FADI). *J* Orthop Sports Phys Ther 1999; 29: A32–A33.
6. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. Spine 2000; 25: 3186–3191.
7. Guillemin F, Bombardier C, Beaton D. Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. J Clin Epidemiol 1993; 46: 1417-1432.
8. Guillemin F. Cross cultural adaptation and validation of health status measures. Scand J Rheumatol 1995; 24: 61-63.
9. Leigheb M, Janicka P, Andorno S, Marcuzzi A, Magnani C, Grassi F. Italian translation, cultural adaptation and validation of the "American Orthopaedic Foot and Ankle Society's (AOFAS) ankle-hindfoot scale". Acta Biomed 2016; 87: 38-45.
10. Leigheb M, Vaiuso D, Rava E, et al. Translation, Cross-Cultural Adaptation, Reliability, and Validation of the Italian Version of the American Orthopaedic Foot and Ankle Society - MetaTarsoPhalangeal-InterPhalangeal Scale (AOFAS-MTP-IP) for the hallux Acta Biomed 2019; 90(12S): 118-126.
11. Fitzpatrick R, Davey C, Buxton MJ, Jones DR. Evaluating patient based outcome measures for use in clinical trials. Health Technol Assess 1998; 2: 1-74.
12. Streiner DL, Norman GR. Health Measurement Scales: A Practical Guide to Their Development and Use. Oxford, England: Oxford University Press; 1995.
13. Der Heyde R. Chapter 6 - Assessment of Functional Outcomes. In: Fundamentals of Hand Therapy - Clinical Reasoning and Treatment Guidelines for Common Diagnoses of the Upper Extremity. Eds Elsevier 2007: 98-113.
14. Ibrahim T, Beiri A, Azzabi M, Best AJ, Taylor GJ, Menon DK. Reliability and validity of the subjective component of the American Orthopaedic Foot and Ankle Society Clinical Rating Scales. J Foot Ankle Surg 2007; 46: 65-74.
15. Leigheb M, Sabbatini M, Baldrighi M, et al. Prospective Analysis of Pain and Pain Management in an Emergency Department. Acta Biomed 2017; 88(4S): 19-30.

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Original article

Haglund's Syndrome: endoscopic or open treatment?

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Summary. *Background and aim of the work.* With the term "Haglund›s syndrome" we define a condition characterized clinically by pain at the insertion of Achille›s tendon and, anatomopathologically, due to the presence of retrocalcaneal bursitis and at times associated with an insertional Achille›s tendinopathy. The aim of the work is to correlate the most reliable and reproducible treatment possible to the aforementioned variables of Haglund›s syndrome. *Methods.* The classic syndromic picture is characterized by pain caused by retrocalcaneal bursitis. In some cases, symptoms of insertional tendinopathy are associated with bursitis pain. In those frameworks where symptoms were mainly exacerbated by the bursitis inflammation we have used an endoscopic technique for the resection of the underlying bone deformation and the bursa. An open technique, described in the literature as bridge sutures, was used for those patients with tendinopathic problems. While a homologous PRP unit was infiltrated in patients with degenerative insertional tendinopathy. *Results.* The group of patients that participated to the study was heterogeneous in age and functional requirements therefore presenting different anatomopathological characteristics. For these reasons considerations with correct statistical meaning are not possible. Despite different post-operative programs; patients demonstrated optimal clinical and functional recovery. There were no local neurological or skin complications. *Conclusions.* Haglund›s syndrome can have different clinical and anatomopathological patterns where conservative treatment is unsuccessful surgical solutions must be adopted. The latter have shown to be reliable and reproducible with a very low rate of complications. (www.actabiomedica.it)

Key words: Haglund, Achille›s tendinopathy, bursitis, posterior endoscopy, open surgery

Introduction

Pavlov defined the concept of Syndrome in 1928, describing those pathologies that affected the insertional district of the Achille's tendon and that Haglund himself had genuinely defined achillodynia's. The anatomopathological element responsible mainly for pain in Haglund's syndrome is represented by the retrocalcaneal bursitis. The retrocalcaneal bursa occupies, together with adipose tissue, an anatomical space ventral to the Achilles tendon called the Kager triangle, whose geometric limits on the sagittal plane are bone (postero-superior portion of the calcaneus) and tendon (anteriorly Flexor Hallux Longus tendon and posteriorly the Achille's tendon). (1,2)

The inflammation of the bursa can result from a repeated conflict between the calcaneal postero-superior spur and the ventral portion of the Achille's tendon, which can occur often in ankle dorsal flexion. The patients presenting with a cavus foot where the heel is more vertical than normal are predisposes to bone-tendon contact even in normal conditions increasing the likelihood to develop this conflict. The inflammation of the bursa can also result from repeated plantar flexion movements of the foot and ankle. In this particular condition it is detected an abnormal and repeated thrust of the most distal portion of the retrocalcaneal bursa between the calcaneus and Achille's tendon insertion to the bone. Pain originating from the bursitis can in some cases have a mixed nature with the

addition of Achilles's insertional tendonopathy pain. Insertional tendinopathies can be characterized by intratendinous calcified deposits or by areas of fibrillary disarrangement which modify the so-called "enthesic organ".

Once the clinical picture is precisely defined and after the failure of conservative treatment, it is necessary to plan a surgical procedure that has the goal of eliminating the causes of pain.

Due to the peculiarity of these presentations a sole focus to the painful districts will limit a broader understanding of the problem. It will always be useful to asses the global/postural structure with a focus on the lower limb, knowing that some conditions (static or dynamic knee valgus, core problems, cavus foot, etc.) can contribute to determine the syndromic picture and affect the final result of the treatment.

The clinical presentation is mainly characterized by pain, the characteristics of which make it possible to identify its origin.

The pain elicited by retrocalcaneal bursitis may be associated with swelling, which is expressed predominantly postero-laterally. If when performing the squeeze test, which consists of stapling the preachilleum space with the first and second fingers, intense pain is triggered,it's highly likely that a bursitic inflammation is present. It is also possible to perform an xylotest in the preachilleum space. A positive outcome (i.e. it solves more than 50% of the pain); confirms with good reliability that the inflamed bursa is responsible for the clinical picture.

Occasionally the symptoms can be associated with Achille's insertional tendinopathy. In these cases from clinical inspection the area shows signs of inflammation and intense pain at tendon pressure. (3-5)

We must confirm our clinical hypothesis with instrumental investigations. The most helpful are considered X-rays in charge, ultrasound (possibly with its elastographic applications) and MRI.

Latero-lateral radiographies offers us the possibility to Identify and quantify the hypertrophy ~~or not~~ of the postero-superior portion of the calcaneus and the signs of insertional calcific tendinopathies. Today with digital radiographs it is also possible to highlight the appearance of the diaphanous of the Kager's triangle. Normally this space has a perfect diaphanous appearance and therefore does not show areas "dirtied" by bursitic inflammation. (Figure 1)

Lines can be drawn on radiographs to calculate bone exuberance (Pavlov's lines).

The ultrasound represents a very precise diagnostic and instrumental technique in analyzing the insertional structure of the tendon.

With the use of a MRI it is possible to highlight and confirm the presence of areas of retrocalcaneal bursitis, excluding other causes of posterolateral pain of the hindfoot having the possibility to quantify the tendon structure very well at the insertion level. (6,7)

The right mix of clinical and instrumental information allows to classify the different presentations of Haglund's syndromes and to choose the right surgical approach given the failure of conservative treatments. As previously stated the surgical procedures utilized to treat these presentations are mainly two. In the absence of tendinopathic component, the minimally invasive endoscopic technique proposed by Van Dijk was used. Classical instruments for arthroscopy are frequently used (arthroscope and 4.5 mm burs 30 ° optics). Only in a few cases a 3.5 burs and 70 ° optics was necessary. In the latter surgical technique the patient is positioned prone with the foot exceeding the edge of the operating bed, free to be mobilized without the use of any traction system. A pneumoischemic strap was used and

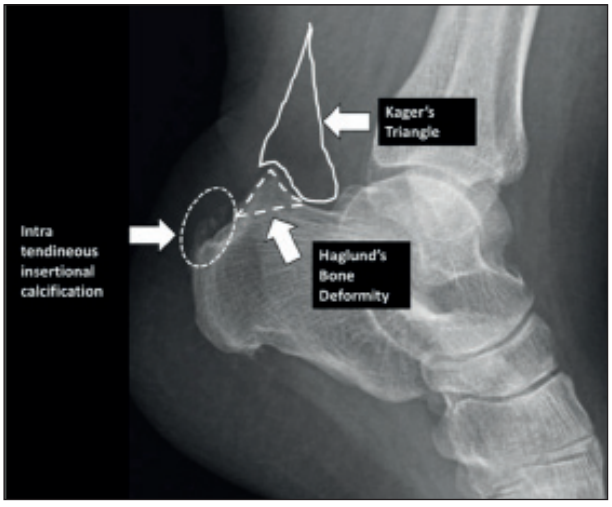

Figure 1. The X-Ray in lateral-lateral projection shows a typical picture of Haglund S. with hypertrophy of the postero-superior portion of the calcaneum, the triangle of kager not perfectly diaphanous and calcific insertional tendonopathy

para-achille's tendon posterior portals were executed (postero-medial and postero-lateral). After marking the profile of the postero-superior calcaneal tuberosity and the margins of the Achille's tendon on the skin portals were marked. During this procedure the posterior medial and posterior lateral portals are found at the same level and the incision of the skin and a careful separation of the deep tissues with a mosquito clamp can be initiated deepening towards the Kager triangle. After orienting yourself in this confined space, with the motorized removal of the adipose and bursitic tissue, the posterosuperior portion of the calcaneus was skeletonized and we were concerned with identifying the bursitic portion of the Achilles tendon. Before starting the surgery in order to be sure of being able to resect the right portion of the posterosuperior part of the calcaneus, an ampliscopic control in lateral lateral view was undertaken and a Kirshner wire inserted into the calcaneus at the right level and with the right inclination to represent the bone resection limit . During the endoscopy and with the use of an ossivorous reamer we deepen in the resection up to the visualization of the K wire. (figure 2).

The open techniques (more or less minimally invasive) described in the literature are various. Among these, the suture bridge technique was recently introduced and indicated for insertional tendinopathies allowing the approach to the pre achilleus space (to the bursa and to the often hypertrophic posterosuperior portion of the heel). This technique involves a J-like skin incision that starts at the medial parachilleus level and directs distally towards the center. Afterwards, a minimum detachment from the heel insertion and a split of the Achilles tendon are performed. After resection of the bone deformation, of the adipose and bursitic tissue and of any calcifications or degenerate tendon areas, the intervention ends with its re-insertion with various types of anchors and using various materials. The most used in the literature are soft anchors. (8-16) (Figure 3).

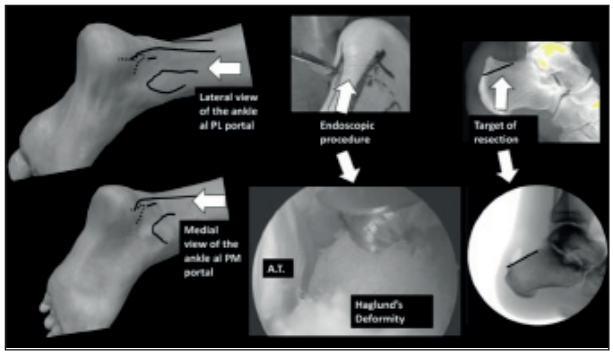

Figure 2. In the left part in evidence the para-achilleus portals, postero medial and postero lateral; in the center in evidence the operating dynamics and the use of spherical burr for the removal of the postero-superior calcaneus portion; in the right part the pre-operative determination of the heel bone to be removed and intra-operative control.

In recent years c/o the central laboratory of the AUSL of Romagna as part of the haematology/blood bank donation center, have concentrated the platelets from the donor bags to more than 300/mlx10^3. The homologous plasma with concentrated platelets, in single units of 5 ml, can be used after the activation with thrombin and calcium gluconate. Only in one case where the tendon component has been operated, especially on a degenerative basis, the Achilles tendon is infiltrated with the homologous PRP before suturing the skin.

Materials and Methods

From the operating register of the Operations Unit of Orthopedics and Traumatology of the Hospital of Forlì in the period 2004-2019, 47 patients operated for Haglund's syndrome were extrapolated, trying to form two groups as comparable as possible.

23 patients had had endoscopic surgery and 24 patients had an open technique.

Figure 3. In the left part are MRI Images in axial and sagittal view with signs of bursitis and degenerative tendinopathy. In the right part a step of the open surgery procedure and X-Ray post operative view.

Of the 23 endoscopic surgeries, 5 were women and 18 men.

Of the 24 open surgery procedures, 6 were women and 18 men.

Only in one case did we infiltrate the Achilles' reinstatement and tenorraphy site with a homologous PRP.

Pre and post operative evaluation was made with VISA-A. The VISA-A includes 10 questions that correspond to a score. The maximum score is 100 points. Subjective assessments of daily, work and sports activities are collected. (17)

To signal a progress towards well-being slightly slower for patients treated with open surgery and also a residual, but temporary, discomfort to the pressure on the Achilles tendon at its insertion. Very likely this figure reflected the different post-operative treatment followed in the two types of surgical approach.

After the endoscopy procedure the patient can immediately start a program of ankle mobilization and load within pain tolerance. For patients operated with the suture bridge technique, a period of immobilization of the ankle was respected, applying a walker with heel rise, for 25 days. During these 25 days a pain tolerant load was allowed. After 25 days of immobilization, the actual functional neuro-myo-functional recovery begins.

Results

Pre-operative VISA-A score range between 25 to 33/100 points.

In post operative evaluation the patients without Achille's tendinopathy have registred a VISA-A score of 95/100, while those with Achille's tendinopathy have registred a VISA-A score of 80/100.

All patients were satisfied with the result.

No recurrence of symptoms has been reported, no persistent skin problems for surgical incision in open surgery patients

Possible the report of reduction of sensation to the cutaneous touch to the postero-lateral region of the heel among the patients operated with open technique, with spontaneous transient character of the symptom.

It is difficult to isolate the benefit of the homologues PRP injections. In infiltrated patients who undertook an MRI 3 months post-intervention, a good T1 weighted signal of the treated tendon structure was found. Obviously, these particular data have no scientific value, but given the good clinical and instrumental results, it is preferred to carry out this infiltration even after checking the literature produced on the topic of regenerative medicine applied to tendons.

Discussion

Recently, an attempt has been made to adopt a terminology for the pathologies of the Achilles insertion district which present a peculiar clinical, anatomical- topographical and histological presentation.

In Van Dijk›s work of 2011 (18) the term Haglund›s syndrome corresponds to a painful swelling from inflammation of the retrocalcaneal bursa and, sometimes, insertional tendinopathy of the yarrow. In the absence of one of these parameters we will speak of Haglund›s exostosis (s and hypertrophy of the postero-superior portion of the heel is prevalent) or bursitis in the absence of tendinopathic aspects.

The information derived from instrumental investigations (hypertrophy of the posterior calcaneal portion, calcific deposits in the tendon at the insertional level, areas of tendon degeneration, signs of inflammation) together with clinical data allow to choose the most correct therapeutic approach.

The first approach must be conservative (heel elevations, orthosis prepare ad hoc , program with eccentric exercises, avoiding those that involve dorsal flexion, physical therapy). If conservative treatments fail, surgical treatment should be performed. The endoscopic or minimally invasive approaches adopted have already been described in their advantageous and disadvantageous aspects in the literature. Where the indications are evident, endoscopic treatment has made it possible to shorten the time of post-operative recovery and to bring into play all the advantages of the minimally invasive surgery.

Surely the endoscopic approach is considered a challenging technique were all the possible pitfalls should be acknowledged in order to avoid them. One

major risks is of not completely removing the exuberant posterosuperior bone portion, especially in its more lateral and lateral portions. The bone residue in these portions of the posterior superior tuberosity of the heel is synonymous with clinical failure due to the persistence of pain. A careful use of the motorized vehicle is paramount not to damage the Achilles tendon. Particular attention must also be paid to the level of the portals in order not to incur in a physical conflict between instruments and the patient›s calf.

Conclusions

After a correct clinical and antomo-pathological diagnosis an adeguate surgical treatment must be achieved. The reliability and reproducibility of the surgical techniques adopted allow to face the prevalent components of Haglund syndrome with a high success rate.

References

1. Canoso JJ, Liu N, Traill MR, Runge VM. Physiology of the retrocalcaneal bursa. Annals of the rheumatic diseases 1988; 47: 910-912.
2. Theobald P, Bydder G, C Dent, Nokes L, N Pugh, Benjamin M . The functional anatomy of Kager's fat pad in relation to retrocalcaneal problems and other hindfoot disorders. J. Anat 2006; 208: 91-97.
3. Thomas JL et al. The diagnosis and treatment of the heel pain: a clinical practice guidline-revision 2010. J foot ankle surg 2010; 49: S1-S19.
4. Mayerson MS, Mc Garvey W. Disorders of the Achilles tendon insertion and Achilles tendinitis. Instr Course Lect 1999; 48: 211-218.
5. Den Hartog BD. Insertional Achilles tendinosis: pathogenesis and treatment. Foot Ankle Clin N Am 1999; 14: 639-650.
6. Van Sterkenburg MN, Muller B, Maas M, Sierevelt IN, Van Dijk CN. Appearance of the wheight-bearing lateral radiograph in retrocalcaneal bursitis. Acta Orthopaedica 2010; 81: 387-390.
7. Singh R, R Rohilla, Siwach RC, Magu NK, Sangwan SS, Sharma A. Diagnostic significance of radiologic measurements in posterior heel pain. The foot 2008; 18: 91-98.
8. Carreira D, A Ballard. Achilles tendoscopy. Foot Ankle Clin N Am 2015; 20: 27-40.
9. Jerosch J. Endoscopic calcaneoplasty. Foot Ankle Clin N Am 2015; 20: 149-165.
10. Solan M, M Davies. Management of insertional tendinopathy of Achilles tendon. Fott Ankle Clin N Am 2007; 12: 597-615.
11. Van Dijk CN, Van Dyk GE, Scholten PE, Kort NP . Endoscopic calcaneoplasty. Am J Sports Med 2001; 29: 185-189.
12. Scholten PE, Van Dijk CN. Endoscopic calcaneoplasty. Foot Ankle Clin N Am 2006; 11: 439-446.
13. DeVries JG, Su mmerhays B, Guehlstorf DW. Surgical correction of Haglund's triad using complete detachment and reattachment of the Achilles tendon .. J foot ankle surg 2009; 48: 447-451.
14. Wiegerinc k JI, Kok AC, Van Dijk CN. Surgical treatment of chronic retrocalcaneal bursitis. Arthroscopy 2012; 28: 283-293.
15. Van Sterkenburg MN, Groot M, Sierevelt IN, Spennacchio PA, Kerkhoffs GM, Van Dijk CN. Optimization of portal placement for endoscopic calcaneoplasty. Arthroscopy 2011; 27: 110-1117.
16. Lohrer H, Nauck T, Dorn NV, Konerding MA . Comparison of endoscopic and open resection for Haglund tuberosity in a cadaver study. Foot and ankle international 2006; 27 (6): 1-6.
17. Maffulli N, Longo GU, Testa V, Oliva F, Capasso G, Denaro V. Italian Transalatione of the VISA-A score for tendinopathy of the main body of the Achilles tendon. Disability and Rehabilitation 2008; 30(20-22): 1635-1639
18. Van Dijk CN, Van Sterkenburg MN, Wiegerinck JI, Karlsson J, Maffulli N. Terminology for Achilles tendon related disorders. Knee Surg Sports Traumatol Arthrosc. 2011; 19: 835-41.

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Original article

The *"Ball in Basket"* Technique for Tibiotalocalcaneal Fusion

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Summary. Tibiotalocalcaneal arthrodesis (TTCA) in severe bone deficit represents a complex challenge for expert orthopedic surgeons also. This study aims to illustrate a surgical technique, defined as "ball in basket", that facilitates the fitting of the structural bone graft (femoral head from bone bank) and its placement, in order to fill the bone gap during instrumented arthrodesis. The proposed technique includes the preparation of the recipient bone surfaces with acetabular convex reamers and of concave reamers to shape the bone graft from bone bank. This preparation guarantees a maximum congruence of the bone surfaces and a greater stability of the bone graft during the placement of the fixation devices to optimize the bone fusion and to provide a good patient clinical outcome. The preliminary results obtained for two patients, initially presenting with severe anatomical deformity associated with severe bone gap, are described. Patients underwent clinical and radiographic follow-up evaluations (respectively at 4 and 30 months of follow-up) showing radiographic healing and good functional recovery. The results are encouraging, although long-term studies and a wider cohort of patients are necessary to consider this technique a reliable aid in case of severe bone deficit. (www.actabiomedica.it)

Key words: Tibiotalocalcaneal, TTCA

Introduction

The arthrodesis procedure is recommended in case of severe joint disease or severe deformities. The indications for arthrodesis include severe instability of bone and ligaments, surgical revision of ankle prostheses or previous arthrodesis, bone defects secondary to neoplasm or traumatic injuries. Other additional indications consist of post-traumatic arthritis, avascular necrosis of the talus, degenerative rheumatic diseases, Charcot neuroarthropathy, deformities secondary to neuromuscular diseases (1,2, 3).

In particular, the most frequent indications in relation to the tibiotalocalcaneal arthrodesis (TTCA), that includes the subtalar joint in the fusion, are the failure of ankle implant (70%), the failure of a previous arthrodesis (20%) and the traumatic injury (10%) (4).

In literature, more than 30 techniques of tibiotalocalcaneal arthrodesis with different surgical approaches and fixation devices are described. The elevated number of different alternative methods derives from the fact that the complication rate can reach, based on the clinical records, the 50% as well (1).

Therefore, the variability of the results dictates the research of an appropriate solution aimed to guarantee the best possible stability of the bone graft and the stabilization of the arthrodesis with an adequate fixation device.

Numerous fixation devices are available for the joint fusion surgery, although the intramedullary nailing provides a few advantages as compared to other fixation systems including the preservation of the alignment, of the length and of the stability of the anatomical segment and an increased rigidity of the construct (5).

The TTCA performed with intramedullary nailing was described for the first time by Adams in 1948, whereas in 1994 Kile et al. published the retrograde intramedullary nailing technique, supported by a variety of studies (6-8).

The entity of the contact area represents a fundamental factor in the process of the fusion of two bone segments (9-11), for this reason a severe loss of bone stock represents a condition that can compromise the result, as well as increasing the difficulty of the surgical procedure.

The most frequently used bone graft techniques to fill the segment deficit are the iliac crest tricortical bone grafts and the allografts (12-14).

In literature, the reported success rate regarding the different bone graft techniques of structural *autograft* or *allograft* vary from 48% to 93%, based on the analyzed case studies and on the proposed technique (4, 9, 11, 15, 16).

The allografts, with no living cells, provide the structure and the matrix of the bone tissue for in situ colonization (11). These grafts are absorbed by the host more slowly than an autograft since they can generate an immune response that can potentially delay the osteoinduction phase.

For this reason, it is significantly important to generate a construct that provides the maximum possible stability.

Hence, finding an appropriate solution to guarantee the maximum possible stability of the graft and the stabilization of the arthrodesis with an efficient fixation device becomes fundamental.

Nonunion of the bone segments, infections, delayed healing of the surgical wound, neurovascular lesions, arthritis or rearfoot joint laxity, misalignment, chronic swelling, stress fractures, often due to a change in the weight-bearing distribution, and painful scar tissue (2) represent a few of the possible complications.

The most frequent complication is the nonunion of the anatomical segments, reported in literature with values between the 11% and 40%, related to the avascular necrosis of the talus (1) in most cases.

The reported failure percentage results even higher if a revision surgery of a previous arthrodesis is required. This highlights the importance of an accurate patient selection, a precise surgical technique, and a monitoring of the outcomes over the time (17).

This study analyzes two cases treated with TTCA with retrograde nailing and structural *allograft* prepared following the *"ball in basket"* technique, for two different diseases: a traumatic injury and a severe rearfoot deformity secondary to subtalar arthrodesis and placement of screws.

Materials and Methods

The used technique consists of preparing the site of the graft and the graft itself following the *"ball in basket"* technique once the joint is reached with the most adequate surgical approach.

The expression *"ball in basket"* for this type of technique is due to the high congruence between the receiving site and the bone graft. The preparation of the new cavity between the talar articular surface and the distal tibial articular surface was performed with EP-Fit™ Smith & Nephew (Smith&Nephew AG Aarau - CH) (Figure 1) convex acetabular reamers with increased diameter, whereas the preparation of the femoral head was performed with (Wright Medical Group N.V. Memphis Tennessee - USA) convex humeral head reamers with decreased size holding the graft still with Codivilla type reduction forceps. (Figure 2, 3)

Thus, the contact surfaces result more uniform, granting a higher congruence and stability (Figure 4).

A Valor™ (Wright Medical Group N.V. Memphis Tennessee - USA) retrograde intramedullary nail was carefully chosen as fixation device in both cases to stabilize the construct.

Clinical and radiographic follow-up evaluations showed radiographic healing.

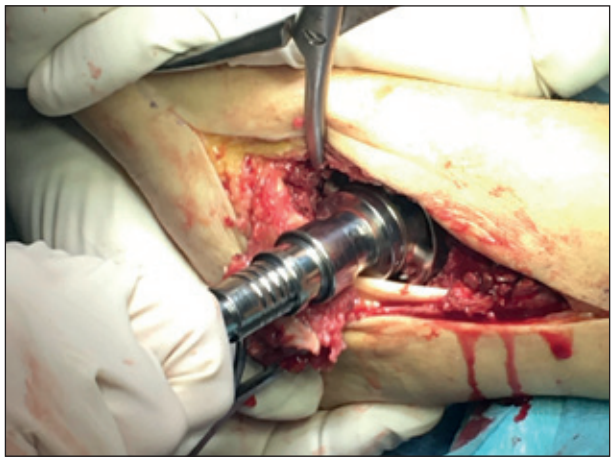

Figure 1. preparation of the new cavity

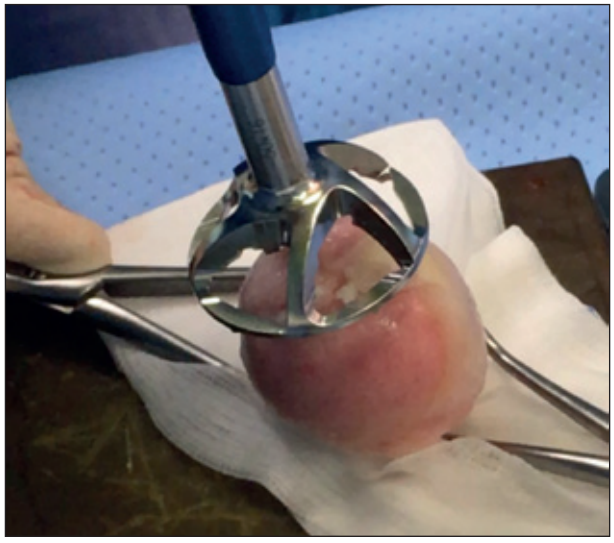

Figure 2. Femoral Head Preparation

Case 1

Female patient of 15 y/o arrived at the Emergency Room of San Bortolo Hospital of Vicenza following to a severe fall-related traumatic injury with evidence of multiple abdominal contusions (pulmonary, hepatic, and renal injuries), multiple vertebral fractures and upper and lower extremities fractures respectively burst fracture of the talus and calcaneus and fracture of lateral aspect of the calcaneus, bimalleolar fracture, 4th metatarsal fracture and cuboid fracture on the right side and calcaneal fracture-dislocation, talar body fracture, lateral malleolus fracture and cuboid fracture on the left side (Figure 5 a/b/c). Hemodynamic stabilization and neurosurgical procedure of vertebral stabilization of patient were performed urgently.

Figure 3. Femoral head before grafting

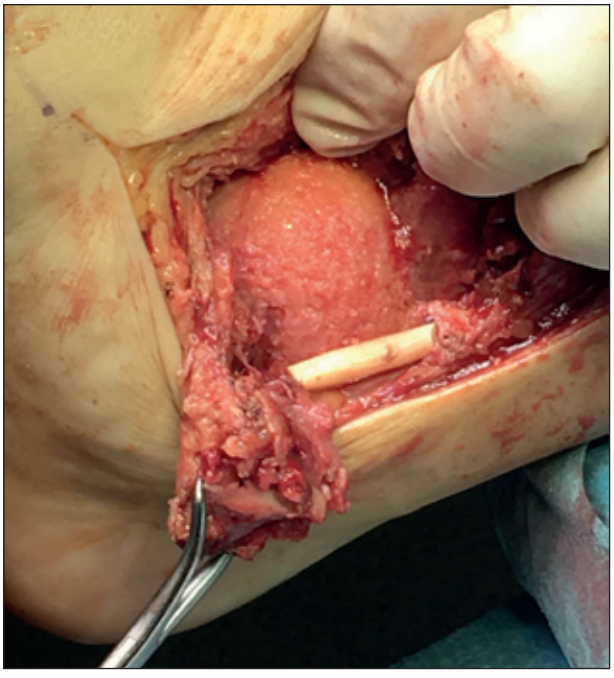

Figure 4. Final position of the graft

Figure 5. (A) Preoperative CT scan (Sagittal view), (B) Preoperative CT scan (Axial view), (C) Preoperative CT scan (3D Reconstruction)

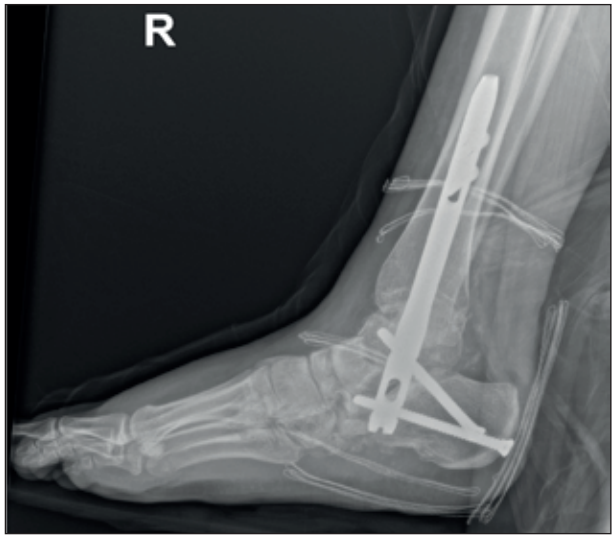

Figure 6. PostOperative X-Ray

The complicated traumatic injuries of right foot and ankle were treated with TTCA with placement of intramedullary nail and structural bone graft using the "*ball in basket*" technique immediately considering the severe comminuted fracture and the loss of bone stock.

The joint was reached with medial transmalleolar approach between the tendons of the tibialis anterior and posterior muscles. The talus bone showed evidence of significant comminution and severe loss of bone stock, whereas the thalamic calcaneal articular surface resulted intact. Therefore, one Valor™ (Wright Medical Group N.V. Memphis Tennessee - USA) nail (150/10 mm) and two screws (posteroanterior calcaneal and subtalar) were used following the "*ball in basket*" technique (Figure 6).

Patient performed clinical and radiographic follow-up plan of 30 months with bone reaction course monitoring until total assimilation of the bone graft and no complications were reported.

During the last clinical and radiographic follow-up evaluation at 30 months, a weight-bearing study was performed showing complete joint fusion and compliance of the normal ratio between the leg and foot axis (Figure 7 a/b).

Case 2

Female patient of 62 y/o with rheumatoid arthritis referred for severe bilateral rearfoot valgus deformity in status-post subtalar arthrodesis complicated by talar necrosis and consequent joint collapse (Figure 8 a/b).

The right joint was reached with lateral transmalleolar extended to the 4th metatarsus.

Therefore, one Valor™ (Wright Medical Group N.V. Memphis Tennessee - USA) nail (200/10 mm) and three screws (lateromedial, calcaneocuboid and talocalcaneal) were used following the "*ball in basket*" technique.

Clinical and radiographic follow-up plan of 4 months of patient was performed (Figure 9 a/b, Figure 10 a/b). During this time range, our assessment showed no evidence of mobilization of the fixation devices and presence of initial signs of osseointegration reaction with no signs of bone graft failure.

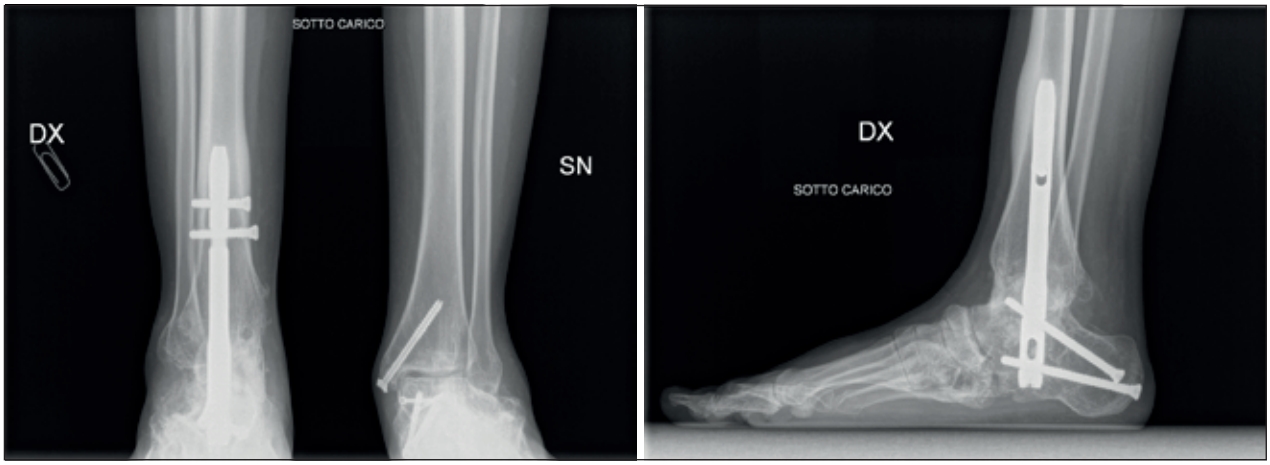

Figure 7. (A) X-Ray at 30 months follow-up, (B) X-Ray at 30 months follow-up

Figure 8. (A) Preoperative X-Ray AP ankle view), (B) Preoperative X-Ray (AP foot view)

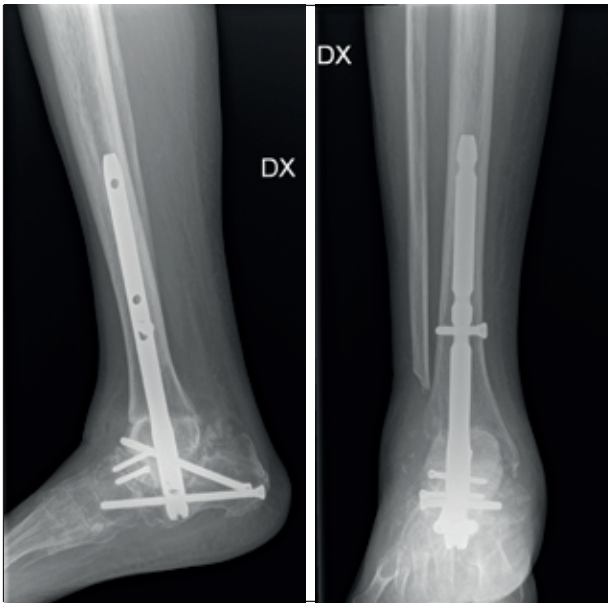

Figure 9. (A) 4 months follow-up X-Ray (Ankle Lateral view), (B) 4 months follow-up X-Ray (Ankle AP view)

Discussion

The *"ball in basket"* technique used in patient with different disorders (one case of status-post traumatic injuries and one case of previous surgical procedure failure) resulted flexible and reliable.

It represents a surgical method not simple to be performed and it requires a certain expertise of the surgeon, who must be familiar with both the anatomical

Figure 10. (A) Clinical presentation at 4 months follow-up (Right side correction compared to severe contralateral deformity), 4 months follow-up X-Ray (Ankle AP view), (B) Clinical presentation at 4 months follow-up (Right side correction compared to severe contralateral deformity)

region and the most adequate arthrodesis techniques. Furthermore, the surgeon must be skilled to prepare adequately the bone graft and the contact surfaces using tools not usually used in these body segments.

The concave reamers used for the preparation of the bone graft, in comparison with the use of the cutting tools, facilitate the reduction of the surface irregularities allowing the total removal of the residual cartilage, and provide the ideal features for an optimal osseointegration, as reported in literature (9).

The use of convex reamers for articular surfaces guarantees the removal of each joint cartilage residual, of fiber tissues and sclerotic bone, offering a bleeding layer of bone ready to accept the convex bone graft.

This surgical technique was named "ball in basket" specifically for the high congruence obtained with the preparation.

Our method ensures a higher sphericity of the bone graft with a better exposure of the spongious bone, compared to the technique proposed by Cuttica et al. (9) that uses BHR Smith & Nephew reamers type to prepare the bone graft.

In our opinion, a preoperative CT Scan study with 3D reconstruction is essential to obtain the most accurate result in order to use the proposed technique and provides the detection of a few fundamental parameters: the bone gap and the optimal diameter of the milling.

The femoral head from bone bank was selected for the *"ball in basket"* technique since it is easily available and can be prepared precisely.

Furthermore, in comparison with the autologous tissue, it provides a sufficient quantity of material, ensuring a reduction of the surgical time and a reduction of the postoperative pain.

Based on our clinical experience, the retrograde intramedullary nail was considered more suitable as stabilization system in this technique since, as reported in literature likewise, it results to be the tool that guarantees the best long-term results (5).

We recommend a long period of approximately 60 days with no weight-bearing, and afterwards a gradual recovery and regular free ambulation after 12 weeks due to the wide contact surfaces and the volume of the bone graft obtained with the femoral head.

The osseointegration process could furtherly be supported with the use of growth factors such as platelet-rich plasma (PRP) or mesenchymal stem cell (MSC), although these techniques require additional studies to evaluate the actual effectiveness in this specific application.

Conclusions

The *"ball in basket"* technique provides an optimal accuracy between the receiving site and the bone graft (a sphere in a cavity) and the stability of the bone surfaces, facilitating the introduction of the fixation device in order to obtain a stable construct with most excellent healing perspectives of the arthrodesis.

In our opinion, despite the reduced number of cases, the proposed technique has the features to ensure an optimal integration and stability of the bone graft, with a good recovery of the volumes and good final clinical outcomes.

The results that we obtained are encouraging, although a wider cohort of patients is crucial to determine the reliability and reproducibility of this technique in order to be recommended in selected cases with severe bone deficit diseases.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Cooper PS. Complications of ankle and tibiotalocalcaneal arthrodesis. Clin Orthop Relat Res 2001; 391: 33–44.
2. Mendicino RW, Catanzariti AR, Saltrick KR, et al. Tibiotalocalcaneal arthrodesis with retrograde intramedullary nailing. J Foot Ankle Surg 2004; 43(2): 82–86.
3. Pellegrini MJ, Schiff AP, Adams SB, DeOrio JK, Easley ME, Nunley JA. Outcomes of tibiotalocalcaneal arthrodesis through a posterior achilles tendon-splitting approach. Foot Ankle Int 2016; 37: 312–19.
4. Escudero MI, Poggio D, Alvarez F, Barahona M, Vivar D, Fernandez A. Tibiotalocalcaneal arthrodesis with distal tibial allograft for massive bone deficits in the Ankle. Foot Ankle Surg 2019; 25(3): 390–97.
5. Fox IM, Shapero C, Kennedy A. Tibiotalocalcaneal arthrodesis with intramedullary interlocking nail fixation. Clin Podiatr Med Surg 2000; 17: 19–31.
6. Jeng CL, Campbell JT, Tang EY, Cerrato RA, Myerson MS. Tibiotalocalcaneal arthrodesis with bulk femoral head allograft for salvage of large defects in the ankle. Foot Ankle Int 2013; 34: 1256–66.
7. Adams JC. Arthrodesis of the ankle joint: experiences with the transfibular approach. J Bone Joint Surg Br 1948; 30B: 506–11.
8. Kile TA, Donnelly RE, Gehrke JC, Werner ME, Johnson KA. Tibiotalocalcaneal arthrodesis with an intramedullary device. Foot Ankle Int 1994; 15: 669–73.
9. Cuttica DJ, Christopher FH, Femoral head allograft fot tibiocalcaneal fusion using a cup and cone reamer technique. J Foot Ankle Surg 2011; 50: 126–29.
10. Myerson MS, Neufeld SK, Uribe J. Fresh-frozen allografts in the foot and ankle. J Bone Joint Surg Am 2005; 87: 113–20.
11. Mendecino SS, Kreplick AL, Walters JL. Open ankle arthrodesis. Clin Podiatr Med Surg 2017; 34(4): 489–502.
12. Asomugha EU, Hartog Den BD, Junko JT, Alexander IJ. Tibiotalocalcaneal fusion for severe deformity and bone loss. J Am Acad Orthop Surg 2016; 24: 125–34.
13. Schill S. Ankle arthrodesis with interposition graft as a salvage procedure after failed total ankle replacement. Oper Orthop Traumatol 2007; 19: 547–60.
14. Berkowitz MJ, Clare MP, Walling AK, Sanders R. Salvage of failed total ankle arthroplasty with fusion using structural allograft and internal fixation. Foot Ankle Int 2011; 32: 493–502.
15. Neufeld SK, Uribe J, Myerson MS. Use of structural allograft to compensate for bone loss in arthrodesis of the foot and ankle. Foot Ankle Clin 2002; 7(1): 1–17.
16. Thomason K, Eyres KS. A technique of fusion for failed total ankle replacement of the ankle: tibio-allograft-calcaneal fusion with a locked retrograde intramedullary nail. J Bone Joint Surg Br 2008; 90: 885–88.
17. Kitaoka HB, Anderson PJ, Morrey BF. Revision of ankle arthrodesis with external fixation for non-union. J Bone Joint Surg Am. 1992; 74(8): 1191–200.

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Original article

Neglected complete bilateral Achilles tendon rupture. Clinical case presentation, treatment and follow-up

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Summary. *Background and aim of the work:* subcutaneous Achilles tendon lesions are common degenerative tendon tears, often related to sport activities, multiple pharmacotherapies and internal medical comorbidities. Neglect an Achilles tendon lesion can affect walk ability, while neglect a bilateral lesion could really lead to a serious limitation of self-sufficiency in daily living. We report a case of chronic bilateral Achilles tendon lesion successful treated with LARS augmentation, along with some clinical considerations concerning the clinical outcome. *Methods:* we report a case of a chronic bilateral Achilles tendon lesion in an elderly man with multiple comorbidities, successful treated with LARS reconstruction, along with some considerations concerning possible intraoperative issues and the clinical outcome. *Results:* good functional result was obtained as documented with pre and postoperative American Orthopedic Foot And Ankle Society Scale and the "Foot And Ankle Disability Index", without complications. *Conclusions:* a bilateral Achilles tendon rupture is a very disabling pathology, that needs prompt diagnosis and treatment to prevent further complications. LARS reconstruction could be an effective method in selected patients to avoid some intraoperative issues related to patient comorbidities and ability to follow complex postoperative rehabilitation protocols. (www.actabiomedica.it)

Key words: bilateral, Achilles tendon, lesion, chronic, LARS

Background and aim of the work

Achilles tendon rupture is increasing in time in younger and older patients and is mostly related to sport activities, chronic corticosteroids and fluoroquinolones therapy and internal medicine comorbidities (1, 2). Typically, this is a pathology more frequent in males between the third and fifth decade of life, with acute injuries occurring in younger patients (3). Diagnosis of Achilles tendon rupture is mostly clinical, consisting in finding a palpable gap in the Achilles tendon region and a positive Thompson test (4) related to the specific medical history; whereas in doubtful cases and to confirm the diagnosis ultrasonography or MRI should be performed (5).

A bilateral Achilles tendon rupture is a very disabling pathology, that needs prompt diagnosis and treatment, to ensure a fast and complete recovery to the patient (6).

In literature there are few descriptions of bilateral simultaneous Achilles tendon ruptures and neglected Achilles tendon rupture that can cause some problems to the patient and the surgeon in terms of a full functional recovery and surgical options (7,8); but it's hard to find cases with both the conditions combined (9).

Various techniques are described for reconstructing chronic Achilles tendon lesions with autologous grafts and plasty, but these are not free of complications and often require a wide surgical exposure (10-13).

Materials and Methods

In June 2015 a 76 year old man came to our service (where at that time most of the authors were working) bringing a MRI of both legs, done few days earlier, showing a complete bilateral Achilles tendon rupture with large areas of tendinosis and a tendinous gap of 5 cm in the right and 4 cm in the left one.

The patient was able to walk independently, although with the help of two crutches and limping. Walking was achieved with flat foot step bilaterally and in absence of the push-off phase. The physical examination revealed a bilateral hypotrophy of the triceps surae muscles, a positive Thompson and Matles test and a palpable gap proximal to the distal insertion of the Achilles tendon bilaterally (Figure 1). In the same consult the patient revealed that the beginning of symptoms dated back in February of the same year, after feeling a strong pain in the right Achilles region, in the context of an accidental fall. Within a few days, he felt the same pain in the left Achilles region while walking up the stairs, consequently needing two crutches to walk.

The bilateral Achilles tendon lesions, related to those episodes, were misunderstood with simple ankle sprains by his primary care physician, and so treated with anti-inflammatory drugs, ice and ankle braces. Following failure to resolve symptoms the patient underwent to a specialist examination with a neurologist, which resulted negative.

Four months after the injury, persisting the gait abnormality, was prescribed a MRI of booth legs and the patient was addressed to our service, allowing us to diagnose the bilateral Achilles tendon rupture. The patient clinical history revealed a chronic atrial fibrillation treated with oral anticoagulants, an ascending aorta ectasia, a previous spontaneous pneumothorax, HCV in treatment with interferon, a hiatal hernia, a low grade of kidney failure, a BPH and a rheumatic polymyalgia in treatment with corticosteroids (5mg prednisone 1 pill per day) for more than 15 years.

In July 2015 in our service a bilateral surgical reconstruction of the Achilles tendon with implantation of one LARS per side was performed, with a one day hospitalization.

Intraoperatively (Figure 2) we found a tendinous gap as described in the MRI (5 cm in the right Achilles tendon and 4 cm in the left one), in presence of fatty degeneration of both tendon stumps, also beginning to involve the belly muscles of the triceps surae, conditions that could make dangerous the use of tendon plasty or transfers, thus necessitating the use of distal transosseus tunnels and interference screws in the calcaneus and proximal transfascial suture of the synthetic ligament (Figure 3). Postoperatively bilateral below knee plaster cast were made with the ankle in neutral position, allowing pro-

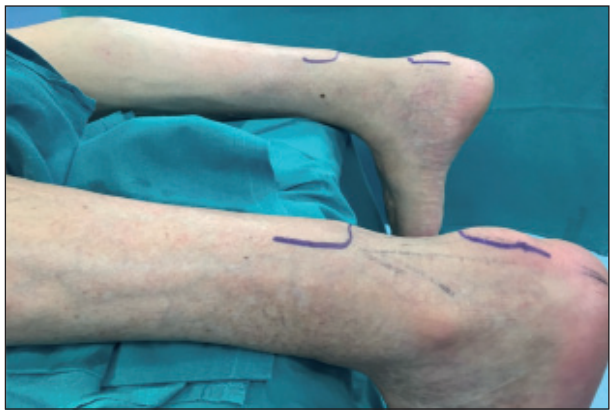

Figure 1. Clinical presentation and patient position on the operating table

Figure 2. Intraoperative view: remnants of ruptured native tendon

tected weight bearing with a walker for four weeks. At thirty days postoperatively we removed the plaster casts, allowing passive and active mobilization of the ankles to gain range of motion and muscles strengthening with protected weight bearing for thirty days more. At 60 days postoperatively the walker was substituted with crutches allowing complete weight bearing.

Results

We made serial evaluations of disability according to the American Orthopedic Foot And Ankle Society Scale (AOFAS) and the "Foot And Ankle Disability Index" (FADI), preoperatively and postoperatively, listed below:

AOFAS preoperatively: 43%	FADI preoperatively: 23,1
AOFAS at 3 months: 50%	FADI at 3 months: 40
AOFAS at 6 months: 85%	FADI at 6 months: 63,7
AOFAS at 9 months: 87%	FADI at 9 months: 71,2
AOFAS at 12 months: 92%	FADI at 12 months: 85,6

We also prescribed a control MRI at 8 months postoperatively showing apparently good LARS integration (Figure 4).

Twelve months after the procedure, the patient gained a good autonomy level in walking and in daily life activities, being satisfied about the functional recovery and the surgery outcome (Figure 5).

Interestingly however, persisted a subjective feeling of gait instability, referred by the patient as a sensation of "walking in the dark", or "blinded", especially on uneven grounds, needing a walking stick not to weight bear rather as a way to feel the ground. To investigate this disequilibrium we prescribed a new neurologic consult and a head CT, to rule out central or peripheral nervous degenerative disorders, obtaining a

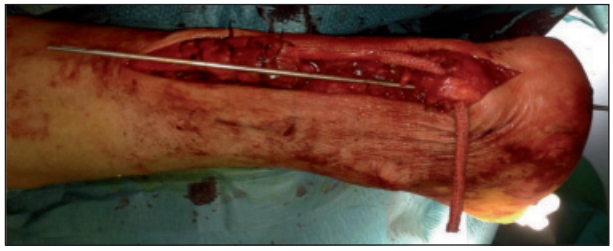

Figure 3. Lars implantation: transosseus tunnel and transfascial proximal suture

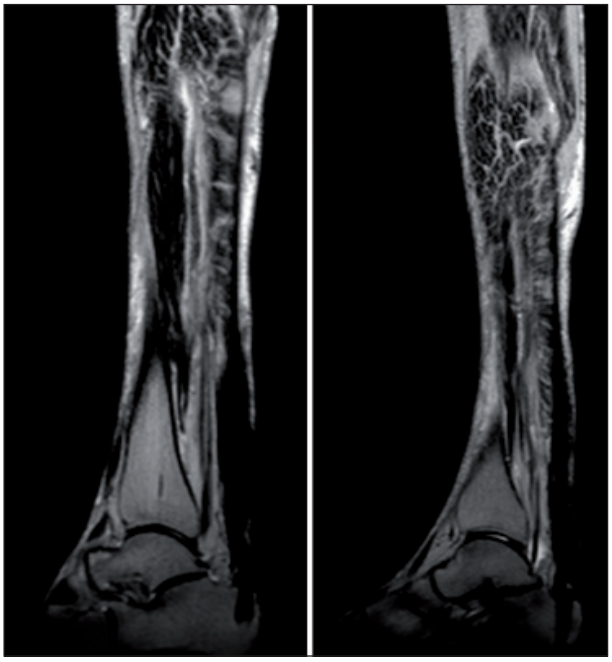

Figure 4. Two sagittal postoperative MRI view showing LARS integration in the calcaneus tunnel and fatty degeneration of calf muscles

Figure 5. Postoperative active standing on forefoot

negative result.

Analyzing this condition, and starting from the knowledge that an Achilles tendon rupture produces a deficit in ankle proprioception (14) the most likely hypothesis was that we were in presence of a quite complete loss of proprioception previously conveyed by the Achilles tendons, now substituted by the synthetic ligaments.

In relation to this hypothesis therefore, we prescribed an intensive program of proprioceptive exercises, partially improving the symptoms.

Discussion and conclusions

The bilateral simultaneous Achilles tendon reconstruction with LARS allowed us to restore an anatomical entity by then degenerated, with a very short surgical time, avoiding large surgical dissection of soft tissues to harvest autologous tendons and complications related to surgical wounds healing, ensuring a hight primary weight bearing resistance (15,16).

All of these factors surely contributed to a good recovery, in a short time related to the pathology and the little patient ability to follow complex postoperative rehabilitation protocols, with a hight level of patient and surgeon satisfaction, avoiding dangerous postoperative complications.

LARS reconstruction could be an effective method in selected patients to avoid some intraoperative issues related to patient comorbidities and ability to follow complex postoperative rehabilitation protocols.

Anyway further studies should investigate the relationship between the use of synthetic ligaments in chronic Achilles tendon reconstruction and their influence on ankle proprioception.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Hess G. W. Achilles tendon rupture: a review of etiology, population, anatomy, risk factors, and injury prevention. Foot ankle spec. 3.1 (2010): 29-32.
2. Matsumoto K., Hukuda S., Nishioka J., Asajima S. Rupture of the Achilles tendon in rheumatoid arthritis with histologic evidence of enthesitis. A case report. Clin. Orthop. Relat. Res. 280 (1992): 235-240.
3. Vosseller, J.T., Ellis S.J., Levine D.S. et al. Achilles tendon rupture in women. Foot Ankle int 34.1 (2013): 49-53.
4. Soroceanu A., Sidhwa F., Aarabi S., Kaufman A., Glazebrook M. Surgical versus nonsurgical treatment of acute Achilles tendon rupture: a meta-analysis of randomized trials. J Bone and Jt. Surg. American volume 94.23 (2012): 2136.
5. Cary D.V. How to diagnose and manage an acute Achilles tendon rupture. JAAPA-J AM ACAD PHYS 22.8 (2009): 39-43.
6. Chalmers J. Treatment of Achilles tendon ruptures. J Orthop Surg Res 8.1 (2000): 97-99.
7. Habusta S.F. Bilateral simultaneous rupture of the Achilles tendon. A rare traumatic injury. Clin. Orthop. Relat. Res. 320 (1995): 231-234.
8. Gabel S., Manoli A. Neglected rupture of the Achilles tendon. Foot Ankle Int 15.9 (1994): 512-517.
9. Dhillon M.S., Chauhan D., Kumar V, Saini U.C. Reconstruction of bilateral spontaneous chronic idiopathic Achilles tendon rupture using LARS ligament: case report. The Foot 20.4 (2010): 154-157.
10. Wegrzyn J., Luciani J.F., Philippot R., Brunet-Guedj E., Moyen B., Besse J.L. Chronic Achilles tendon rupture reconstruction using a modified flexor hallucis longus transfer. Int. Orthop. 34.8 (2010): 1187-1192.
11. Sarzaeem M.M., Lemraski M.M.B., Safdari F. Chronic Achilles tendon rupture reconstruction using a free semitendinosus tendon graft transfer. Knee Surg. Sports Traumatol. Arthrosc. 20.7 (2012): 1386-1391.
12. Us A.K., Bilgin S.S., Aydin T., Mergen E. Repair of neglected Achilles tendon ruptures: procedures and functional results. Arch. Orthop. Trauma Surg. 116.6-7 (1997): 408-411.
13. Mendicino S.S., Reed T.S. Repair of neglected Achilles tendon ruptures with a triceps surae muscle tendon advancement. J Foot Ankle Surg 35.1 (1996): 13-18.
14. Bressel E., Larsen B.T., McNair P.J., Cronin J. Ankle joint proprioception and passive mechanical properties of the calf muscles after an Achilles tendon rupture: a comparison with matched controls. CLIN BIOMECH 19.3 (2004): 284-291.
15. Chen J., Xu J., Wang A., Zheng M. Scaffolds for tendon and ligament repair: review of the efficacy of commercial products. Expert Rev Med Devices 6.1 (2009): 61-73.
16. Ibrahim S.A.R. Surgical treatment of chronic Achilles tendon rupture. J Foot Ankle Surg 48.3 (2009): 340-346.

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Case report

Reinsertion of distal biceps ruptures with a single anterior approach: analysis of 14 cases using tension-slide technique and interference screw

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Summary. *Background:* Several techniques of surgical repair of biceps tendon ruptures are described in literature. Cortical button repair have shown minimal loss of elbow flexion, supination and strength. In this retrospective study we report the outcomes in terms of elbow function and complications of tension-slide technique and interference screw. *Matherials and methods:* 14 patients with complete distal biceps tendon rupture were included in the retrospective study and treated with the same tension-slide technique (BicepsButton® - Arthrex, Inc, Naples, Florida) evaluating the clinical and functional outcomes and the complication rate with a follow-up average of 18 months. *Results:* The flexion recovered compare to the healthy contralateral was 96% (min 115° - max 135°; average 128°), the extension was 97% (min: -2° - max 15°; average 4°), the supination was 90% (min 20° - max 90°; average 75°), the pronation was 95% (min 15° - max 90°; average 76°). The mean Disabilities of Arm, Shoulder and Hand (DASH) score was 8.1 ± 10.5 and Mayo Elbow Performance Score overall (MEPS) score was 97.6 ± 8.2. Two patients had LABCN paresthesia, one case, treated 2 months after injury, had posterior interosseus nerve palsy. One patient had heterotopic ossification at the radiological examination without consequences for the clinical performances. No case of non-traumatic tendon re-rupture and no case of ROM deficiency > 20%. In all case the cortical button remains well positioned and no case of osteolysis were reported. *Conclusions:* Distal biceps tendon repair with BicepsButton® system seems to be a safe, relyable and reproducible technique providing excellent clinical, functional and radiological outcomes. Comparing with other techniques the BicepsButton® system has the advantages of the single approach procedures, the reduction of surgical time and risk of heterotopic ossifications. (www.actabiomedica.it)

Key words: distal biceps rupture, single approach, tension-slide technique, interference screw

Introduction

Distal biceps tendon ruptures are typical injuries of middle aged male. The incidence is 3% of all biceps injuries and 10% of all tendon injuries (1). The common mechanism of injury is an eccentric extension force loaded on a extended and supinated forearm. Most cases occur in dominant arm at the bicipital tuberosity on the radius (2,3). Pain and reduced strength in forearm supination is common at clinical examination. In rare cases conservative treatment is an option, but this can lead to chronic arm pain and weakness of forearm supination (4-7). Surgical repair is considered the standard of care and several techniques involving variety of fixation methods and either 1 or 2-incision approaches have been reported in literature (8-12). A systematic review of repair techniques, reported lowest complication rate for cortical button repair (13) and other authors demonstrate the association with minimal loss of elbow flexion, supination strength and motion (comparing with contralateral side) (14). At our institution, after several years where we had used

a double incision approach for the treatment of distal biceps tendon ruptures, since two years, we prefer the new technique of repair with a single incision anterior approach, cortical button fixation and interference screw. The aim of the study is to assess the elbow function and complications of this surgical technique.

Materials and Methods

Fourteen patients (all male) with an average age of 42 (min. 35 - max. 73) and complete distal biceps tendon rupture (11 of 14 dominant arm) were operated between January 2018 and June 2019 by same senior surgeon and same tension-slide technique (BicepsButton® - Arthrex, Inc, Naples, Florida). All patients were physically active, 5 of them elite atlethes.

Before surgery all patients had instrumental examination with ultrasound, 7 of 15 underwent magnetic resonance imaging (MRI).

The patients were clinically evaluated by measuring the degrees of pronation/supination, flexion/extension, documenting areas of hypoesthesia, neurological pain. The Mayo Elbow Performance score (MEPS) and Disabilities of Arm, Shoulder and Hand score (DASH) were also completed. Radiographs were taken at the review visit and were used to confirm appropriate placement of a cortical button against the far cortex of the radial tuberosity and to assess for heterotopic ossifications. After 90 days an ultrasound assessment was made for allows the return to sport activities. The average follow up was 18 months (range 6-24).

Surgical treatment

Each patient is positioned supine, the tourniquet is applied to the injured arm, the elbow is extended and forearm supinated to protect the posterior interosseous nerve (PIN). A minimally invasive, 3 cm transverse incision, over the antecubital fossa is performed. After dissection of the subcutaneous tissues, brachioradialis muscle belly was identified and reflected laterally to protect the motor branch of the radial nerve. The median nerve was identified and lateral antebrachial cutaneous nerve (LABCN) is carefully discerned from biceps brachii muscle to avoid secondary traction. In the distal portion a series of vein (the so-called leash of Henry) and the recurrent branches of the radial artery are often coagulated of ligated. The ruptured tendon was mobilized and was followed proximally to the myotendinous junction under direct visualization (Figure 1). Light traction is performed to determine whether it could be reattached to the bicipital tuberosity. The distal degenerated portion of the biceps tendon is resected and 2-3 cm - Krackow sutures are placed in the tendon. The free suture ends were than passed through the cortical button. The radial tuberosity is palped with the index finger and than using a blunt, curved hemostat that must be carefully inserted into the biceps channel. The radial tuberosity is cleaned up from the soft tissues and drilled bicortically, restoring the native footprint anatomy as suggested by recent literature (15) (Figures 2,3). Accurate washing and sucking are mandatory to prevent het-

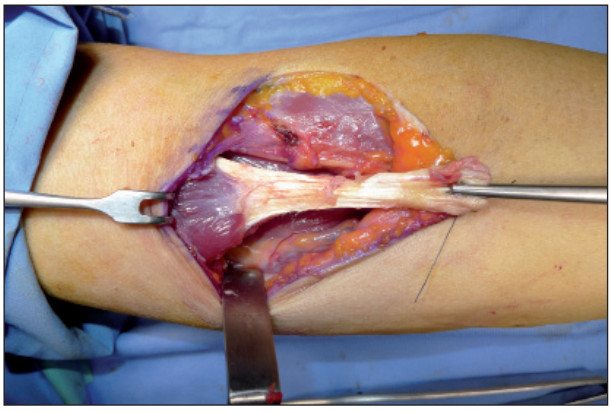

Figure 1. Injuried biceps tendon mobilization and exposition.

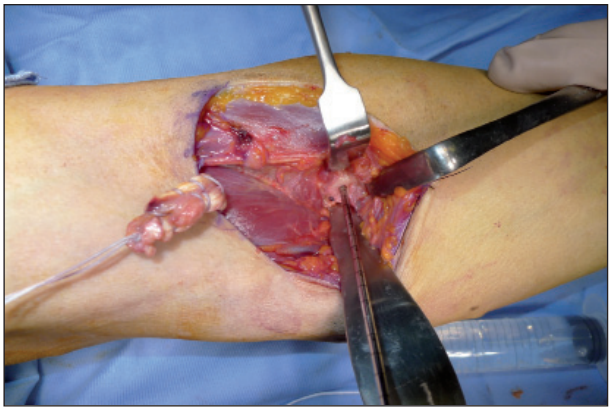

Figure 2. Drilling into the radial tuberosity at 90° to its longitudinal axis and 0 to 30° ulnar angle with patient's forearm in full supination (anatomic footprint).

erotopic ossification caused by bone debris spreading. The elbow was slightly flexed to relieve tension on the biceps tendon and maximally supinated. The cortical button was delivered through the drill-hole and past the posterior radial cortex (Figure 4). It was flipped blindly to secure the tendon on top of the tuberosity. Tension was placed on the traction suture to lock the button and than applied to the zip strand to pull the biceps tendon into the tunnel. An interference screw is positioned into the hole to ensure the final fixation and position (Figures 5-6). The elbow were immobilized using a sling at 90° of flexion and 45° of supination for one week. Passive rehabilitation in tolerated range of motion was initiated after 10-15 days and muscle strengthening beginning after 6 weeks following our rehabilitation protocol (16).

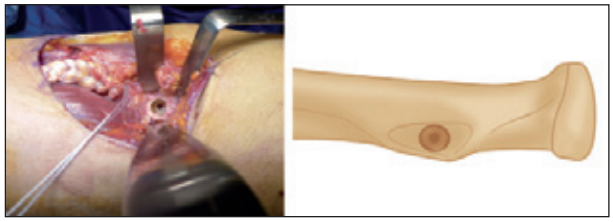

Figure 3. Bicortical radial holes and the end of the biceps tendon with suture (on the left).

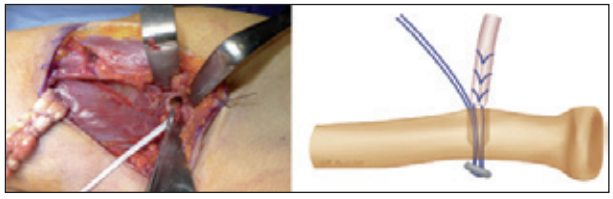

Figure 4. Delivering of the cortical button through the drill-holes.

Figure 5. Tensioning of the tendon and cortical screw positioning into the hole.

Figure 6. Final intraoperative result of the procedure.

Results

All patients were reviewed by an independent examiner. The flexion recovered compare to the healthy contralateral was 96% (min 115° - max 135°; average 128°), the extension was 97% (min: -2° - max 15°; average 4°), the supination was 90% (min 20° - max 90°; average 75°), the pronation was 95% (min 15° - max 90°; average 76°). The mean Disabilities of Arm, Shoulder and Hand score was 8.1 ± 10.5 and Mayo Elbow Performance Score overall score was 97.6 ± 8.2.

All elite players, after measurements of flexion and supination strength (compared to contralateral), returned to play sport (RTP), 3 athletes returned to prior level of performance (RPP).

Two patients had LABCN paresthesia, one case, treated 2 months after injury, had posterior interosseus nerve palsy.

One patient had heterotopic ossification at the radiological examination without consequences for the clinical performances.

No case of non-traumatic tendon re-rupture and no case of ROM deficiency > 20%.

In all case the cortical button remains well positioned and no case of osteolysis were reported (Figure 7).

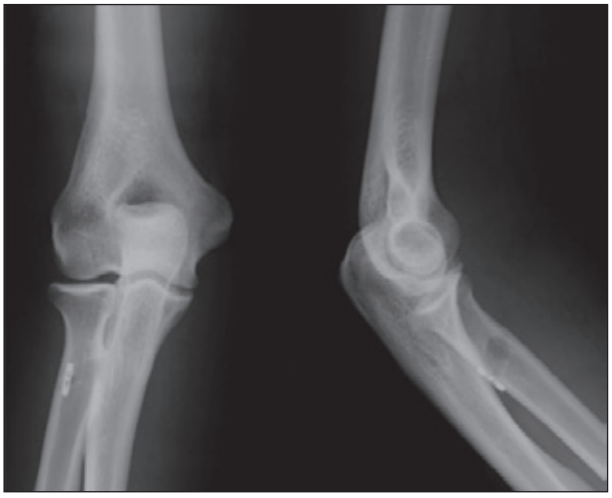

Figure 7. X-ray control at the final follow-up

Discussion

Distal portion of the biceps tendon lesion occurs typically in middle-aged male people and the arm is frequently the dominant as reported in our series (11 of 14). The superiority of surgical treatment compared to the conservative, in terms of functional recover, is largely demonstrated in literature (5,17). In our series all patients, also the oldest, had strong motivation to return to prior activities. For all these reasons in all cases we decided for surgical treatment.

Both one-incision approach (using suture anchors, endobutton or biotenodesis screw) and double-incision approach technique are reported in literature (18-22). No statistically significative differences were observed relative to ROM recovery (22), but advantages of the double-incision exposure is anatomic reinsertion on the radial tuberosity and consequent restoration of strength in supination and flexion (23). An advantage of one-incision technique is reducing the risk of radioulnar synostosys (24), in our series we reported only one case of this complication.

In our study the recovery of flexion and extension were 96% and 97% of those of the contralateral elbow respectively, outcomes comparable to availably literature (14). These satisfactory outcomes are probably related to early mobilization in our rehabilitation program.

In our patient MEPS overall score was considered excellent and DASH overall score was not significantly different from the normative value for the general population.

Three elite athletes returned to prior levels of performance, with excellent flexion and supination strength measured at the end of follow-up. This may be attributable to the cortical button with interference screw surgical technique that allowed strong fixation between bone and biceps tendon.

The BicepsButton® (Arthrex, Inc, Naples, Florida) system as other endobutton-type devices allows a mini-open approach, the tendon is easily pulled into the transosseus tunnel (1) and the tension of the repair can be controlled (25,26). As reported in other studies we suggest drilling into the bone at the native footprint, 90° to its longitudinal axis and 0 to 30° ulnar angle with patient's forearm in full supination to increase the margin of safety and strength of supination of the biceps tendon (1,15,27).

The intraosseus placement and fixation with interference screw allows better healing and early rehabilitation without recurrence of rupture. Failure of poly-L-lactide (PLLA) interference screws with significant osteolisys, tunnel enlargement and radius fractures have been reported (28). PEEK (Poly-ether ether-ketone) screws didn't show that complication in our series according to the recent literature (29).

We found two case (14,3%) of LABCN neuroapraxia, a common complication in both sigle-incision and double-incision technique, probably due to a fibrosis near to the nerve or a significant traction on the retractors and this is in line with the systematic review of Watson et al (30). A case (7,1%) of PIN transient palsy, with complete recovery in 8 months is reported, may be due to delay of surgery more than one month (45 days) after the rupture. A meta-analysis conducted by Amin et al (31) reported an incidence of PIN palsy of 1,7% for anterior surgery higher than double-incision technique. Remains difficult to compare our rate with the literature on the basis of the small number of patients treated.

In our series we didn't observe case of re-rupture, probably the endobutton-type technique needs a higher energy absorbed before failure compared to suture anchor techniques, as reported in other studies (32-34). However the absence of re-rupture could be also a reflection of our smaller sample size.

Regarding cost/benefits analysis, although this system is clearly more expensive than others (i.e. suture anchors) we could consider and suggest this procedure, in particular in young player, on the basis of the satisfactory clinical outcomes and RPP rate.

The present study had several limitations: first of all the retrospective design but also the small sample size and the relatively short follow up. The strength of our study was that all patients were treated by the same surgeon and were analyzed by the same observer at the follow up.

Conclusions

Distal biceps tendon repair with BicepsButton® system seems to be a safe, relyable and reproducible

technique providing excellent clinical, functional and radiological outcomes. The strong stability of the surgical fixation with the combined biotenodesis screw and endobutton technique allows early rehabilitation without high rate of complications and re-roptures. Comparing with other techniques the BicepsButton® system has the advantages of the single approach procedures, the reduction of surgical time and risk of heterotopic ossifications.

References

1. Alech-Tournier F, Elkholti K, Locquet V, Ninou M, Gibert N, Pozzetto M, Breden F et al. Outcomes of distal biceps tendon reattachment using the ToggleLoc™ fixation device with ZipLoop™ technology with single mini-open technique. Eur J Orthop Surg Traumatol 2019;29(4):925-31.
2. Morrey BF. The elbow and its disorders. Elsevier Health Sciences, New York (2009).
3. Athwal GS. Management of elbow trauma, an issue of handclinics 31-4, E-Book. Elsevier Health Sciences, New York (2016).
4. Morrey BF, Askew LJ, An KN, Dobyns JH. Rupture of the distal tendon of the biceps brachii. A biomechanical study. J Bone Joint Surg Am 1985;67(3):418-21.
5. Baker BE, Bierwagen D. Rupture of the distal tendon of the biceps brachii. Operative versus non-operative treatment. J Bone Joint Surg Am 1985;67(3):414-7.
6. Agins HJ, Chess JL, Hoekstra DV, Teitge RA. Rupture of the distal insertion of the biceps brachii tendon. Clin Orthop Relat Res 1988 Sep;234:34-8.
7. Bell RH, Wiley WB, Noble JS, Kuczynski DJ. Repair of distal biceps brachii tendon ruptures. J Shoulder Elbow Surg 2000;9(3):223-6.
8. Boyd HB, Anderson LD. A method for reinsertion of the distal biceps brachii tendon. J Bone Joint Surg Am 1961;43(7):1041-3.
9. Barnes SJ, Coleman SG, Gilpin D. Repair of avulsed insertion of biceps. A new technique in four cases. J Bone Joint Surg Br 1993;75(6):938-9.
10. Lintner S, Fischer T. Repair of the distal biceps tendon using suture anchors and an anterior approach. Clin Orthop Relat Res 1996;322:116-9.
11. Sotereanos DG, Pierce TD, Varitimidis SE. A simplified method for repair of distal biceps tendon ruptures. J Shoulder Elbow Surg 2000;9(3):227-33.
12. Bain GI, Prem H, Heptinstall RJ, Verhellen R, Paix D. Repair of distal biceps tendon rupture: a new technique using the Endobutton. J Shoulder Elbow Surg 2000;9(2):120-6.
13. Watson JN, Moretti VM, Schwindel L, Hutchinson MR. Repair techniques foracute distal biceps tendon ruptures: a systematic review. J Bone Joint Surg Am 2014;96(24):2086-90.
14. Huynh T, Leiter J, MacDonald PB, Dubberley J, Stranges G, Old J, Marsh J. Outcomes and Complications After Repair of Complete Distal Biceps Tendon Rupture with the Cortical Button Technique. JBJS Open Access 2019;4(3). pii: e0013.1-6.
15. Bellringer SF, Phadnis J, Human T, Redmond CL, Bain GI. Biomechanical comparison of transosseus cortical button and footprint repair techniques for acute distal biceps tendon ruptures. Shouder Elbow 2020;12(1)54-62.
16. Porcellini G, Rotini R, Stignani Kantar S, Di Giacomo S. The elbow: principles of surgical treatment and rehabilitation. Springer 2018.
17. Tarallo L, Lombardi M, Zambianchi F, Giorgini A, Catani F. Distal biceps tendon rupture: advantages and drawbacks of the anatomical reinsertion with a modified double incision approach. BMC Musculoskelet Disord 2018;19(1):364.
18. Balabaud L, Ruiz C, Nonnenmacher J, Seynaeve P, Kehr P, Rapp E. Repair of distal biceps tendon ruptures using a suture anchor and an anterior approach. Hand Surg Br 2004;29(2):178–82.
19. Citak M, Backhaus M, Seybold D, Suero EM, Schildhauer TA, Roetman B. Surgical repair of the distal biceps brachii tendon: a comparative study of three surgical fixation techniques. Knee Surg Sports Traumatol Arthrosc 2011;19(11):1936–41.
20. Gupta RK, Bither N, Singh H, Kapoor S, Chhabra A, Garg S. Repair of the torn distal biceps tendon by endobutton fixation. Indian J Orthop 2012;46(1):71–6.
21. Tarallo L, Zambianchi F, Mugnai R, Costanzini CA, Catani F. Distal biceps tendon rupture reconstruction using muscle-splitting double-incision approach. World J Clin Cases. 2014;2(8):357–61.
22. Christopher L Camp MD, et al. Single-incision technique for repair of distal biceps tendon avulsions with intramedullary cortical button. Arthroscopy Techniques. 2016;5(2):303–7.
23. Grewal R, Athwal GS, MacDermid JC, Faber KJ, Drosdowech DS, El-Hawary R, King GJ. Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: a randomized clinical trial. J Bone Joint Surg Am 2012;94(13):1166–74.
24. Greenberg JA, Fernandez JJ, Wang T, Turner C. EndoButton-assisted repair of distal biceps tendon ruptures. J Shoulder Elbow Surg 2003;12:484–490.
25. DiRaimo MJ, Maney MD, Deitch JR. Distal biceps tendon repair using the toggle loc with zip loop. Orthopedics 2008;31:1201–1203.
26. Kodde IF, Bekerom MPJ van den, Eygendaal DE. Reconstruction of distal biceps tendon ruptures with a cortical button. Knee Surg Sports Traumatol Arthrosc 2013;23(3):919–925.
27. Lo EY, Li C-S, Van den Bogaerde JM. The effect of drill trajectory on proximity to the posterior interosseous nerve during cortical button distal biceps repair. Arthroscopy 2011;27:1048–1054.
28. Potapov A, Laflamme YG, Gagnon S, Canet F, Rouleau DM. Progressive osteolysis of the radius after distal biceps

tendon repair with the bioabsorbable screw. J Shoulder Elbow Surg 2011;20: 819-826.
29. Matthews EC, Brinsden MD, Murphy AJ, Guyver PM. The biotenodesis screw and endobutton technique for repair for acute distal biceps tendon rupture. Clin Arch Bone Joint Dis 2018;1:006.
30. Watson JN, Moretti VM, Schwindel L, Hutchinson MR. Repair techniques for acute distal biceps tendon ruptures: a systematic review. J Bone Joint Surg Am 2014; 96A(24):2086–90.
31. Amin NH, Volpi A, Sean Lynch T, Patel RM, Cerynik DL, Schickendantz MS, Jones MH. Complications of distal biceps tendon repair: A Meta-analysis of single-incision versus double-incision surgical technique. Orthop J Sports Med 2016;4(10):2325967116668137.
32. Spang JT, Weinhold PS, Karas SG. A biomechanical comparison of EndoButton versus suture anchor repair of distal biceps tendon injuries. J Shoulder Elbow Surg 2006;15:509–514.
33. Chavan PR, Duquin TR, Bisson LJ. Repair of the ruptured distal biceps tendon: a systematic review. Am J Sports Med 2008;36:1618–1624.
34. Mazzocca AD, Burton KJ, Romeo AA, Santangelo S, Adams DA, Arciero RA. Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. Am J Sports Med 2007;35:252–258.

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Original article

Reliability of open architecture anchors in biocomposite material: medium term clinical and MRI evaluation. Our experience

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Summary. *Objectives*: Comparing radiologic bone ingrowth and the clinical outcomes of an open-construct (PEEK) (polyether ether ketone) suture anchor with those of a bio-composite suture anchor (glycolic polylactic acid anchors, beta-tricalcium phosphate and calcium sulphate) in patients with arthroscopic rotator cuff repair. *Methods*: From August 2017 to January 2019, 33 patients of both sexes, aged between 44 and 78 years underwent arthroscopic rotator cuff repair for tears considered repairable with an extension not exceeding 4 cm. The bioabsorbable anchors used comprised glycolic polylactic acid/beta-tricalcium phosphate/calcium sulphate, and the non-absorbable anchors in polyetheretherketone (PEEK). All patients underwent MRI evaluation at 12 months postoperatively to determine complications and identify any re-tear. *Results*: Clinical scores showed an improvement from both clinical and functional point of view. There were no statistically significant changes compared to the physical examination. On radiographs, mobilizations, anchor pull-outs or other complications did not occur in each group. *Conclusions:* Shoulder function improved after complete repair of the rotator cuff and similar clinical results were achieved regardless of the material and shape of the suture anchor. The bioabsorbable anchors in innovative open architecture material seem to have results comparable to peek anchors. Unfortunately, further studies are needed to define the advantages in using one material compared to the other. (www.actabiomedica.it)

Key words: open architecture anchors, shoulder, rotator cuff, tear, tendon repair, arthroscopy.

Summary

The advent of modern suture anchor technology has not only revolutionized arthroscopic treatment options for management of complex shoulder pathology, but also engendered a scientific research of innovative materials to identify the ultimate composition and design. What began as an open procedure with trans-osseous suture fixation has evolved dramatically with the widespread adoption of an arthroscopic, anchor-based technique for rotator cuff repair. The open architecture anchors have an exclusive design that allows to reduce the material between the tendon and the bone, favouring the entry of blood into

the anchor. This should allow new bone ingrowth within the central canal within 12 weeks after implantation as evidenced in preclinical studies (1, 2). Furthermore, the reduction in the amount of material implanted in the shoulder compared to traditional anchors with a solid core should make an eventual surgical revision easier. Third generation anchors were made using PLLA (poly-L-lactic acid), PDLA (poly-D-lactic acid) or PEEK (polyetheretherketone) as base material. Some components are added to third generation anchors such as tricalcium beta-phosphate and calcium sulphate to obtain new bio-composite materials with greater osteoconductive properties. Although suture anchors are one of the most important advances in rotator cuff arthroscopic repair, their design and composition continue to improve. The goal of these changes is to facilitate bone formation and repair strength to achieve better clinical results and fewer complications.

Introduction

Tendon injuries of the rotator cuff are very common. Wear and tear is the most common mechanism of the tendon failure, related to the aging process of the individual. For this reason, this pathology shows a significant increase after the age of 50 years, although it is increasingly common to diagnose these lesions even in people under the age of 40 years, certainly due to the attention that patients begin to place on painful shoulders, as well as the technological improvement of diagnostic tools. The incidence of rotator cuff injury varies from 5% to 40%, and of course the prevalence increases with age up to 51% in patients over the age 80 of years (3). An epidemiological study by Yamamoto et al. have highlighted, an incidence of 20% of asymptomatic lesions in the population under study (4). The absence of symptoms was correlated with an involvement of the non-dominant side, with the negativity of subacromial impingement signs and with the presence of good functionality of the deltoid and periscapular muscles. Among the four anatomical elements of the so-called rotator cuff, the tendon most often affected by the rupture is the supraspinatus. Recent studies have highlighted how sex and associated pathologies, in particular metabolic and endocrine ones, can play a significant role in the progression of the tendon lesion. In fact, female sex appears to be more affected and moreover women seem to have less functional recovery after post-surgical rehabilitation. It also appears that thyroid diseases (5) represent a risk factor in the development of atraumatic lesions as well as diabetes and dyslipidaemias.

A full comprehensive classification of all the complex anatomical and clinical variables related to rotator cuff tears is not yet available. This classification help the surgeon to understand the characteristics of the lesion and to repair it as evidenced in some clinical studies (6). Among the systems that evaluate the size of the lesion, one of the most commonly used is that developed by DeOrio and Cofield (7). They classified the ruptures of the anterior-posterior part of the tendon, worn by the humeral head, measuring them during the surgery. The system detects small breaks if they are < 1 cm, medium if they are between 1 and 3 cm, massive if they are > 5 cm in thickness.

Obviously the treatment changes according to the type of lesion, so it ranges from simple infiltrative therapy (8) to surgical treatment (arthroscopic and non-arthroscopic) (9). Moreover, a systematic observation of MRI parameters could help the surgeon to predict the impossibility to obtain complete repair of rotator cuff tear (RCT) and to consider different surgical approach, as shown in other studies (10, 11, 12). Although suture anchors are one of the most important advances in rotator cuff arthroscopy, their design and composition continues to improve; first generation anchors (metal anchors) allowed good fixation, but several complications, including implant loosening and migration with secondary joint damage. The second generation anchors (in polyglycolic acid) resulted in a rapid dissolution after about 4 weeks with loss of stability. Those of the third generation were made using PLLA (poly-L-lactic acid), PDLA (poly-D-lactic acid) or PEEK (polyetheretherketone) as base material. Components are sometimes added to third generation anchors (13, 14, 15) such as tricalcium beta-phosphate and calcium sulphate, to obtain new bio-composite materials with greater osteoconductive properties (Table 1).

Table 1. Composition third generation anchors used in the study

PLGA Co-glycolic poly-L-lactic acid (65%)	β-tricalcium phosphate (15%)	Calcium sulphate (20%)
Has a long history of clinical use[16]	Longer-term (18 months) absorption profile for sustained bone formation[18]	Shorter-term (4-12 weeks) absorption profile for enhanced early bone formation and calcium release[20]
Degradation rate faster than PLLA[17]. Comprised of natural products: lactic acid and glycolic acid	Osteoconductive (physical) – Serves as a scaffold to allow for bone ingrowth[19]	Osteoconductive (biochemical) – Associated with increased levels of local growth factors[21]

Table 2. Study demographic data

	Group A	Group B	p
n° patients	15	18	
μAge ± SD (min-max), yr	67,13 ± 11,99 (60-78)	58,16 ± 8,20 (44-72)	p = 0,0162
Sex (male)	7 (46,67%)	11 (61,11%)	p = 0,494
Affected side = dominant side	12 (80%)	15 (83,33%)	p = 1
Constant pre-op ± SD	61,14 ± 15,6	53,6 ± 13,13	p = 0,162
ASES pre-op ± SD	48,46 ± 16,16	49,51 ± 10,84	p = 0,838

Legend: SD = standard deviation.

Materials and Methods

This retrospective cohort study covers the period from August 2017 to January 2019, 33 patients of both sexes (18 men and 15 women), aged between 44 and 78, were eligible for the inclusion criteria, with a RCT considered repairable at the preoperative assessment and with an extension not exceeding 4 cm measuring in preoperative-MRI. These patients were asked about the dominant limb and the side affected by the RCT. The patients were divided into 2 groups: 18 repairs have been done with glycolic polylactic acid anchors, beta-tricalcium phosphate and calcium sulphate (group B), and 15 repairs with non-absorbable peek anchors (group A); demographic data are reported in Table 2. Patients were administered internationally validated clinical-functional scales (Constant Score and ASES Score) (22, 23) in the preoperative and 12 months of follow-up, in addition to an accurate physical examination (grading of abduction, elevation, internal and external rotation). MRI checks were performed on all patients after 12 months of follow-up to evaluate any failures according to the assessment proposed by Sugaya et al. (24) (Table 3), degree of osteolysis and reabsorption (25) (Table 4, 5).

Table 3. Criteria developed by Sugaya et al. to evaluate tendon healing

	Sugaya classification
Type 1	Sufficient thickness, homogeneous tendon (low signal on T2 images)
Type 2	Sufficient thickness, partial high-intensity from within the tendon
Type 3	Inufficient thickness, without discontinuity
Type 4	Minor discontinuity on more than one slice, suggesting a small tear
Type 5	Major discontinuity suggesting a moderate or large tear

Table 4. Resorption grades of the anchors

Grading	**Anchor resorption**
Grade 1	Clearly visible
Grade 2	Visible
Grade 3	Barely visible, partially oedematous bleaching
Grade 4	Complete resorption

Statistical analysis

Descriptive analysis was performed to characterize the study population.

Chi-square, Mann-Whitney U test, T-student or Fisher's exact test were used to compare groups, as appropriate. A $p < 0.05$ was considered statistically significant in all analyses. All analysis were perfomed using STATA software version 13 (StataCorp, College Station, TX).

Results

In the international scores there was an improvement from both clinical and functional point of view in both patient groups with a comparable trend between groups A and B. There were no statistically significant changes compared to the physical examination. All of the 33 patients achieved 12-month follow-up: 18 of them performed repair with glycolic polylactic acid, beta-tricalcium phosphate and calcium sulphate (Figure 1), and 15 of them with peek anchor (Figure 2). To MRI, according to the Sugaya classification, group A registered 3 type 1, 12 type 2 and 3 type 3; in group B there are 2 type 1, 11 type 2 and 2 type 3 (Table 6).

On MRI, mobilizations, anchor pull-outs or other complications did not occur in group A and B (Table 7).

Discussion

The study showed that the degree of bone growth in PEEK anchors was comparable to that of anchors with biocomposite material in the healing phases. Shoulder function improved after complete repair of the rotator cuff, regardless of material. The complication rate on postoperative magnetic resonance imaging and, in particular, the re-rupture rate at 12 months did not show significant differences between the 2 groups. Recently, materials have been made to increase biocompatibility and reduce bone-related complications. Kim et al. (26, 27) suggested that both the regulation of polymer properties and the integration of osteoconductive material improved biocompatibility and revealed that biocomposite suture anchors reduced the extent of cyst formation around anchors and osteolysis.

The criteria for an ideal bioabsorbable implant are different; as evidenced by the study of Speer and Warren (28) and that of Milewski et al. (29), a good suture anchor must firstly provide adequate initial fixation force to adhere the soft tissues to the bone and maintain satisfactory strength over time to promote the mechanical integrity of the tissues themselves; it must be made with completely safe materials

Table 5. Grading of osteolysis reaction of the anchors

Grading	Anchor osteolysis
Grade 0	without fluid signal
Grade 1	with a punctual fluid signal within the anchor area
Grade 2	with separable sections of anchor material and fluid accumulation at the tip of the anchor

Table 7. Results of our analysis (2)

Open architecture anchors in biocomposite material Follow-up 1y	
Grading of the resorption (min-max) (1-4)	82% grade 3 18% grade 2
Grade of osteolysis (min-max) (0-2)	88% grade 0 12% grade 1

Table 6. Clinical and radiological results (1)

		Group A	Group B	
		Follow-up 1y	Follow-up 1y	
μ Constant Score post-op ± SD		94,64 ± 4,43	95 ± 4.251	p = 0,829
μ ASES Score post-op ± SD		96± 1,7	95,83 ± 4,27	p = 0,893
Sugaya class (post-op)	Type 1 (%)	13,3	16,7	
	Type 2 (%)	73,3	66,7	
	Type 3 (%)	13,3	16,7	

Legend: SD = standard deviation.

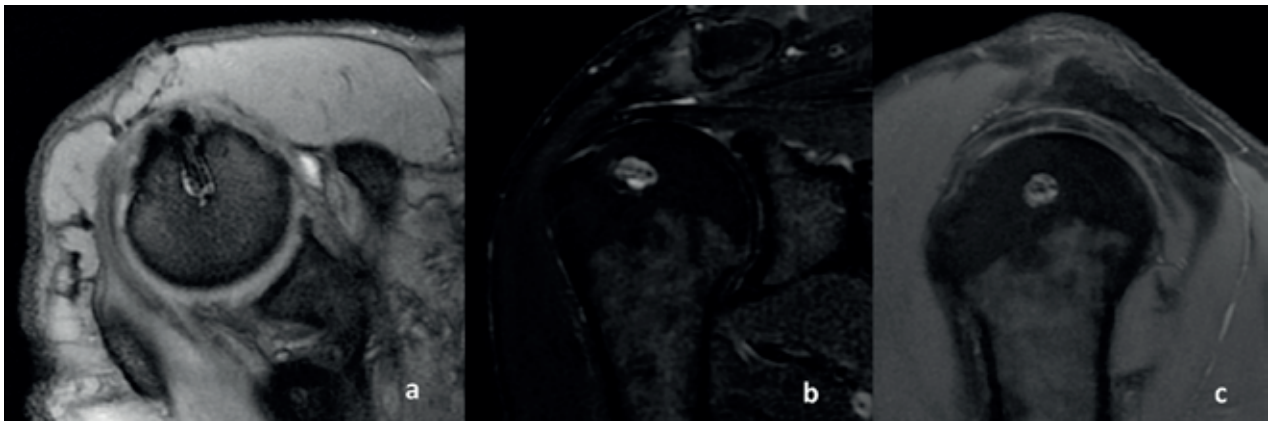

Figure 1. Open architecture anchor, 1 year. Right shoulder: T2 Axial (a), STIR Cor (b), FS T2 Sag (c) sequences.

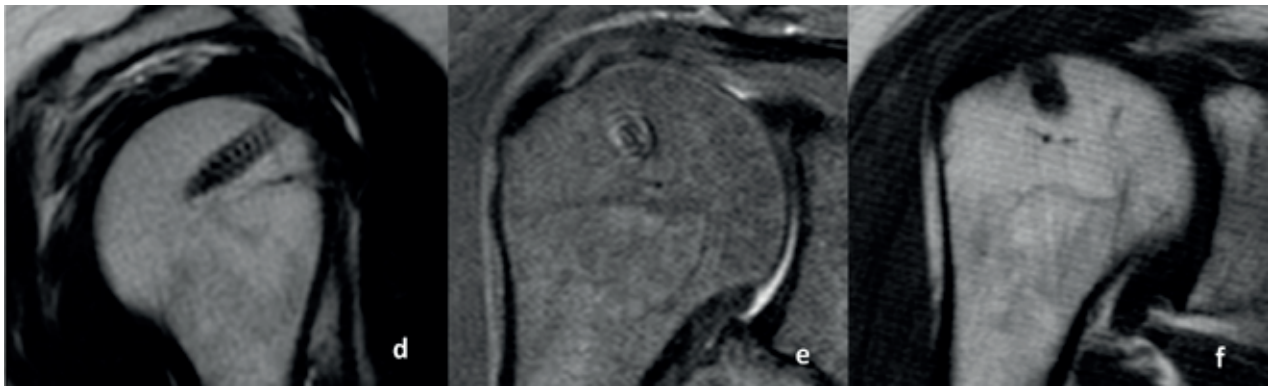

Figure 2. Peek anchor, 1 year. Right shoulder: FS T2 Sag (d), STIR Cor (e), FS T1 Cor (f) sequences.

(no toxicity, antigenicity, pyrogenic or carcinogenic activity); it must not be bioabsorbed too slowly to avoid potential breakage and migration of the anchor; finally, it must be completely replaced by the bone. However, due to the nature of the biodegradable material, bone growth in the anchor requires a prolonged period of time. As the work of Barber et al. suggests (30), the anchors in biocomposite material are completely degraded after 3 years from implantation. Certainly, the already demonstrated potential advantages of open architecture anchors should not be underestimated (they avoid the use of metal, good biocompatibility, good resistance, rapid re-absorption, advantage in case of overhauls, low complications intended as pull outs, foreign body reactions, synovitis, anchor fragmentation, bone cysts, osteolysis). In a study by Chahla J. et al. (31) open architecture anchors led to higher bone growth surrounding the anchor and greater total bone mineral mass within the anchor due to its larger volume.

Limitations

This study has certain limitations. We used limited number of patients. However, measurements taken from the MRI imaging and all the clinical evaluations were done by different examiner; furthermore, the pre and post operative MRI, where the measurements were done, were not performed in a single centre and by the same radiologist; lastly, group B patients are on average younger than group A patients.

Conclusion

Shoulder function improved after complete repair of the rotator cuff and similar clinical results were achieved regardless of the material and shape of the suture anchor. The anchors in innovative open architecture material in glycolic polylactic acid, tricalcium beta-phosphate and calcium sulphate seem to have results comparable to peek anchors, in terms of medium-term clinical-functional results and medium-term imaging. Certainly further studies are needed to define the advantages in using one material compared to the other.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Aug Deprés-Tremblay G, Chevrier A, Snow M, Hurtig MB, Rodeo S, Buschmann - Rotator cuff repair: a review of surgical techniques, animal models, and new technologies under development. J Shoulder Elbow Surg. 2016.
2. Bulman S, Cotton N, Barnes G. Bone&Joint Science -Vol6(2)Dic 2016.
3. Templenhof S, Rupp S, Seil R. Age related prevalence of rotator cuff tears in asymptomatic shoulders. J Shoulder Elbow Surg 199;8:296–9.
4. Yamamoto A, Takagishi K, Osawa T, et al. Prevalence and risk factors of a rotator cuff tear in the general population. J Shoulder Elbow Surg 2010;19:116–20.
5. Francesco Oliva, Leonardo Osti, Johnny Padulo and Nicola Maffulli. Epidemiology of the rotator cuff tears: a new incidence related to thyroid disease. Muscles Ligaments Tendons J. 2014 Jul-Sep; 4(3): 309–314.
6. Di Benedetto ED[1], Di Benedetto P, Fiocchi A, Beltrame A, Causero A. Partial repair in irreparable rotator cuff tear: our experience in long-term follow-up. Acta Biomed. 2017 Oct 18;88(4S):69–74.
7. DeOrio J.K., Cofield . "Results of a second attempt at surgical repair of a failed initial rotator-cuff repair". J. Bone Joint Surg Am 1984 Apr; 66(4):563–7.
8. Di Benedetto P, Di Benedetto ED, Beltrame A, Gisonni R, Cainero V, Causero A. Arthroscopic rotator cuff repair with or without PrP: our experience. Acta Biomed. 2016 Apr 15;87 Suppl 1:75–83.
9. Iannotti JP. Full-thickness rotator cuff tears: factors affecting surgical outcome. J Am Acad Orthop Surg 1994; 2: 87–95.
10. Di Benedetto P, Beltrame A, Cicuto C, Battistella C, Gisonni R, Cainero V, Causero A. Rotator Cuff Tears Reparability Index Based on Pre-Operative MRI: Our Experience. Acta Biomed, 90 (1-S), 36–46. 2019 Jan 10.
11. Kim JY, Park JS, Rhee YG. Can Preoperative Magnetic Resonance Imaging Predict the Reparability of Massive Rotator Cuff Tears? Am J Sports Med. 20 Jun;45(7): 1654–1663. doi: 10.1177/0363546517694160. Epub 2017 Mar 8.
12. Kuptniratsaikul V, Laohathaimongkol T, Umprai V, Yeekian C, Prasathaporn N. Pre-operative factors correlated with arthroscopic reparability of large-to-massive rotator cuff tears. BMC Musculoskelet Disord. 2019 Mar 18;20(1):111.
13. Denard PJ, Burkhart SS. The evolution of suture anchors in arthroscopic rotator cuff repair. Arthroscopy. 2013;29: 1589–1595.
14. Sugaya H, Maeda K, Matsuki K, Moriishi J. Repair integrity and functional out-come after arthroscopic double-row rotator cuff repair. A prospective outcomestudy. J Bone Joint Surg Am 2007;89:953–60.
15. Long-term degradation of poly-lactic co-glycolide/β-tricalcium phosphate biocomposite anchors in arthroscopic bankart repair: a prospective study. Randelli P, Compagnoni R, Aliprandi A, Cannaò PM, Ragone V, Tassi A, Cabitza P. Arthroscopy. 2014 Feb;30(2):165–71.
16. Suchenski et. al. (2010) J. Arthro. and Rel. Res. Vol. 26(6).
17. Chih-Chu Chang, Section IV:44, "Biodegradable Polymeric Biomaterials" in The Biomedical Engineering Handbook. Bronzino JD Ed. CRC Press.
18. Costantino and Friedman (1994) Otolaryngol Clin North Am. 1994 Oct;27(5).
19. Ogose et al (2006) Biomaterials Vol. 27(8).
20. Pietrzak and Ronk (2000) J Craniofacial Surg. Vol 11(4).
21. Walsh et al (2003) Clin. Orthop. Rel. Res. Vol 406.
22. Constant CR, Murley AHG. A clinical method of functional assessment of the shoulder. Clin Orthop. 1987;214: 160–164.
23. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness.Michener LA, McClure PW, Sennett BJ.J Shoulder Elbow Surg. 2002 Nov-Dec;11(6):587–94.
24. Yoshida M, Collin P, Josseaume T, Lädermann A, Goto H, Sugimoto K, Otsuka T. Post-operative rotator cuff integrity, based on Sugaya's classification, can reflect abduction muscle strength of the shoulder. Knee Surg Sports Traumatol Arthrosc. 2018 Jan;26(1):161–168.
25. Vonhoegen J, John D, Hägermann C. Osteoconductive resorption characteristics of a novel biocomposite suture anchor material in rotator cuff repair. J Orthop Surg Res. 2019 Jan 9;14(1):12.
26. Kim SH[1], Oh JH, Lee OS, Lee HR, Hargens AR. Postoperative imaging of bioabsorbable anchors in rotator cuff repair. Am J Sports Med. 2014 Mar;42(3):552–7.
27. Kim SH, Kim DY, Kwon JE, Park JS, Oh JH. Perianchor cyst formation around biocomposite biodegradable suture anchors after rotator cuff repair. Am J Sports Med

2015;43:2907–2912.
28. Speer KP, Warren RF. Arthroscopic shoulder stabilization: a role for biodegradable materials. Clin Orthop Relat Res. 1993;291:67–74.
29. Milewski, MD, Diduch, DR, Hart, JM, Tompkins M, Ma SY, Gaskin, CM. Bone Replacement of Fast-Absorbing Biocomposite Anchors in Arthroscopic Shoulder. Labral Repairs American Journal of Sports Medicine. 2012;40(6): 1392–1401.
30. Barber FA, Dockery WD, Cowden CH 3rd. The degradation outcome of biocomposite suture anchors made from poly L-lactide-co-glycolide and beta-tricalcium phosphate. Arthroscopy 2013;29:1834–1839.
31. Chahla J, Liu JN, Manderle B, Beletsky A, Cabarcas B, Gowd A, Inoue N, Chubinskaya S, Trenhaile S, Forsythe B, Cole B, Verma N. Bony Ingrowth of Coil-Type Open Architecture Anchors Compared with Screw-Type PEEK Anchors for the Medial Row in Rotator Cuff Repair. A Randomized Controlled Trial, Arthroscopy: The Journal of Arthroscopic and Related Surgery (2020).

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Original article

Two rotator cuff tear repair techniques for sovraspinatus tendon tear: transosseous sharc-ft vs single row repair

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Summary. *Background:* Despite rotator cuff repair techniques have developed significantly in last decade, pushed by the progress in technology and materials, the treatment of rotator cuff tears and re-tears is still a big challenge for shoulder surgeons. The aim of this study is to perform clinical and radiological evaluation (ultrasound and MRI) of patients treated with transosseous sharc-ft, and single row techniques for sovraspinatus rotator cuff tear at 6, 12 and 24 months follow up. *Methods:* Twenty-eight consecutive patients who underwent arthroscopic repair for rotator cuff tear were enrolled in the study and divided in two different groups: group A (14 patients) underwent a single row technique repair; group B (14 patients) underwent a transosseous sharc-ft technique repair. All participants had MRI or ultrasound examination confirmed full-thickness tears of sovraspinatus tendon before surgery. All the patients underwent clinical evaluation at 45 days, 3 months, 6 months, 12 and 24 months post-operatively with VAS, Dash, Constant and ASES score. Diagnostic ultrasound examination was performed at 6 months follow up while the MRI examination at 1 and 2 year follow up. *Results:* The whole primary variables didn't show any significant difference and the groups were homogenous (age, Goutallier fatty infiltration, VAS, DASH, Constant, ASES). Some statistically significant differences are visible at discrete variables in a specific time: Dash at 12 months and Constant at 24 months show a significant improvement versus single-row technique. *Conclusion:* The arthroscopic transosseous repair technique with sharc-ft showed excellent results with little significant statically difference between this technique and the single row for this kind of lesion after 1 year of follow-up. Clinical data from this study confirmed, with the help of ultrasound examination and MRI, the excellent clinical outcome obtained by the patients. Further studies are needed to find differences between these techniques in the repair of large and massive rotator cuff lesions. (www.actabiomedica.it)

Key words: rotator cuff repair, sovraspinatus, transosseous, arthroscopic repair

Introduction

Despite rotator cuff repair techniques have developed significantly in last decade, pushed by the progress in technology and materials, the treatment of rotator cuff tears and re-tears is still a big challenge for shoulder surgeons. Many authors have already analyzed the percentage of re-tear in rotator cuff repair comparing different type of suture techinques: single row (SR), double row (DR), transosseous equivalent (TE), showing a lower percentage in re-tear for TE or DR technique (1).

Recently Park et al have confirmed the better outcome of suture bridge (transosseous equivalent)

technique in rotator cuff repair reporting a lower percentage of re-tears at 6 months and a better clinical follow up in comparison to what reported by Miller in a previous study (2).

Transosseous repair technique of rotator cuff tear, in particular with the use of sharc-ft device, has already been studied from a biomechanical stand point showing better biomechanical performance in the extension of foot print coverage and contact pressure (3).

The aim of this study is to perform a clinical and radiological evaluation (ultrasound and MRI) of patients treated with transosseous sharc-ft and single row techniques for sovraspinatus rotator cuff tear at 45 days, 3 months, 6 months, 12 and 24 months follow up.

Materials & Methods

Patients

From March 2014 to January 2016 twenty-eight consecutive patients who underwent arthroscopic repair for rotator cuff tear in the Orthopaedic and Traumatologic Department (Polyclinic University Hospital in Modena) were enrolled in the study and randomly divided in two different groups: group A (14 patients) underwent a single row technique repair (Table 1); group B (14 patients) underwent a transosseous sharc-ft technique repair (Table 2). All participants had MRI or ultrasound examination confirmed full-thickness tears of sovraspinatus tendon before surgery. The indication for surgery was, in all cases, after failure of a non-operative management. All the patients signed informed consent before participating in the study. Tear size satisfying our inclusion criteria (3 cm in greatest dimension) was confirmed at the time of surgery in all patients under arthroscopic visualization. The tear size was the same among the two groups (in compliance with the inclusion criteria). Exclusion criteria were: tears of two or more tendons; massive tear more than 3 cm of dimension; subscapularis tendon tear; Goutallier classification more than 3; gleno-hu-

Table 1: preoperative data Group A

GROUP A																			
Preoperative data																Preoperative clinic			
History							Surgery					Rotator cuff tear							
N°	Patient	Age	Sex	Sport	Affected side	Dominant side	Treatement	Type	Deviat. protoc.	CLBB tenotomy	Acromionplasty	Form	Position	Patte	Goutallier	VAS	DASH	Constant	ASES
1	**C.G.**	58	F	no	sx	dx	02/04/14	Single-row	\	Yes	No	L	Superior	2	1	4	62,07	52	43,3
2	**G.M.R.**	68	F	no	dx	dx	04/06/14	Single-row	\	Yes	Yes	L	Superior	2	2	7	49,11	44	36,67
3	**B.M**	53	F	no	sx	dx	06/05/15	Single-row	\	No	Yes	L	Superior	1	1	6	10	72	72
4	**C.D.**	53	M	no	dx	dx	07/05/15	Single-row	\	No	Yes	L	Superior	1	1	9	25	63,5	43,3
5	**N.A.**	61	F	no	dx	dx	13/05/15	Single-row	\	Yes	Yes	U	Superior	1	1	6	71	23	20
6	**M.C.**	58	M	no	dx	dx	27/05/15	Single-row	\	Yes	Yes	U	Superior	1	1	5	72	6,5	70
7	**M.A.**	39	M	thay boxe	dx	sx	22/07/15	Single-row	\	Yes	Yes	U	Superior	2	1	7	73	36	41,6
8	**Z.M**	54	F	no	dx	sx	09/09/15	Single-row	\	Yes	Yes	L	Anterior	1	1	4	31,25	66	56
9	**B.R.**	61	F	no	dx	dx	09/09/15	Single-row	\	Yes	No	U	Superior	1	1	3	43,33	61	58
10	**Z.A.**	59	M	no	dx	dx	24/09/15	Single-row	\	Yes	Yes	L	Anterior	2	2	4	47,5	47	46,9
11	**A.R.**	45	M	no	dx	dx	01/10/15	Single-row	\	No	Yes	U	Superior	2	2	0	23,33	65	61,3
12	**G.C.**	61	F	no	dx	dx	08/10/15	Single-row	\	No	Yes	U	Superior	1	1	5	37,17	58	62,3
13	**C.G.**	38	M	no	dx	dx	11/12/15	Single-row	\	No	Yes	L	Anterior	1	1	2	47,5	46	50
14	**S.C.**	50	F	no	dx	dx	08/01/16	Single-row	\	Yes	Yes	L	Superior	1	1	6	24,2	57	55
AVERAGE		**54**												**1,4**	**1,2**	**5**	**44**	**49,8**	**51,8**

Table 2. preoperative data Group B

	GROUP B																		
	Preoperative data															Preoperative clinic			
		History						Surgery				Rotator cuff tear							
N°	Patient	Age	Sex	Sport	Affected side	Dominant side	Treatement	Type	Deviat. protoc.	CLBB tenotomy	Acromionplasty	Form	Position	Patte	Goutallier	VAS	DASH	Constant	ASES
1	**D.M.**	55	M	no	dx	dx	05/03/14	Sharc-FT	\	Yes	Yes	L	Anterior	1	1	6	45	63	58,33
2	**B.R.**	61	F	no	sx	dx	07/05/14	Sharc-FT	\	Yes	Yes	L	Anterior	2	1	6	29,31	47	48,33
3	**B.M.**	60	F	no	dx	dx	18/06/14	Sharc-FT	\	Yes	No	L	Superior	2	2	5	57,41	42	40,01
4	**M.T.**	62	M	no	dx	dx	29/10/14	Sharc-FT	\	Yes	Yes	L	Superior	1	1	8	53,5	28	23,35
5	**P.A.A**	48	F	no	dx	dx	03/12/14	Sharc-FT	\	No	Yes	L	Superior	2	1	7	34,2	37	35
6	**T.L.**	60	F	no	dx	dx	23/04/15	Sharc-FT	\	Yes	Yes	L	Superior	1	2	6	51	45	42
7	**R.B.**	64	F	no	dx	dx	23/04/15	Sharc-FT	\	Yes	Yes	L	Superior	1	2	7	57,8	33	27
8	**B.F.**	57	M	no	sx	dx	19/05/15	Sharc-FT	\	Yes	Yes	L	Superior	1	1	2	3	84	85
9	**M.L.**	54	F	no	dx	dx	04/06/15	Sharc-FT	\	No	No	U	Superior	1	1	4	62	26	43,3
10	**V.G.**	58	M	tennis	dx	dx	12/08/15	Sharc-FT	\	No	Yes	L	Anterior	1	1	0	17,5	75,5	81,6
11	**M.M.**	44	M	no	dx	dx	16/09/15	Sharc-FT	\	Yes	Yes	L	Anterior	1	1	4	40	58	56
12	**O.M.**	59	M	no	dx	dx	24/09/15	Sharc-FT	\	Yes	No	U	Superior	1	1	0	0	90	89
13	**F.E.**	60	F	no	dx	dx	02/12/15	Sharc-FT	\	No	yes	L	Anterior	2	1	3	57,69	61	58,3
AVERAGE		**57**												**1,3**	**1,2**	**4**	**39,1**	**53**	**52,9**

meral arthritis; neurologic lesion; acromion-clavicular disease; metabolic disease; smoke habit more than 20 cigarettes per day.

Surgery

The same experienced shoulder surgeon performed all rotator cuff repairs. All procedures were performed with the patient under general anesthesia and supplemented with a preoperative interscalene block placed under ultrasound guidance.

Sovraspinatus tendon repair was performed using the single row (group A) or the transosseous technique (group B) previously described by Pellegrini et al (Fig. 1) (4).

All patients were immobilized after surgery using an abduction sling for 3 weeks (Donjoy Ultrasling III AB 45°, DJ Orthopedics, LLC, Vista, California) and after this initial phase a standardized supervised physical therapy protocol was initiated (Fig. 2). Patients were instructed to remove the abduction sling only for daily bathing and dressing needs during the first 3 weeks after surgery, and passive range of motion, excluding pendulums, was not permitted during this period. The rehabilitation protocol included pas-

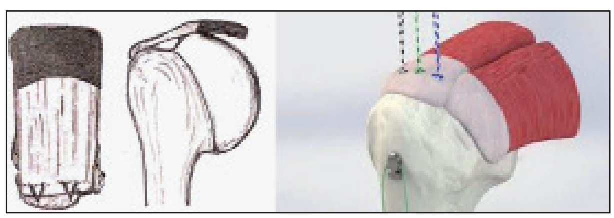

Figure 1. comparison between single-row technique vs. Sharc-ft technique

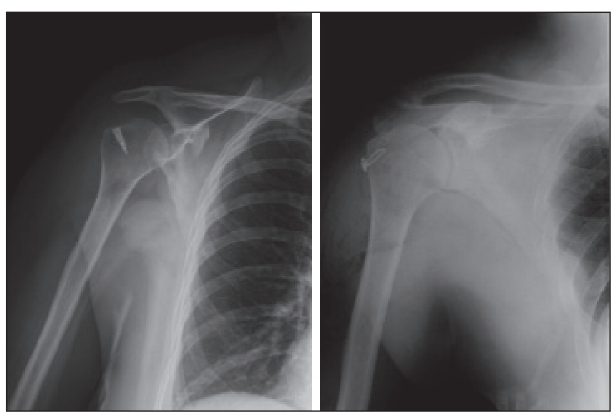

Figure 2. post-operative X-Ray: anchor vs. Sharc-ft

sive range of motion from weeks 2 to 6, with active and active-assisted range of motion thereafter. A focused strengthening program was initiated at week 10.

Clinical evaluation, Ultrasound and MRI

All the patients underwent clinical evaluation at 45 days, 3 months, 6 months, 12 months and 2 year post-operatively with VAS, Dash, Constant and ASES score (5-7).

Diagnostic ultrasound examination was performed at 6 months follow up while the MRI examination at 1 and 2 year follow up.

Ultrasound examination was performed using ultrasound scanner (Model iU22 Philips) with linear high-frequency probe (L12-5 MHz). A tendon was considered not torn if at ultrasonography continuous and stretched fibers over the humeral head and no alteration of ultrasound signal was visualized (8;9).

At the time of 12 months and 24 months follow up, all the patients underwent an MRI evaluation with a 1,5 Tesla MRI in order to evaluate the foot print coverage and the integrity of the tendon repaired. The tendon evaluation was performed according to Sugaya et al classification (10).

In addition, X-ray examination of the shoulder was performed in true AP and axillary projection. Authors look for osteolytic lesion around sharc-ft device, suggestive for device mobilization.

Statistical analysis

MATLAB software (MathWorks, Natick, MA, USA) was used to perform statistical analysis of data. The normal distribution of the data was checked and one-way repeated ANOVA or the nonparametric Friedman test was used to evaluate the effect of the repair. Sample size was calculated with the aim to achieve a minimum beta value higher than 0.8 statistical power (alpha = 0.05) for scores data analysis; 13 cases were calculated as an adequate number (1 standard deviation was set to consider the difference as statistically significant). Because of the possibility of drop-out, a higher number of patients were included in the study (i.e. 14 patients). A multiple-comparison test was used for pairwise post hoc analyses. Data analysis was applied to evaluate homogeneity between groups involved in the study and single scores have been compared at different timing.

A two-tailed p value < 0.05 was considered significant.

Results

One patients of group B was excluded from the study for personal reason. The T- Student test used for statistical analysis showed no differences ($P > 0,05$) in the two groups of patients enrolled in terms of pre study evaluation (Age, Goutallier fatty infiltration, tendon retraction, VAS, DASH, ASES and Constant score collected before the study). The whole primary variables didn't show any significant difference and the groups were homogenous.

Group A

This patients group underwent single row technique repair; the mean age was 54 years (min 38 – max 68). The 14 patients were 8 women and 6 men; for 10 patients the shoulder was the dominant side. Nine patients underwent biceps tenotomy and 12 patients acromionplasty. The sovraspinatus tear was L-shape tear for 8 patients and U-shape in the other 6.

At the time of 45 days after surgery the clinical follow up showed a VAS value of 5.3, a Dash score of 43.2 a Constant score of 39.5 and an ASES score of 41.

At 90 days of follow up the Group A patients had a VAS value of 3.6, a Dash score of 26.7 a Constant score of 60.8 and an ASES score of 65.5.

At 6 months the clinical data collected were: VAS value of 2.1, a Dash score of 21.3 a Constant score of 62.7 and an ASES score of 71.5. In ultrasound examinations authors found no case of re-tear at 6 months of follow up confirmed by the good to excellent clinical outcome emerged with the scores collected (table 1). Moreover, at X-ray examination authors find no osteolytic lesion.

At 1 year follow-up the patients had a VAS value of 1.7, Dash score of 13.2, Constant score of 75 and an ASES score of 80.3. Authors find a re-tear with the MRI evaluation. (Fig. 3).

At 2 years clinical examination showed a VAS value of 1.5, Dash score of 9.1, Constant score of 78.6

and an ASES score of 83. The patients enrolled in the study underwent the MRI control showing same results already collected in the previous MRI control. The patient with re-tear confirmed by poor clinical outcome asked for a new surgical approach (Table 3).

Group B

This patients group underwent transosseous shark-ft technique repair; the mean age was 57 years (min 44 – max 64). The 13 patients were 7 women and 6 men; for 11 patients the shoulder affected was the dominant side. Nine patients underwent biceps tenotomy and 10 patients acromionplasty. The sovraspinatus tear was L-shape tear for 11 patients and U-shape in the other 2.

At the time of 45 days after surgery the clinical follow up showed a VAS value of 4.7, a Dash score of 42.8 a Constant score of 37.7 and an ASES score of 37.82.

At 90 days of follow up the Group B patients had a VAS value of 2.8, a Dash score of 22.6 a Constant score of 64.5 and an ASES score of 71.4.

At 6 months the clinical data collected were: VAS value of 1.2, a Dash score of 12.8 a Constant score of 73.5 and an ASES score of 78.6. In ultrasound examinations authors find no case of re-tear at 6 months of follow up confirmed by the good to excellent clinical outcome emerged with the scores collected (table 2). Moreover at X-ray examination authors found no osteolytic lesion (Fig. 4).

At 1 year follow-up the patients had a VAS value of 0.9, Dash score of 3.5, Constant score of 82.5 and an ASES score of 85; none of the Group B cohort had re-tear at radiological examination with MRI.

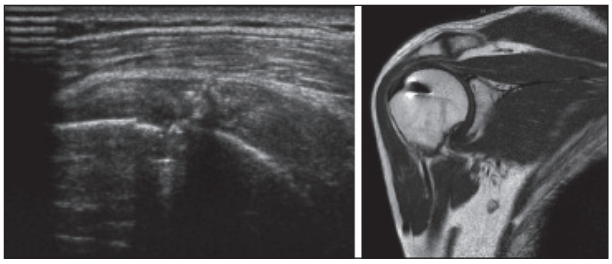

Figure 3. Ultrasound evaluation at 6 months and MRI evaluation at 24 months for patient treated with screw fixation (group A)

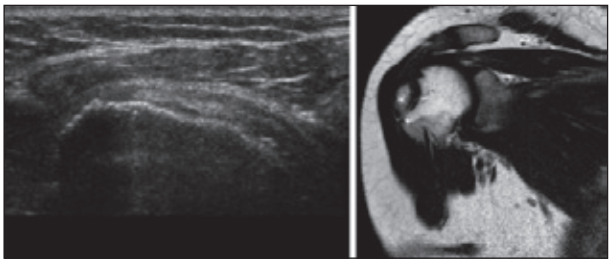

Figure 4. Ultrasound evaluation at 6 months and MRI evaluation at 24 months group B.

Table 3. clinic evaluation Group A at 24 months

GROUP A											
		Clinic evaluation 24 months				MRI					
N°	**Patient**	**VAS**	**DASH**	**Constant**	**ASES**	**Healing**	**Re-tear**	**Sugaya**	**Goutallier**	**Complications**	**Other**
1	**C.G.**	5	61,2	49,5	43,3	NO	YES	5	3	Pain	\
2	**G.M.R.**	0	0	88	90	YES	NO	1	0	NO	\
3	**B.M**	0	1	92	98	YES	NO	1	0	NO	\
4	**C.D.**	2	1,7	84	90	YES	NO	1	1	NO	\
5	**N.A.**	1	12,4	68	70,3	YES	NO	3	1	NO	\
6	**M.C.**	2	5,8	74	81,6	YES	NO	2	0	NO	\
7	**M.A.**	0	4,2	82	96,6	YES	NO	1	0	NO	\
8	**Z.M**	1	5,8	76	88,3	YES	NO	1	0	NO	\
9	**B.R.**	1	2,9	85	93,3	NOT PERFORMED					
10	**Z.A.**	6	20,6	55	60	YES	NO	1	0	NO	AC arthritis
11	**A.R.**	1	0,8	93	90	NOT PERFORMED					
12	**G.C.**	0	0	85	86,3	YES	NO	1	0	NO	\
13	**C.G.**	2	2,5	91	78,9	YES	NO	1	0	NO	\
14	**S.C.**	0	8,6	78	94,9	NOT PERFORMED					
						11 MRI, 91% healing					
						1 AC arthritis, 9%					
AVERAGE		**1,5**	**9,1**	**78,6**	**83,0**			**1,6**	**0,5**		

At 2 years clinical examination showed a VAS value of 0.9, Dash score of 2.9, Constant score of 87.1 and an ASES score of 89.4. The patients enrolled in the study underwent the MRI control showing same results already collected in the previous MRI control (Table 4).

To summarize the data comprehension we evaluate from a statistical standpoint the various variables as a function of time. We used a two-sample t-test procedure and the null hypothesis, intended as the difference between two population means is equal to zero (H0: m1 - m2 = 0) and tests it against an alternative hypothesis two-tailed (m1 - m2 ≠ 0). If the test's p-value is less than the chosen significance level 0,05, we reject the null hypothesis. (tab 5). Some statistically significant differences are visible at discrete variables in a specific time: Dash at 12 months and Constant at 24 months show a significant improvement versus single-row technique.

Discussion

Rotator cuff tears are usually associated with pain, weakness and loss of function. In particular this kind of lesions occur both in heavy worker population as well as sedentary people leading to poor autonomy in daily activities and frequently to an important social cost. Moreover, repair technique for these lesions are usually difficult and associated with a re-tear rate.

One report published in 2007 involved a prospective series of 106 patients with rotator cuff tears repaired using a double-row technique (11); Although the overall re-tear rate was 17%, the re-tear rate in large to massive rotator cuff tears was 40% on MRI. In the same year, the re-tear rate of large to massive tears was reported to be 17% using the double-row technique (11). Huijsmans et al reported a failure rate in double-row repairs of large to massive cuff tears of 36% on ultrasonography (12).

Table 5. statistical analysis of various variables as a function of time

Timing	45 days	3 months	6 months	12 months	24 months
	p-value	p-value	p-value	p-value	p-value
VAS	0,577	0,580	0,268	0,280	0,346
DASH	0,962	0,602	0,147	0,036	0,176
Constant	0,776	0,529	0,133	0,079	0,050
ASES	0,608	0,354	0,218	0,159	0,188

Table 4. clinic evaluation Group B at 24 months

GROUP B											
		Clinic evaluation 24 months				MRI					
N°	Patient	VAS	DASH	Constant	ASES	Healing	Re-tear	Sugaya	Goutallier	Complications	Other
1	D.M.	1	5,4	86,5	88	YES	NO	1	0	NO	\
2	B.R.	0	1,7	73,5	79,6	YES	NO	1	0	NO	\
3	B.M.	0	1,8	88	93	YES	NO	1	1	NO	AC arthritis
4	M.T.	0	1.7	85	86,6	YES	NO	1	0	NO	AC arthritis
5	P.A.A	1	1.7	89	93,3	YES	NO	1	0	NO	\
6	T.L.	3	5,8	88	76,6	YES	NO	1	0	NO	AC arthritis
7	R.B.	0	0,8	95	100	YES	NO	1	1	NO	AC arthritis
8	B.F.	0	0,8	96,6	100	YES	NO	1	0	NO	\
9	M.L.	3	1,7	90	85,6	YES	NO	1	0	NO	AC arthritis
10	V.G.	0	0,8	89	100	YES	NO	1	0	NO	\
11	M.M.	0	1.2	97	92,6	YES	NO	1	0	NO	\
12	O.M.	2	2,5	77	86,6	YES	NO	1	0	NO	\
13	F.E.	2	7,5	78	80	YES	NO	1	0	NO	AC arthritis
						13 MRI, 100% healing					
						6 AC arthritis, 45%					
AVERAGE		0,9	2,9	87,1	89,4			1,0	0,2		

The above cited studies were performed using arthroscopic double-row repair. On the other hand, several studies have employed arthroscopic suture bridge repair. One study in 2008, 25 patients who had undergone arthroscopic suture bridge repair at a mean follow-up of 14.61 months and MRI resulted in 88% of repairs healed; however, massive tears cases in that study were only 3 (13).

This study is the first in literature evaluating re-tear after transosseous repair technique with the use of sharc-ft for rotator cuff repair; authors opted for using ultrasound examination at 6 months follow-up as previously reported in many papers (1,2) supported by Codsi (14). In the community setting, ultrasound may be used to evaluate the integrity of a repaired rotator cuff tendon and represents a comparable alternative to MRI when evaluating the integrity of a rotator cuff repair (14).

Both diagnostic ultrasound and magnetic resonance imaging (MRI) are used for investigation of the presence and severity of rotator cuff lesions. There is no consensus as to which is the more accurate and cost-effective study. Shoulder ultrasound has the advantage of being relatively inexpensive and widely available and permits dynamic imaging. However, several papers have reported wide variability in the ability of ultrasound to accurately differentiate between partial thickness and full-thickness rotator cuff tears, particularly between observers (15-17). For this reason the authors choose to follow the patients at 1 and 2 year after surgery with the MRI evaluation.

Rutten MJ et al. (2010) refuted the hypothesis that ultrasound of the shoulder is operator-dependent and related to experience. In this study, there was excellent agreement for the detection of rotator cuff tears, which only slightly improved with the increasing experience of the general radiologist. Accuracy of rotator cuff tear detection was high and in accordance with the results in the literature (18).

In our study the whole primary variables didn›t show any significant difference and the groups were homogenous (age, Goutallier fatty infiltration, VAS, DASH, Constant, ASES). Some statistically significant differences are visible at discrete variables in a specific time: Dash at 12 months and Constant at 24 months show a significant improvement versus single-row technique. The MRI evaluation at 1 year follow up shows, moreover, how the transosseous techniques can help the evaluation of tendon repair avoiding the screw interference and bone edema around the screws.

The transosseous approach has been known as a valid repair strategy. Over time, various criticisms were made about this technique mainly ascribable to two main categories: technical difficulties mainly related to the reproducibility in an arthroscopic environment and stability of the construct (in the suture–bone contact area).

The authors believe that the problems above described can be solve in a transosseous approach by interposing a device isolating sutures from bone (Sharc-Ft®). With this new approach, a direct impingement is avoided and, in the closed ring configuration, the contact pressure is mitigated and the risk of local bone damage reduced. This also prevents the user to know the value of bone density (3). As reported by Baudi et al, transosseous repair with sharc-ft had good to excellent clinical outcome at one year follow-up but the rate re-tear was not investigated in that study (19).
The transosseous techniques can also help in the re-tear patients treatment avoiding the step of screw removal or the use of new screws.

Conclusion

Results from this study confirmed with the help of ultrasound examination and MRI the excellent clinical outcome obtained by our patients. Despite of the limited number of subjects, all patients involved in the study were affected by rotator cuff with a sovraspinatus tear less than 3 cm, therefore creating a homogeneous group of patients confirmed with statistical analysis. Furthermore, few studies in literature have the support of an MRI evaluation to confirm the re-tear percentage of the previous tendon repairs.
The arthroscopic transosseous repair technique with sharc-ft shown excellent results with little significant statically difference between this technique and the single row for this kind of lesion starting from 1 year follow up.
Further studies are needed to find differences between these techniques in the repair of large and massive rotator cuff lesions.

Compliance with Ethical Standards: No founding for this study. Conflict of Interest: Authors have no conflict of interest. Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent: Informed consent was obtained from all individual participants included in the study.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Miller BS, Downie BK, Kohen RB, Kijek T, Lesniak B, Jacobson JA, Hughes RE, Carpenter JE (2010) When do rotator cuff repair fail? Serial ultrasound examination after arthroscopic repair of large and massive rotator cuff tears. Am J Sports Med Oct;39(10):2064-70.
2. Park JY, Lhee SH, Oh KS, Moon SG, Hwang JT (2013) Clinical and ultrasonographic outcomes of arthroscopic suture bridge repair for massive rotator cuff tear. Arthroscopy Feb;29(2):280-9.
3. Mantovani M, Baudi P, Paladini P, Pellegrini A, Verdano MA, Porcellini G, Catani F (2014) Gap formation in a transosseous rotator cuff repair as a function of bone quality. Clin Biomech Apr;29(4):429-33.
4. Pellegrini A, Lunini E, Rebuzzi M, Baudi P, Verdano MA, Ceccarelli F (2015) Arthroscopic rotator cuff tear transosseous repair system: the Sharc-FT® by Taylor®. Arthroscopy Techniques; 4(3): 201-205.
5. Constant CR, Murley AHG (1987) A clinical method of functional assessment of the shoulder. Clin Orthop 214:160-164.
6. Hudak PL, Amadio PC, Bombardier C (1996) Development of an upper extremity outcome measure: the DASH (disability of the arm, shoulder and hand) (corrected). The Upper Extremity Collaborative Group (UECG). Am J Ind Med 29:602-608.
7. Lippitt S, Harryman D, Matsen D (1993) A practical tool for evaluating function: the Simple Shoulder Test. The shoulder: a balance of mobility and stability. Rosemont, IL: American Academy of Orthopaedic Surgeons. 501-18.
8. Teefey SA, Rubin DA, Middleton WD, Hildebolt CF, Leibold RA, Yamaguchi K (2004) Detection and quantification of rotator cuff tears: comparison of ultrasonographic, magnetic resonance imaging, and arthroscopic findings in seventy-one consecutive cases. J Bone Joint Surg Am;86-A:708 –716.
9. De Jesus JO, Parker L, Frangos AJ, Nazarian LN (2009) Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. AJR Am J Roentgenol;192(6):1701 –1707
10. Sugaya H, Maeda K, Matsuki K, Moriishi J (2007) Repair integrity and functional outcome after arthroscopic double-row rotator cuff repair. A prospective outcome study. J Bone Joint Surg Am May;89(5):953-60.
11. Lafosse L, Brozska R, Toussant B, Gobezie R (2007) The outcome and structural integrity of arthroscopic rotatori cuff repair with use of the double-row suture anchor technique. J Bone Joint Surg Am Jul;89(7):1533-41.
12. Huijsmans PE, Pritchard MP, Berghs BM, van Rooyen KS, Wallace AL, de Beer JF (2007) Arthroscopic rotator cuff repair with double-row fixation. J Bone Joint Surg Am Jun;89(6):1248-57.
13. Frank JB, ElAttrache NS, Dines JS, Blackburn A, Crues J, Tibone JE (2008) Repair site integrity after arthroscopic transosseous-equivalent suture-bridge rotator cuff repair. Am J Sports Med Aug;36(8):1496-503.
14. Codsi MJ, Rodeo SA, Scalise JJ, Moorehead TM, Ma CB (2014) Assessment of rotator cuff repair integrity using ultrasound and magnetic resonance imaging in a multicenter study. J Shoulder Elbow Surg Oct;23(10):1486-72.
15. Martin-Hervas C, Romero J, Navas-Acien A, Reboiras JJ, Munuera L (2001) Ultrasonographic and magnetic resonance images of rotator cuff lesions compared with arthroscopy or open surgery findings. J Shoulder Elbow Surg 10: 410–15.
16. Teefey SA, Hasan SA, Middleton WD, Patel M, Wright RW, Yamaguchi K (2000) Ultrasonography of the rotator cuff. J Bone Joint Surg Am 82: 498–504.
17. Hodler J, Fretz CJ, Terrier F, Gerber C (1988) Rotator cuff tears: correlation of sonographic and surgical findings. Radiology 169: 791–4.
18. Rutten MJ, Jager GJ, Kiemeney LA (2010) Ultrasound detection of rotator cuff tears: observer agreement related to increasing experience. AJR Am J Roentgenol Dec;195(6).
19. Baudi P, Rasia Dani E, Campochiaro G, Rebuzzi M, Serafini F, Catani F (2013) The rotatort cuff tear repair with a new arthroscopic transosseous system: the Sharc-FT(Ò). Musculoskelet Surg Jun;97 Suppl 1:57-61

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Original article

GPS guided reverse shoulder arthroplasty: an anatomic dissection study

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Summary. *Background and aim of the work:* The reverse shoulder arthroplasty (RSA) has risen exponentially, this has entailed an increasing number of complications and reoperations. In RSA, loads are transferred directly to the glenoid component. As a result, failure of the glenoid component is one of the most common complications. CT 3D preoperative planning, patient-specific and the possibility of performing a more precise and controlled surgical gesture in the operating room are increasingly important. The use of the GPS navigation on CT 3D planning has proved to be useful above all in terms of accuracy, reliability and the possibility of reproducing the planned gesture preoperatively. *Methods:* This study analyzes the precision, safety, and reproducibility of the GPS system for the reverse shoulder prosthesis tested on 6 scapulohumeral cadaver specimens, subsequently subjected to anatomical dissection to verify the correct positioning of the glenoid components and the percentage of appropriateness in the field of planning previously virtually assumed. *Results:* Postoperative macroscopic dissection revealed no central peg perforated or screws malpositioned, no leaking from the bone or injury to the adjacent neurovascular structures. The average length of the screws was 42 mm (range 36 mm to 46 mm) for the lower screw and 40 mm for the upper one (range 36 mm to 42 mm). *Conclusions:* This cadaver study has shown that GPS navigation offers greater efficiency in baseplate and screws placement and can avoid intra- and postoperative complications. (www.actabiomedica.it)

Key Words: GPS, Shoulder arthroplasty, Navigation, RSA

Introduction

For a decade, total shoulder arthroplasty (TSA) has been the gold-standard treatment for end-stage arthritis of the glenohumeral joint. However, TSA in patient with concomitant rotator cuff pathology has been associated with early failure due to the high rate of glenoid looseing (1). Recently, however, reverse shoulder arthroplasty (RSA) has emerged as an alternative surgical option. RSA provides a mechanical advantage for shoulder elevation in patients with rotator cuff disease (2). An aging population, improved implant designs, and broader indications have all been implicated for increasing volume and utilization (3). RSA has risen exponentially, and this has entailed an increasing number of complications and reoperations (4). Zumstein et al. reported a 20% rate of postoperative complications; 105 implants required reintervention: 79 (10.1%) surgical revisions and 26 (3.3%) reoperations. The complication rate was almost 3-fold higher in cases of revision for the failure of the anatomic implant than in primary RSA: 33.3% vs. 13.4%[4].

With these semi-constrained prostheses, loads applied to the humerus are transferred directly to the fixation of the glenoid component. As a result, failure of the glenoid component fixation is one of the most common complications of the reverse total shoulder (5,6). The glenoid component position must be optimized for version, inclination, and overhang to maximize the bone stock available for fixation. A review

of articles regarding reverse total shoulder prostheses, especially those showing glenoid component fixation failure, reveals a wide variability in the placement of glenoid fixation screws in the limited bone available in the scapula (7). On the other side, several cadaveric studies have demonstrated considerable natural variability in anatomic parameters of the glenoid: this variability affects prosthesis design, instrumentation, and intraoperative implantation techniques. When the scapular anatomy is distorted, as is often the case in rotator cuff tear arthropathy or in revision shoulder arthroplasty where reverse total shoulder arthroplasties are often used, achieving secure purchase with each screw may be even more difficult. Inferior scapular bone resorption, or notching, associated with the reverse total shoulder prosthesis may jeopardize the security of the inferior screw (8). For primary osteoarthritis, the most common pattern is glenoid wear with varying degrees of posterior subluxation of the humeral head. Inflammatory arthritis is often associated with central glenoid erosion, which may be accompanied by the presence of cysts within the glenoid vault. Anterior glenoid erosion can also be encountered (9). Moreover, the anatomy "beyond the glenoid fossa" thus became a factor in screw fixation strength and potential injury (10). An important neurovascular structure at risk from screw position and drill bit plunge is the suprascapular nerve. The suprascapular nerve provides motor innervation to the supraspinatus and infraspinatus with some branches to the teres minor (11). The major innervation of the teres minor is provided by the axillary nerve, which also provides motor supply to the deltoid and the teres minor. On average, the axillary nerve is approximately 32 mm from the inferior glenoid, although this position may vary with arm position (12), while the suprascapular nerve is, on average, 1.8 cm from the posterior superior glenoid rim (13). Pain sensory innervation to the glenohumeral articulation is largely supplied by the suprascapular nerve, axillary nerve, and lateral pectoral nerve. The inferior, lateral, and anterior joint structures are supplied by branches from the axillary nerve. The posterior, medial, and superior joint supply come from the suprascapular nerve and lateral pectoral nerve. Injury to these nerves could lead to increased postoperative pain and suboptimal outcomes (14).

In consideration of all the elements described above, an adequate CT 3D preoperative planning, patient-specific, is increasingly important, and also the possibility of performing a more precise and controlled surgical gesture in the operating room. In recent years, in this regard, we could benefit to the GPS navigation technology, already developed and implemented in hip and knee prosthetics, and which today in shoulder prosthetic seems to offer the greatest advantages, this in consideration of the reduced bone surface on where you need to work and the proximity to all the neurovascular structures around that may be at risk. The use of the GPS navigation on CT 3D planning has proved to be useful above all in terms of accuracy, reliability and the possibility of reproducing the planned gesture preoperatively directly in the operating room. This study analyzes the precision, safety, and reproducibility of the Exactech GPS system for the reverse shoulder prosthesis tested on 6 scapulohumeral cadaver specimens, subsequently subjected to anatomical dissection to verify the correct positioning of the glenoid components and the percentage of appropriateness in the field of planning previously virtually assumed.

Materials and Methods

Six paired fresh-frozen cadaver scapulothoracic specimens were obtained from patients who had not undergone previous surgery on the shoulder or scapula. The mean age was 66 years (range, 58-72). Preoperative computed tomography (CT) scans were performed on each specimen. The scan was of the entire scapula in the axial plane, with the specimen in the supine position and the arm in an adducted position to the side. The tube current was set to at least 120 kV (peak) with image reconstruction using a convolution bone kernel with a field of view of 154 to 410 mm and a standard image matrix size of 512 _ 512 pixels, yielding between 200 and 450 images. The interslice distance was between 0.3 and 1.0 mm. The CT file was sent to the manufacturer for uploading into the surgical planning software and rendering it to a 3-dimensional model for visualization. CT scans were loaded into the RSA planning software (Exactech) and manually segmented by the manufacturer to re-

construct the shoulder in a 3-dimensional model for preoperative planning. Glenoid version, inclination, and any wear or deformity were accurately measured for all specimens, and the surgeon provides to plan the best virtual positioning of baseplate and screws on the planning software (Fig. 1).

A deltopectoral approach was used for all procedures, taking care of exposing the superior surface of the coracoid to place the GPS tracker using two screws to its inferolateral base. At this point, the recognition phase of the glenoid surface and anatomic landmarks begins using a handheld tracker on the surface that recognizes and matches the specimen scapula with the virtual planning model (Fig. 2). After registration, the software provided 2- and 3-dimensional guidelines to achieve the preoperative plan. At this point, every next phase from drilling, reaming and positioning of the baseplate and screws were performed under image-guided navigation using instruments with trackers mounted and GPS guided.

Postoperatively, all glenoids were dissected and possible perforation of the central peg of the glenoid base plate or malposition of the 2 screws concerning the glenoid vault or surrounding soft tissues was assessed (Fig. 3). In addition, the coracoid process and the position of the reference pins were verified. Then, all glenoid specimens received a multi-slice CT scan and the position of the glenoid baseplate and the locking screws were studied. Glenoid component version relative to the long axis of the scapula was measured on the first axial cut below the coracoid process. Glenoid component tilt was measured on the oblique cut relative to the frontal axis of the scapula. The positioning of the superior and inferior locking screws was assessed on the axial, coronal, and sagittal cuts.

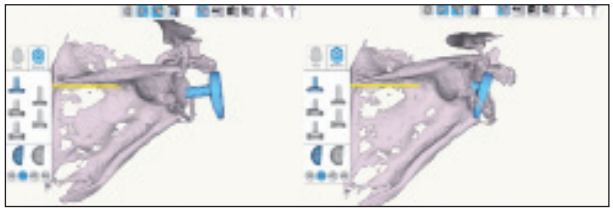

Figure 1. Virtual planning of baseplate positioning.

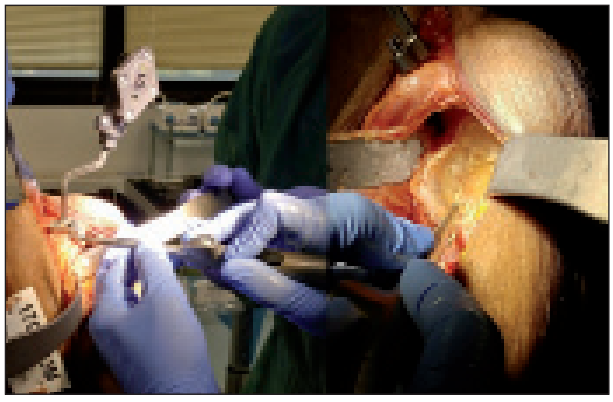

Figure 2. Matching phase of the glenoid surface and anatomic landmarks with the virtual planning model.

Results

Preoperative CT scans did not show bone loss or deformity in any specimen. The mean native glenoid version was 5.6° (range -2° to +7°). The mean version of the glenoid was 3.1° of anteversion (range 0° to +8°). The mean tilt of the glenoid component was -5.4° of inferior tilt (range -2° to -10°). The range of error for the version was ±2° compared to the ideal position planned before. For component tilt, the range of error was ±3°. Postoperative macroscopic dissection revealed no central peg perforated or screws malpositioned, no leaking from the bone or injury to the adjacent neurovascular structures. The average length of the screws was 42 mm (range 36 mm to 46 mm) for the lower screw and 40 mm for the upper one (range 36 mm to 42 mm).

During the 6 computer-assisted navigation procedures, there were no complications reported related to the placement of the 2 fixation pins in the coracoid process. There was no need for an extended surgical approach, and the reference remained stable and visible for the navigation station throughout the complete procedure.

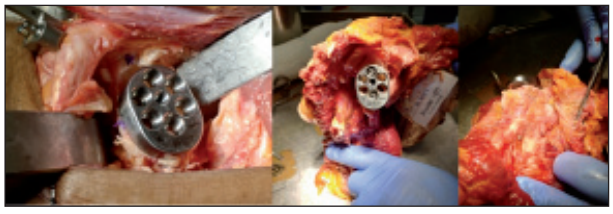

Figure 3. Sacpula dissection. Central peg and screws positioning verification.

Discussion

The glenoid component positioning in RSA is crucial to prevent failure, loosening and biomechanical mismatch that affect the function and clinical result. Crucial is the coverage by the baseplate of the glenoid surface and the correct positioning in terms of version, inclination, and off-set, equally essential part is the positioning of the longest screws possible but which at the same time do not cause injury to adjacent structures or impingement (9,15). However, the glenoid anatomy presents an extreme variability from one subject to another, without taking into account that in the arthrosis and arthritic scapulohumeral joints this is upset especially in terms of bone quality and bone stock. Furthermore, the difficult surgical exposure of the glenoid, the limited size and difficult visualization of anatomical reference landmarks may jeopardize optimal placement and stable bone fixation of the base plate and screws. Lastly, mispositioned screws may be harmful to the surrounding soft tissues, such as the axillary (inferior screw) or suprascapular (superior screw) nerve, blood vessels, or rotator cuff muscles. This cadaver study has shown that GPS navigation offers greater efficiency in baseplate and screws placement and can avoid intra- and postoperative complications.

We believe that the possibility of implanting longer screws is directly correlated with the resistance of the glenoid implant and therefore with its duration. The navigation allows us to always implant the longest possible screw without leaking from the bone and risking injuries to adjacent noble structures. Concerning the positioning of the base-plate and gleno-sphere it is now established that any malposition leads inevitably to failure of the system, for this fundamental is the precision to the minimum degree (16).

While the specimens in the current study did not show severe glenoid bone loss, we know how arthrosis pathology can subvert the anatomy of the glenoid and how much every anatomical landmark can be distorted, it is precisely in this situation that GPS navigation takes on an increasingly important role. This is even truer in revisions, where often there is a need to tackle a lack of bone and poor quality.

This study showed how useful CT 3D programming is to identify the best positioning of each component and the usefulness of receiving directly in the operating room real-time feedback on the change in position, version, and tilt of the glenoid component and improves the accuracy of their placement. This real-time guide allows going beyond all the problems of surgical exposure of the glenoid, anatomical variability and safety in the positioning of the components. We showed how the variability in the positioning of the baseplate was 2-3 degrees in the various planes, an accuracy that is difficult to reproduce without navigation assistance.

There are, however, several main disadvantages of this image-based system. First of all the higher costs of instrumentation and software compared to the classical technique, secondly the increase in surgical times, and finally, the need often to enlarge the surgical access to discover the coracoid and the risk related to the positioning of the tracker to break the coracoid itself. Obviously, we think that if the result consists of improving the positioning and therefore both the function and longevity, these are acceptable compromises.

There are several limitations to this study. First, the limited number of specimens investigated in navigated and control specimens. Second, the absence of a control group. Third, we did not perform biomechanical tests to compare the initial stability of the glenoid component. Surely a long-term follow-up of a large number of patients is needed to confirm the hypothesis that navigation may improve long-term functional outcomes.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Westermann RW, Pugely AJ, Martin CT, Gao Y, Wolf BR, Hettrich CM. Reverse Shoulder Arthroplasty in the United States: A Comparison of National Volume, Patient Demographics, Complications, and Surgical Indications. Iowa Orthop J. 2015;35:1-7.
2. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. J Bone Jt Surg - Ser A. 2011;93(24):2249-2254. doi:10.2106/JBJS.J.01994
3. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, com-

plications, reoperations, and revisions in reverse total shoulder arthroplasty: A systematic review. J Shoulder Elb Surg. 2011;20(1):146-157. doi:10.1016/j.jse.2010.08.001
4. Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res. 2016;102(1):S33-S43. doi:10.1016/j.otsr.2015.06.031
5. Nyffeler RW, Werner CML, Gerber C. Biomechanical relevance of glenoid component positioning in the reverse Delta III total shoulder prosthesis. J Shoulder Elb Surg. 2005;14(5):524-528. doi:10.1016/j.jse.2004.09.010
6. Chebli C, Huber P, Watling J, Bertelsen A, Bicknell RT, Matsen F. Factors affecting fixation of the glenoid component of a reverse total shoulder prothesis. J Shoulder Elb Surg. 2008;17(2):323-327. doi:10.1016/j.jse.2007.07.015
7. Giannotti S, Bottai V, Dell'Osso G, et al. Thirty-six consecutive reverse shoulder arthroplasties in cuff arthropathy: Our experience with the anterosuperior approach. Eur Orthop Traumatol. 2014;5(3):293-298. doi:10.1007/s12570-014-0248-0
8. Scalise JJ. Reverse total shoulder arthroplasty. Minerva Ortop e Traumatol. 2009;60(1):55-59. doi:10.2106/00004623-200707000-00011
9. Codsi MJ, Iannotti JP. The effect of screw position on the initial fixation of a reverse total shoulder prosthesis in a glenoid with a cavitary bone defect. J Shoulder Elb Surg. 2008;17(3):479-486. doi:10.1016/j.jse.2007.09.002
10. Hart ND, Clark JC, Wade Krause FR, Kissenberth MJ, Bragg WE, Hawkins RJ. Glenoid screw position in the Encore Reverse Shoulder Prosthesis: An anatomic dissection study of screw relationship to surrounding structures. J Shoulder Elb Surg. 2013;22(6):814-820. doi:10.1016/j.jse.2012.08.013
11. Plancher KD. Sports Medicine : Shoulder. 2012:113-116.
12. Bigliani LU, Dalsey RM, McCann PD, April EW. An anatomical study of the suprascapular nerve. Arthrosc J Arthrosc Relat Surg. 1990;6(4):301-305. doi:10.1016/0749-8063(90)90060-Q
13. Wang J, Singh A, Higgins L, Warner J. Suprascapular neuropathy secondary to reverse shoulder arthroplasty: A case report. J Shoulder Elb Surg. 2010;19(3):e5. doi:10.1016/j.jse.2009.10.004
14. Cofield RH. Bone grafting for glenoid bone deficiencies in shoulder arthritis: A review. J Shoulder Elb Surg. 2007;16(5 SUPPL.):273-281. doi:10.1016/j.jse.2007.03.005
15. Harman M, Frankle M, Vasey M, Banks S. Initial glenoid component fixation in "reverse" total shoulder arthroplasty: A biomechanical evaluation. J Shoulder Elb Surg. 2005;14(1 SUPPL.):S162-S167. doi:10.1016/j.jse.2004.09.030
16. Lévigne C, Boileau P, Favard L, et al. Scapular notching in reverse shoulder arthroplasty. J Shoulder Elb Surg. 2008;17(6):925-935. doi:10.1016/j.jse.2008.02.010

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Original article

Antegrade intramedullary nailing in proximal humeral fractures: results of 23 cases

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Summary. *Introduction:* the metaepiphyseal fractures of the proximal humerus represent 5% of all fractures and mainly affect elderly patients. The type of treatment remains controversial. This retrospective study aimed to evaluate the clinic and radiographic results of 23 patients affected by two or three fragments fractures of the proximal humerus with or without metaphyseal extension treated with antegrade intramedullary nailing. *Materials and Methods:* all patients were clinically evaluated using the "Constant score" (CS) and individual satisfaction was assessed with a visual scale (VS). Moreover**,** the fracture's healing process and the neck shaft angle (NSA) were assessed radiographically. *Results:* the mean follow-up was 72 months (24-120). Clinical evaluation and individual satisfaction were positive in most cases (mean CS 79,39 and VS 3,17). Worse results were observed in patients over 65 years. *Discussion:* among the different surgical options intramedullary nailing ensures good fracture stability and high consolidation rate. The entry point through the rotator cuff is of main importance as well as proximal nail positioning and choice of the locking screws length. In this study the functional results of the shoulder were worse in the elderly, who were supposed to have already a degenerated rotator cuff. *Conclusions:* antegrade intramedullary nailing should be considered a valid therapeutic option in this type of fractures. The surgical technique may influence functional results, as consequence of iatrogenic damage of the rotator cuff. (www.actabiomedica.it)

Key words: proximal humerus, fracture, nailing, trauma.

Introduction

Fractures of the proximal humerus are very common, representing about 5% of all fractures in adults (1).

Their incidence, which currently stands at a value of 105 per 100,000 people/year, is growing, especially in two types of patients: elderly women with osteoporosis, usually following an accidental fall with a low energy trauma, and young males, after a high energy trauma (2,3).

Several studies (4, 5) assessed that females have a double risk of being affected by proximal humerus fractures compared to males; these studies also report that according to AO classification up to 90% these fractures are type A and B (extra-articular, unifocal or bifocal) and only 8% are type C (intra-articular) (6).

The type of treatment is decided after a clinical and radiographic evaluation. Most proximal humeral fractures are not displaced or minimally displaced, and conservative treatment is the most indicated, especially in low-demanding patients and in those who have a high surgical risk (7, 8).

Surgical approach is recommended in displaced fracture and in high-demanding patients. A variety of surgical techniques have been developed, including plating, percutaneous pinning, joint replacement, and humeral nailing (7, 9-11).

Open reduction and internal fixation (ORIF) is the most used method (7, 9-11). The direct exposure of the fracture site offers the advantage of directly manipulating the bone fragments and positioning the implant. This type of approach, however, can interfere with the healing process and increase the risk of humeral head osteonecrosis. Despite the advantage of direct visualization of the fracture site, ORIF requires a precise knowledge of the fracture geometry and of the deforming forces involved.

Intramedullary nailing (IMN) is particularly suitable for multi-fragmentary fractures of the surgical neck and meta-diaphysis, where the tuberosity and the humeral head remain in a single fragment.

IMN offers both biological and mechanical advantages. This surgical procedure is performed without opening the fracture site and it allows to respect the periosteal blood supply and to promote physiological bone healing processes. In addition, the position of the nail is closer to the humerus mechanical axis if compared to other fixation devices, which guarantees greater resistance. It also assures greater primary stability with less stress in flexion on locking screws, if compared to plates and screw systems, where especially in osteoporotic bone, the implant pull-out is still a possible complication.

The aim of this study was to evaluate clinical and radiological outcomes of 23 metaepiphyseal fractures of the proximal humerus treated with antegrade IMN.

Materials and methods

All patients affected by proximal humerus fracture who were surgically treated in our department between January 2009 and December 2017 were analysed. One hundred and eleven patients (30 males and 81 females), aged between 18 and 98 (mean age: 61 years), were then analysed. In the study two or three fragments fractures with or without metaphyseal extension according to the Neer classification, and operated with antegrade nailing (T2 Proximal Short and Long Nail, Stryker), were included. All subjects treated conservatively or with another device and younger than 18 years of age were excluded.

According to the inclusion criteria and after the exclusion of those who were not contactable or deceased, data regarding the 23 remaining cases were collected from the clinical charts and surgery register.

This study was conducted in accordance with the principles of Declaration of Helsinki. All patients signed informed consent about the treatment they were subjected and the processing of their personal data.

For each patient gender, age at the time of surgery, follow-up time, dominance, type of trauma (low or high energy), type of nail, complications and revision surgery were recorded.

All the pre-operative, post-operative and follow-up radiological images were downloaded from the radiology digital archive and then studied. If the CT scan was available, also this exam was downloaded and examined.

All the fractures were classified according to Neer's and AO classifications.

All patients were operated on in the "beach-chair" position using X-ray imaging. The image intensifier placed at the patient's head allowed both AP and axillary views to be obtained, which enabled fracture reduction, nail insertion site and positioning to be checked, as well as length and progression of proximal locking screws. In all cases the ADI approach was used. The skin incision was about 2 cm anterior to the middle portion of the acromion. After the deltoid muscle fibres were split longitudinally and the clavipectoral fascia was sectioned, the underlying rotator cuff was exposed and cut parallel to the direction of its fibres, at about 1 cm medial to the greater tuberosity. The underlying nail insertion site is localised in a cartilaginous area of the humeral head which is well aligned with the humeral medullary canal (12). After surgery all subjects were immobilized for two weeks in a brace. Fourteen days after surgery a passive and assisted kinesis was allowed. Active movements started always 1 months following surgery.

At follow up, each patient was clinically evaluated and the range of motion was measured with a goniometer. The functional results were determined with the Constant Score test (13). Also, the personal satisfaction was evaluated with a visual scale from 1 to 4 (1=unsatisfied, 2=little satisfied, 3=satisfied, 4= very

satisfied). Finally, fracture healing and Neck Shaft Angle (NSA) were assessed on the last available x-ray.

NSA is defined as the intersect between a line along the humeral shaft axis and a line perpendicular to the anatomical neck. This angle measures the proximal humeral displacement on the coronal plane (14). Its value is approximately 135° (14,15) and is measured on true anterior-posterior (AP) radiographs.

A statistical analysis of the collected data was then performed using the SPSS 20.0 software (IBM Corp. Armonk, NY, USA). The Constant Scores between operated and healthy arms were compared with the T Test and the Wilcoxon-Mann-Whitney test; a second statistical analysis of the same parameters through the Pearson Correlation Index wanted to highlight how the Constant Score scores were related to the patient's age.

Results

Twenty-three patients, 17 females (73.9%) and 6 males (26.1%) were recruited. The average patients' age at the time of surgery was 66.04 years (range 25-86). Two fragment fracture was observed in 8 cases and three fragment type in 15. Metaphyseal extension was associated in 12 subjects. According to AO classification fractures were always of type A and B.

The non-dominant limb was involved in 12 cases (52.2%). In 20 cases (88%) the long variant of the nail was implanted whereas the short one was used in other 3 (12%). The mean follow-up was 72 months (range 24-129). Traumatic mechanism was of low energy in 16 subjects (15 female and 1 male) and of high energy in 7 (5 males and 2 females). The average Constant Score of the operated side was 79.39 (range 42-100), whereas the mean CS of the non-operated was 89.67 (range 58-100). The distribution of the CS scores is illustrated in Figure 1.

The mean satisfaction with the VS was 3.17.

All fractures healed. Nonunions and malunions were never observed. No device needed to be removed after fracture healing and only in 2 cases one of the proximal locking screws had to be removed because of pain. The average measured NSA was 133.08 ° (range 108° - 150°). In two cases (8%) the NSA was less than

	CONSTANT SCORE Operated side		CONSTANT SCORE Non-operated side	
	N° cases	%	N° cases	%
EXCELLENT (>70)	16	70	22	96
VERY GOOD (60-69)	3	13	0	0
GOOD (40-59)	4	17	1	4
FAIR (30-39)	0	0	0	0
POOR (<30)	0	0	0	0

Figure 1. Distribution of CS in both arms

A

	Average	N	Standard deviation	Average standard error
• CONSTANT SCORE OPERATED SIDE	79.391	23	18.0800	3.7699
• CONSTANT SCORE NON OPERATED SIDE	89.674	23	11.3444	2.3655

B

	Paired differences					t	gl	Sign.
	Average	Standard deviation	Average standard error	Difference confidence interval 95%				
				Inferior	Superior			
CONSTANT SCORE OPERATED SIDE - CONSTANT SCORE NON OPERATED SIDE	-10.2826	14.5866	3.0415	-16.5903	-3.9749	-3.381	22	.003

C

	N	Correlation	Sign.
• CONSTANT SCORE OPERATED SIDE	23	.592	.003
• CONSTANT SCORE NON OPERATED SIDE			

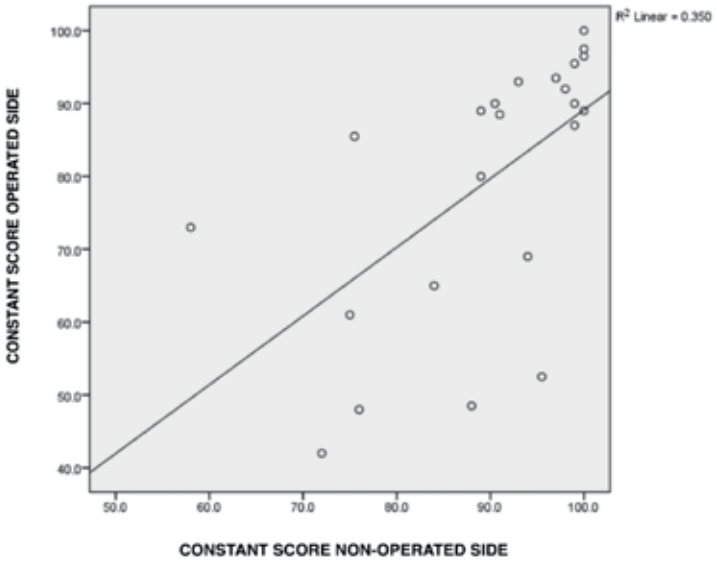

Figure 2. T test of CS without statistically significative differences

120° and this value correlated with unsatisfactory outcome.

The analysis by means of the "t Test" revealed a non-statistically significant difference between the values of the CS of the operated side and those of the non-operated one as shown in the figure 2.

The Wilcoxon-Mann-Whitney test, which allows the comparison between the two values (figure 3) showed a statistical significance difference. If the hypothesis was null, as in our case, the difference did not exist and the two groups were similar. Therefore, these analyses showed that there was not a statistically significant decrease in the post-operative functionality of the operated limb.

The Pearson Correlation Index (figure 4), highlighted how the CS scores are related to patient's age. Younger patients have higher Constant Score values, and therefore better functionality of the shoulder, both on the operated and non-operated side. On the other hand, aging (≥65 years) was associated to lower Constant Score values but also in these subjects the comparison of the values of the two arms (operated vs. non-operated) was similar.

NULL HYPOTHESIS	TEST	Sign.	Ris.
The median of differences between the OPERATED SIDE CONSTANT SCORE and NON OPERATED SIDE CONSTANT SCORE is 0	Wilcoxon-Mann-Whitney test	.002	Refuse the null hypothesis

Figure 3. Wilcoxon-Mann-Whitney test without differences of CS

		AGE'	CONSTANT SCORE OPERATED SIDE	CONSTANT SCORE NON OPERATED SIDE
AGE	Pearson Correlation	1	-.534**	-.609**
	Sig. (2-tailed)		.009	.002
	N	23	23	23
CONSTANT SCORE OPERATED SIDE	Pearson Correlation	-.534**	1	.592**
	Sig. (2-tailed)	.009		.003
		23	23	23
CONSTANT SCORE NON OPERATED SIDE	Pearson Correlation	-.609**	.592**	1
	Sig. (2-tailed)	.002	.003	
	N	23	23	23

**. Correlation is significant at the 0,01 level (2-tailed)

Figure 4. Pearson Correlation Index with correlation between CS and age

Discussion

Epidemiological studies show an exponential increase of proximal humerus fractures after the fifth decade due to the low quality of elderly patient's bone. In fact, the decrease of the trabecular density and the cortical weakening expose the elderly population to a higher risk of fracture even with low energy traumatic mechanism. In addition, female individuals were found to have a double risk, compared to male (16).

In this study, patients aged between 25 and 86 years were evaluated. Both women in the perimenopausal age and young men were included. The average age of the patients was 66 years. According to what literature reports, most of them (74%) were women as consequence of low energy traumas.

Despite the numerous available classifications, it is difficult to categorize all proximal humeral fractures, even with the help of CT imaging, and considering all patients' characteristics, it is also demanding to choose the best treatment.

Indeed, these fractures are challenging for several reason, such as osteoporotic bone in the elderly, articular surface involvement, possible onset of AVN of the humeral head and reconstruction of collapsed fragments (17,18).

There are currently several treatment options and in literature there is no univocal consensus (18-21).

Rangan did not support the trend of increased surgery for patients with displaced 2-parts fractures of the proximal humerus. He stated that there is no significant difference between surgical treatment compared with nonsurgical among patients with displaced proximal humeral fractures involving the surgical neck (22).

However, most of the Authors did find that surgery improved the position of the fracture fragments (12,17). In fact, the dislocation of two or more fragments requires surgical stabilization since the interposition of soft tissues could induce an important joint dysfunction and a non-union of the fracture (23,24).

According to Neer classification, several Authors studied outcomes after surgery. Lekic (25) suggested that either ORIF or IMN for a two-parts fracture provides acceptable fixation and similar results in terms of shoulder range of motion. Although complication rates were low and there were no statistically significant difference between the two groups, a trend toward increased complications in the IMN group was noted. Despite reoperation and complication rates remain high, Wong (26) concluded that IMN of acute, displaced two- and three parts fractures yields satisfactory clinical outcomes. Sobel (27) reported that in selected patients, IMN may present advantages over ORIF, as their implantation requires shorter surgical time and results in less fracture site pain reported by patients with 3-part fractures.

In conclusion, in literature it is described that IMN and ORIF yield similar functional long-term results in patients with proximal humeral fractures even though ORIF has better outcomes in 4-part fractures (13,22-27).

In this study, the most frequent fracture pattern was three-fragments fracture (n°15), followed by two-fragment fractures (n°8) and the 4 part ones were excluded.

Authors decided to treat them with an IMN of 3rd generation. Third generations nails were designed to improve some disadvantages of previous ones. In first-generations nails, the inability to ensure unstable fracture fragments and lack of rotational control often led to fixation failure; in second generation nails an inadequate security of the proximal interlocking screws was observed.

Third-generation nails evolved to solve the issue of proximal screw loosening and ultimate fixation failure. This led to the arrival of more secure locking mechanisms for proximal screw fixation in order to allow fixed angular stable constructs. The proximal bending offers insertion options laterally, just inside the greater tuberosity, or centrally, through the articular surface at the top of the humeral head. Strategic proximal locking holes enable locking of the lesser tuberosity, the greater tuberosity, and the humeral head. Threaded proximal locking holes allow increased holding strength in the nail, analogous to locking plate and screw fixation.

The purpose of nailing is to provide stability to a reduced fracture that allows early motion to rehabilitate the shoulder and to improve patient outcomes that may have otherwise been theoretically achieved with conservative management.

In literature, the most common complications of IMN is loss of reduction (24%) followed by fracture malunion (21%); in this study we detect no case of

malunion nor loss of reduction. Most of these complications developed 12 months after surgery, and average follow-up was 63 months. Another serious complication is osteonecrosis of humerus head (AVN) (higher in three-fragment fractures than in two-fragment fractures) (26); it has been reported to happen in 4% of IMN cases, whereas it occurs in about 10.8% of internal fixation and in 26% of cases treated with percutaneous fixation. In the present study no case presented this complication. This can be justified by the lower invasiveness of IMN insertion technique, although AVN radiological signs could appear after several years.

Authors wants to stress the importance of a precise surgical technique. Antegrade nailing is not extra-articular, and its main disadvantage is that it crosses the rotator cuff and the articular cartilage of the humeral head. For this reason the entry point is crucial and Authors always used the ADI approach in which the damage to the rotator cuff is more likely to heal, as it occurs in a well vascularised area, and the nail is inserted in a more medial position of the humeral head, localised in a cartilaginous area of relatively low biomechanical importance, which allows for a more linear access to the medullary canal (28).

Authors also wants to highlight two other surgical steps that they consider of main importance. Correct proximal nail positioning beneath the level of humeral head articular cartilage avoid subacromial impingement syndrome. Furthermore, the wrong length of the proximal locking screws can also cause problems to the deltoid muscle and lead to subacromial impingement syndrome at extreme degrees of abduction and extrarotation (12).

Authors assessed radiographically fractures healing, neck shaft angle and possible loosening of the implant. At final follow-up, despite the mean age of our patients, all fractures healed and no case needed total implant removal, in only two cases a locking screw was removed.

Clinical results of the present study on both sides were found to be similar. Statistical tests showed that there was no statistically significant decrease in the post-operative functionality of the fractured limb and treated with intramedullary nailing. However, functional results were worse in elderly patients (≥65 years). This datum probably depends on the fact that these patients often suffer of a pre-existing rotator cuff tear (29). Anyway, in these subjects the function of both arms at follow-up was comparable.

Literature reports a mean Constant Score (CS) value of 72.8 after intervention (13,25-27,30,31), whereas results of the present study were even better with a mean CS of 79.39 (range 42-100).

This mismatch could be due to the small number of recruited patients and this was an important limit of the study. Another limit was the heterogeneous sample with different ages, functional requests and comorbidity; moreover, we did not compare IMN to other techniques and we retrospectively analysed the data.

Conclusion

Results observed confirm that antegrade intramedullary nailing is a valid surgical option for fractures with 2-3 fragments with or without metaphyseal extension of the proximal humerus. Functional outcomes depend on the correct entry point, proximal nail positioning and the length of the proximal locking screws. Patients older than 65 years of age have worse results in a possible context of degeneration of the rotator cuff.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Vachtsevanos L, Hayden L, Desai AS, Dramis A. Management of proximal humerus fractures in adults. World J Orthop 2014; 5(5): 685–93.
2. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. Acta Orthop Scand 2001; 72: 365–71.
3. Benazzo, Ceccarelli, Cerulli, Villani, Sasso. Ortopedia e traumatologia. Milano : Monduzzi Editore, 2010.
4. Knowelden J, Buhr AJ, Dunbar O. Incidence of fractures in persons over 35 years of age. A report to the MRC working party on fractures in the elderly. Brit J Prev Soc Med 1964; 18: 130–41.
5. Donaldson LJ, Cook A, Thomson RG. Incidence of fractures in a geographically defined population. J Epidemiol Community Health 1990; 44(3): 241–5.
6. Orthopaedic Trauma Association Committee for coding

and Classification, Fracture and dislocation compendium. J Orthop Trauma. 1996; 10(suppl 1): v–ix,1–154.
7. Bell JE, Leung BC, Spratt KF, et al. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal humeral fractures in the elderly. J Bone Joint Surg Am 2011; 93(2): 121–31.
8. Chu SP, Kelsey JL, Keegan TH, et al. Risk factors for proximal humerus fracture. Am J Epidemiol 2004; 160: 360–7.
9. Rosas S, Law TY, Kurowicki J, et al. Trends in surgical management of proximal humeral fractures in the Medicare population: a nationwide study of records from 2009 to 2012. J Shoulder Elbow Surg 2016 Apr; 25(4): 608–13.
10. Plath JE, Kerschbaum C, Seebauer T, et al. Locking nail versus locking plate for proximal humeral fracture fixation in an elderly population: a prospective randomised controlled trial. BMC Musculoskelet Disord 2019 Jan 10; 20(1): 20.
11. A.A. Frombach et al 2017. Humeral Head Replacement and Reverse Shoulder Arthroplasty for the Treatment of Proximal Humerus Fracturesm. DOI: 10.2174/187432500 1711011108
12. Pogliacomi F, Devecchi A, Costantino C, Vaienti E. Functional long-term outcome of the shoulder after antegrade intramedullary nailing in humeral diaphyseal fractures. Chir Org Mov 2008; 92(1): 11–6.
13. Constant-Murley Shoulder Outcome Score. https://www.physio-pedia.com/Constant-Murley_Shoulder_Outcome_Score#cite_note-mm-2
14. Assunção JH, Malavolta EA, Beraldo, RA Gracitelli MEC, Bordalo-Rodrigues M, Ferreira Neto AA. Impact of shoulder rotation on neck-shaft angle: A clinical study.
15. Jia X, Chen Y, Qiang M, et al. Postoperative Evaluation of Reduction Loss in Proximal Humeral Fractures: A Comparison of Plain Radiographs and Computed Tomography. Orthopaedic Surgery 2017; 9(2): 167–73.
16. Lind T, Kroner TK, Jensen J. The epidemiology of fractures of the proximal humerus. Arch Orthop Trauma Surg 1989; 108 (5): 285–7.
17. Jinn Lin. Effectivness of locked nailing for displaced three-part proximal humeral fractures. The journal of Trauma Injury, Infection, and critical care 2006; 61: 363–74.
18. Lin J, Shen PW, Hou SM. Complications of locked nailing in humeral shaft fractures. J Trauma 2003; 545 (5): 943–9.
19. Szyszkowitz R, Seggl W, Schleifer P, Cundy PJ. Proximal humeral fractures management: techniques and expected results. Clin Orthop 1993; 292: 13–25.
20. Dilisio MF, Nowinski RJ, Hatzidakis AM, Fehringer EV. Intramedullary nailing of the proximal humerus: evolution, technique, and results. *J Shoulder Elbow Surg*. 2016; 25(5): e130–e138.
21. Koval KJ, Gallagher MA, Marsicano JG,et al. Functional outcome after minimally displaced fractures of the proximal part of the humerus. *J Bone Joint Surg Am* 1997; 79(2): 203–7.
22. Rangan A, Handoll H, Brealey S, et al. Surgical vs Nonsurgical Treatment of Adults With Displaced Fractures of the Proximal Humerus. JAMA 2005; 313(10): 1037.
23. Robinson CM, Christie J. The two part proximal humeral fracture: a review of operative treatment using two techniques. Injury 1993; 24: 123–5.
24. Schippinger G, Szyszkowitz R, Seibert FJ. Current concepts in the treatment of proximal humeral fracture. Curr Orthop 1997; 292: 203–14.
25. Lekic N, Montero MN, TakemotoRC, Davidovitch R, Egol KA. Treatment of two-part proximal humerus fractures: intramedullary nail compared to locked plating. HSS J 2012 Jul; 8(2): 86-91.
26. Wong J, Newman JM, Gruson KI. Outcomes of intramedullary nailing for acute proximal humerus fractures: a systematic review. Journal of Orthopaedics and Traumatology 2016; 17(2): 113–22.
27. Sobel A, et al. Fixation of a Proximal Humerus Fracture With an Intramedullary Nail. J Orthop Trauma 2017; 31: S47–S49.
28. Riemer BL, Butterfield SL, D'Ambrosia R, Kellam J. Seidel intramedullary nailing of humeral diaphyseal fractures: a preliminary report. Orthopedics 1991; 14: 239–46.
29. De Filippo M, Bertellini A, Sverzellati N, Pogliacomi F, Costantino C, Zappia M, Corradi D, Vitale M, Garlaschi G, Zompatori M. Multidetector computed tomography arthrography of the shoulder: diagnostic accuracy and indications. Acta Radiol 2008 Jun; 49(5): 540–9.
30. Murena L, Canton G, Vulcano E, Surace MF, Cherubino P. Treatment of humeral shaft aseptic nonunions in elderly patients with opposite structural allograft, BMP-7, and mesenchymal stem cells. Orthopedics 2014 Feb; 37(2): e201–6.
31. Dall'Oca C, Maluta T, Leone N, Micheloni GM, Lavini F. The treatment of proximal humeral fractures with a "Polarus" intramedullary nail. Acta Biomed 2014 Sep 24; 85 Suppl 2 : 25–30.

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Original article

Predictive value of valgus head-shaft angle in identifying Neer 4-part proximal humerus fractures. A radiographic and CT-scan analysis of 120 cases

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Summary. *Background and aim of the work:* Understanding the fracture morphology and its relation to the expected outcome and risk of complications is fundamental for proximal humerus fractures (PHFs) management. Most Neer 3- and 4-part fractures may deserve surgical treatment. Unfortunately, plain x-rays may not be able to differentiate between a 3- or 4-part fractures unless an axillary or analogue projection is carried out. Aim of the present study is to evaluate whether a high valgus head-shaft angle degree is predictive of a Neer 4-part rather than a 3-part fracture. *Methods:* The study included 120 3-(75 cases) and 4-(45 cases) part PHFs (valgus displaced in 98 cases), M:F ratio = 1:2.6, mean age 65.7 years, classified on CT scan images. The humeral head shaft angle was calculated on AP x-rays and statistically correlated with 3 and 4-part fractures to identify values predictive of 4-part fracture. *Results:* Valgus head/shaft angle was significantly higher in 4-part fractures, especially in the valgus displaced group ($p < 0.001$). A cutoff value of 168.5° was identified as predictive of a 4-part fracture with a sensibility of 74% and specificity of 78%. Increasing by 1 degree the humeral head-shaft angle, the chance to have a 4-part fracture increases of 3% in the whole population and of 11% in the valgus sub-group. *Conclusion:* The severity of PHF can be predicted analysing valgus head shaft angle on AP x-rays with a sensibility of 74% and specificity of 78% in identifying a 4-part fracture with a cutoff value of 168.5°.

Key words: proximal humerus fractures, 4-part fracture, predictive value, valgus displacement, humeral head-shaft angle

Background and aim of the work

Proximal humerus fractures (PHFs) are the third most common fragility fractures after proximal femur and distal radius fractures. Incidence varies between 82 and 105 per 100.000 person/year (1,2). Proper treatment for these fractures is currently matter of debate in the literature. Several indications and treatment options have been described without a clear evidence about outcome (3). About 80% of PHFs have a stable configuration, with absent or minimal displacement. In these cases, mostly 2-part fractures according to Neer classification, excellent results may be achieved with conservative treatment. Displaced or comminuted PHFs may also be better treated conservatively in patients over 85 years old affected by severe osteoporosis, cognitive impairment or significant comorbidities (4-7). In rare cases, below 1%, surgical indication for PHFs is considered absolute. The remaining about 20% may benefit from surgical intervention. Most

Neer 3- and 4-part fractures, that represent about 13-16% of all PHFs, belong to this group. Nonetheless, whether reduction and fixation or primary arthroplasty may be better indicated in these cases is still matter of debate (4). Correct indication should consider the expected outcome, functional demand, compliance of the patient and surgeon experience (8). Ideally, fracture reduction and fixation should be preferred to arthroplasty because of the better clinical results achieved in uncomplicated cases with anatomic reconstruction (9,10). On the other hand, especially in fragility osteoporotic fractures, osteosynthesis is frequently related to complications mostly deriving from the surgeons insufficient understanding of risk factors for humeral head avascular necrosis (AVN) and failure of fixation (11,12). Thus, "understanding" the fracture morphology and its relation to the expected outcome and risk of complications is fundamental. The key elements to detect are severity of tuberosities displacement and comminution, valgus or varus humeral head impaction/displacement, fracture of the humeral head (true or false head split), associated gleno-humeral dislocation, metaphyseal comminution, humeral head fragment thickness and quality of cortical and trabecular bone (8,9). To reach this goal radiographic analysis is necessary. Unfortunately, plain x-rays may not be easy to interpret or may not be able to differentiate between a 3- or 4-part fractures unless an axillary or analogue projection is carried out. For all the above reasons CT scans with 3D reconstruction are typically used to better evaluate PHFs and are considered essential in pre-op planning. Nonetheless, plain x-rays might give substantial information about the severity of PHF if correctly interpreted, especially in distinguishing between Neer 3- and 4-part fractures. Indeed, detecting a displaced lesser tuberosity fracture is needed to distinguish between Neer 3- and 4-part PHFs, which may significantly influence fracture management. However, data show that most patients prefer not to undergo a traditional axillary projection (13), and that even when explicitly requested by the orthopedic surgeon in a complete trauma series, this projection is often not performed (14). Nonetheless, severe valgus displacement has been classically associated to Neer 4-part fractures (10), whereas valgus impacted fractures may present as 2, 3 or 4-part fractures, without clear association with the severity of valgus displacement according to the literature (2,6,15). Aim of the present study is to analyze whether severity of PHF can be predicted on AP shoulder plain x-rays based on the valgus humeral head-shaft angle. The null hypothesis is that a high valgus head-shaft angle degree is predictive of a Neer 4-part rather than a 3-part fracture.

Materials and Methods

All the 279 patients undergoing surgical treatment for PHF at the Cattinara Hospital Orthopedic and Traumatology Unit between January 1st 2016 and May 31st 2019 were considered for the present study. Patients with Neer 3- and 4-part fractures, documented with both pre-operative x-rays and CT scans, were selected for radiographic retrospective evaluation by one of the authors (B.M.). Exclusion criteria were the following: Neer 2 parts fractures; fractures extending to the humeral shaft; low quality pre-op x-rays that did not enable proper radiographic evaluation. The included cases AP x-rays were evaluated by two of the authors (R.N., M.G.) in order to calculate the head-shaft angle. This angle is formed by the intersection of two axis: the humeral shaft axis *(the neck-shaft line)* and the humeral head axis (the *anatomical neck line or inclination line)* (Figure 1). The *neck-shaft line* is obtained drawing a line parallel to the cortical shaft whilst the *inclination line* is obtained drawing a line between the great tuberosity apex and the highest point of the inferior articular surface (10). The angle formed by the intersection of these lines is known as the inclination angle: 90° are added to the inclination angle to obtain the humeral head-shaft angle. This angle is defined as the angle created by the intersection of the neck-shaft line and the perpendicular line to the articular inclination line. Physiologically this angle lies between 135° and 150°. A subgroup including only the valgus head-shaft angle patients (> 150°) was identified and data evaluation was carried out on the whole population and on the valgus head-shaft angle group, comparing 3- and 4-part fractures subgroups.

Statistical analysis was performed on all the population and on the subgroup. The variables were analyzed descriptively through the mean, standard deviation,

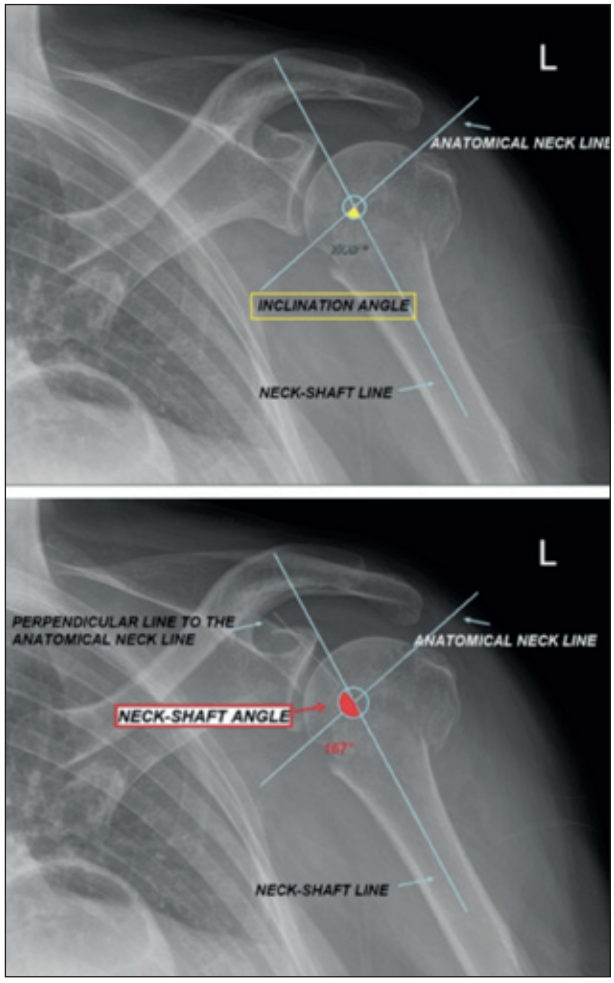


Figure 1. (A) Inclination angle, (B) neck-shaft angle of a valgus 3-part fracture

minimum and maximum values, and 95% confidence intervals. ANOVA test was used to compare the humeral head-shaft angle means of both groups. A ROC curve was created to evaluate the humeral head-shaft angle discrimination capacity to identify 3- or 4-part fractures in both groups. To further discriminate between 3- and 4-part fractures the optimal cutoff with *Youden's Index* (*j = sensibility + sensitivity –1*) was calculated. Finally, a univariate logistic regression was carried out to calculate OR to estimate the probability of increasing valgus humeral head-shaft angle to predict a 4-part fracture compared to a 3-part fracture. Statistical significance was considered with p-value < 0.05.

Results

Applying exclusion and inclusion criteria, a population of 120 PHF cases were selected for the present study. In detail, excluded patients did not undergo preoperative CT scans in 69 cases, presented with a 2-part fracture in 72 cases or with fractures extending to the humeral shaft in 3 cases and in 15 cases the low preop x-rays quality hindered proper angles measurement. Of the 120 included patients 34 were male (28.3%) and 86 were female (71.7%), with a M:F ratio = 1:2.6 and a mean age of 65.7 years (*SD 12.15*). A 3-part fracture was present in 75 patients (62.5%) while a 4-part fracture in 45 patients (37.5%). Mean head-shaft angle in the whole population was 160.75° (*SD 17.68, CI 157.56-163.94, range 110°-219°*). In detail, 3-part fractures humeral head-shaft angle had a mean value of 158.01° (*SD 14.04, CI 154.78°-161.24°, range 110°-186°*), while the 4-part fracture humeral head-shaft angle had a mean value of 165.31° (*SD 21.9, CI 158.73°-171.89°, range 117°-219°*). The difference between the two groups resulted to be statistically significant (*p = 0.028*). (Table 1a)

A subgroup of 98 patients displaying a valgus humeral head-shaft angle was identified (Figure 2). The remaining 22 patients displayed a normal angle in 12 cases and a varus humeral head-shaft angle (< 135°) in 10 cases, equally distributed in 3 and 4-part fractures. The mean head-shaft angle in the valgus head-shaft angle subgroup had a mean value of 166.74° (*SD 12.5, CI 164.24-169.25, range 150°-219°*). A 3-part fracture was present in 64 patients (65.3%), with a mean head-shaft angle value of 162.50° (*SD 8.42, CI 160.40°-164.60°, range 152°-186°*), while a 4-part fracture was present in 34 patients (34.7%). With a mean head-shaft angle of 173.74° (*SD 14.94, CI 169.52°-179.95°, range 150°-219°*). The difference between the two groups resulted to be statistically significant (*p < 0.001*). (Table 1b)

The calculation of ROC curve to evaluate the discriminatory power of the humeral head-shaft angle between 3 and 4-part fractures demonstrated an AUC for the total population of 0.64 (*CI 0.53-0.76*) and for the valgus humeral shaft angle sub-group of 0.79 (*CI 0.69-0.89*). (Table 2)

The optimal cutoff to discriminate between a 3- and a 4-part fracture in the total population was

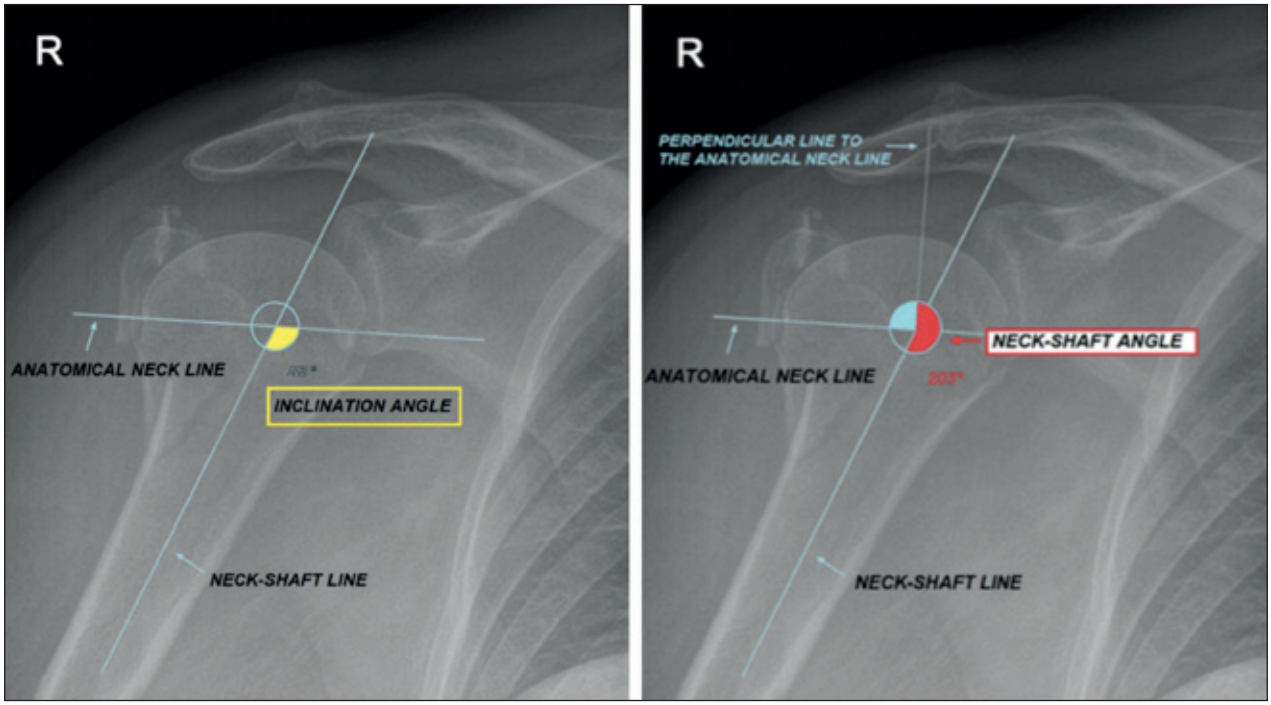


Figure 2. (A) Inclination angle, (B) neck-shaft angle of a valgus 4-part fracture

Table 1. Humeral head-shaft angle in 3- and 4-part PHFs: a) Total population; b) valgus humeral head-shaft angle sub-group

a)

Total population				
	3 parts (n = 75)	4 parts (n = 45)	Tot (n = 120)	p value
Mean and Standard Deviation of the head-shaft angle	158.01 ± 14.04	165.31 ± 21.9	160.75 ± 17.68	0.028
Min value	110	112	110	
Max value	186	219	219	

b)

Valgus humeral head-shaft angle subgroup				
	3 parts (n = 64)	4 parts (n = 34)	Tot (n = 98)	*P value*
Mean and Standard Deviation of the head-shaft angle	162.5 ± 8.42	174.74 ± 14.94	166.74 ± 12.50	< 0.001
Min value	152	150	150	
Max value	186	219	219	

168.5° (sensibility 56%, specificity 81%, Younden's Index = 0.52). The optimal cutoff to discriminate between a 3- and a 4-part fracture in valgus sub-group was 168.5° (sensibility 74%, specificity 78%, Younden's Index = 0.52). Compared with the *Boxplot* of the whole population, the *Boxplot* of the valgus subgroup showed many outliers for severe valgus angles (Table 3). The *Odds Ratio* for the whole population was *1.03* (*C.I. 1.00-1.05)* and for the valgus sub-group was *1.11 (C.I. 1.06-1.175)*. Hence, increasing by 1 degree the humeral head-shaft angle, the chance to have a 4-part fracture increases of 3% in the whole population and of 11% in the valgus sub-group.

Table 2. ROC curve

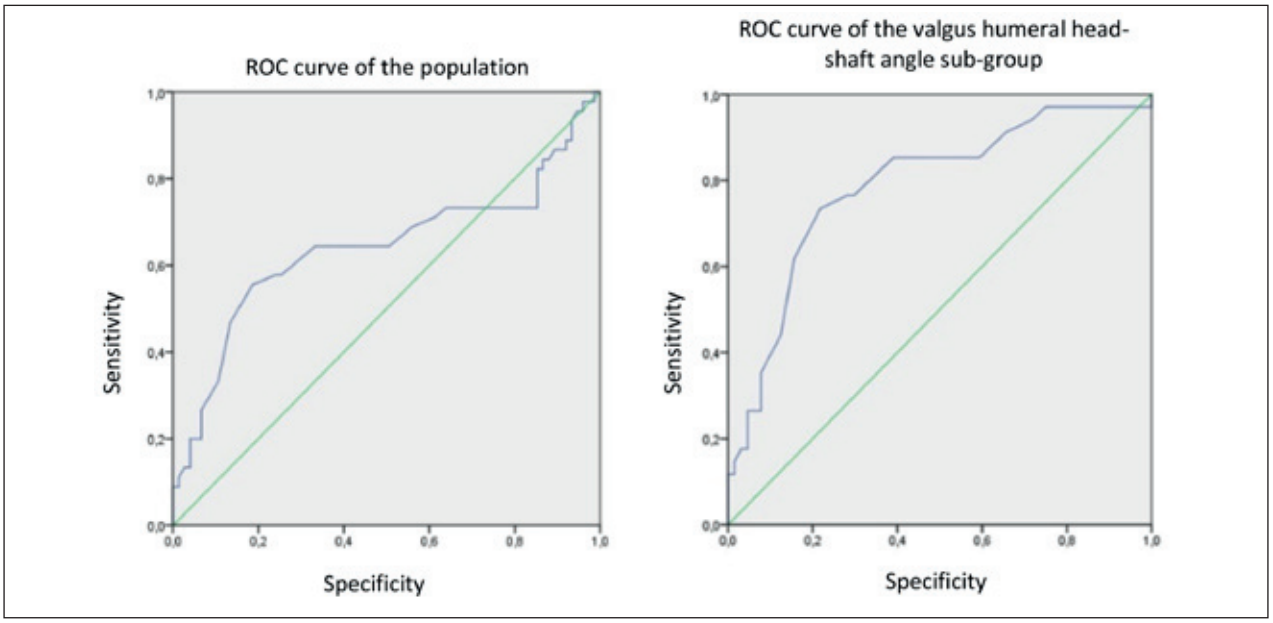
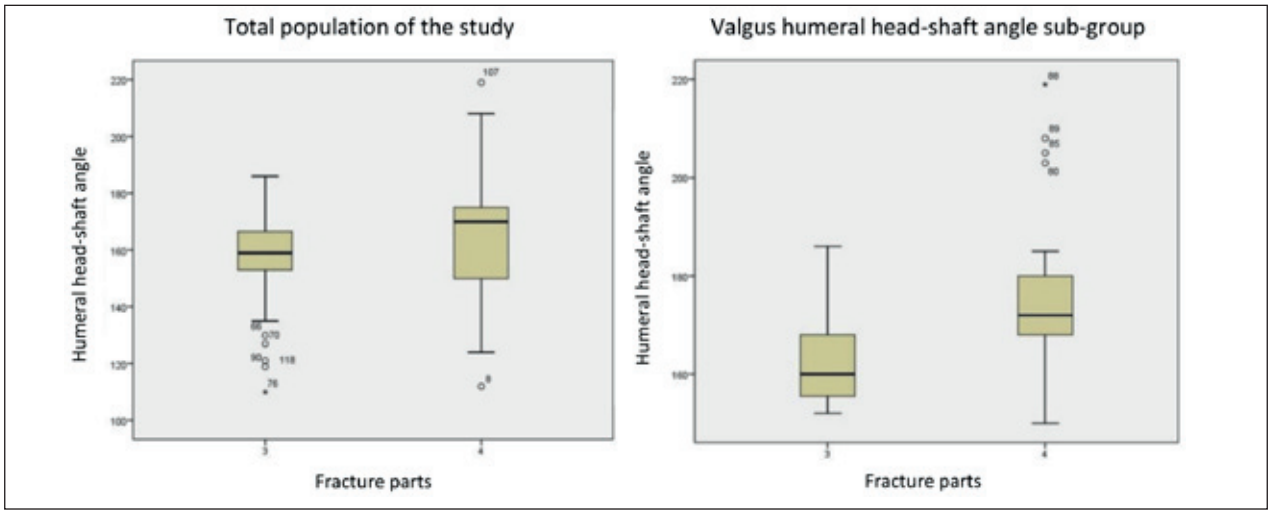


Table 3. Boxplot of both groups



Discussion

Management of Neer 3- and 4-part fractures is often complex and there is no consensus on best treatment option (11). In the literature, nearly 70% of these fractures affect patients >60 years of age, data consistent with the average age of the present study (65.7yrs). Analysis of the relation between age and fracture patterns shows that the most complex patterns occur in older patients (2). Fracture pattern is often the first factor taken into account when defining treatment strategy (4). PHF are mostly minimally displaced and usually involve the surgical neck and greater tuberosity, in these cases treatment through immobilization alone is a well consolidated practice with acceptable clinical outcomes (16-18). Nonetheless, more complex fracture patterns

are not uncommon. Incidence of 3- and 4-part PHF is considered to be around 13-16%. The prevalence rises considerably when taking into account population studies that consider inpatients as well as outpatients data. A study conducted in Finland by Launonen et al. found that whilst 2-part PHF may be the most frequent type of fracture pattern, 3- and 4-part PHFs account for more than a quarter of all PHFs, respectively 19% and 7% (1). The difference in incidence rates can be explained by poor intra- and interobserver sensitivity in assessing and properly classifying PHFs found in all proximal humeral classifications, Stig Brorson found this to be particularly true when assessing 4-part PHFs (19).

Fracture patterns with valgus displacement of the humeral head have been thoroughly described in the literature. The "classical" fracture pattern is characterized by a 4-part fracture with a lateral displacement and rotation of the humeral head (19), the humeral head collapses due to traumatic forces which lead to shortening of the humerus and displacement of the tuberosities. Another specific fracture pattern known as "valgus impacted" is characterized by impaction of humeral head into the humeral shaft with variable displacement of the tuberosities. Integrity of the medial hinge and calcar and the presence of continuity between head and lesser tuberosity are important pro- tective factors in avoiding avascular necrosis of the humeral head (6). Most studies in literature attribute to this fracture pattern an average valgus angle > 160° and a greater tuberosity displacement > 1 cm (15,20-22). Jakob et al. were the first to describe this fracture pattern reporting its prevalence and prognosis. The AO classification describes sub-groups in which impaction of the humeral head into the proximal humeral metaphysis is the principle deformity (15). Court Brown et al. found that fractures with humeral head impaction (classified as B1.1 according to the AO classification) can manifest with variable levels of displacement: minimally displaced, 2- part fractures, 3- part fractures and 4-part fractures (2). There is a lack of literature reports that associate the valgus angle of PHFs with 3- or 4-part fractures, the only data available focus on prosthetic design or functional outcome after treatment (10,23-25). Given the difficulty of obtaining an axillary view to detect a lesser tuberosity fracture in the emergency department and the previous description of severe valgus displacement association with 4-part fractures, recognizing a predictive value of a given valgus angle to be associated with 3 or 4-part fractures might be useful for clinical practice. The present study included 120 PHFs in 120 patients, 75 patients with a 3-part fracture and 45 with a 4-part fracture. The average humeral head-shaft angle was 160°, with 36 patients presenting a severe valgus humeral head-shaft angle (>170°). Notably, patients with a 4-part fracture averaged a humeral head-shaft angle of 174.74°, data aligned with previous literature reports (14). However, the present study data show a direct correlation of valgus humeral head-shaft angle and 3- and 4-part fractures, which was not previously reported at our knowledge. When the valgus humeral head-shaft angle is superior to the cutoff value of 168.5° it is possible to determine whether the fracture is a 3-part fracture or a 4-part fracture with a sensibility of 74% and specificity of 78%. When compared to sensibility and specificity values obtained in the total population, respectively 56% and 81%, the valgus subgroup values become more relevant. Nonetheless, the AUC of 0.79 of the humeral head-shaft angle in the valgus sub-group is significant in discriminating between 3- and 4-part PHF, especially when compared to the whole population AUC of 0.64. Furthermore, it was particularly interesting to find that the chance of finding a 4-part fracture compared to a 3-part fracture increased only by 3% per 1° increase of humeral head-shaft angle in the whole population, while in the valgus sub-group this chance increased by 11%. Taken into account these data it is correct to assume that a fracture with a severe valgus angle (>170°) has a very high chance to be a 4-part fracture.

Conclusions

The severity of a PHF with valgus head displacement can be predicted by analyzing the humeral head-shaft angle, which is easily obtainable from simple AP X-rays, with a sensibility of 74% and specificity of 78% in detecting a 4-part fracture when a cut-off of 165.8° is considered. This simple measurement might be a clinically useful tool to suspect a more complex fracture pattern and thus to guide treatment planning, especially when CT scan is not available.

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References

1. Launonen AP, Lepola V, Saranko A, Flinkkila T, Laitinen M, Mattila VM. Epidemiology of proximal humerus fractures. Arch Osteoporos 2015;10(1):209
2. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. Acta Orthop Scand 2001;72(4):365–371
3. Hasty EK, Jernigan EW 3rd, Soo A, Varkey DT, Kamath GV. Trends in surgical management and costs for operative treatment of proximal Humerus fractures in the elderly. Orthopedics 2017;40:e641–7
4. Neer CS II. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am 1970;52:1077–89
5. Iyengar JJ, Devcic Z, Sproul RC, Feeley BT. Nonoperative treatment of proximal humeral fractures. A systematic Review. J Orthop Trauma 2011;25:612–617
6. Court-Brown CM, Cattermole H, McQueen MM. Impacted valgus fractures (B1.1) of the proximal humerus. The results of non-operative treatment. J Bone Joint Surg Br 2002;84:504–8
7. Murray IR, Amin AK, White TO, Robinson CM. Proximal humeral fractures: current concepts in classification, treatment and outcomes. J Bone Joint Surg Br 2011;93:1–11.
8. Hertel R, Hemfing A, Stiehler M, Leunig M. Predictors of humeraL head ischemia after intracapsular fracture of the proximal humerus. J Shoulder Elbow Surg 2004;13: 427–433
9. Shrader MW, Sanchez-Sotelo J, Sperling JW, Rowland CM, Cofield RH. Understanding proximal humerus fractures: image analysis, classification, and treatment. J Shoulder Elbow Surg 2005;14:497–505
10. Canbora MK, Kose O, Polat A, Konukoglu L, Gorgec M. Relationship between the functional outcomes and radiological results of conservatively treated displaced proximal humerus. Int J Shoulder Surg 2013;7(3):105–109.
11. Rose SH, Melton LJ, Morrey BF, Ilstrup DM, Riggs BL. Epidemiologic features of humeral fractures. Clin Orthop 1982;168:24–30
12. Vallier HA. Treatment of proximal humerus fractures. J Orthop Trauma 2007;21:469–76
13. Geusens E, Pans S, Verhulst D, Brys P. The modified axillary view of the shoulder, a painless alternative. Emerg Radiol 2006;12(5):227–230.
14. Berkes MB, Dines JS, Birnbaum JF, Lazaro LE, Lorich TC, Little MT, Nguyen JT, Lorich DG. The axillary view typically does not contribute to decision making in care for proximal humeral fractures. HSS J 2015;11(3):192e197
15. Jakob RP, Miniaci A, Anson PS, Jaberg H, Osterwalder A, Ganz R. Four-part valgus impacted fractures of the proximal humerus. J Bone Joint Surg Br 1991;73: 295–8
16. Handoll HHG, Ollivere BJ, Rollins KE. Interventions for treating proximal humeral fractures in adults. Cochrane Database Syst Rev 2012;12:CD000434
17. McLaurin TM. Proximal humerus fractures in the elderly are we operating on too many? Bull Hosp Jt Dis 2004;62: 24–32
18. Jobin CM, Galdi B, Anakwenze OA, Ahmad CS, Levine WN. Reverse shoulder arthroplasty for the management of proximal humerus fractures. J Am Acad Orthop Surg 2015;23(3):190–201
19. Brorson S, Bagger J, Sylvest A, Hrobjartsson A. Diagnosing displaced four-part fractures of the proximal humerus: a review of observer studies. Int Orthop 2009;33:323–327
20. Robinson CM, Page RS. Severely impacted valgus proximal humeral fractures. Results of operative treatment. J Bone Joint Surg Am 2003;85:1647–55
21. Robinson CM, Longino D, Murray IR, Duckworth AD. Proximal humerus fractures with valgus deformity of the humeral head: the spectrum of injury, clinical assessment and treatment. J Should Elb Surg 2010;19:1105–1114
22. Catalano L, Dowling R. Valgus impacted fracture of the proximal humerus. J Hand Surg Am 2011;36(11): 1843–1844
23. Dheenadhayalan J, Prasad VD, Devendra A, Rajasekaran S. Correlation of radiological parameters to functional outcome in complex proximal humerus fracture fixation: A study of 127 cases. J Orthop Surg 2019;27(2) 1–8
24. Iannotti JP, Lippitt SB, Williams GR. Variation in neck-shaft angle: influence in prosthetic design. Am J Orthop 2007;36:9–14
25. Poeze M, Lenssen AF, Van Empel JM, Verbruggen JP. Conservative management of proximal humeral fractures: Can poor functional outcome be related to standard transscapular radiographic evaluation? J Shoulder Elb Surg 2010; 19:273–81

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Original article

Simple and stable elbow dislocations: results after conservative treatment

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Summary. *Background and aim of the work:* In adults, elbow dislocations are second in frequency after shoulder dislocations. They are often the result of a trauma due to accidental falls on the palm of the hand with the elbow flexed. In most cases this mechanism produces a posterior dislocation of the radius and ulna with respect to the humerus. The therapeutic approach was usually conservative in the past and it was characterized by manual reduction and plaster immobilization. More recently, as consequence of biomechanic and pathophysiology studies, the management of these injuries has gradually changed. The current trend is to immobilize the elbow only for few days and to evaluate its stability several times. In case of instability surgery may be indicated. The aim of this study was to assess the outcomes of simple stable elbow dislocations treated conservatively between january 2012 and december 2018. *Methods:* Twenty-six patients were included. All subjects underwent to a follow-up visit, in which clinical functional tests were performed in order to evaluate any stiffness in flexion-extension, prono-supination and instability in varus-valgus. In addition, patients were asked to complete three questionnaires (DASH, MEPS, SF-36) to evaluate how much the pathology interfered with ADL's. *Results:* Outcomes showed that prolonged immobilization increased stiffness in flexion and extension with the need of longer reabilithation. The recovery of prono-supination was instead always optimal. ADL's migth be influenced by the traumatic event and its management. *Conclusions:* Results of conservative treatment of simple elbow dislocation are generally satisfactory. A precise flow-chart of the patient management after trauma is essential in order to detect unstable lesions and to plan the correct therapy. This is the basis for the prevention of joint stiffness and long-term insatbility.

Key words: elbow, dislocation, stiffness, instability.

Introduction

In adults traumatic elbow dislocation are second in frequency only to shoulder dislocation in large joints and they occur at an approximate rate of 6-13/100000 per year (1-4). The most common injury mechanism is a falls onto an outstretched hand with the elbow in flexion. About 60% of dislocations occur in the non-dominant limb. The primary stability of the elbow is maintained by bone and ligament structures; the first are represented by the coronoid and the olecranon, the second by the lateral and medial collateral ligaments. The secondary stabilizers are represented by the radial capitellum, the joint capsule and the muscles, with a lesser role than the primary ones. Before proceeding with the manual reduction of the dislocation it is nec-

essary to perform an X-ray to confirm the suspected clinical diagnosis and make sure that there are no associated fractures. The reductive maneuver is usually performed in general anaesthesia or deep sedation. It is essential to evaluate the stability of the joint complex, by carrying out specific tests (varus-valgus stress, "postero-lateral pivot-shift test"). Actually, most simple dislocations do not require surgery and are managed conservatively with early range of motion. If the elbow remains unstable and the joint continues to dislocate, surgery should be indicated (5-7).

The aim of this study was to assess the outcomes of 26 simple stable elbow dislocations treated conservatively between january 2012 and december 2018 at the Orthopaedic Clinic of the University Hospital of Parma.

Materials and methods

Twenty-six patients with simple elbow dislocation treated at the University Hospital of Parma between January 2012 and December 2017 were enrolled. This study was conducted in accordance with the principles of Declaration of Helsinki. All patients signed informed consent about the treatment they were subjected and the processing of their personal data.

Patients younger than 18 years of age and those with fracture-dislocations were excluded. Treatment was the same described in the introduction for reduction and acute evaluation of the stability followed by plaster application with elbow at 90° degrees of flexion for seven days. After seven days the plaster was removed and a clinical visit was made to check again the stability of the elbow. If the joint was stable a specific articulated brace was then applied (-40° to full flexion from day 7 to 14 and -20° to full flexion from day 15 to 21). In 6 out of 26 patients a non articulated plaster was applied for three weeks. Each patient was contacted by telephone, inviting him to return to the Orthopaedic Clinical to carry out a check-up visit. Furthermore, it was asked to bring the previous documentation with regards to the patient's diagnostic and therapeutic process. During the visit the patient was asked to tell their own experience, focusing on the dynamics of the trauma, on the attempt to manual reduction, on the duration of maintenance of the plaster cast, on any symptoms present before and after the removal of the plaster and on the duration of rehabilitation treatment. After collecting these informations, the patient underwent a clinical visit, during which with a protractor the degrees of movement in flexion-extension and prono-supination were assessed. Joint stability was also evaluated by subjecting the elbow to varus-valgus stress and through the "milking maneuver". In addition, a clinical examination was performed to assess any nervous alterations, focusing on the innervation territories of the ulnar, median and radial nerve. All assessments were compared to those of the contralateral limb. Ultimately the patient was asked to fill in three questionnaires (MEPS, DASH and SF-36), through which it was possible to evaluate how much the pathology influenced the subject's normal daily activities (ADL's).

This study aimed to evaluate the outcome of subjects treated for elbow dislocation with reference to the optimal functioning of the contralateral limb. Based on these considerations, it was likely to assume that the performance of the affected limb was worse than the contralateral, more formally the following hypotheses were formulated:

- H1: The DASH score is higher in subjects who had an elbow dislocation compared to the optimal limb performance.
- H2: The working DASH score is higher in subjects who had an elbow dislocation compared to the optimal limb performance.
- H3: SF36 physical activity is less in subjects who had an elbow dislocation compared to optimal performance.
- H4: the SF36 physical role limitations is less in subjects who had an elbow dislocation than the optimal performance.
- H5: SF36 physical pain is less in subjects who had an elbow dislocation than optimal performance.
- H6: SF36 general health is lower in subjects who had an elbow dislocation compared to optimal performance.
- H7: SF36 vitality is less in subjects who had an elbow dislocation compared to optimal performance.
- H8: the SF36 social activities is less in subjects who had an elbow dislocation than the optimal performance.

- H9: the SF36 emotional role limitations is less in subjects who had an elbow dislocation than the optimal performance.
- H10: SF36 mental health is less in subjects who had an elbow dislocation than the optimal performance.
- H11: MEPS pain is less in subjects who had an elbow dislocation than the optimal limb performance.
- H12: the MEPS movement is less in subjects who had an elbow dislocation than the optimal limb performance.
- H13: the MEPS stability is lower in subjects who had an elbow dislocation compared to the optimal performance of the limb.
- H14: MEPS activity is lower in subjects who had elbow dislocation compared to optimal limb performance.

Statistic Analysis

The experimental sample consisted of 26 subjects (18 males and 8 females with an average age of 43 years). The data analysis was carried out with the IBM SPSS statistical analysis software (ver. 23). To test the experimental hypotheses, the Mann-Whitney nonparametric U test was used for the comparison between means. Significance was accepted at a p-value level < 0.05.

Results

The mean follow-up was 40 months (range 12-96). All patients had an initial conservative treatment for 3 weeks. Twenty-one patients out of 26 recovered full ROM in comparison to contralateral elbow (figure 1 and 2). Five on 26 showed a mean deficit in extension of 20° (range 10-30°) despite more intense and lasting rehabilitation (mean rehabilitation time 60 days). All these five cases did not do early range of motion as they had a fixed plaster for all the duration of the treatment. Prono-supination movements were complete and similar in both sides. The mean rehabilitation time was 40 days (range 25-80). Joint stability was maintained at follow-up as already demonstrated at the moment of injury and 7 days later. As well, there was no impairment of radial, ulnar and median nerve.

Table 1 shows the averages of the parameters analyzed.

Hypotheses H1, H3, H6, H7, H8 and H10 were

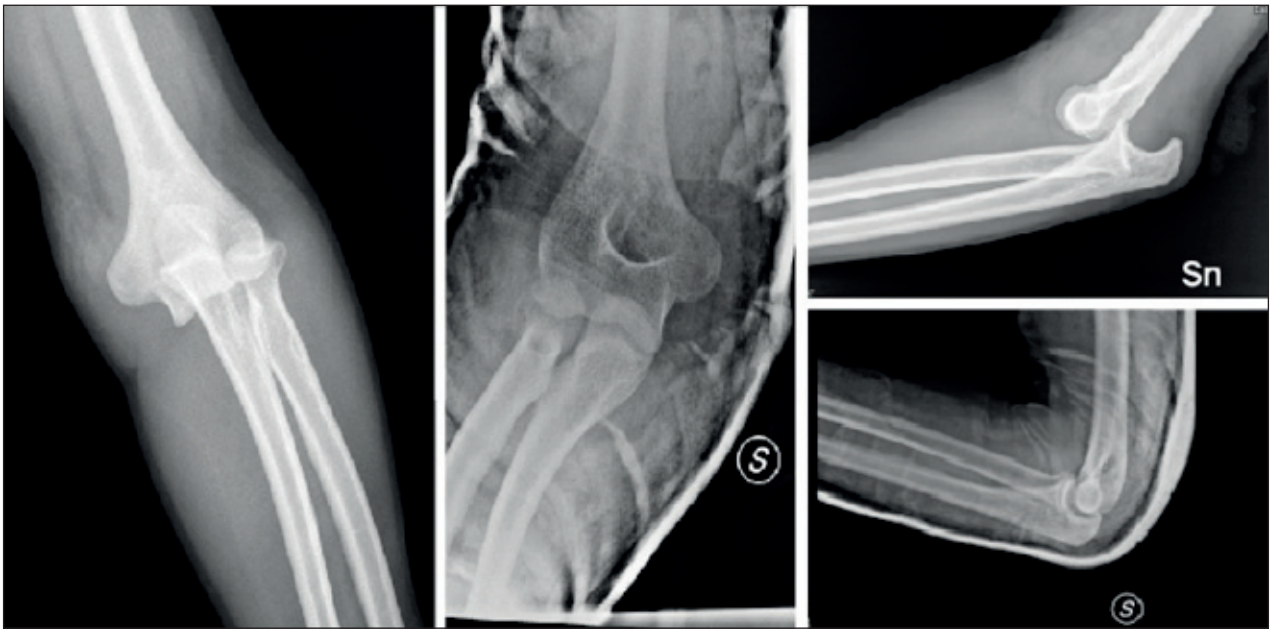

Figure 1. Simple dislocation of the left elbow. X-rays before and after reduction

Figure 2. One year follow-up. X-ray and clinical evaluation with full recovery

Table 1. Value of the scores.

	Minimum	Maximum	Average	Std. Deviation
DASH	1,00	2,73	1,3023	,51098
Working DASH	1,00	2,75	1,2500	,50000
Physical Activity	50,00	100,00	90,7692	14,55538
Physical role limitation	,00	100,00	78,8462	33,61261
Physical pain	32,00	100,00	82,5385	25,49057
General Health	47,00	100,00	76,8462	17,44442
Vitality	20,00	100,00	69,2308	21,09958
Social activities	62,00	100,00	91,1538	11,99893
Emotional role limitations	,00	100,00	87,0769	29,07021
Mental health	28,00	100,00	76,6923	19,32781
MEPS Pain	15,00	45,00	41,5385	8,98717
MEPS Mouvment	20,00	20,00	20,0000	,00000
MEPS Stability	10,00	10,00	10,0000	,00000
MEPS Activity	15,00	25,00	24,2308	2,77350

supported; conversely, the hypotheses H2, H4, H5, H9, H11, H12, H13 and H14 were not supported.

- The data showed that the DASH score regarding the limb that underwent elbow dislocation was greater than the contralateral limb (H1). The difference between the optimal score and that of the affected limb was significant (p-value = 0.006) and was equal to 0.3023. Therefore, there was a slight residual disability. This data was reinforced by the fact that the H2 hypothesis was null (p-value = 0.186); in fact, there were no significant differences between the working DASH of the diseased limb and that of the healthy contralateral limb.
- Patients diagnosed with elbow dislocation had a lower SF36 physical activity than optimal performance (H3). The difference was 9.2308 (p-value = 0.019); therefore it could be considered a difference of moderate level.
- The data regarding the SF36 general health (H6) showed a significant difference between the patient and the optimal performance, with a value of 23.1538 (p-value = 0.000).
- Patients with elbow dislocation had a SF36 vitality (H7) of 30.7692 lower than the optimal performance (p-value = 0.000).
- By examining the data regarding the SF36 social activities (H8) they were lower than the optimal performance. The difference was 8.8462 (p-value = 0.044).
- Sick subjects had a lower mental health SF36 than optimal performance (H10), with a difference of 23.3077 (p-value = 0.000).
- Patients with elbow dislocation did not show significant differences in terms of performance compared to the optimal condition with reference to:
  - working DASH (H2); p-value = 0.186
    SF36 physical role limitations (H4); p-value = 0.101
  - SF36 physical pain (H5); p-value = 0.101
    SF36 emotional role limitations (H9); p-value = 0.336
  - MEPS pain (H11); p-value = 0.511
  - MEPS movement (H12); p-value = 1,000
  - MEPS stability (H13); p-value = 1,000
  - MEPS activity (H14); p-value = 0.762.

Discussion and conclusion

The study results suggest that, although patients generally report favorable long-term functional out-

comes after a simple elbow dislocation, these lesions are not entirely benign.

The data analyzed by the DASH questionnaire show that a slight deficit remains after the treatment of elbow dislocations, although this is more correlated with the daily activities of high difficulty (lifting weights, making intense efforts) but does not interfere with the work activities of the patient. The impact of this slight deficit could be further investigated in the future, with the aim of verifying the existence of differences according to specific work activities. More specifically, it may be useful to assess the existence of difficulty about work activities that require a more intense use of the upper limb, and in particular of the elbow.

The results of SF36 physical activity also show that patients with elbow dislocation have a significant reduction in performance compared to optimal values. This evidence provides further support for the results obtained from the analysis of the DASH score, noting the persistence of consequences on the patient's long-term activity.

The results of the MEPS are, on the contrary, in the normal range, and therefore appear in contrast to those obtained from the two aforementioned questionnaires. However, it should be noted that the MEPS analyzes the activity parameter through parameters that concern basic activities that require minimal efforts (combing, personal hygiene, feeding, wearing a shirt, putting on shoes) in a general way. On the contrary, DASH investigates even more complex actions, such as pushing a heavy door, gardening, carrying a heavy object. The contradiction between the two questionnaires is therefore only apparent and confirms that the impact of elbow dislocation over time only detects certain activities.

As regards the data about the general health of the patient, vitality, social activities and mental health, it has been possible to highlight that patients suffering from elbow dislocations have significantly lower values than what would be optimal performance. This evidence requires an in-depth analysis which can be carried out through a research design between groups; one consisting of patients diagnosed with elbow dislocation and an equivalent control group (by age, sex, lifestyle, etc.) with subjects who have not had an elbow dislocation. A study of this type will allow to assess if there is a correlation between the pathology and the state of vitality, mental health, etc.

During the study, it was found that patients have no long-term residual pain. This was assessed through remote and near pathological anamnesis collected during follow-up visits. This evidence was confirmed by the data obtained from the SF36 physical pain and the MEPS pain ($M = 41.5385$; p-value $= 0.511$). However, all patients reported experiencing severe pain after removing the plaster cast and during rehabilitation treatment. During the study it also emerged that, at the removal of the plaster splint, the elbow was completely blocked and it was necessary for the patients to carry out a long rehabilitation therapy with active and passive physiokinesis to unlock the joint. The recovery time was shorter for patients who had been immobilized for less time and underwent early range of motion.

According to the most recent studies, conservative treatment remains the one of choice in this type of injury. Reports (8-12) that compared a group of patients with simple elbow dislocation treated conservatively with a group treated surgically at the same clinic, underlined that the outcome was better in terms of residual pain, ROM, complications and recovery of motility in the group of patients treated conservatively, with the same clinical lesion.

Collecting the data in the literature regarding the treatments (9-12), it emerged that there is a lot of heterogeneity in the timing of maintenance of the plaster cast and the resumption of movements. Current trends indicate that the elbow, if stable, should be immobilized in a brace with joint release as soon as possible (2). The literature is clear that the outcome is all the better the earlier the elbow is mobilized (13).

Therefore, given the same condition, it would be appropriate to standardize a treatment for all patients, also supported by the fact that those who receive early mobilization have a fast and safe recovery and return to work early without an increased risk of complications (14).

The clinical evaluation of the stability of the elbow immediately after reduction and 7 days after the trauma also remains fundamental. Chronic instability could be particularly disabling and in older patients may require elbow replacemente (15-18).

If the elbow is stable, full flexion and extension down to -40 degrees for the first 7 days and then down to -20 degrees 15 days after the first immobilization is granted. If the elbow is unstable, an articulated elbow brace is placed, + 110 ° of flexion is allowed but the extension is limited to -70 ° for 7 days. After this time, the varus-valgus stress is re-evaluated and, if the elbow is still unstable, MRI is performed to evaluate any lesions of the primary and secondary stabilizers of the elbow and surgery is indicated (figure 3).

By evaluating the patients of the study, it was noted that some were immobilized for twenty one days, others for seven, regardless of the year in which the elbow was immobilized. The plaster cast maintained at 90 ° of flexion for all 3 weeks period is not without consequences, the main of which is rigidity, which requires longer rehabilitation (12).

As regards the clinical evaluation of the patients it emerged, that especially in these cases, it was not possible to fully recover the flexion-extension, while maintaining minimum deficits, varying between 5 and 10 degrees, which do not compromise daily activities (as demonstrated by the fact that the average MEPS movement for the patients analyzed is 20, compatible with the normal range). The recovery of prono-supination is instead optimal. The varus-valgus stress tests and the milking maneuver were negative, demonstrating a good stability of the elbow after the therapeutic treatment.

In conclusion, the clinical findings agree with the data of the questionnaires in indicating that the pathology has a satisfactory outcome and that it has limits only in the presence of heavy activities.

There are some limitations in this study: 1) the sample size was small; 2) it was a single centre investigation. Nevertheless, our results are similar to those in the literature and they confirm that conservative treatment is indicated in stable elbow dislocations.

Authors believe that satisfactory results depends on a correct management (from diagnosis to therapy) of these patients which aims to detect unstable lesions and to plan the correct therapy. This is the basis for the prevention of joint stiffness and long-term instability.

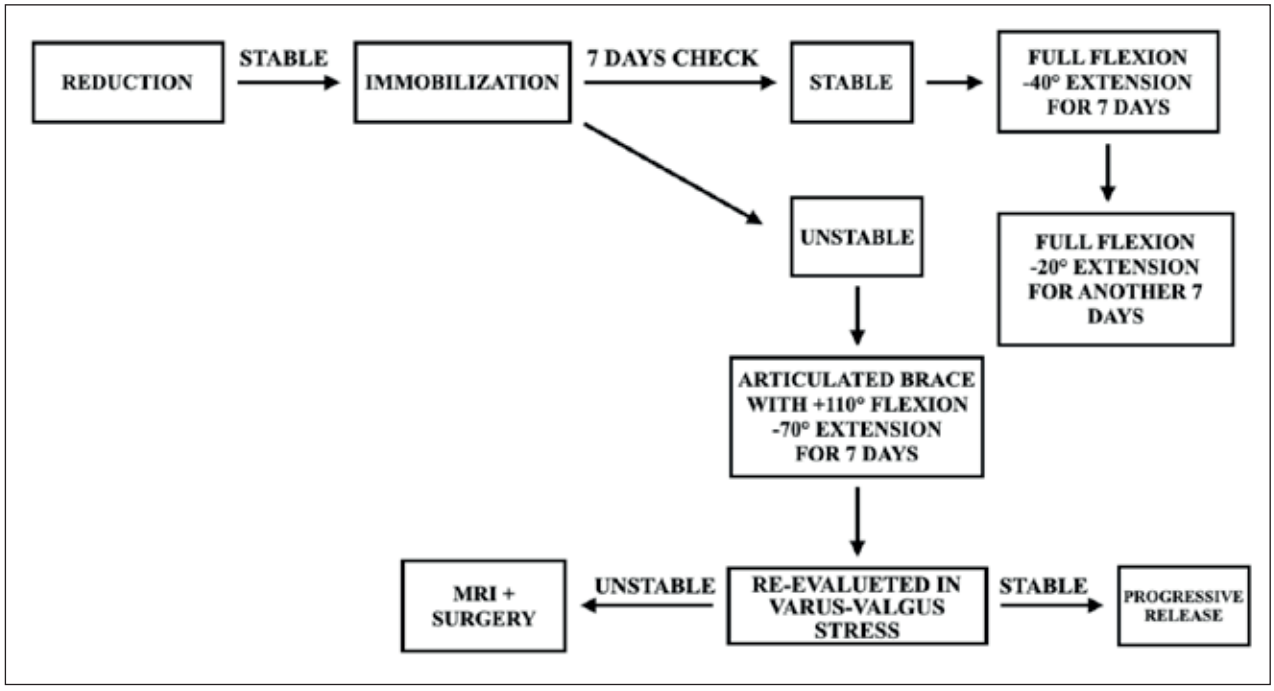

Figure 3. Flow-chart of treatment in elbow dislocation

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Josefsson PO, Nilsson BE. Incidence of elbow dislocation. Acta Orthop Scand 1986 Dec; 57(6): 537–8.
2. Hobgood ER, Khan SO, Field LD. Acute dislocations of the adult elbow. Hand Clin 2008 Feb; 24(1): 1–7.
3. Cusick MC, Bonnaig NS, Azar FM, Mauck BM, Smith RA, Throckmorton TW. Accuracy and reliability of the Mayo Elbow Performance Score. J Hand Surg Am 2014 Jun; 39(6): 1146–50.
4. Stoneback JW, Owens BD, Sykes J, Athwal GS, Pointer L, Wolf JM. Incidence of elbow dislocations in the United States population. J Bone Joint Surg Am 2012 Feb 1; 94(3): 240–5.
5. Mehlhoff TL, Noble PC, Bennett JB, Tullos HS. Simple dislocation of the elbow in the adult. Results after closed treatment. J Bone Joint Surg Am 1988 Feb; 70(2): 244–9.
6. Hobgood ER, Khan SO, Field LD. Acute dislocations of the adult elbow. Hand Clin 2008 Feb; 24(1): 1–7.
7. Ross G, McDevitt ER, Chronister R, Ove PN. Treatment of simple elbow dislocation using an immediate motion protocol. Am J Sports Med 1999 May-Jun; 27(3): 308–11.
8. Krticka M, Ira D, Flek M, Svancara J, Pikula R. A Comparative Study of Conservative Functional Treatment versus Acute Ligamentous Repair in Simple Dislocation of the Elbow in Adults. Indian J Orthop 2018 Nov-Dec; 52(6): 584–9.
9. Schnetzke M, Aytac S, Keil H, et al. Unstable simple elbow dislocations: medium-term results after non-surgical and surgical treatment. Knee Surg Sports Traumatol Arthrosc 2017 Jul; 25(7): 2271–9.
10. Mehlhoff TL, Noble PC, Bennett JB, Tullos HS. Simple dislocation of the elbow in the adult. Results after closed treatment. J Bone Joint Surg Am 1988 Feb; 70(2): 244–9.
11. Kesmezacar H, Sarıkaya IA. The results of conservatively treated simple elbow dislocations. Acta Orthop Traumatol Turc 2010; 44(3): 199–205.
12. Coulibaly NF, Moustapha NM, Djoumoi HH, Lamine S, Badara GA, Daniel SA. Management Of Recent Elbow Dislocations: Functional Treatment Versus Immobilization; A Prospective Study About 60 Cases. Open Orthop J 2017 May 30; 11: 452–9.
13. McCabe MP, Savoie FH 3rd. Simple elbow dislocations: evaluation, management, and outcomes. Phys Sportsmed 2012 Feb; 40(1): 62-71.
14. Iordens GI, Van Lieshout EM, Schep NW, et al. Trial Investigators. Early mobilisation versus plaster immobilisation of simple elbow dislocations: results of the FuncSiE multicentre randomised clinical trial. Br J Sports Med 2017 Mar; 51 (6): 531–8.
15. Pogliacomi F, Galavotti C, Cavaciocchi M, Corradi M, Rotini R, Ceccarelli F. Total elbow arthroplasty following traumas: mid-term results. Acta Biomedica 2013; 84(3): 212–8.
16. Pogliacomi F, Aliani D, Cavaciocchi M, Corradi M, Ceccarelli F, Rotini R. Total elbow arthroplasty in distal humeral nonunion: clinical and radiographic evaluation after a minimum follow-up of three years. J Shoulder Elbow Surg 2015 Dec; 24(12): 1998–2007.
17. Pogliacomi F, Schiavi P, Pedrazzini A, Nosenzo A, Tocco S, Ceccarelli F. Modified Mason type III and IV radial head fractures: results of different treatments. Acta Biomedica 2015; 86(3): 242–50.
18. Corradi M, Frattini M, Tocco S, Panno B, Pogliacomi F. Linked semi-constrained total elbow prosthesis in chronic arthritis: results of 18 cases. Musculoskeletal Surgery vol. 94; Suppl 1/May 2010: 11–23.

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Case report

Contraceptive subcutaneous device migration: what does an orthopaedic surgeon need to know? A case report and literature review

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Summary. Subdermal contraceptive implant is approved in more than 60 countries and used by millions of women around the world. Although relatively safe in nature, their implantation and removal may be associated with potential complications, some of which may require surgical intervention. Two types of peripheral neurological complications are reported: complications related to compressive neuropathy caused by device decubitus and complications related to device improper removal**.** An healthy 35-year-old woman come to our attention for paresthesia from medial side of right elbow to fourth and fifth fingers. Tinel sign was positive on medial side of distal third of right arm, above the elbow, as well. Clinical history of patients revealed a subcutaneous placement of a etonogestrel implant 3 years before. Patients reported disappearing of tactile feeling of subcutaneous contraceptive implant since two months. At clinical examination, implant was not felt in its original subcutaneous place. X-rays control revealed its proximal and deep migration. Surgical exploration for subcutaneous contraceptive implant removal revealed it lying on the ulnar nerve. Patient referred immediate paresthesia disappearing after surgery. At 1 month follow up no motor or sensory alteration were evident. Removal of implants inserted too deeply must be carefully performed to prevent damages to nervous and vascular structures and it should be performed by operators who are very familiar with the anatomy of the arm. In case of chronic neuropathy caused by implant nerve compression only an appropriate patients information about rare but possible neuropathic symptoms related to device migration and a careful medical history collecting can avoid a mistaken diagnosis of canalicular syndrome. (www.actabiomedica.it)

Key words neuropathy, subcutaneous contraceptive implant, implant migration, ulnar nerve

Introduction

Subdermal implantable devices are commonly used for long-acting contraception in the United States and Europe (1, 2). Although relatively safe, their implantation and removal may be associated with potential complications, some of which may require surgical intervention (3-7). Despite migrations is a rare complication associated with contraceptive implants, widespread use of this well-established method of contraception makes it a misleading complication to know.

Case presentation

An healthy 35-year-old woman presented to the our hospital with complaint of paresthesia in her right upper extremity. Paresthesia was referred from medial side of right elbow to fourth and fifth fingers. A cubital tunnel syndrome was immediately suspected. Physical examination was negative for tenderness or pain. The only clinical sign different from a classic cubital tunnel syndrome was a weak Tinel sign at cubital tunnel; indeed Tinel sign was positive on medial side of distal

third of right arm, above the elbow, as well. Clinical history of patients revealed a subcutaneous placement of a etonogestrel implant 3 years before. Patients reported disappearing of tactile feeling of subcutaneous contraceptive implant since two months. At clinical examination, Implant was not felt in its original subcutaneous place. X-rays control revealed its proximal and deep migration (Fig 1). Motor nerve conduction study revealed a reduced conduction velocity, delayed latency, and decreased amplitude and area, which were consistent with ulnar nerve compression at the elbow joint. Ultrasonography showed a hyperechogenic structure near the ulnar nerve. Surgical treatment was attempted because the symptoms were progressively worsened. A little longitudinal incision slightly wider than the diameter of the small finger of the operator so that the finger was introduced to check implant positioning. Then brachial fascia between the biceps and triceps muscle was opened by scissors and the ulnar nerve was visualized. Surgical exploration of the sulcus revealed migrated contraceptive implant lying on the ulnar nerve (Fig 2). Implant was removed (Fig 3). Patient referred immediate paresthesia disappearing. At 1 month follow up no motor or sensory alteration were evident.

Figure 1. Pre-operative x-rays control: evidence of implant device proximally and deeply migrated, near to ovalar radiopaque marker (correct position).

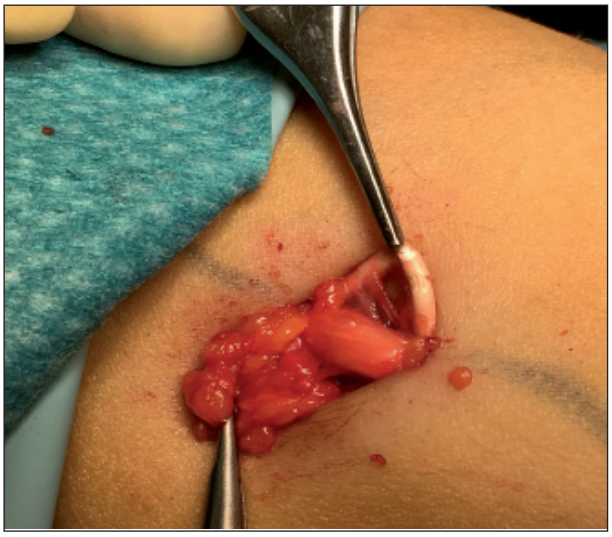

Figure 2. Intraoperative find of migrated contraceptive implant device lying on the ulnar nerve

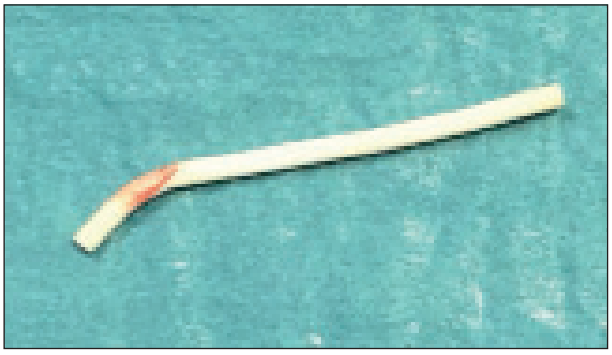

Figure 3. Removed implant device

Discussion

Contraceptive subdermal implants were specifically designed to provide contraceptive efficacy by inhibiting ovulation. They provide long-acting, highly effective reversible contraception. All subdermal implants for clinical use in humans release synthetic progestin from polymers for extended duration. These methods offer an excellent contraceptive option for women who have contraindications to combined hormonal methods and an option for any woman who desires long term protection against pregnancy that is rapidly reversible. Typical use of this implant achieves a contraceptive protection exceeding 99% (8-10).

The most common subdermal contraceptive devices are etonogestrel (Implanon, Nexplanon) and levonorgestrel (Norplant) implants. They consist of a 2mm x 4 cm single and multiple rod-shaped implants of ethylene vinylacetate copolymer, containing 68 mg

of etonostrogel that are inserted under the skin by physician or health care professionals under local anesthetic. Newer models, such as Nexplanon, consist of a rigid tube preloaded in the needle of a disposable applicator for ease of release. Its suggested positioning is 6-8 cm above the elbow, in the non dominant arm (5, 10, 11).

According to injection technique, the tip of the applicator must be angled at less than 30 degrees in order to reach the skin, subcutaneous tissue, dermis, and sub-dermal tissue to avoid complications of deep insertion and endovascular insertion (12).

The subdermal etonogestrel contraceptive implant has a current approved duration of 3 years. Studies about its effectiveness for 2 additional years during which no pregnancies were recently published (13).

Before the removal physician must locate the implant by palpation. Movements and migrations of the system are quite rare and usually of few millimetres. Once the device has been located, it is necessary to press the proximal end in order to cause a lifting of the distal end. Identified the distal portion, after local anaesthesia, a small skin incision is practiced on this zone (10).

Ideal positioning of the implant is surprising on the orthopaedic point of view. In fact, in the proximal arm region, the ulnar nerve runs on the triceps, immediately deep to the subcutaneous investing fascia and just behind the medial intermuscular septum. Medial intermuscular septum divides ulnar nerve from basilica vein and median nerve (14, 15). If the injection angle is not proper, it could lead to the insertion of the device in the muscle or fascia. Although the implant can be effective even if located in the muscle or fascia, complications may arise (10). For this reason, physician must locate the implant by palpation immediately after insertion. However, there is no absolute or necessary indication for the early removal of the device in case of failed or doubtful localization through palpation or in case of migration of the system because contraceptive function of the device is preserved (10, 16, 17).

A more frequent complication due to implant migration is difficulty in palpating it before its removal. If the location of the device is in doubt or if the device is deep and the operator is not sufficiently experienced, the most correct approach is to directly contact the manufacturer, who will provide guidance on reference centers experienced in the removal of implants difficult to locate (8,4).

In case of implant migration ultrasound represents preferable exam because it avoids exposure of women to radiation and it is the most accurate procedure because it provides a three dimensional image. In case of ultrasound implant detection, removal procedure may be performed under ultrasound control. Persaud et Al (18) reported 119 patients in which ultrasound guide was necessary to implant removal without significant complications.

The X-ray may be also used to confirm the presence of the implant and identify the area where it is located. In case of axillary migration magnetic resonance imaging (MRI) can be suggested. Motor nerve conduction study can confirm a nerve compression (10, 11, 18).

Significant migrations (>2 cm) are uncommon, and primarily occur caudally looking to the insertion site. Serious but very rare cardiopulmonary complications after a contraceptive implant migration in pulmonary artery (5,18,19) ,brachial artery (6,20), cephalic vein (21) are reported.

An orthopaedic surgeon or hand surgeon can be involved in case of implant migration in two cases: patient with peripheral neuropathy or difficulty to implant removal by gynaecologist. Multiple case reports have described implant-related injuries to the median (22-23), ulnar (7, 24-29), and medial antebrachial cutaneous nerves (30).

Two types of peripheral neurological complications are reported: complications related to compressive neuropathy due to device decubitus or complications related to device improper removal.

Acute peripheral neuropathy related to the insertion of a contraceptive is a rare complication associated with excessive injection angle. Saeed et Al (26) described a case of a woman presented one day post insertion of a contraceptive implant with paraesthesia along the ulnar distribution of her hand and forearm, as well as shooting pain on palpating the course of the ulnar nerve. Ultrasonography found the implant to be lying in the subfascial plane of the inner arm. During surgical removal the implant was found lying in the perineurium of the ulnar nerve, causing ulnar

nerve neuropathy. Osman et Al (30) described a young woman with ulnar nerve paraesthesia post insertion that resolved spontaneously.

A chronic ulnar neuropathy was described in a patient experiencing intermittent left-hand numbness and weakness with associated claw-hand deformity over a 2-year period. Ultrasonography revealed a hyper echogenic structure impinging the ulnar nerve, which they attributed to a contraceptive implant inserted 10 years prior. The patient's recovery was not described in the report (27).

As we described, in case of chronic compression, risk of wrong diagnosis is concrete. No cutaneous sign of implant positioning can be detected during arm examination. Only referred history of subcutaneous contraceptive implant can make suspicious orthopaedic surgeon and exclude a diagnosis of cubital ulnar syndrome.

The majority of complications cases have been associated with the removal of difficulty sited implants rather than insertion. Lefebvre et Al (15) reported a case of ulnar nerve injury caused by improper removal manoeuvres during an attempted in-office removal of a deeply implanted device. Accidental nerve grasp caused an ulnar nerve traumatic neuroma needing a surgical reconstruction of the ulnar nerve.

An acute ulnar nerve neuropathy was reported one day post implant (24). Patient referred to a Plastic Surgery Department and Ultrasonography found the implant to be lying in the subfascial plane. On exploration in the operation theatre, the implant was found lying in the perineurium, with the nerve itself intact. Three months after removal of the implant, all her ulnar nerve functions apart from a slight residual sensory alteration had returned to normal. Two cases of median nerve injury following inappropriate dissection of the arm to remove an "impalpable" device have been reported (23) highlighting the need, in case of impalpable device, to study the patient with imaging techniques and to try the removal by qualified surgeon.

Despite symptoms related to implant migration are rarely described, worldwide growing use of subdermal contraceptive implants makes this complications more and more studied and prevented (31-33). For this reason subcutaneous contraceptive implant migration represents a debated topic in current obstetrician and gynaecological oriented literature. A recent systematic review of literature (34) identified 63 papers describing implant migrations. This study systematically selected 12 patients with fourteen nerve injuries. Two injuries was reported during or before device insertion and 12 during removal. The medial antebrachial cutaneous and median nerves were primarily affected. The primary reasons for nerve injury were pulling or grasping of the nerve after mistaking it for the implant. Neurapraxia was the most common lesion and was treated primarily with implant removal and clinical surveillance.

Ismail et al (4) measured the distance between the skin wound and the caudal end of the implant following 100 implant insertion. Thirty-four patients showed migration caudally and only 3 demonstrated cranial migration, which in one case was over 2 cm. None demonstrated migration deep into subcutaneous tissues or muscle.

A recently published multicenter study (35) of 4294 practitioners demonstrated 357 removal-related events among the 5701 removal evaluation forms. Eight (0.1%) of the removal reports described referral to a surgeon or interventional radiologist for removal of an etonogestrel implant. Seven of these eight referrals led to successful surgical implant removal

Conclusion

Subdermal implantable devices are commonly used for long-acting contraception in all over the world. Nerve injuries related to subdermal contraceptive implant generally involved patients with non-palpable implants. For this reason removal of implants inserted too deeply must be carefully performed to prevent damages to nervous and vascular structures and it should be performed by operators who are very familiar with the anatomy of the arm. Therefore patients with non-palpable implant should be treated by a neurosurgeon, a plastic surgeon or, especially in Europe, by an orthopaedic surgeon.

Orthopaedic surgeon likewise must know possibility of peripheral neuropathy doe to implant migration and must suspect it throughout medical history collecting. Gynaecologist must provide an appropriate patients information about rare but possible neuro-

pathic symptoms related to device migration to avoid a mistaken diagnosis of canalicular syndrome.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Diedrich JT, Klein DA, Peipert JF. Long-acting reversible contraception in adolescents: a systematic review and meta-analysis. Am J Obstet Gynecol. 2017; 216(4):364.e1-364.e12.
2. Thaxton L, Lavelanet A. Systematic review of efficacy with extending contraceptive implant duration. Int J Gynaecol Obstet. 2019; 144(1):2-8
3. Mourtialon P, Tixier H, Loffroy R, Maillart JC, Calmelet P, Dellinger P, Vanwymeersch S, El Hassani R, Douvier S and Sagot P. Vascular complication after insertion of a subcutaneous contraceptive implant. Acta Obstet Gynecol Scand. 2008; 87(11): 1256-8.
4. Ismail H, Mansour D, Singh M. Migration of Implanon. J Fam Plann Reprod Health Care. 2006; Jul;32(3):157-9.
5. Barlow-Evans R, Jaffer K and Balogun M. Migration of a contraceptive subcutaneous device to the pulmonary artery. BMJ Case Rep. 2017: bcr-2017-219259.
6. Rowlands S, Mansour D and Walling M. Intravascular migration of contraceptive implants: two more cases. Contraception 2017; 95(2): 211-214.
7. Smith JM, Conwit RA and Blumenthal PD. Ulnar nerve injury associated with removal of Norplant implants. Contraception 1998: 57(2): 99-101.
8. Hohmann H, Creinin MD. The contraceptive implant. Clin Obstet Gynecol 2007; 50(4):907-17.
9. Graesslin O, Korver T. The contraceptive efficacy of Implanon: a review of clinical trials and marketing experience Eur J Contracept Reprod Health Care. 2008; 13 Suppl 1:4-12.
10. Palomba S, Falbo A, Di Cello A, Materazzo C, Zullo F. Nexplanon: the new implant for long-term contraception. A comprehensive descriptive review. Gynecological Endocrinology 2012; 28(9): 710–721.
11. Lefebvre R, Hom M, Leland H, Stevanovic M. Peripheral nerve injury with Nexplanon removal: case report and review of the literature. Contracept Reprod Med. 2018; Oct 22;3:15.
12. Evans R, Holman R, Lindsay E. Migration of Implanon: two case reports. J Fam Plann Reprod Health Care. 2005; 31: 71-72.
13. Ribeiro BC, Nogueira-Silva C, Afonso H, Silva PO, Reis ID. Use of etonogestrel implant beyond approved duration: prolonged contraceptive effectiveness Eur J Contracept Reprod Health Care. 2018; 23(4):309-310.
14. Rinker B. Nerve Transfers in the Upper Extremity: A Practical User's Guide. Ann Plast Surg. 2015; 74 Suppl 4: S222-8.
15. Mazurek MT, Shin AY. Upper extremity peripheral nerve anatomy: current concepts and applications. Clin Orthop Relat Res. 2001; 383:7-20.
16. Grentzer J, McNicholas C, Peipert JF. Use of the etonogestrel-releasing contraceptive implant. Expert Rev Obstet Gynecol. 2013; 8(4):337–344.
17. Shulman LP, Gabriel H. Management and localization strategies for the nonpalpable Implanon rod. Contraception. 2006; 73(4):325–330.
18. Persaud T, Walling M, Geoghean T, Buckley O, Stunnel H, Torregiani WC. Ultrasound guided removal of Implanon devices. Eur Radiol. 2008;18: 2582-2585.
19. Kang S, Niak A, Gada N, Brinker A, Jones SC. Etonogestrel implant migration to the vasculature, chest wall, and distant body sites: cases from a pharmacovigilance database. Contraception. 2017; 96(6): 439-445.
20. D'Journo CB, Vidal V, Agostini A. Intravasculary pulmonary migration of a subdermal contraceptive implant. Ann Thoracic Surg 2015; 99(5): 1898.
21. Mourtialon P, Tixier H, Loffroy R, Maillart JC, Calmelet P, Dellinger P, Vanwymeersch S, El Hassani R, Douvier S and Sagot P. Vascular complication after insertion of a subcutaneous contraceptive implant. Acta Obstet Gynecol Scand. 2008; 87(11): 1256-8.
22. Christensen JM, Caggiano NM, Giladi AM, Iorio ML. Median nerve injury after removal of subdermal implantable contraceptive. Hand 2017; 13(3): 6-9.
23. Gillies R, Scougall P, Nicklin S. Etonogestrel implants: a case studies of median nerve injury following removal. Aust Fam Physician 2011; 40:799–800.
24. O'Grady EE, Power DM. Ulnar nerve injury on removal of a contraceptive implant. Practitioner. 2016; 260:21–4.
25. Belyea C, Ernat J, Gumboc R. Removal of a contraceptive implant from the brachial neurovascular sheath. J Hand Surg [Am] 2017; 42: e115–7.
26. Saeed A, Narayan N and Pandya A. Contraceptive Implant–Related Acute Ulnar Neuropathy: Prompt Diagnosis, Early Referral, and Management Are Key. Eplasty 2018; 18: e28.
27. Ong J, Therimadasamy A, Wilder-Smith E. Teaching NeuroImages: ulnar neuropathy related to a contraceptive subdermal implant. Neurology. 2014; 83: e147-8.
28. Restrepo CE, Spinner RJ. Major nerve injury after contraceptive implant removal: case illustration. J Neurosurg. 2016; 124:188–9.
29. Wechselberger G, Wolfram D, Pulzl P, Soelder E, Schoeller T. Nerve injury caused by removal of an implantable hormonal contraceptive. Am J Obstet Gynecol. 2006; 195:323–6.
30. Osman N, Dinh A, Dubert T, Goubier J. A new cause for iatrogenic lesion of the ulnar nerve at the arm: contraceptive hormonal implant. Report of two cases. Chir Main 2005; 24:181–3.
31. Voedisch A, Hugin M. Difficult implant removals. Curr

Opin Obstet Gynecol. 2007; 29(6):449-457.
32. Chevreau J, Krief D, Abou Arab O, Zitoun M, Foulon A, Sergent F, Gondry Factors associated with removal difficulties of etonogestrel-containing contraceptive implants (Nexplanon®). J. Eur J Obstet Gynecol Reprod Biol. 2018; 224:81-84.
33. Vidin E, Garbin O, Rodriguez B, Favre R, Bettahar-Lebugle K. Removal of etonogestrel contraceptive implants in the operating theater: report on 28 cases. Contraception. 2007; 76(1):35-9.
34. Laumonerie P, Blasco L, Tibbo ME, Leclair O, Kerezoudis P, Chantalat E, Mansat P. Peripheral Nerve Injury Associated with a Subdermal Contraceptive Implant: Illustrative Cases and Systematic Review of Literature. World Neurosurg. 2018; 111:317-325.
35. Creinin MD, Kaunitz AM, Darney PD, Schwartz L, Hampton T, Gordon K. The US etonogestrel implant mandatory clinical training and active monitoring programs: 6 year experience. Contraception. 2017; 95:205-210.

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Case report

Van Neck-Odelberg disease in a 8-year-old children: a rare case report

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Summary. *Introduction.* osteochondrosis of ischiopubic synchondrosis (IPS)" also known as van Neck-Odelberg disease (VNOD), is a syndrome characterized by an atypical ossification pattern of the ischiopubic joint. Because of its non-unequivocal radiological features, which can mimic stress fracture, infection disease, neoplasm or post-traumatic osteolysis, these different diagnoses need to be rule out. *Case presentation.* We present an 8-year-old, obese, right limb dominant child that complained only slight groin pain and a limp on left side for more than 20 days. Neither the patient nor his parents recall any trauma. On clinical examination, no swollen lymph nodes were noticeable. After digital pressure, the patients reported a dragging feeling in the left groin, radiating into the medial left thigh and limitation of Range of Motion (ROM) were present. Thus, a plain X-ray and MRI were performed, revealing VNOD on left ischiopubic ramus. The boy was then treated with regular NSAID and pain adapted full weight bearing and a clinical check at 30 and 60 days was performed. At the last visit, the symptoms were completely disappeared and the patient totally recovered left hip function. *Conclusion.* Diagnosis of VNOD is challenging and clinical presentation is not pathognomonic. So, other benign or severe conditions need to be rule out. Once this disease is diagnosed, the prognosis is generally favourable. (www.actabiomedica.it)

Key word: Van Neck-Odelberg, groin pain, limp in children, osteochondrosis

Introduction

Osteochondrosis of ischiopubic synchondrosis (IPS)" also known as van Neck-Odelberg disease (VNOD), is a syndrome characterized by an atypical ossification pattern of the ischiopubic joint. The term "Osteochondritis Ischiopubica" was coined by van Neck in 1924 when referring to evident changes found at ischiopubic zone in radiographs taken in prepubescent age group (1).

The IPS is a temporary joint that exist only in childhood. It results from two ossification centres located in ischiopubic region and divided by a thin fibrocartilaginous band, hence forming a synchondrosis (2).

Its ossification usually occurs before puberty with progressive thinning of cartilaginous band followed by bony union. This process is generally asymptomatic, but very few prepuberal children experience groin pain and limping (3).

Because of its non-unequivocal radiological features, which can mimic stress fracture, infection disease, neoplasm or post-traumatic osteolysis, these different diagnoses need to be rule out (4).

Case presentation

We present an 8-year-old, obese, right limb dominant child who came to our clinic because of a slight groin pain and a limp on left side for more than 20 days. Neither the patient nor his parents recall any trauma. The body temperature was normal.

On clinical examination, no swollen lymph nodes were noticeable and no swelling of the hip or general/local skin abnormalities were observed. No other joints and extremities were affected.

After digital pressure, the patients reported a dragging feeling on the left groin, radiating into the medial left thigh. On passive mobilization of left limb, limitation of Range of Motion (ROM) of 30° in abduction and 10° in extension compared to contralateral side was present. Thus, a MRI in suspected epiphysiolysis of the hip was performed, instead revealing VNOD on left ischiopubic ramus (Fig 1-3). On routine laboratory test, including erythrocytes sedimentation rate and C-protein, we did not observe any abnormalities.

The young patient was then treated conservatively with rest and NSAID as needed. Walking with pain adapted full weight bearing was permitted, whereas sport-related activities were forbidden. Moreover, local low-frequency magnetic field therapy was prescribed for 4 hours per day.

The patient was visited at 30 days at our clinic, when we observed the complete resolution of groin pain and ROM limitation in extension, whereas a slight limping and limitation of 10° in abduction were still present. We prescribed treatment continuation throughout other 30 days. After 60 days, the patient was able to walk without any limping and left hip ROM was totally recovered.

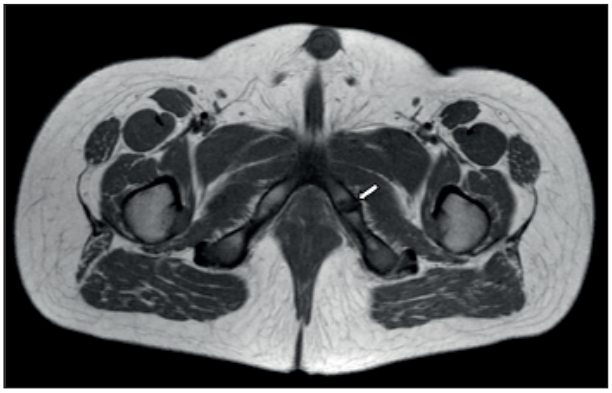

Figure 1. Magnetic resonance imaging transverse plane T1. The lesion is visible as hypointensity signal (white arrow)

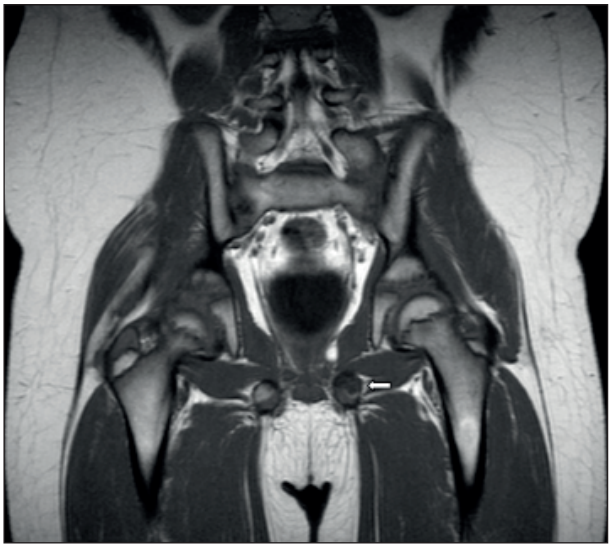

Figure 2. Magnetic resonance imaging coronal plane T1. The lesion is visible as hypointensity signal (white arrow)

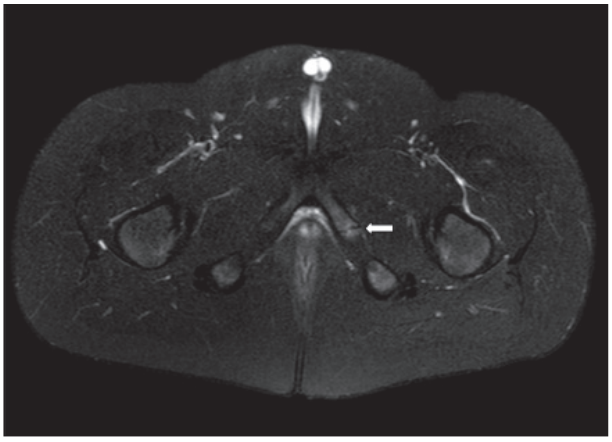

Figure 3. Magnetic resonance imaging transverse plane T2. The lesion is visible as hyperintensity signal (white arrow)

Discussion

Several theories describing etiopathogenesis of VNOD have been proposed. The characteristic radiological finding is the typical enlargement of one of the ischiopubic synchondroses, with radiolucent and osteolytic areas. The typical MRI findings include changes in bone marrow and perilesional soft tissue edema (5-6).

This condition develops in children between the ages of 4 and 16 years. The majority of cases are asymptomatic findings and are detected after plain anteroposterior hip radiography carried out for other reasons (3).

However, some cases are thought to be symptomatic and may correlate to X-Ray and MR findings, suggesting stress related pathology.

Asymmetrical enlargement of the IPS is a thought to be related to asymmetrical mechanical stress of the muscles over each hemipelvis, ie adductors, gemellus and iliopsoas. This produces constant movement of the IPS, with an inflammatory reaction, and delayed union of the cartilage layers and ossification centres (5, 7-8).

Wait *et al*. evaluated 10 cases of VNOD and suggested the hypothesis that the condition results from an excessive pull of the hamstring tendon on the ischial tuberosity (3).

Some Authors have been related the unilateral enlargement of IPS to limb dominance. The explanation for which could rely in different forces applied on the ground by weight bearing leg, which is non-dominating compared to the dominating leg (5).

However, the tumor-like appearance on plain radiograph may lead to stress fractures, neoplasm or infection process. The medical history, laboratory test and MRI facilitate the different diagnosis.

Conclusion

Diagnosis of Van Neck-Odelberg disease is challenging and clinical presentation is not pathognomonic. So, other benign or especially severe conditions need to be rule out. Once osteochondritis of IPS is diagnosed, the prognosis is generally favourable.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Macarini L, Lallo T, Milillo P, Muscarella S, Vinci R, Stoppino LP. Case report: Multimodality imaging of Van Neck-Odelberg disease. Indian J Radiol Imaging 2011;21(2):107-110.
2. Herneth AM, Trattnig S, Bader TR, Ba-Ssalamah A, Ponhold W, Wandl-Vergesslich K, et al. MR imaging of the ischiopubic synchondrosis. Magn Reson Imaging 2000;18(5):519-524.
3. Wait A, Gaskill T, Sarwar Z, Busch M. Van Neck disease: osteochondrosis of the ischiopubic synchondrosis. J Pediatr Orthop. 2011;31:520–4.
4. Oliveira F. Differential diagnosis in painful ischiopubic synchondrosis (IPS): a case report. Iowa Orthop J. 2010;30:195–200.
5. Herneth AM, Philipp MO, Pretterklieber ML et-al. Asymmetric closure of ischiopubic synchondrosis in pediatric patients: correlation with foot dominance. AJR Am J Roentgenol. 2004;182 (2): 361-5.
6. Ceroni D, Mousny M, Anooshiravani-Dumont M, Buerge-Edwards A, Kaelin A. MRI abnormalities of the ischiopubic synchondrosis in children: a case report. Acta Orthop Belg. 2004;70:283–6.
7. Neitzschman HR. Radiology case of the month. Hip trauma. Normal physiologic asymmetric closure of the ischiopubic synchondroses. J La State Med Soc 1997;149(6):186-188.
8. Kloiber R, Udjus K, McIntyre W, Jarvis J. The scintigraphic and radiographic appearance of the ischiopubic synchondroses in normal children

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Case report

Delayed diagnosis and treatment of a psoas abscess as a link between spondylodiscitis and septic necrosis of the femoral head: a case report

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Summary. *Background:* Infections of the spine and hip joint are not common and, as described in literature, they are occasionally linked by a psoas abscess. In patients suffering back pain with history of spondylodiscitis, the spine as primary source of infection for a secondary psoas abscess should always be included in differential diagnosis. A delay in diagnosis of the psoas abscess could lead to septic femoral head necrosis. *Case report:* A case of a 65-year-old woman affected by septic femoral head necrosis due to spondylodiscitis and secondary psoas abscess is reported; the patient needed a specific antibiotic therapy then undergoing a total hip arthroplasty (THA). *Discussion and conclusion:* Diagnoses of lumbar spine infection and psoas abscess are difficult and often delayed. Since the symptoms of both are non-specific, high degree of suspicious is necessary. In psoas abscess, an early diagnosis is important, because a delayed treatment could result in septic femoral head necrosis requiring both a prolonged antibiotic therapy and a THA. (www.actabiomedica.it)

Key words: Spine, Hip, Infection, Spondylodiscitis, Psoas abscess, Femoral head necrosis.

Background

Infections of the spine and hip are not common, but they are serious conditions requiring an early diagnosis and an appropriate treatment [1]. Both infections are occasionally associated with a psoas abscess: in fact, infection of the spine can cause a psoas abscess [2, 3, 4], which could lead to a septic hip arthritis [5]. The high susceptibility of the psoas muscle to infections is explained by its peculiar anatomy: infectious agents can access the muscle by either direct extension or via haematogenous seeding. In most cases, organisms reach this muscle for contiguity from kidneys, ureters, pancreas, large and small intestine and from the spine (secondary psoas abscess). Moreover, the blood supply of the muscle is a predisposing factor for the haematogenous spread from distance sources (primary psoas abscess) [6]. The classic signs, including fever, flank pain and limp, are erratically present and diagnosis is often delayed by misinterpretation as arthritis, joint infection, urologic or abdominal disorders [7].

Incidence of spine-associated psoas abscess increase in case of previous spondylodiscitis, invasive procedures on the spine and recurring tuberculosis in industrialized countries.

The spine as primary source of infection for secondary psoas abscess should always be included in differential diagnosis, especially in patients suffering back or hip pain with history of spondylodiscitis [4].

Case report

In July 2018 a 65-year-old woman referred to the emergency department complaining lumbar pain irradiated to the left lower limb which was investigated

with plain X-rays (Figure 1 A, B) and then she was discharged with a sciatica diagnosis and corticosteroid treatment. Three weeks later, she experienced increasing pain in the left groin and knee, making weight-bearing impossible on that limb. She arrived at our attention and during the physical examination there was no evidence of neither pulmonary or abdominal symptoms nor fever, the left hip joint range of motion was painfully restricted in all directions. A plain radiograph and a CT scan of the left hip showed osteoarthritic changes at an advanced stage, heterogeneous density of femoral head and suspected signs of fracture (Figure 2 A, B). Therefore, she was hospitalized for further investigations. First blood exams showed increased WBC (19500/μL) with neutrophilic preponderance (94.3%) and a CRP of 15.11 mg/dL.

In the following days an increase of the body temperature up to 38.7 °C was recorded and multiple blood samples for colture were obtained and the patient started an empiric antimicrobial therapy with intravenous administration of Ciprofloxacin at the dosage of 400 mg every 12 hours. Meanwhile she underwent a hip and lumbar MRI that revealed hip joint edema, intra-articular effusion and altered signal intensity in the femoral head as well as in the acetabulum, neighboring soft tissues and L4 vertebral body.

Five days later microbiological coltures from blood samples showed the presence of *Staphylococcus Aureus* and a specific antimicrobial therapy was set up adding 2 gr of IV Oxacillin every 4 hours to the Ciprofloxacin. A few days later there was a reduction in WBC count (11500/μL) and in CRP blood levels (13.51 mg/dL).

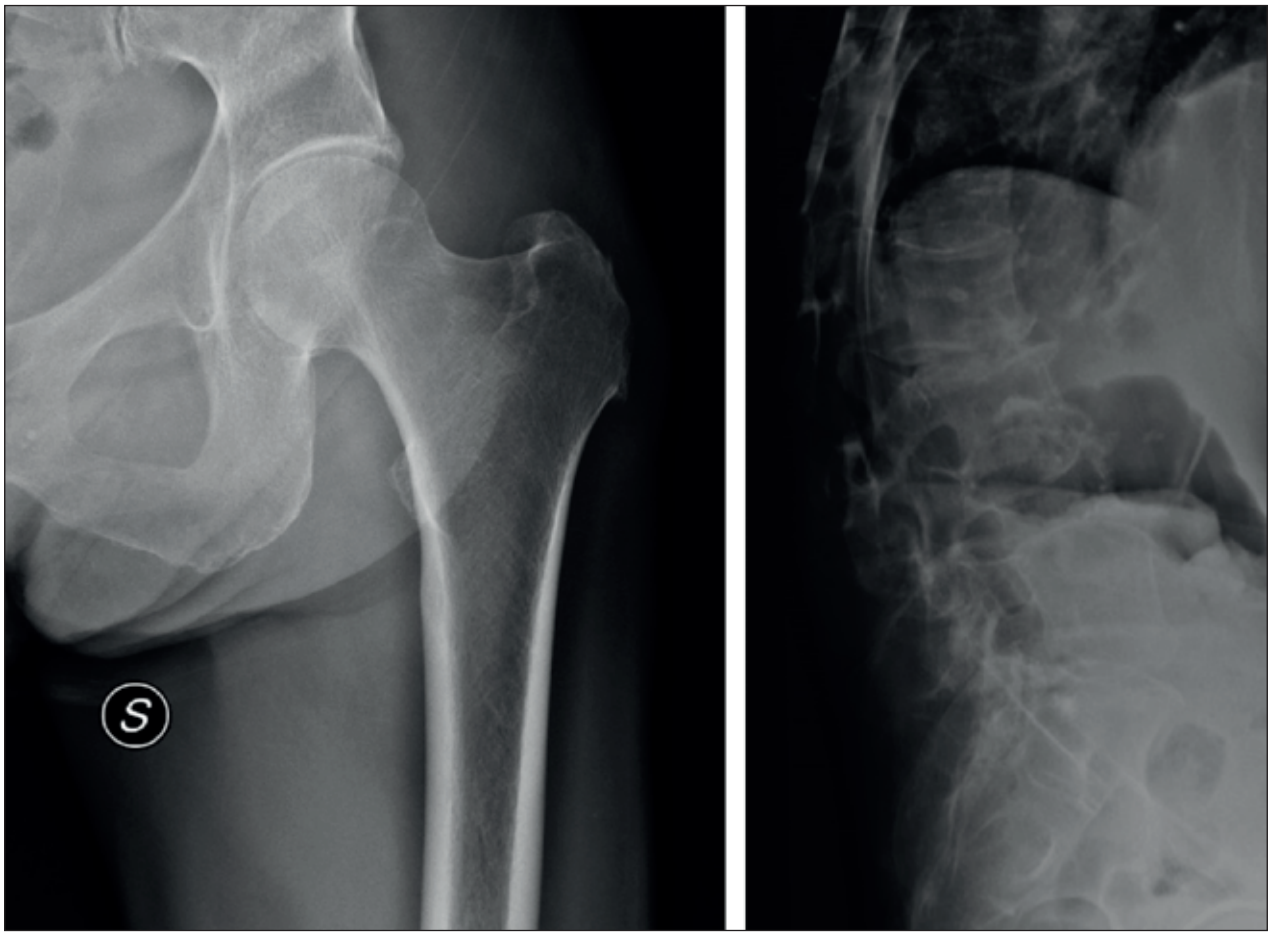

Figure 1. Left hip (A) and lumbar spine (B) X-rays performed at the first access to the emergency room

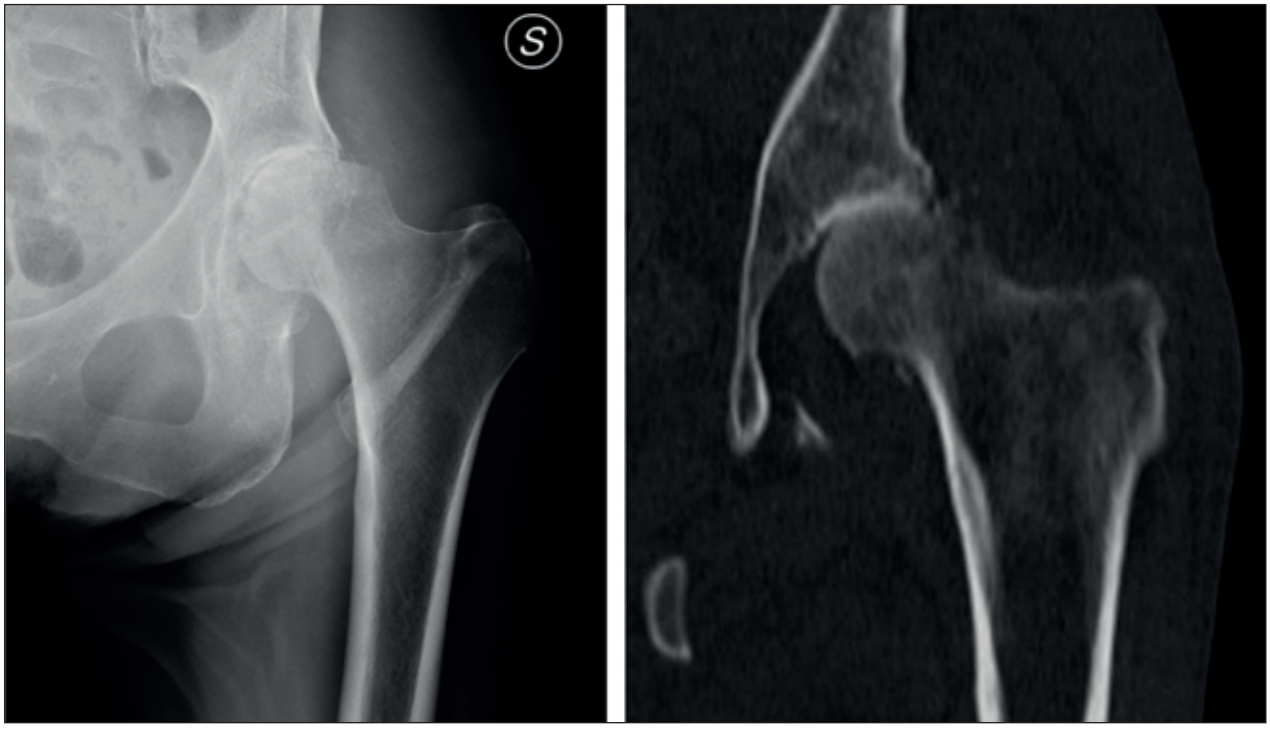

Figure 2. Left hip X-ray (A) and CT-scan (B) performed 3 weeks after the first access to the ER

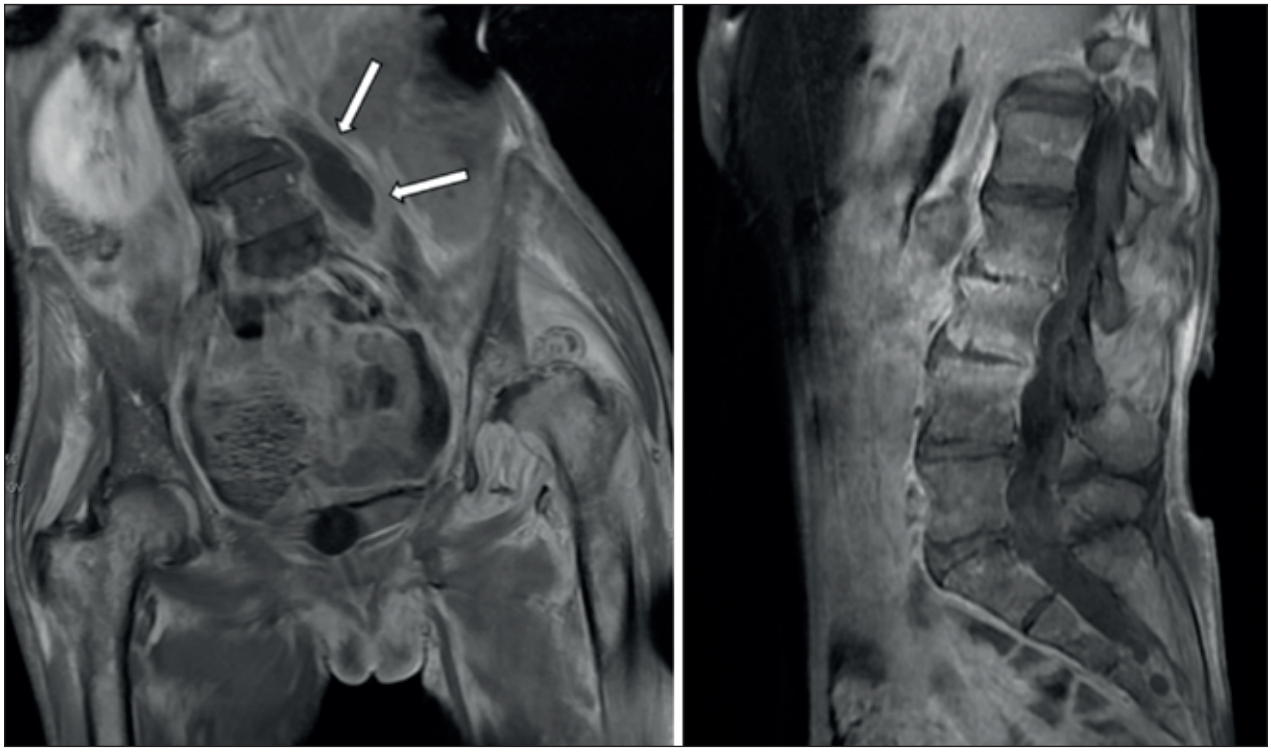

Figure 3. Contrast-enhanced MRI of the pelvis (A) and lumbar spine (B) showing altered and diffuse signal intensity of L2-L4 vertebrae. The psoas abscess is indicated by the arrows.

An additional contrast-enhanced MRI of the lumbar spine and pelvis showed an altered and diffuse signal intensity in the L2-L4 vertebrae and surrounding soft tissues and a fluid collection in the context of psoas muscle as well as in the hip joint demonstrating a pyogenic spondylodiscitis with secondary psoas abscess and hip joint infection (Figure 3 A, B). Blood exams taken at this time showed a normalization of WBC count (7100/μL) and a further decrease in CRP blood levels (7.94 mg/dL).

Forty days after hospital admission, an abdominal and pelvis CT scan with contrast was performed which still revealed an organized fluid collection in the psoas measuring 21 × 22 × 53 mm, effusion in the left hip with another organized fluid collection posteriorly to the femoral head (Figure 4). It also showed a cranial acetabular breakthrough and femoral head resorption. Additional L2 CT-guided ago-biopsy was performed and revealed only diffuse fibrosis of the vertebral body. The patient remained apiretic and laboratory exams became normal after five weeks of intravenous antibiotic therapy, so we decided to shift IV administration to 500 mg of oral Levofloxacin a day; moreover, left hip pain was decreasing though weightbearing was still prohibited.

Three months after admission and specific antibiotic therapy, patient underwent a new pelvis and hip MRI (Figure 5) which showed persistent enhancement of the hip while psoas collection was disappeared, allowing to stop antibiotics.

A labelled leukocytes scintigraphy was performed two months later and did not reveal any infection site, so on May 2019, 10 months from the symptoms onset, she underwent preoperative tests including a pelvis and left hip X-ray which showed increased femoral head deformity and cranial acetabular breakthrough following septic osteonecrosis (Figure 6).

On June 2019, once established the absence of S. Aureus in the nasal, inguinal and axillary swab, the patient underwent THA with a cemented "dual-mobility" cup and a cementless stem through direct anterior approach (Profemur Z stem ®, Liberty cup ®, MicroPort Orthopedics, Shanghai, China). Intraoperative findings revealed abundant capsular fibrosis, both femoral head and acetabulum resorption and severe acetabular deformity. Intraoperative samples

Figure 4. Abdominal and pelvis CT scan with contrast after 40 days from admission : the psoas abscess is indicated by the arrows

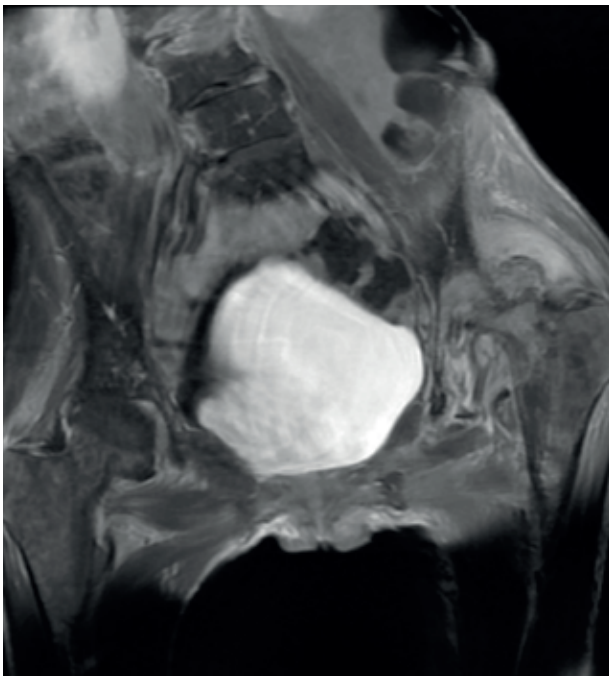

Figure 5. Pelvis and hip MRI after 3 months with no evidence of residual psoas abscess. At this time antibiotic therapy was therefore suspended

Figure 6. Left hip AP X-ray at 10 months from symptoms onset, preoperatively to total hip replacement, showing severe femoral head deformity and cranial acetabular breakthrough following septic osteonecrosis

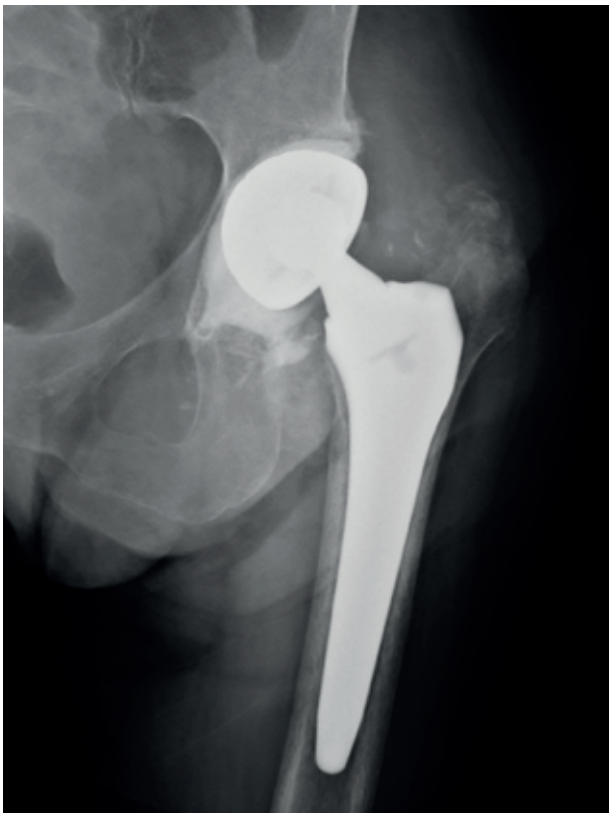

Figure 7. AP X-ray of total hip replacement at 9-months follow-up. The implant consisted in a cemented "dual-mobility" cup and a cementless stem through a direct anterior approach

submitted for coltural examination were thereafter negative and a short-term 24 hours postoperative antibiotic prophylaxis with amoxicillin was administrated.

At 9-months follow-up, there were no clinical, laboratory or radiographic signs of infection in the left hip and lumbar spine and there were no radiographic signs of mobilization of THA loosening (Figure 7).

Discussion

This case is explanatory of how a delayed diagnosis of spondylodiscitis complicated with a psoas pyogenic abscess could lead to a septic femoral head necrosis requiring a THA as a unique final solution.

To our knowledge, there are a few similar cases described in literature [5, 10].

Secondary psoas abscess is caused by the spread from an adjacent infectious process; in the study of the Japanese group of Wong et al. infectious spondylitis, among all the causes, was found to be the most common for secondary psoas abscess [11]. Pyogenic spondylodiscitis is indicated as one of the most frequent cause of secondary psoas abscess in many others studies. In fact, Ricci et al. noted that 10% of secondary psoas abscess cases were caused by disc infection [9]; Walsh et al. reported 4 out of 11 patients with an iliopsoas abscess who had lumbar osteomyelitis or disc space infections [8] and Muckley et al. emphasized the spine as the source of infection for a secondary psoas abscess [4]. Wong et al [11] also noted that spondylitis is the main manifestation of haematogenous osteomyelitis in middle-aged patients (>50 years old), with *S. Aureus* involved in most cases. The reported case is in line with this evidence. Besides, the literature support to think this infection been primarily originated in the lumbar spine, because a psoas abscess only rarely extends proximally [1].

Due to nonspecific symptoms, diagnosis of psoas abscess is frequently missed at initial presentation in the emergency room. Most patients complain back, hip or flank pain and this may lead to misdiagnoses of sciatica, arthritis or joint infection. Only few patients present the classical triad of fever, back pain and a groin or flank mass. Often, only with aggravating symptoms (progressive back pain, weight loss, unilateral leg swelling, loss of hip extension) further examinations are taken. Furthermore, initial antibiotic treatment may compromise early diagnoses through amelioration of symptoms and signs of infection. Common laboratory findings with psoas abscess include leukocytosis, elevated ESRs, elevated blood urea nitrogen levels and pyuria. Elevation of the CRP level usually corresponds to the extent of infection [4].

Kumagai et al. [1] proposed some infection pathways from psoas abscesses into the hip joint. One of these was through the iliopsoas bursa: this structure has been found to communicate with the hip joint in many examined cadavers [5]. One more pathway proposed is the spread along the iliopsoas muscle, which crosses the hip joint capsule at the thinnest portion between the iliofemoral and iliopubic ligaments [3]. We consider that in the reported case the infection started as hematogenous spondylodiscitis, spreading distally through the psoas muscle as an ossifluent abscess and then penetrated the hip joint via the iliopsoas bursa. This hypothesis seems to be likely looking at the imaging.

Radiologic patterns for psoas abscess (loss of psoas shadow, abnormal soft-tissue shadows, gas inclusions, bony destruction of the spine and abscess calcification) are not consistently found.

For diagnostic imaging of psoas abscesses, CT has been established as the standard imaging study to assess the characteristics and extent of an abscess and diagnostic rates of 88-100% are reported[12]. Besides, accurate CT imaging can demonstrate any co-existing causative retro- or intra-peritoneal disease [11].

Immediately following the diagnosis of iliopsoas abscess, a prompt treatment is mandatory: it consists in abscess drainage (surgical or percutaneous) and appropriate antimicrobial therapy [12]. For secondary abscess, it is essential to associate abscess drainage with causative treatment of the primary infectious focus: drainage alone may result in recurrence rates up to 50% [4].

In the reported case the severe complication occurred of a septic hip arthritis followed by a femoral head osteonecrosis was probably due to a delayed diagnosis and a missed immediate abscess drainage, which led to a successful but prolonged antibiotic therapy, finally requiring the implantation of a THA for the severe degenerative hip changes, with a doubtful long-term implant survival.

Conclusion

Diagnoses for lumbar spine infection and psoas abscess are difficult and often delayed, as the symptoms of both are non-specific [1]. A high degree of suspicious in necessary to achieve early diagnosis of psoas abscess in older patients with nonspecific symptoms. In patients with infection signs and back or hip pain or history of spinal surgery, psoas abscess should always be considered.

In case of psoas abscess, early diagnosis is crucial because any delayed treatment can result in poor results [2, 8, 9].

Orthopedic surgeons should know that both the lumbar spine and hip joint communicate through the psoas muscle, making it possible for infection to spread. Thus, patients with suspect of infection in those areas needs an early investigation through MRI or CT scan in order to determine the extension of the infection.

CT-guided percutaneous catheter drainage or surgical drainage with appropriate antibiotic therapy represents an effective treatment in most patients to prevent further complications.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Kumagai K, Ushiyama T, Kawasaki T, Matsusue Y. Extension of lumbar spine infection into osteoarthritic hip

through psoas abscess. J Orthop Sci (2005) 10:91–94.
2. Gruenwald I, Abrahamson J, Cohen O. Psoas abscess: case report and review of the literature. J Urol 1992; 147:1624–6.
3. Levitin B, Rubin LA, Rubenstein JD. Occult retroperitoneal abscess presenting as septic arthritis of the hip. J Rheumatol 1982; 9:904–8.
4. Muckley T, Schütz T, Kirschner M, et al. Psoas abscess: the spine as a primary source of infection. Spine 2003; 28: E106–13.
5. Beredjiklian PK, Adler L, Wong K, et al. Prevertebral abscess with extension into the hip joint. Am J Orthop 2001; 30:572–5.
6. Mallick IH, Thoufeeq MH, Rajendran TP. Iliopsoas abscesses. Postgrad Med J 2004; 80:459–62.
7. Chern CH, Hu SC, Kao WF, et al. Psoas abscess: making an early diagnosis in the ED. Am J Emerg Med 1997; 15:83–8.
8. Walsh TR, Reilly JR, Hanley E, et al. Changing etiology of iliopsoas abscess. Am J Surg 1992; 163:413–6.
9. Ricci MA, Rose FB, Meyer KK. Pyogenic psoas abscess: worldwide variations in etiology. World J Surg 1986; 10:834–43
10. Kaku N, Tsumura H, Takashita M, et al. Two cases of pyogenic coxitis following pyogenic spondylitis. Orthop Traumatol (Seikei Geka To Saigai Geka) 2000; 49:1015–20 (in Japanese).
11. Wong OF, Ho PL, Lam SK. Retrospective review of clinical presentations, microbiology, and outcomes of patients with psoas abscess. Hong Kong Med J 2013; 19:416–23.
12. Santaella RO, Fishman EK, Lipsett PA. Primary vs secondary iliopsoas abscess: presentation, microbiology and treatment. Arch Surg 1995; 130:1309–13.

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Case report

Fourth generation head fracture in ceramic-on-polyethylene bearing after hip revision surgery: a case report

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Summary. Fourth generation ceramic bearings (BIOLOX delta, CeramTec AG; Phlochingen, Germany) were developed to reduce wear debris and improve fracture resistance. A case of a fourth generation head fracture in ceramic-on-polyethylene (COP) coupling after hip revision surgery is reported. A 58-year-old man was admitted to our department for increasing hip pain following a direct trauma which occurred during skiing activity 4 months before. Six years earlier, he had undergone a right cementless revision surgery with a 36-mm BIOLOX delta femoral head on polyethylene liner for metallosis and foreign body reaction after primary total hip replacement for hip osteoarthritis. At admission, radiological evaluation revealed a fracture of ceramic femoral head requiring a new revision surgery. Extensive synovectomy, lavage and capsulectomy were performed. Both acetabular cup and femoral stem were well fixed with no damage of trunnion, and therefore they were retained. A 36-mm internal diameter polyethylene acetabular liner was inserted along a 36-mm BIOLOX delta head with a BioBall adapter XL. The postoperative course was uncomplicated. At 1-year follow-up, the patient had a complete functional recovery. To our knowledge, BIOLOX delta ceramic femoral head fracture after COP hip revision surgery has not been previously reported. (www.actabiomedica.it)

Key words: total hip arthroplasty, revision hip surgery, ceramic-on-polyethylene, BIOLOX delta ceramic head, fracture

Introduction

In the last two decades, use of ceramic bearings in THA has been increased thanks to improved mechanical properties. In 2003 BIOLOX delta ceramic bearings (BIOLOX delta, CeramTec AG; Phlochingen, Germany) were developed in total hip arthroplasty (THA). Addition of Zirconium, Chromium and Strontium that stabilizes composite alumina matrix has resulted in increased fracture resistance of BIOLOX delta compared with BIOLOX forte ceramic bearings introduced in 1994 (BIOLOX Forte CeramTec AG; Phlochingen, Germany) (1). However, breakage of the ceramic components is still a serious concern requiring revision surgery. Ceramic fractures occur mainly because of defects in ceramic production, direct or continued trauma, or improper surgical technique (2). Femoral head breakage is likely to correlate more frequently with ceramic-on-ceramic (COC) than with ceramic-on-polyethylene (COP) bearings. BIOLOX delta femoral head fracture is a rare complication following THA (3-6), and fracture of BIOLOX delta head coupled with a polyethylene liner has been exceptionally described in primary THA (6). This case report describes a BIOLOX delta femoral head breakage which was observed after COP revision THA. To our knowledge, this occurrence in revision THA has not been previously reported.

Case report

A 58-year-old male patient was admitted to our department because of increasing right groin pain and functional impairment. He sustained a direct trauma to the area of the greater trochanter during skiing activity 4 months before with no hip disability. At the age of 44, he had undergone a primary cementless COC THA because of hip osteoarthritis. Six years ago, both prosthetic components were revised due to metallosis and foreign body reaction using a 54 mm acetabular cup (Pinnacle Acetabular Shell, DePuy Orthopaedics, Inc., Warsaw, Indiana) with a 36 mm polyethylene acetabular liner (Pinnacle Marathon cross-linked, DePuy Orthopaedics, Inc., Warsaw, Indiana), a modular femoral revision stem (S-ROM Total Hip System, DePuy Orthopaedics, Inc., Warsaw, Indiana), and a 36 mm BIOLOX delta alumina ceramic femoral head (CeramTec, Phlochingen, Germany), +9 neck length and 11/13 tapered cone head.

At first admission to our department, physical examination revealed groin pain and limited hip mobility with no clinical signs of infection. Plain radiograph of the pelvis showed radiopaque fragments inferior to the ceramic femoral head and no signs of loosening (Figure 1). Multi-Slice Computed Tomography (CT) confirmed the breakage of the ceramic femoral head with two major fragments, showing acetabular inclination and anteversion of 44° and 32°, respectively (Figure 2). Revision surgery was performed with the patient in supine position through an anterolateral Watson-Jones approach under spinal anesthesia. Breakage of the ceramic head, which included two gaps at the opposite sites close to the stem neck (Figure 3), and acetabular polyethylene wear were found. The broken head, the two large fragments and most of the smaller fragments, and the acetabular liner were removed. Extensive synovectomy, lavage, capsulectomy and accurate debridement were performed to decrease residual ceramic fragments in the soft tisseus. Both acetabular cup and femoral stem were well fixed with no damage of trunnion and therefore they were retained. A 36-mm internal diameter polyethylene acetabular liner with elevated rim and a 36-mm BIOLOX delta with a BioBall (Merete; Berlin, Germany) adapter XL (+7, 11/13 mm) were implanted. Immediately after surgery, the patient

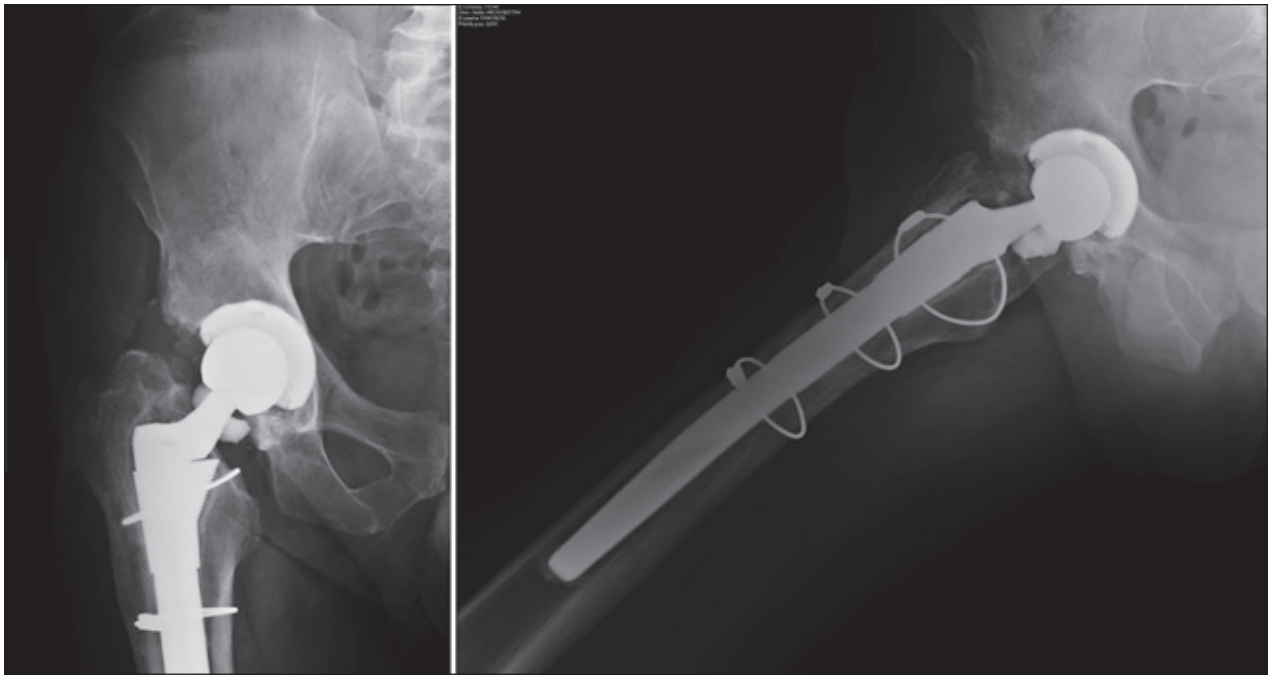

Figure 1. Anteroposterior (a) and lateral (b) radiographs at presentation revealing ceramic head fracture

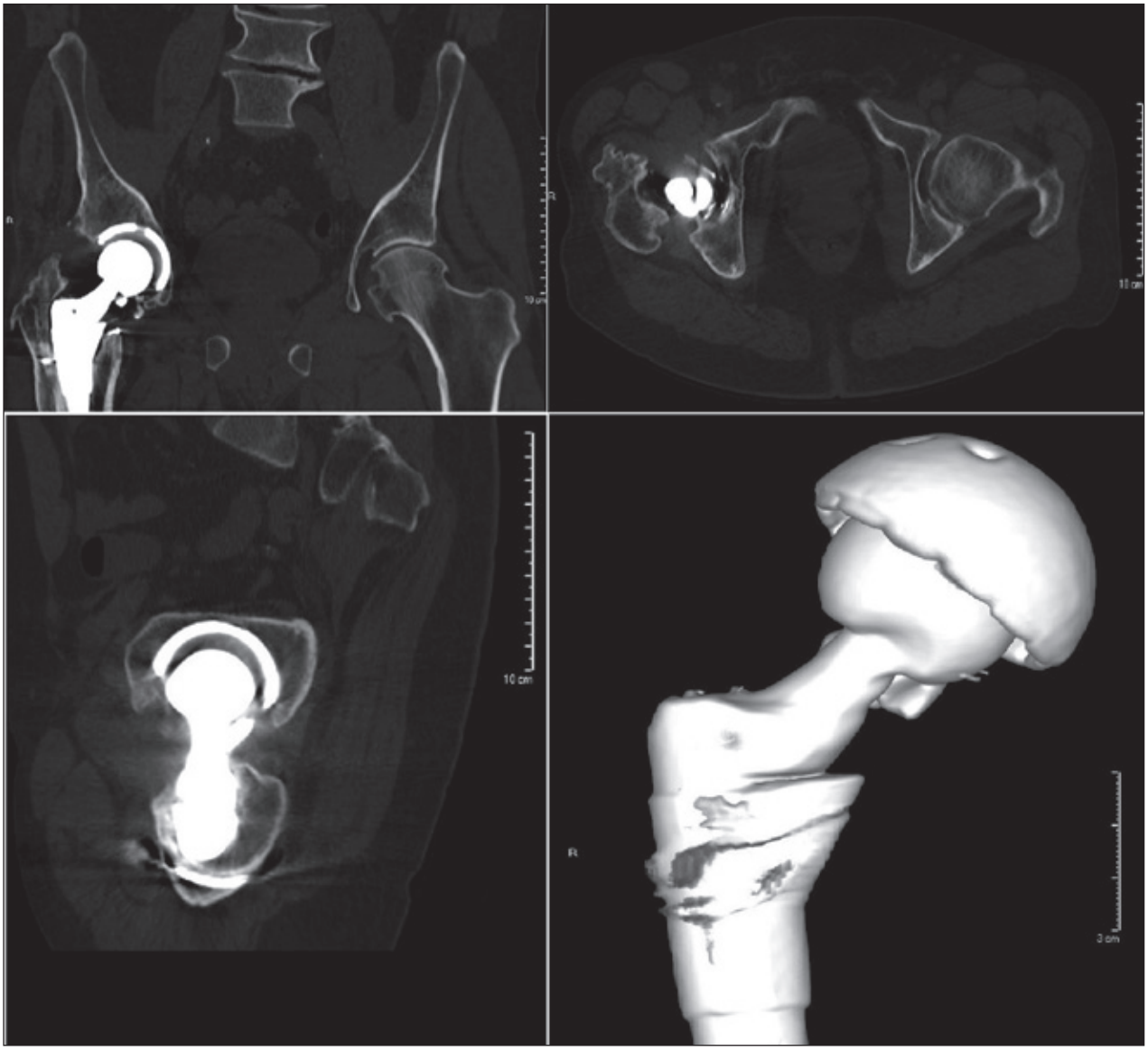

Figure 2. Computed Tomography scans demonstrating fragmentation of the ceramic femoral head

started rehabilitation with weight-bearing as tolerated with crutches for one month. At 1-year follow-up, the patient had a complete hip function recovery with no pain and satisfactory radiological result (Figure 4).

Discussion

Ceramic breakage is a serious complication following THA. Data obtained from CeramTec register show that the incidence of BIOLOX delta ceramic femoral head fracture is about 0,001% (28 out of 2.78 millions) (7). As reported by Si et al. in a systematic review and meta-analysis of 13 randomized controlled trials, higher head fracture in COC group with a risk ratio of 6.02 when compared with COP bearing was found (8). Moreover, ceramic head fracture occurred only in short neck heads (1). As stated in table 1 (Table 1), only 3 cases of fracture of BIOLOX delta femoral head have been described after primary COP total hip replacement (4-6). In revision hip surgery, the breakage of a ceramic head is a rare occurrence, which

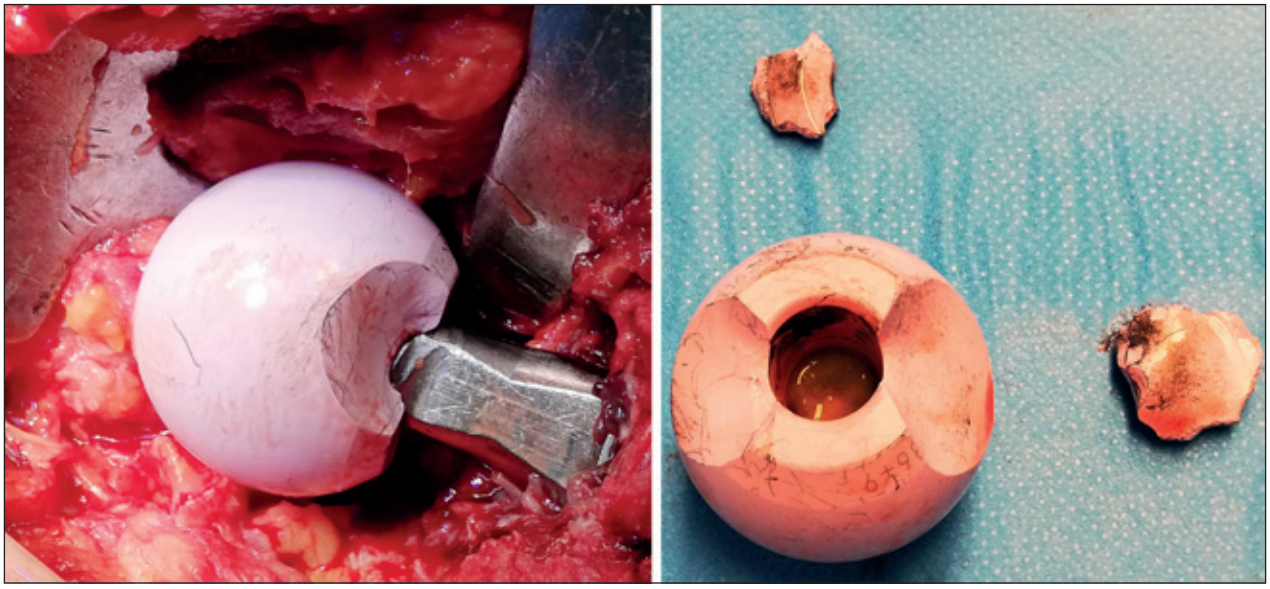

Figure 3. Intraoperative findings showing the broken ceramic head and two gaps at the opposite sites close to the stem neck (a), and two large fragments of the femoral head (b)

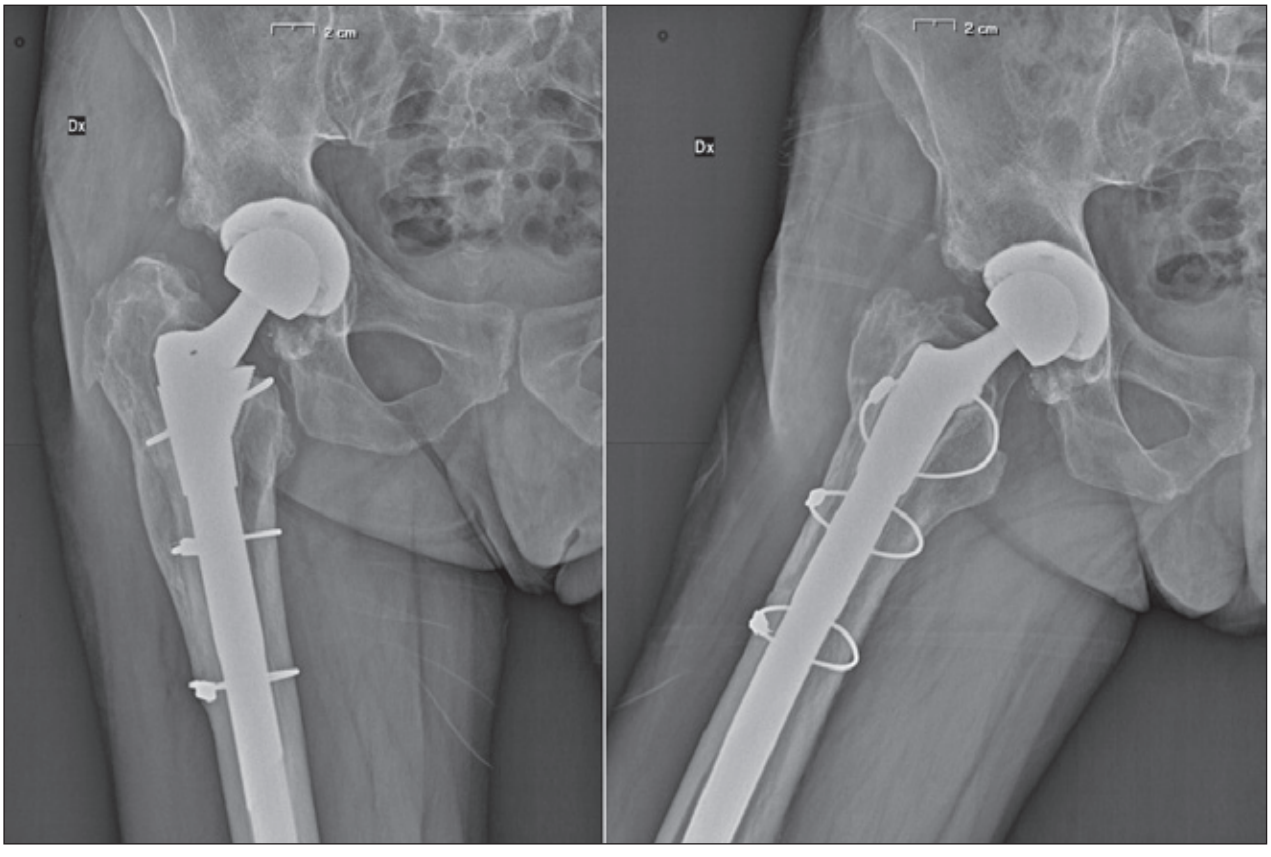

Figure 4. Postoperative x-ray after partial component hip revision, including replacement of the polyethylene acetabular liner and a BIOLOX delta femoral head with a BioBall adapter

Table 1. Cases of BIOLOX delta ceramic head fracture with ceramic-on-polyethylene coupling

Author	Year	Head Diameter	Cause
Heiner et al. [4]	2014	36 mm	Bicycle accident
Pomeroy et al. [5]	2015	32 mm	Atraumatic
Rankin et al. [6]	2019	32 mm	Slip and fall (symptomatic after 2 months)

was reported in 2014 by Tai et al. with a COC coupling (3). Although many studies previously described this dramatic complication, the incidence in hip revisions has never been detailed. The present study reports the breakage of a BIOLOX delta femoral head which occurred after revision THA with a COP bearing, and to our knowledge it has not been previously reported.

Ceramic fractures may occur acutely, but more frequently during normal activity, due to stress and fatigue on the implant (1). As reported by Rankin et al. in 2019, we believe in "slow crack growth": a crack initiation in the surface of alumina matrix by repeated stress event on the implant that ultimately propagate to all the ceramic head until its fracture (6). Only this event may explain the delayed rupture that we observed.

Clinical signs are hip pain, limited range of motion and sometimes a creaking or squeaking sound; a duller clicking sound is indicative of rupture (1). X-rays are generally diagnostic because fragments of ceramic head are radiopaque. CT provides additional information of head fractures, debris wear and component positioning (9).

Treatment consists of early hip revision to prevent local and systemic complications. Surgery should include accurate debridement and extensive synovectomy to remove all ceramic debris and avoid dissemination of the sharpest fragments that can be abrasive for the taper (1). After removal of the femoral head and the acetabular liner, it is essential to check components stability and trunnion state. A marked damage of the trunnion is an indication to replace the femoral stem. Revision surgery may consider COC and COP bearings. In the presence of a breakage of the ceramic component, Garcia et al. advise caution with the use of metal femoral head, as small ceramic fragments can cause 3rd-body wear with massive metal debris and severe local and general complications (10). As reported in our case, if femoral stem is well fixed with no damage to the trunnion, the use of a metal adapter is a good system to match the head on the 11/13 taper and to obtain optimum hip stability and elongation.

Conclusion

This case for the first time describes a fourth generation alumina ceramic femoral head breakage with a COP bearing after hip revision surgery. Fracture of ceramic head may result in mechanical and biological problems if mismatched. This case confirms the need to carefully evaluate the status of fourth generation alumina ceramic components in symptomatic patients, especially following traumatic events. Early revision surgery is essential to prevent local and systemic complications. During surgery, it is necessary to remove all fragments for preventing early failure induced by sharp debris.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Rambani R, Kepecs DM, Mäkinen TJ, Safir OA, Gross AE, Kuzyk PR. Revision total hip arthroplasty for fractured ceramic bearings: a review of best practices for revision cases. J Arthroplasty 2017; 32(6): 1959–64.
2. Huet R, Sakona A, Kurtz SM. Strength and reliability of alumina ceramic femoral heads: review of design, testing, and retrieval analysis. J Mech Behav Biomed Mater 2011; 4(3): 476–83.
3. Tai SM, Parker L, de Roeck NJ, Skinner JA. Recurrent catastrophic ceramic femoral head failure in total hip arthroplasty. Case Rep Orthop 2014; 2014.
4. Heiner AD, Mahoney CR. Fracture of a BIOLOX Delta ceramic femoral head articulating against a polyethylene liner: A case report. JBJS Case Connect 2014; 4(4): e97.
5. Pomeroy E, Rowan F, Masterson E. Atraumatic fracture of a BIOLOX delta ceramic femoral head articulating with a polyethylene liner: A case report. JBJS Case Connect 2015; 5(4): e112.

6. Rankin CS, Robinson PG, Beattie N, Gaston P. Fracture of a BIOLOX delta ceramic femoral head: A case report and update of the literature. JBJS Case Connect 2019; 9(4): e336.
7. Lee GC, Kim RH. Incidence of modern alumina ceramic and alumina matrix composite femoral head failures in nearly 6 million hip implants. J Arthroplasty 2017; 32(2): 546–51.
8. Si HB, Zeng Y, Cao F, Pei FX, Shen B. Is a ceramic-on-ceramic bearing really superior to ceramic-on-polyethylene for primary total hip arthroplasty? A systematic review and meta-analysis of randomised controlled trials. Hip Int 2015; 25(3): 191–8.
9. Trivellin G, Sandri A, Bizzotto N et al. Ceramic liner fatigue fracture: 3-D CT findings in a late recurrent THA dislocation. Orthopedics 2013; 36(1): e101–4.
10. Olmedo-Garcia NI, Zagra L. High risk of complications using metal heads after ceramic fracture in total hip arthroplasty. Hip Int 2019; 29(4): 373–8.

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Case report

Subtrocantheric nonunion following fracture of an arthrodesed hip: a case report

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Summary. In recent years in the era of successful of total hip replacement, hip arthrodesis is rarely performed. The anatomy and biomechanics of an arthrodesed hip is altered, thus influencing the treatments strategies in case of fracture or nonunions. This case report describes the management and therapeutic solution for the treatment of subtrochanteric nonunion in a patient with hip arthrodesis. Satisfactory outcomes were finally obtained after a double surgical procedure. (www.actabiomedica.it)

Key words: hip, arthrodesis, fracture, nonunion.

Introduction

Total hip replacement (THR) has become the treatment of choice for most hip patologies and the indications for arthrodesis are few in selected cases (1,2). They include isolated arthritis of the hip in young patients engaged in manual work, or those with severe muscular deficits (3). Furthermore, this procedure is more often performed in the developing world, Furthermore, in young patients with septic arthritis. The most effective technique for obtaining a stable hip arthrodesis is a topic of debate. Several surgical procedures with varying rates of success have been described including the use of plates and screws, intramedullary nails and external fixators (4-9).

The increasing incidence regarding proximal femoral fractures in developed countries has been noticed. However, femoral fractures following hip arthrodesis are rare cases (1,10) that need special attention in their treatment strategy. This is related with the fact that conventional treatment options are difficult to apply as consequence of the concomitant altered anatomy and biomechanics. Therefore, nonunions in the atrhodesed hip may have an higher frequency, even if few reports about this topic are described in the literature (11-13).

In this case report Authors, we shall present a patient with a subtrochanteric nonunion following a fracture of the femur which occurred in a hip that had a previous arthrodesis.

Case presentation

This study was conducted in accordance with the principles of Declaration of Helsinki. Patient signed informed consent about the treatment she was subjected and the processing of her personal data. M.C. a 71 years old female was admitted at the emergency department complaining of severe pain as a result of a torsional movement and a subsequent fall on his right hip, that underwent arthrodesis in the past.

Patient has a complex and not clear history. She was born with a hypometry of the lower right limb, and a homolateral hip dysplasia.

At the age of 9 she was submitted to arthrodesis. At the age of 19, she had surgery to lengthen his right femur. At the end of these treatments she was left with a hypometry of about 4 centimeters, but despite that she had a normal life.

Radiographs after trauma showed a subtrochanteric

spiroid fracture of the right femur and the presence of screws in its distal fragment that derived from the previous intervention in a context of severe osteoporosis (figure 1).

As several surgical options have been reported in literature, the choice of the proper surgical technique was not easy. Authors decided to perform open reduction and internal fixation (ORIF) with plate and screws (O'Nil plate 22,5 mm with 2 locking screws of 7 mm diameter, 2 locking screw of 4 mm diameter in the proximal fragment and 5 screws in the distal fragment; 1 of them is a standard screw) (figure 2).

Surgery was performed under general anesthesia.

After two months from surgery the patient was

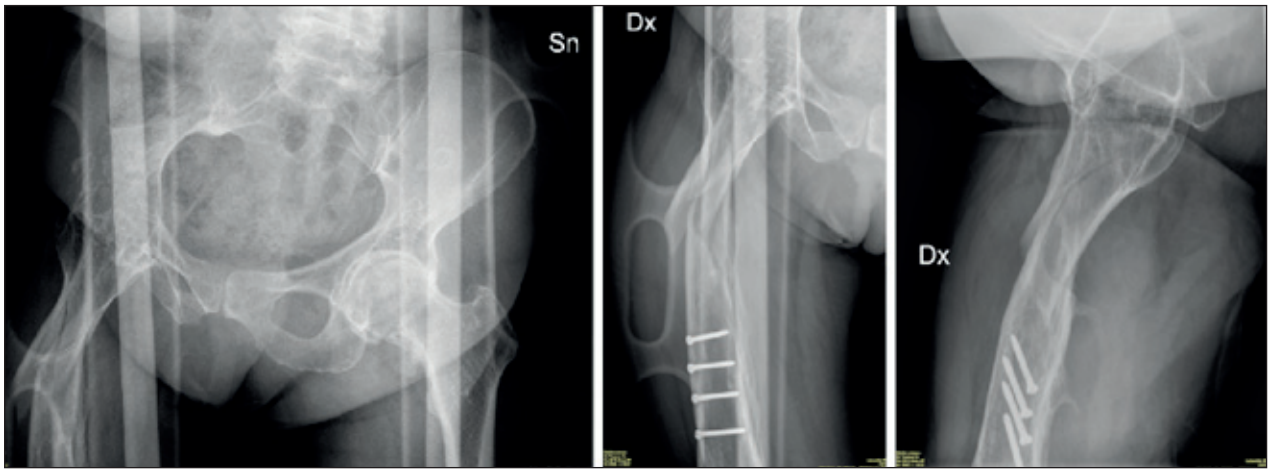

Figure 1. Subtrochanteric right fracture in a previously arthrodesed hip

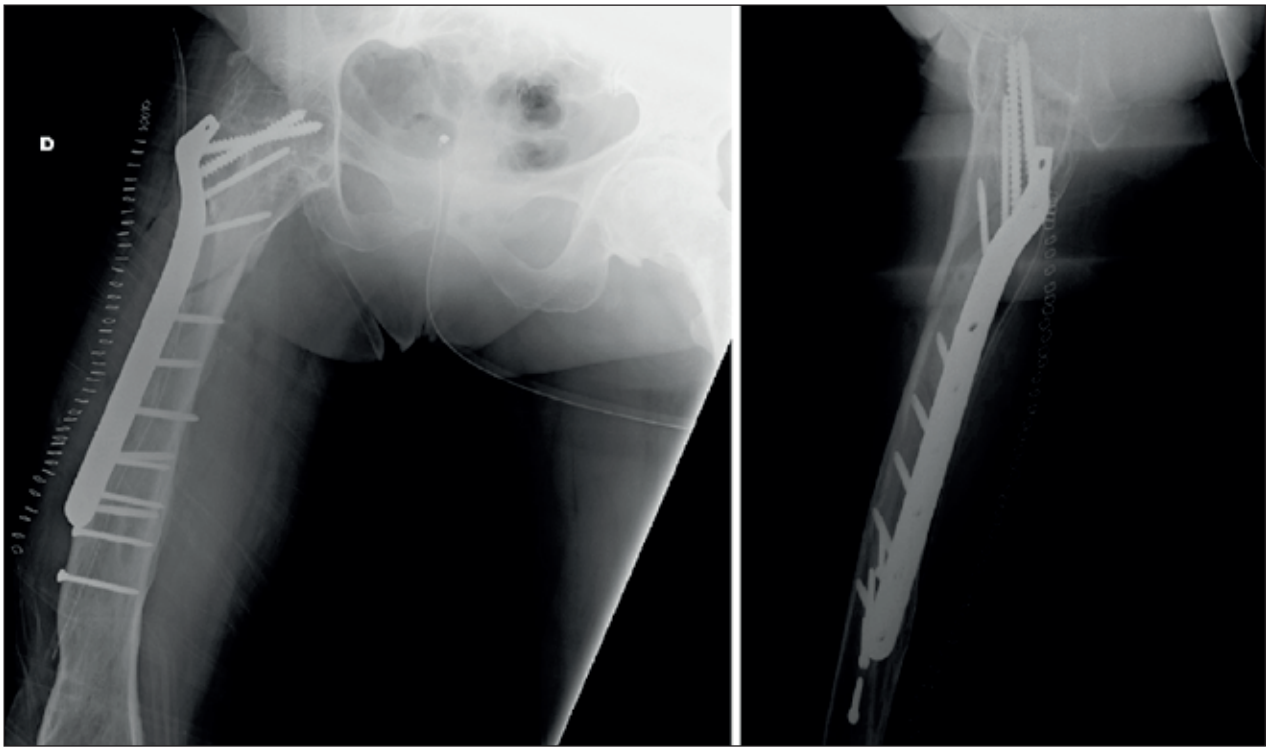

Figure 2. Postoperative x-rays

able to walk with crutches and control X-rays showed a slow bone healing process (figure 3).

After eight month M.C. was admitted again in the emergency ward complaining of severe pain as a result of another torsional movement and a subsequent fall. Radiographs showed a femoral nonunion and the breakage of the plate at the level of the previous fracture (figure 4).

The re-operation consisted in the removal of the broken plate and in a new fixation with a sliding hip screw associated with a cortical bone allograft and local injection of platelet rich plasma (PRP) (figure 5).

Patient had a non weigth bearing period of 2 months. In the following weeks she gradually recovered and at final check (8 months after surgery) pain was absent and nonunion consolidated (figure 6).

Nowadays, she has returned to her daily activities with a quality of life equal to the preinjury condition.

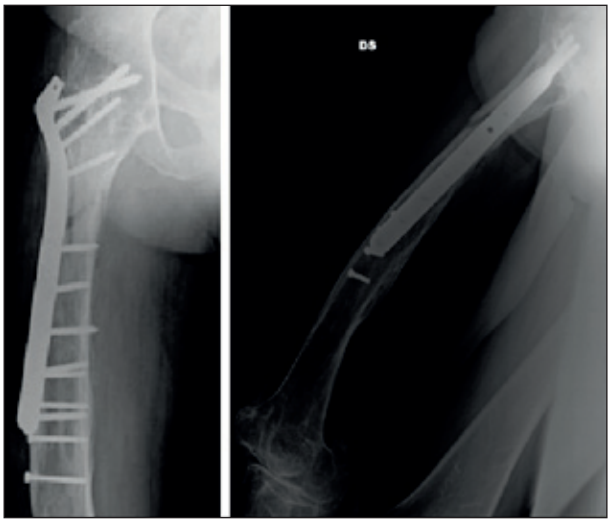

Figure 3. Radiographs 2 months after surgery

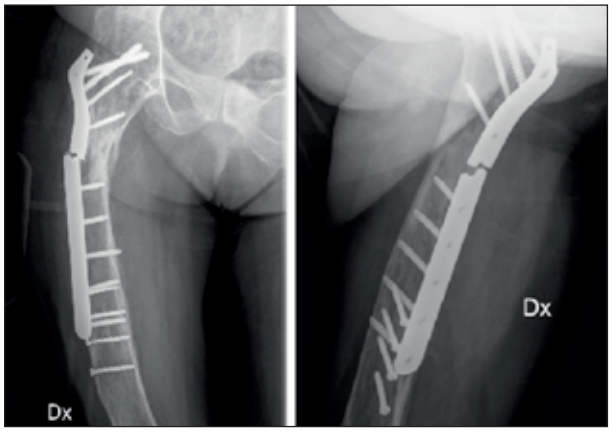

Figure 4. Plate's rupture 8 months after initial osteosynthesis with atrophic nonunion

Discussion

Fractures of the proximal femur are very common in the elderly population and treatment is usually surgical and performed as soon as possible. The particularity of a fracture around a preexisted coxofemoral arthrodesis derives from the fact that this type of lesion is rare, the experience of orthopaedic surgeon is low, and the literature is insufficient regarding this topic. Arthrodesis modifies the anatomy, biomechanics and biology of the femur and lower limb (14-16). Also, it can cause ipsilateral knee and lumbosacral spinal problems as well as atrophy of muscles around hip and

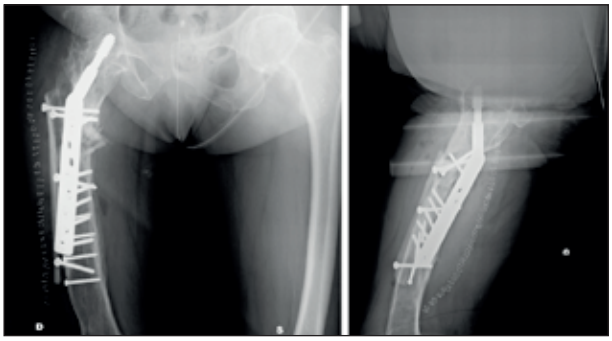

Figure 5. X-rays following sliding hip screw fixation and cortical bone grafting and PRP injection.

Figure 6. X-rays 8 months after second osteosynthesis with consolidation of the nonunion

thigh. A "locked joint" determinates an altered distribution of forces and weight to the next joints, which have more easily early osteoarthritis, axial deviations and fractures (13).

The problem with deciding the correct surgical treatment and implants depends on all these factors.

In literature there are a lot of work recommending surgical treatment in order to avoid complications due to the long bed rest period (17-19).

Intramedullary nailing (IMN) and ORIF are the two possibilities of surgical treatment.

In this case report the first surgery was an ORIF. The conversion in total hip arthroplasty could be a strategy but the fracture was too much distal (20) and IMN was excluded because of technical difficulties related to patient positioning, fracture reduction and altered femoral anatomy (M.C. underwent both an arthrodesis and femoral elongation surgery) (21).

Authors managed to achieve a good reduction and sufficient stability. The patient resumed the load after two months from surgery. Clinical and X-ray follow-up showed a fracture that was healing slowly, but nonunion with plate's rupture developed 8 months after fixation. Different hypotheses could explain this failure. One explanation can be found in the altered bone characteristics of the patient (elderly with a severe osteoporosis). Another may lie in the altered biomechanics of the lower limb. In normal conditions surgical treatment would probably have led to the healing of the fracture, but in patients who have undergone arthrodesis, the way in which the load forces are distributed is very different from the normal condition (10,14,15). Finally, the type of fracture may have favored the development of this complication. Subtrochanteric patterns are associated with a variable incidence of nonunions (rates of 4-13% for extramedullary devices and up to 10% in intramedullary fixation). The main causes of failed consolidation can be associated to the interruption of the medial cortex of the femur, to comminution of the fracture and consequent loss of bone substance, to an imperfect reduction, to an incorrect surgical treatment or to a particular biomechanical conditions of the hip, as present after arthodesis (13,22,23). Subtrochanteric nonunions are difficult to treat and the previous surgeries carried out worsens the local situation. Intramedullary and extramedullary devices also proved to be succesful in these cases (13).

In this specific case the presence of a broken plate and an atrophic nonunion indicated a new internal fixation associated with a cortical bone graft. Authors believe that the use of cortical grafts are essential in order to obtain healing as they guarantee a better biomachanic situation. Furthermore, they are sure that cortical grafts together with PRP determine a biological stimulus as demonstrated by progressive strut osteointegration and bone formation (24-28).

Conclusion

Subtrochanteric femoral nonunions in arthrodesed hip need special attention. Their treatment is difficult and controversial. Torsional stresses from the trunk and lower extremity require rigid fixation to minimize the risk of failure and is recommended a structural and biological supply in order to favor bone healing.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Manzotti A, Confalonieri N, Pullen C. Intertrochanteric fracture of an arthrodesed hip. J Bone Joint Surg B. 2007; 89: 390-92.
2. Zeiler G, Schuh A. Arthrodesis of the hip and its conversion. Orthopaedics 2004; 33: 939-56 (in German).
3. Barnhardt T, Stiehl JB. Hip fusion in young adults. Orthopaedics 1996; 19: 303-6.
4. Schoenecker PL, Johson LO, Martin RA, Doyle P, Capelli AM. Intra-articular hip arthrodesis without subtrochanteric osteotomy in adolescents: technique and short-term follow-up. Am J Orthop 1997; 26: 257-64.
5. Siebenrock KA, Gautier E, Matta JM, Mehne D, Ganz R. New technique for a hip arthrodesis using an anterior approach and a ventral plate. Orthopaedics 1996; 25: 140-5.
6. Bankes MJ, Simmons JM, Catterall A. Hip arthrodesis with the dynamic hip screw. J Pediatr Orthop 2002; 22: 101-4.
7. Onji Y, Kurata Y, Kido H. A new method of hip fusion using an intramedullary nail. J Bone Joint Surg [Br] 1965; 47-B: 690-3.
8. Brien WW, Golz RJ, Kuschner SH, Brien EW, Wiss DA. Hip joint arthrodesis utilizing anterior compression plate fixation. J Arthroplasty 1994; 9: 171-6.

9. Endo N, Takahashi HE, Toyama H, et al. Arthrodesis of the hip joint using an external fixator. J Orthop Sci 1999; 4: 342-6.
10. Shunsuke Asakawa,Takeo Mammoto,and Atsushi Hirano. Proximal Femoral Fracture in Hip Arthrodesis Treated with Double Reconstruction Plates. Hindawi Case Reports in Orthopedics Volume 2017, Article ID 5246080, 5 pages
11. Wagner M, Wagner H. Hip joint arthrodesis using the cobra plate. Indication, technique, outcome. Orthopade 1996 Apr; 25(2): 129-39.
12. Fuchs B, O'Connor MI, Kaufman KR, Padgett DJ, Sim FH. Iliofemoral arthrodesis and pseudarthrosis: a long-term functional outcome evaluation. Clin Orthop Relat Res 2002 Apr; (397): 29-35.
13. Pascarella R, Cerbasi S, Maresca A, Sangiovanni P, Fantasia R. Unusual presentation of recurrent subtrochanteric nonunion in a patient with hip arthrodesis: A case report. Injury 2018 Dec; 49 Suppl 4: S2-S8.
14. Weber BG. (1987) Hip Arthrodesis. In: Tronzo R.G. (eds) Surgery of the Hip Joint. Springer, New York, NY
15. Liechti R. (1978) Biomechanics of Hip Arthrodesis and Internal Fixation: Kinetics and Elastometry. In: Hip Arthrodesis and Associated Problems. Springer, Berlin, Heidelberg
16. Liand B, Aspden RM. Material properties of bone from the femoral neck and calcar femoral of patients with osteoporosis or osteoarthritis. Osteoporosis International 1997; 7(5): 450-6.
17. Wulke AP, Mader K, Pennig D. Femoral neck fracture in an arthrodesed hip treated by a supracondylar intramedullary locked nail. Journal of Orthopaedic Trauma 2004; 18(2): 116-8.
18. Murena L, Moretti A, Meo F, et al. Predictors of cut-out after cephalomedullary nail fixation of pertrochanteric fractures: a retrospective study of 813 patients. Arch Orthop Trauma Surg. 2018 Mar; 138(3): 351-9.
19. Canton G, Giraldi G, Dussi M, Ratti C, Murena L. Osteoporotic distal femur fractures in the elderly: peculiarities and treatment strategies. Acta Biomed 2019 Dec 5; 90(12-S): 25-32.
20. Jones LD, Hampton ER, Ansari EA. A treatment option for femoral neck fractures complicating hip arthrodesis: conversion to a constrained total hip replacement. Eur J Orthop Surg Traumatol 2007; 17: 203-5
21. Wong TC, Rikhraj IS. Femoral Shaft Fracture in a Hip Arthrodesis: Two Cases of Retrograde Interlocking Nailing. Singapore Med J 2004; 45(2) : 85.
22. Pogliacomi F, Pellegrini A, Tacci F, Pedrini MF, Costantino C, Pedrazzini A, Pedrazzi G, Lauretani F, Vaienti E, Ceccarelli F. Risks of subsequent contralateral fractures of the trochanteric region in elderly. Acta Biomed. 2016; 87(3): 275-281.
23. Pellegrini A, Tacci F, Leigheb M, Costantino C, Pedrazzini A, Pedrazzi G, Vaienti E, Ceccarelli F, Pogliacomi F. Injuries of the trochanteric region: can analysis of radiographic indices help in prediction of recurrent osteoporotic hip fractures? Acta Biomed. 2017 Oct 18; 88(4 -S): 43-9.
24. Bernuzzi G, Petraglia ., Pedrini MF, De Filippo M, Pogliacomi F, Verdano MA, Costantino C. Use of platelet-rich plasma in the care of sports injuries: our experience with ultrasound-guided injection. Blood Transfusion 2014; 12 Suppl 1: s229-34.
25. Leigheb M, Pogliacomi F, Bosetti M, Boccafoschi F, Sabbatini M, Cannas M, Grassi . Postoperative blood salvage versus allogeneic blood transfusion in total knee and hip arthroplasty: a literature review. Acta Biomed. 2016 Apr 15;87 Suppl 1: 6-14.
26. Bosetti M, Leigheb M, Boccafoschi F, Brooks R, Cannas M. Regulation of osteoblast and osteoclast functions by FGF-6. J Cell Physiol 2010 Nov; 225(2): 466-71.
27. Bosetti M, Boccafoschi F, Leigheb M, Cannas M. Effect of different growth factors on human osteoblasts activities: a possible application in bone regeneration for tissue engineering. Biomol Eng 2007 Dec.; 24(6): 613-18.
28. Follo F, Dejana DO, Belletti M, Bongiovanni N, Scarpa G, Pezzali P, Borsi S, Sanfilippo L, Lusetti N, Zaini L, Loritto P, Pogliacomi F, Pedrazzini A. Management and effect of platelet-rich plasma on wound healing: small reality of Oglio Po Hospital. Acta Biomed. 2017 Nov 30; 88(5-S): 66-70.

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Case report

Distal femur nonunion treated with retrograde intramedullary nailing and RIA: a case report

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Summary. The current treatment of distal femur fractures includes locking plating and retrograde intramedullary nailing. These fractures are difficult to manage also for experienced surgeons, with results not always satisfactory. Reported nonunion rates now range from 0 to 34%. Factors associated with nonunion include comorbidities, such as obesity and diabetes, as well as the presence of open fractures, medial bone defects and comminuted fractures. This case report summarizes all of these assumptions and it concerns a 58 years old patient who underwent to 6 surgical procedures before to arrive to bone healing. (www.actabiomedica.it)

Key words: distal femur, fracture, nonunion, fixation, plating, nailing.

Introduction

Supra and intercondylar femur fractures are severe injuries that can be challenging also for more experienced surgeon. Although they account for less than 1% of all fractures and between 3% and 6% of femur fractures, their incidence is likely to increase; these types of traumas follow a bimodal age distribution in geriatric (low energy fractures) and young adult population (high energy traumas) (1-3).

The difficulties in their treatment increase in comminuted, intra-articular and open fractures. Their correct management includes the understanding of the fracture characteristics and a careful preoperative planning comprising implant selection.

The intra-articular fracture should be reduced anatomically and fixed in order to prevent postoperative knee osteoarthritis and stiffness. Metaphyseal comminution and bone loss, especially in open fractures, is a well-documented risk of nonunion and sometimes it is necessary to associate bone grafts that improve stability and healing processes (4, 5).

Current treatment options broadly include retrograde intramedullary nailing (RIMN) and open reduction and internal fixation (ORIF); in any case the surgical goal is to obtain best reduction and maximal stability.

This case report confirms the difficulties in the treatment of this type of fracture which healed only after a long period and multiple surgeries.

Case Presentation

This study was conducted in accordance with the principles of Declaration of Helsinki. Patient signed informed consent about the treatment he was subjected and the processing of his personal data.

A 58-year-old obese male was involved in a car accident and sustained a polytrauma characterized by an open comminuted intra-articular distal left femur fracture (figure 1) (AO/OTA 33-C3 and 2 Gustilo-Anderson classification) with bone loss and residual gap of about 6 cm at the level of the anterior and

Figure 1. Clinical assessment of the antero-distal exposure of the thigh.

medial metaphysis (figure 2), and ipsilateral fractures of the second and third metatarsals (figure 3), of the external proximal tibial plateau and of the patella and dislocation of the third metatarsophalangeal joint.

He was initially treated in emergency with debridement of the exposure, stabilization of the distal femur with an external fixator, screw fixation of the ipsilateral tibial fracture and of the metatarsals with Kirschner wires.

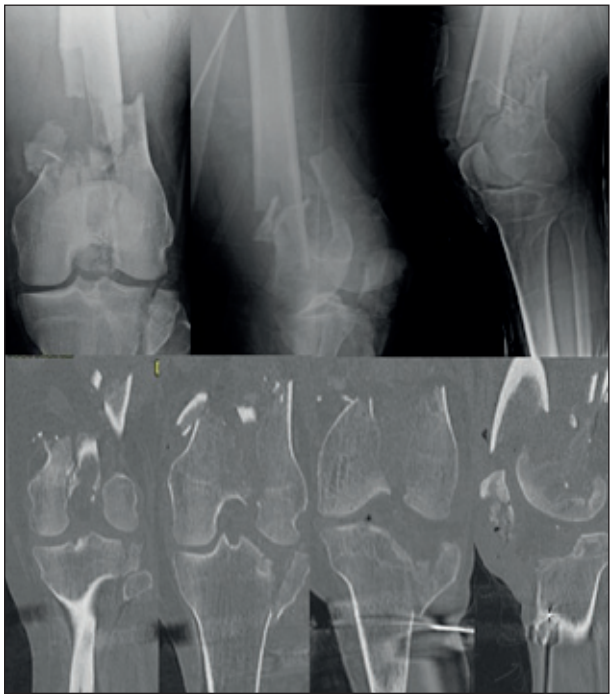

Figure 2. Preoperative knee radiographs and CT views

Figure 3. Preoperative left foot radiographs with fractures of the second and third metatarsals and dislocation of the third metatarsophalangeal joint

Seven days later the final osteosynthesis of the femur was performed with LISS plate and screws in association with anterior and medial cortical allograft; the patella was stabilized with screws (figure 5)

Two months later patients started assisted weigth bearing but in the following period x-rays showed cortical bone graft rupture and metal devices loosening (figure 6).

At this time inflammation indexes were high but scintigraphy with granulocytes excluded an acute infection. The patient underwent a second surgery in which the previous devices were removed and a new osteosynthesis with longer L.I.S.S. plate associated to another autologous cortical allograft and autologous bone from iliac crest was performed (figure 7).

Samples of tissue were taken from nonunion outbreak for microbiological/cultural tests. Bacteriological findings demonstrated Klebsiella Pneumoniae infection, which was treated with targeted antibiotic therapy, up to normalize the inflammation indexes (about 2 months) and another scintigraphy did not show signs of infection.

Eight months after this second surgery patient complained of a sudden pain during walking. The

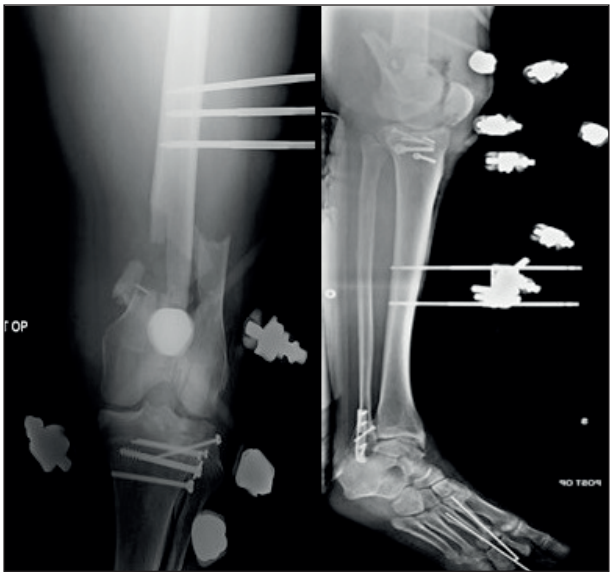

Figure 4. Postoperative x-rays after acute initial surgery

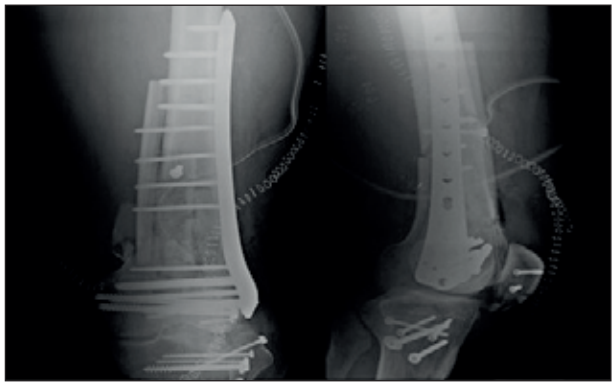

Figure 5. Postoperative radiographs following surgery 7 days after injury

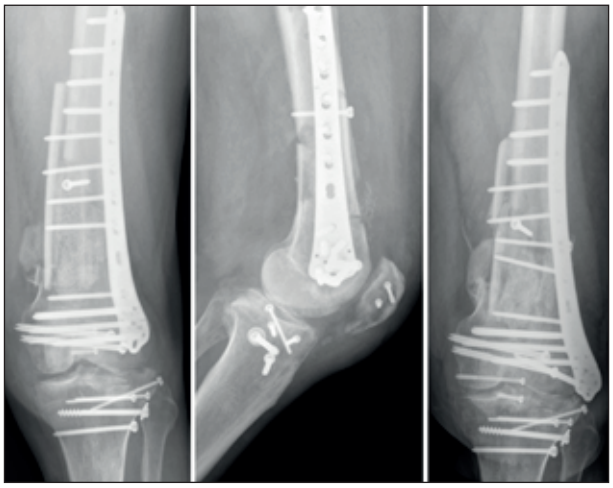

Figure 6. X-rays views 2 and 4 months after surgery with rupture of the cortical graft and device loosening

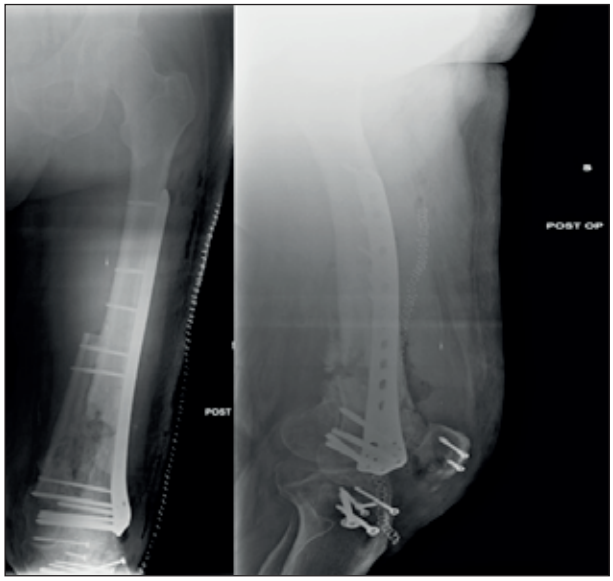

Figure 7. X-rays views after second procedure of osteosynthesis

radiological evaluation revealed the rupture of the plate and cortical graft in a framework of nonunion of the metaphyseal fracture, despite healing of its articular component. Elevated inflammation indexes as well as positive scintigraphy led us to suspect an underlying silent infection (figure 8).

As consequence metallic devices were removed, a large bone resection was performed at the pseudoarthrosis stump, multiple tissue material samples were taken for microbiological/culture tests and an antibiotic-based cement spacer (gentamicin) was placed, according to the Masquelet technique. Temporary fixation was obtained with external fixator (figure 9).

Staphylococcus aureus infection was treated with specific antibiotic therapy for two months. After normalization of the inflammation indexes with negative granulocyte scintigraphy, after 3 months of Masquelet, the final surgery was performed. A retrograde intramedullary nail combined with bone marrow taken from the contralateral femur with the RIA technique and cadaveric bone grafts was applied (figure 10).

The patient started assisted weigth bearing after 2 months and 4 months following last surgery x-rays showed the breakage of the proximal static locking screw, which was removed (figure 11).

The subsequent monthly checks showed progressive radiological and clinical improvements. Eight months after RIMN pain was absent, patients walked without crutches and x-rays showed consolidation (figure 12).

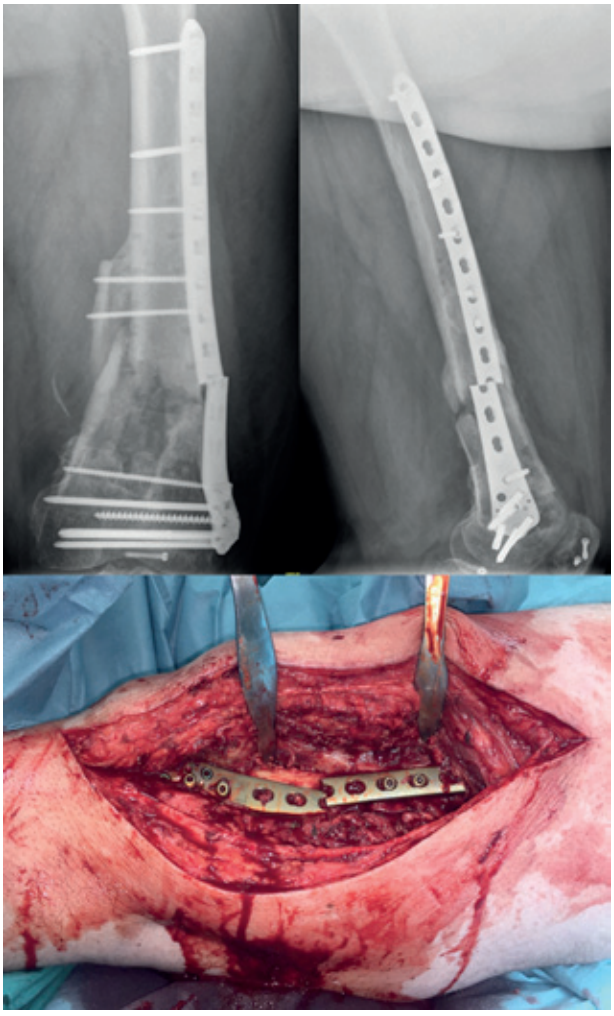

Figure 8. Plate's and cortical graft rupture. Radiographs and intraoperative view

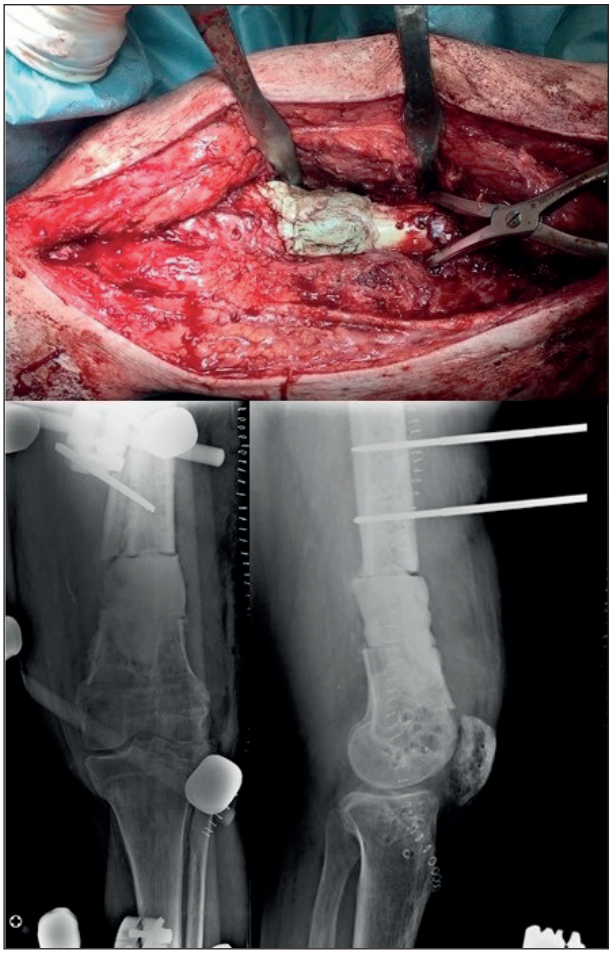

Figure 9. In situ cement spacer and external fixation; intraoperative view and x-rays

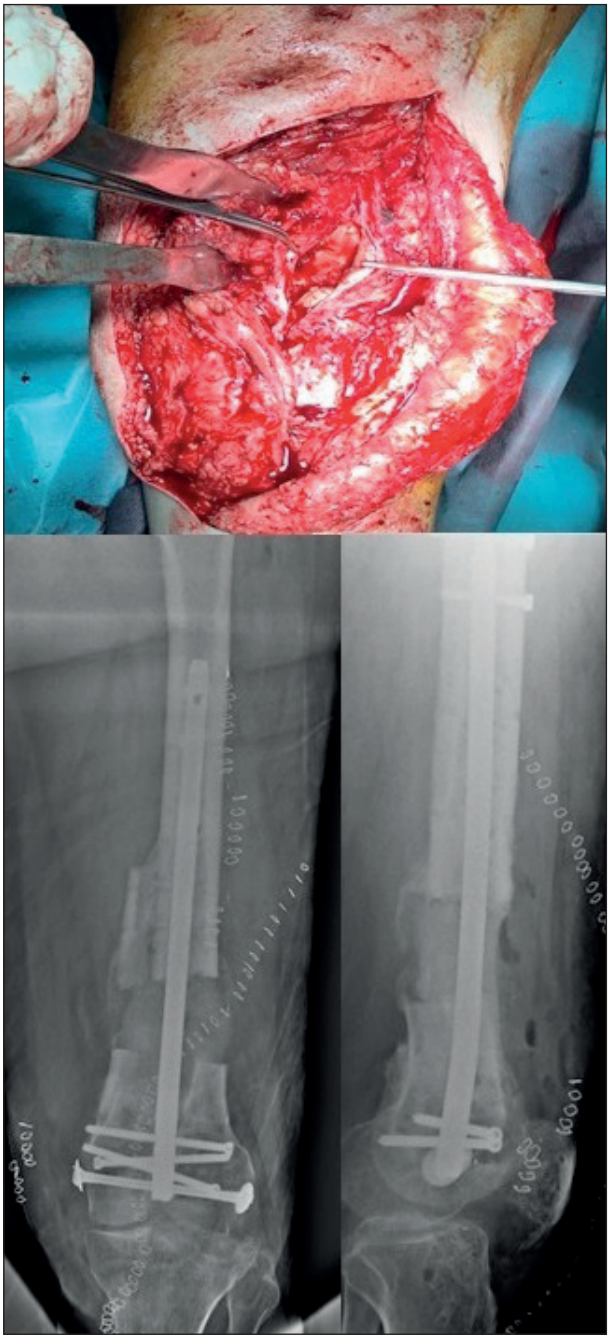

Figure 10. Induced membrane after cement removal and radiographs after RIMN and bone marrow and grafts positioning

Discussion

Distal femur fractures not rarely are characterized by unsatisfactory results; this is also the consequence of their severity that makes these injuries technically challenging to operatively treat also for experienced orthopaedics surgeons (4).

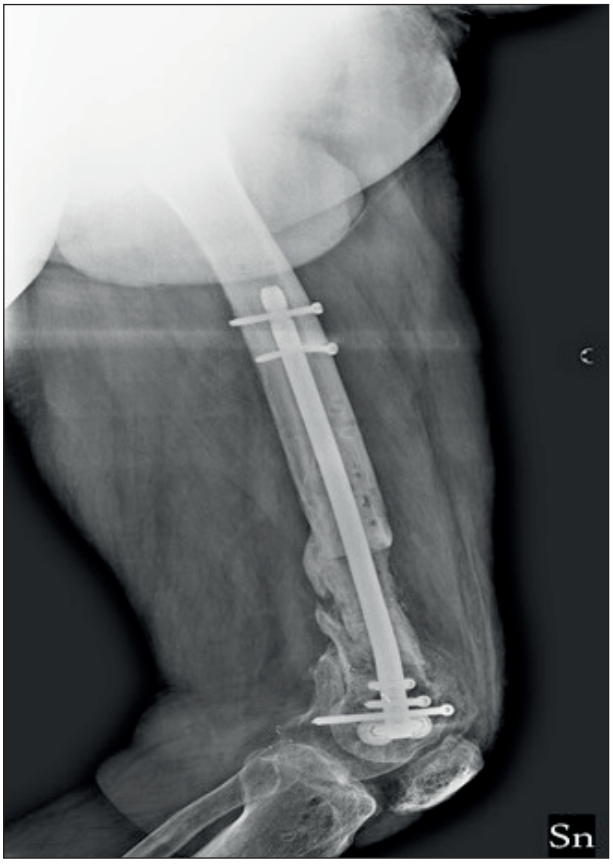

Figure 11. Rupture of the proximal static locking screw.

In the early 1960s, most distal femur fractures were managed conservatively with fracture bracing and traction, achieving acceptable results in 67% to 90% of patients (6). However, with the advent of new surgical techniques and implants, the pendulum shifted from conservative management to surgical stabilization. Through historical review, Henderson and colleagues chronicled the increasing success rates with operative fixation from 52% to 54% in the 1960s, 73.5% to 75% in the 1970s, to 74% to 80% in the 1980s. Steady advances in our understanding of distal femoral anatomy and fracture biology have heralded various implant designs that further optimized successful treatment of these injuries (6).

Nowadays, surgical treatment can either be RIMN or plate fixation, with plate fixation having a wide indication for various fractures types (5, 6); bone grafts can be associated (7-9).

Figure 12. X-rays and clinical evaluation 8 months after last surgery with consolidation of the fracture

Recently, many studies have shown results of the LCP fixation and RIMN fixation. LCP and RIMN have been reported to yield better outcomes than traditional non-locking plates (10). Data from large retrospective cohorts (10-13) suggest that there were no significant differences in clinical outcomes, including time to union and union rates, in patients who underwent LCP and RIMN fixation of the distal femur after fracture.

However, the non union rate lies between 0 and 34%, indicating considerable variation (1,14).

Risk factors for non union and delayed bone union in distal femoral fractures include the presence of open fractures, medial bone defects, obesity and comminuted fractures (14,15) as well as surgical mistakes.

In this case report, in which multiple surgeries were necessary to reach bone healing, all these factors were present.

Authors believe that their initial treatment should be criticized for timing (only 7 days from open fracture to definitive surgical treatment) and methodology. The delicate approach of a multi-fragmentary metadiaphyseal and articular fracture should require a system of synthesis that leads to absolute stability, while avoiding the rigidity of the system itself.

The stable plate-screws connection typical of LISS construct, which reduces the risk of secondary loss of reduction providing stability of the implant, could be compromised by wrong choice of plate length and screw positioning.

The guidelines reported by Gautier et al. suggested that a locking compression plate should be used as a bridging plate in order to achieve relative stability. Additionally, the researchers recommended that the plate length used in simple fractures should be 8–10 times longer than the fracture length, 0–3 empty holes should be left in the surrounding space, the distance space should be ≤ 2 mm, and ≥ 3 screws should be inserted (bicortically) into the proximal and distal bone fragments (16). For comminuted fractures, the guidelines recommend that the plate length should be at least 2–3 times longer than the fracture length and ≥ 3 empty holes should be left in the surrounding fracture site.

For these reasons, Authors are critics on their first fixation surgery; plate was too short and together with the cortical graft both determined too much rigidity and the subsequent failure of the synthesis.

Authors also believe that second osteosynthesis was biomechanically better (plate longer and a more dynamic screws positioning) but at this time there was an underestimation of the below infection.

Finally, last surgery determined bone healing as consequence of a precise global management of the infected nonunion (association of specific antibiotic therapy, Masquelet technique, RIMN and marrow and bone grafts) (17-19).

Though, RIMN demonstrated a significantly higher malunion rate when compared with locked plating (20), Authors are confident that they have restored a good axis to the lower limb without disruption of extensor apparatus (21). This is an important fact with a view to future prosthesis (22-25), that, in this case, has to be considered unavoidable as consequence of the combined articular fractures of femur, patella and proximal tibia.

Conclusion

Nonunions are frequent complications in these patterns of fractures; it is difficult to choose an adequate synthesis, to correctly balance the biological and mechanical stimulus. In this specific case the exposition of the fracture, obesity and the superinfection further hindered the healing precesses. The success of the treatment depends on not underestimating infection and to create a fixation which guarantees this balance. Furthermore, autoologous bone marrow and bone grafts are essentials in osteoinduction of healing processes.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Gwathmey FW Jr, Jones-Quaidoo SM, Kahler D, Hurwitz S, Cui Q. Distal femoral fractures: current concepts. Review. J Am Acad Orthop Surg 2010; 18(10): 597–607.
2. Martinet O, Cordey J, Harder Y, Maier A, Bühler M, Barraud GE. The epidemiology of fractures of the distal femur. Injury 2000 Sep; 31 Suppl 3: C62–3.
3. Santolini E, West R, Giannoudis PV. Risk factors for long bone fracture non-union: a stratification approach based on the level of the existing scientific evidence. Injury 2015 Dec; 46 Suppl 8: S8-S19.
4. Gangavalli AK, Nwachuku CO. Management of Distal Femur Fractures in Adults: An Overview of Options. Orthop Clin North Am 2016 Jan; 47(1): 85–96.
5. Saka N, Watanabe Y, Sasaki G, Kawano H. Corrective Intra-Articular Osteotomy Using a 3D-Printed Model and Induced Membrane Technique for AO/OTA C3 Distal Femur Fracture with Articular Malunion and Metaphyseal Nonunion. Case Rep Orthop 2020 Jan 28; 2020: 1250231.
6. Sain A, Sharma V, Farooque KVM, Pattabiraman K. Dual Plating of the Distal Femur: Indications and Surgical Techniques. Cureus. 2019 Dec 27; 11(12): e6483.
7. Kiyono M, Noda T, Nagano H, et al. Clinical outcomes of treatment with locking compression plates for distal femoral fractures in a retrospective cohort. J Orthop Surg Res 2019 Nov 26; 14(1): 384.
8. Ehlinger M, Ducrot G, Adam P, Bonnomet F. Distal femur fractures. Surgical techniques and a review of the literature. Orthop Traumatol Surg Res. 2013 May; 99(3): 353–60.
9. Smith WR, Ziran BH, Anglen JO, Stahel PF. Locking plates: tips and tricks. J Bone Joint Surg Am 2007 Oct; 89 (10): 2298–307.
10. Meneghini RM, Keyes BJ, Reddy KK, Maar DC. Modern retrogradeintramedullary nails versus periarticular locked plates for supracondylarfemur fractures after total knee arthroplasty. J Arthroplasty 2014; 29: 1478–81.
11. Ebraheim NA, Kelley LH, Liu X, Thomas IS, Steiner RB, Liu J. Periprostheticdistal femur fracture after total knee arthroplasty: a systematic review. Orthop Surg 2015; 7(4): 29–305.
12. N.F. Matlovich, B.A. Lanting, E.M. Vasarhelyi, D.D. Naudie, R.W. McCalden, J.L.Howard, Outcomes of surgical management of supracondylar periprostheticfemur fractures, J. Arthroplasty 32 (2017) 189–92.
13. Ristevsk BI, Nauth A, Williams DS, Hall JA, D.B. Whelan DB, Bhandari M, Schemitsch EH. Systematic review of the treatment of periprosthetic distal femurfractures, J. Orthop Trauma 2014; 28: 307–12.
14. Ricci WM, Streubel PN, Morshed S, Collinge CA, Nork SE, Gardner MJ. Risk factors for failure of locked plate fixation of distal femur fractures: an analysis of 335 cases. J Orthop Trauma 2014 Feb; 28 (2): 83–9.
15. Zlowodzki M, Bhandari M, Marek DJ, Cole PA, Kregor PJ. Operative treatment of acute distal femur fractures: systematic review of 2 comparative studies and 45 case series (1989 to 2005). J Orthop Trauma 2006 May; 20(5): 366–71.
16. Gautier E, Sommer C. Guidelines for the clinical application of the LCP. Injury 2003 Nov; 34 (Suppl 2): B63–76.
17. Bosetti M, Borrone A, Leigheb M, Shastri VP, Cannas M. Injectable Graft Substitute Active on Bone Tissue Regeneration. Tissue Eng Part A. 2017 Dec, Vol.23, N.23–24: 1413–1422
18. Bosetti M, Leigheb M, Boccafoschi F, Brooks R, Cannas M. Regulation of osteoblast and osteoclast functions by FGF-6. J Cell Physiol. 2010 Nov; 225(2): 466–71.
19. Bosetti M, Boccafoschi F, Leigheb M, Cannas M. Effect of different growth factors on human osteoblasts activities: a possible application in bone regeneration for tissue engineering. Biomol Eng 2007 Dec.; 24(6): 613–8.
20. Kim K. Usefulness of bilateral plate fixation for periprosthetic distal femur fracture after total knee arthroplasty. Int J Surg Case Rep 2020 Feb 6; 68: 43–7.
21. Ryan JA, Meyers KN, Dibenedetto P, Wright TM, Haas SB. Failure of the Patellar Tendon with the Patella Evert-

ed versus Noneverted in a Matched-Pair Cadaver Model. HSS J 2010 Sep; 6(2): 134–7.
22. Frattini M, Vaienti E, Soncini G, Pogliacomi F. Tibial plateau fractures in elderly patients. Chir Organi Mov 2009; 93: 109–14.
23. Pogliacomi F, Verdano MA, Frattini M, Costantino C, Vaienti E, Soncini G. Combined arthroscopic and radioscopic management of tibial plateau fractures: Report of 18 clinical cases. Acta Biomed 2005; 76: 107–14.
24. Vaienti E., Scita G., Ceccarelli F, Pogliacomi F. Understanding the human knee and its relationship to total knee replacement. Acta Biomed 2017 Jun 7; 88(2 -S): 6–16.
25. Leigheb M, Pogliacomi F, Bosetti M, et al. Postoperative blood salvage versus allogeneic blood transfusion in total knee and hip arthroplasty: a literature review. Acta Biomed 2016; 87 (Suppl 1): 6–14.

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Case report

Ankle synovial chondromatosis in anterior and posterior compartments. A Case report

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Summary. Synovial chondromatosis is a rare benign disease, the aetiology of which is not clear. It can arise in the synovial membrane of joints, tendon sheaths, or bursae. Synovial chondromatosis is characterized by multiple loose bodies that can grow and cause symptoms such as pain, swelling and a limited range of motion. It can also result in joint damage. We describe the case of a 48-year-old male dancer with ankle synovial chondromatosis. Diagnosis by radiograph and MRI showed multiple lesions in anterior and posterior ankle compartments. The patient was successfully treated with arthroscopic removal of all loose bodies and partial synoviectomy. Clinical follow-ups at one, four and 12 months and again at 10 years, showed the ankle had a full range of motion without pain or swelling. Post-operative radiographs at one month and at 10 years showed no lesions. Synovial chondromatosis is a benign condition with several loose bodies that must be removed to relieve symptoms and avoid future joint damage. The ankle is a rare location for chondromatosis and arthroscopic removal is the treatment of choice with good results. (www.actabiomedica.it)

Key words: ankle synovial chondromatosis, loose bodies removal, arthroscopy, ten years follow-up.

Introduction

Synovial chondromatosis is an uncommon proliferative condition of unknown aetiology, characterized by cartilaginous metaplasia of the synovial cells (1). Synovial chondromatosis is most commonly seen in large joints in males between 20 and 50 years old (2). It is very rare in children (3). The ankle joint represents about 7 % of all locations (4).

Synovial chondromatosis is characterized by multiple loose bodies that can grow and cause symptoms such as pain, swelling and a limited range of motion (5). If non treated, Synovial chondromatosis lead to severe joint damage (4). We report the case of a patient with synovial chondromatosis localized in anterior and posterior ankle compartments, successfully treated by arthroscopic loose bodies removal and partial synovectomy, at ten years follow-up.

Case Report

An active 48-year-old man presented at our Orthopaedic Department with a history of 10 months of pain and swelling in the left ankle. His symptoms were exacerbated by weight bearing and athletic activity. His medical record showed no injuries.

On clinical examination, the ankle joint presented with swelling and pain that was exacerbated by motion. He had a limited range of motion with dorsiflexion of 0 to 20° and plantar flexion of 5°, whereas muscle strength was normal.

Investigations

Serial radiographs of the ankle joint showed lesions in the anterior and posterior compartments with an increase in number and dimension (Fig. 1). Moreover, MRI showed multiple lesions in all compartments and synovial hyperplasia (Fig. 2).

Treatment

The patient underwent ankle arthroscopy under spinal anaesthesia and the use of tourniquet. The patient was treated by standard, first anterior (medial and lateral) and then posterior (medial and lateral) arthroscopic approaches. The arthroscopic examination showed multiple loose bodies with some cartilage fragments still attached to a hypertrophic synovial membrane. The treatment consisted of removing all loose bodies and partial synovectomy. In supine position with the use of distraction, our first step was loose bodies removal from all compartments through standard anterior ankle arthroscopy portals; then with patient in lateral position we proceed to remove the posterior remaining few larges fragments via posterior portals.

Figure 1. X-ray shows multiple lesions in all ankle compartments with typical characteristic and radio-densities of synovial chondromatosis.

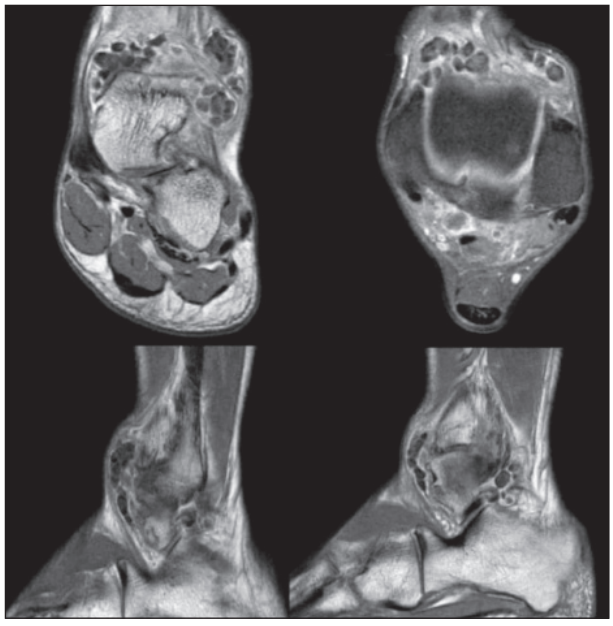

Figure 2. MRI images show multiple loose bodies that are filling and distending the synovial recesses.

Outcome and follow-up

Post-operatively the ankle joint was passively and actively mobilized and partial weight bearing was allowed as tolerated; the patient was able to return to daily activity after one month. Histopathology showed multiple calcified and ossified loose bodies, with lobules of cartilage in the synovial membrane and confirmed the diagnosis of synovial chondromatosis. At clinical follow-ups after one, four and 12 months and again at 10 years, the ankle joint presented a full range of motion without pain or swelling. Post-operative radiographs at one month and at 10 years (Fig. 3) showed an absence of lesions, i.e., no recurrence. After 10 years, the radiographs indicate signs of mild degenerative changes. The patient was able to return to dancing.

Discussion

Synovial chondromatosis is a benign lesion that can grow and cause pain and swelling (6). Ankle joint location is not typical, but ankle bilateral location is also described (7).

Synovial chondromatosis is of unknown origin, characterized by metaplastic changes of the synovial

Figure 3. Post-operative X-ray at 10 years, shows absence of synovial chondromatosis recurrence with middle degenerative changes.

membrane, which develop a series of cartilaginous substance nodules that grow slowly, and are gradually released into the joint space as they detach from the synovial membrane.

Based on Milgram classification (8), synovial chondromatosis can be divided into three consecutive phases: the early phase is described as an active synovial disease without the presence of loose bodies, the intermediate phase with the presence of synovial disease and loose bodies, and the last phase is defined by the presence of loose bodies without synovial involvement.

Synovial chondromatosis patients present with symptoms that include joint pain exacerbated by activity, limited range of motion, joint effusion, and locking of the joint (9). At the beginning of the disease, differential diagnosis includes all causes of pain and swelling. The presence of loose bodies in the joint represents a continuous irritative process of the anatomical structures that severely compromise the balance of the joint with irreversible mechanical damage. Patients suffering from this symptomatology should be tested immediately to establish a correct diagnosis and a specific therapy (10). It is precisely for this reason that loose bodies must be removed as soon as possible, because they can lead to serious joint damage that requires further treatment (1,6).

Differential diagnostics must include testing for all forms of neoplasm that arise around joints and diseases that can cause articular loose bodies such as osteochondral post traumatic lesions, osteochondritis dissecans, rheumatoid arthritis, and tuberculosis arthritis. In the case of recurrences of the disease, malignant degeneration must always be suspected (11, 12).

X-ray imaging can be diagnostic and the presence of mineralized nodules are pathognomonic for synovial chondromatosis (13). Other important investigations are MRI and CT scan. In our case study, MRI revealed several loose bodies and proliferative synovium. The use of intravenous contrast is helpful in separating synovial fluid from synovial tissue with high vascularity. Once removed, the accurate diagnosis of the nature of the lesions must be confirmed through histopathological examination (12).

Treatment should be conservative and should aim to reduce pain, improve mechanical function, and prevent or restrict arthritis progression and chondral damage (14). Traditionally, removal of large loose bodies and partial or subtotal synovectomy were achieved with open arthrotomy. Arthroscopy is a non-invasive procedure and associated with better recovery and less joint damage (14,15). Arthroscopy is very helpful in case of synovial chondromatosis in anterior and posterior compartments.

Conclusion

Synovial chondromatosis is a rare benign condition that can affect joint synovial tissue. In the presence of lesions that cause symptoms or grow in dimension, excision and synoviectomy must be done. Ankle localization in anterior and posterior compartments can be treated by an arthroscopic approach that is linked to low morbidity and early rehabilitation.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Padhan P, Ahmed S. Synovial Chondromatosis. N Engl J Med. 2019;381(14): 1364.
2. Neumann JA, Garrigues GE, Brigman BE, Eward WC. Synovial Chondromatosis. JBJS Rev. 2016 May 10;4(5). pii: 01874474-201605000-00005.
3. Sathe P, Agnihotri M, Vinchu C. Synovial chondromatosis of ankle in a child: A rare presentation. J Postgrad Med. 2020 Apr-Jun;66(2): 112-113.
4. Saxena A, St Louis M. Synovial Chondromatosis of the Ankle: Report of Two Cases With 23 and 126 Loose Bodies. J Foot Ankle Surg. 2017;56(1): 182–186.
5. Pellacci F, Zmerly H. I corpi liberi endoarticolari. Rivista Italiana di Biologia e Medicina, 2001;21(1): 345-347.
6. Peixoto D, Gomes M, Torres A, Miranda A. Arthroscopic treatment of synovial chondromatosis of the ankle. Rev Bras Ortop. 2018;53(5): 622–625.
7. Shearer H, Stern P, Brubacher A, Pringle T. A case report of bilateral synovial chondromatosis of the ankle. Chiropr Osteopat. 2007;15:18.
8. Milgram JW.Synovial osteochondromatosis: a histopathological study of thirty cases. J Bone Joint Surg Am. 1977 Sep;59(6): 792-801.
9. Santiago T, Mariano C. Primary synovial chondromatosis of the ankle joint presenting as monoarthritis. BMJ Case Rep. 2013;2013: bcr2013202186

10. Isbell JA, Morris AC, Araoye I, Naranje S, Shah AB. Recurrent Extra- and Intra-articular Synovial Chondromatosis of the Ankle with Tarsal Tunnel Syndrome: A Rare Case Report. J Orthop Case Rep. 2017;7(2): 62–65.
11. Yu N, Cheng F, Xiao L, Tong P, Wang C. Synovial sarcoma of the foot enlightening etiology: a case report. Acta Biomed. 2010 Dec;81(3):233-6.
12. Urwin JW, Cooper K, Sebro R. Malignant Transformation of Recurrent Synovial Chondromatosis: A Case Report and Review. Cureus. 2019 Oct 4;11(10):e5839.
13. Dheer S, Sullivan PE, Schick F, et al. Extra-articular synovial chondromatosis of the ankle: Unusual case with radiologic-pathologic correlation. Radiol Case Rep. 2020;15(5): 445–449.
14. Kunzler DR, Shazadeh Safavi P, Warren BJ, Janney CF, Panchbhavi V. Arthroscopic Treatment of Synovial Chondromatosis in the Ankle Joint. Cureus. 2017;9(12):e1983.
15. Ozmeric A, Aydogan NH, Kocadal O, Kara T, Pepe M, Gozel S. Arthroscopic treatment of synovial chondromatosis in the ankle joint. Int J Surg Case Rep. 2014;5(12): 1010–1013.

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Case report

Medial epicondyle avulsion after elbow dislocation in an adolescent non-professional soccer player treated with a cannulated screw: a case report

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Summary. Background and aim of the work: Medial epicondyle fractures of the humerus account for 11–20% of all elbow injuries in children and in 30–55% of cases they are associated with an elbow dislocation. Undisplaced fractures are usually treated conservatively but literature is controversial regarding the treatment of displaced fractures (≥5mm) in paediatric fractures. In recent years, there is an emerging consensus that such patients may benefit more from open reduction and internal fixation. Authors report a case of a 15 years old nonprofessional soccer player who suffered of an elbow dislocation with an intra-articular fragment derived from avulsion of the medial epicondyle. *Methods:* Clinical and instrumental evaluation confirmed elbow dislocation with an intra-articular fragment derived of the medial epicondyle. After the reduction an open reduction and internal fixation with cannulated screw was performed. *Results:* Clinical evaluation after 90 days showed resolution of pain and almost complete ROM and complete recovery of strength and of functionality of the operated limb. Furthermore, x-rays demonstrated consolidation of the fracture. *Conclusions:* this case confirms that a precise evaluation of the fracture and its displacement is at the base of satisfactory outcomes. If fracture is displaced ≥5mm and patient is near skeletal maturity open reduction and fixation is indicated. (www.actabiomedica.it)

Key words: elbow, dislocation, medial epicondyle, reduction, fixation, screw, outcome.

Introduction

The medial epicondyle is a traction apophysis which is constantly solicited during elbow movements by the powerful epicondylar muscles and the medial collateral ligament. These structures, thus including capsule, are considered the key of elbow stability (1,2).

Medial epicondyle fractures of the humerus account for 11–20% of all elbow injuries in children and in 30–55% of cases they are associated with an elbow dislocation (3, 4).

Avulsion of the medial epicondyle and elbow dislocation occurs when a valgus force is exerted with the elbow completely or slightly extended. This lesion can only occur as a result of damage of the capsuloligamentous and anteromedial muscular structures (5).

The literature is controversial regarding the management of these pediatric fractures: disagreement lies particularly in identifying the correct treatment for children with considerable displacement (≥5 mm) (6).

Some reports suggest that displaced medial epicondyle fractures can be nonoperatively treated but more than 60% of patients have radiographic nonunion or valgus instability and elbow stiffness is common (7,8).

For these reasons, in recent years, there is an emerging consensus that such patients may ben-

efit more from open reduction and internal fixation (ORIF) (9, 10).

The most commonly used methods for the fixation of displaced fractures include Kirschner wires in younger patients with open physis and screws with or without a washer in adolescent near skeletal maturity (11).

This case reports of a medial epycondile avulsion in an adolescent soccer player near skeletal maturity which was synthesized with 1 cannulated screw.

Case Report

A 15-year-old male, non-professional soccer player, arrived at the emergency department complaining of pain and swelling in his left elbow.

He reported intense pain following a fall on his elbow during a soccer match; no vascular or nervous impairments were detected.

After the clinical visit an elbow dislocation was suspected; x-rays confirmed this suspicion (figure 1).

The patient also underwent to a CT scan, which confirmed the dislocation and also demonstrated the presence of an intra-articular fragment resulting from the avulsion of the medial epicondyle(figure 1).

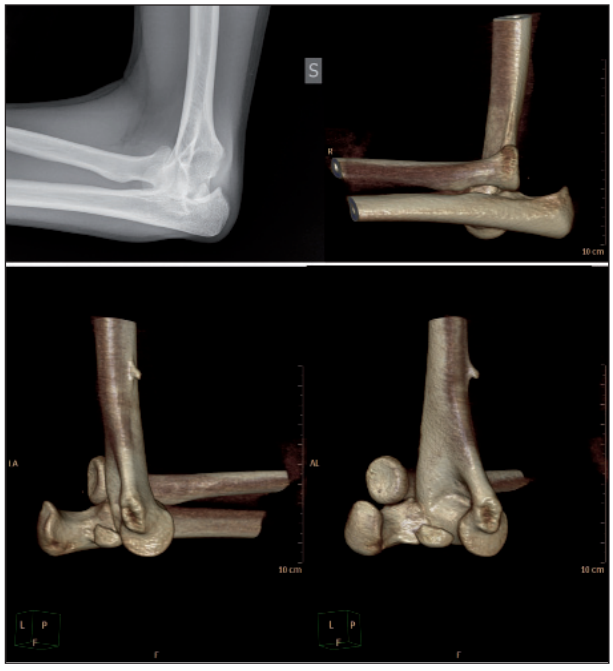

Figure 1. X-ray and 3D CT with fracture-dislocation of the left elbow.

The dislocation was therefore reduced in deep sedation, but clinically valgus instability, and intra-articular impingement could be yet appreciated; no vascular or nervous impairments were detected after the reduction.

Radiographs and a CT following sedation showed the success of the reduction and the presence of a big intra-articular fragment (figure 2).

The day after the patient had ORIF of the fragment with a cannulated screw and a washer though a medial approach.

The ulnar nerve, which is potentially vulnerable during this approach, was identified, isolated and protected (figure 3).

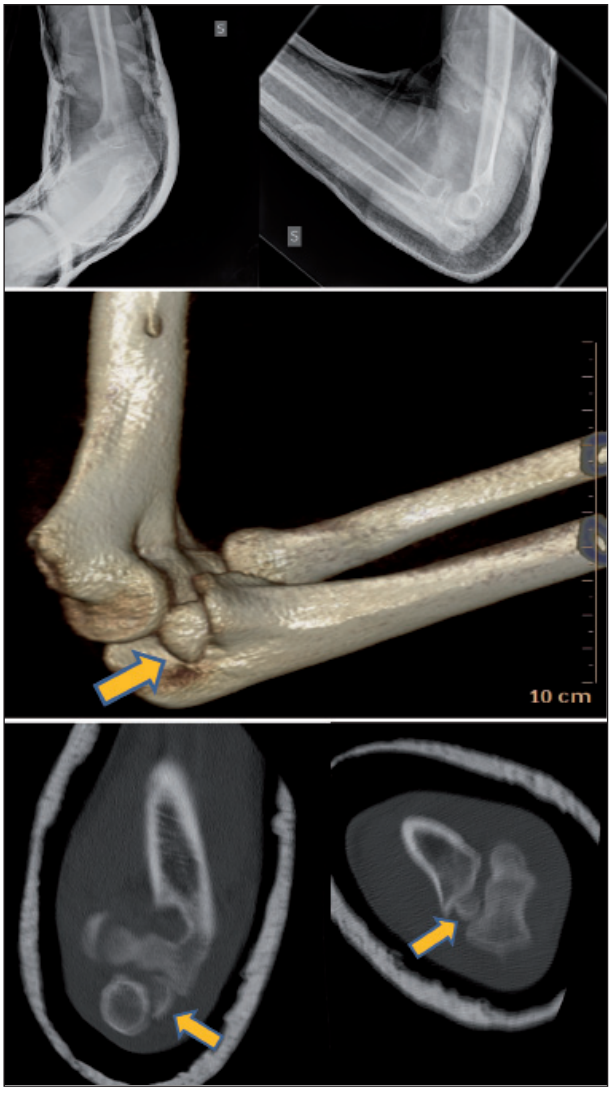

Figure 2. X-rays and 3D CT after reduction. Arrows show intra-articular fragment

The intra-articular fragment was then identified and reduced in its anatomical position; it was first stabilized with a kirschner wire and definitively synthesized with a cannulated half threaded screw with a washer (figure 4 and 5).

After 14 days of cast immobilization patient followed an intensive physiotherapy program of 40 days characterized by progressive assisted active and passive kinesis and idrokinesis therapy.The final check 90 days after surgery showed that the operated limb had no deficit in bending with respect to the healthy one.

In extension, there was a deficit of 5 degrees (table 1); no residual pain and no lack of strength was present.The patient was satisfied with the result achieved. X-rays demonstrated consolidation of the fracture (Figure 6).

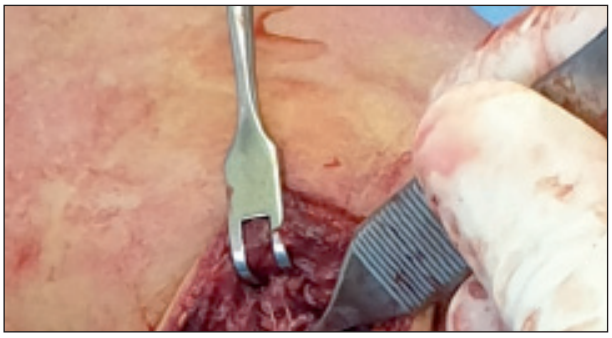

Figure 3. Identification and protection of the ulnar nerve.

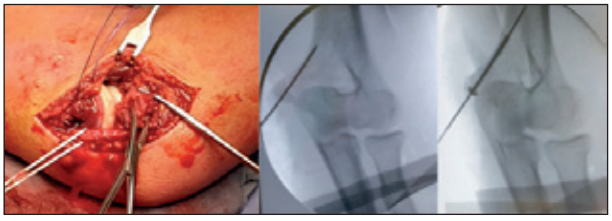

Figure 4. Reduction of the fragment and fixation with a cannulated half threaded screw and one washer.

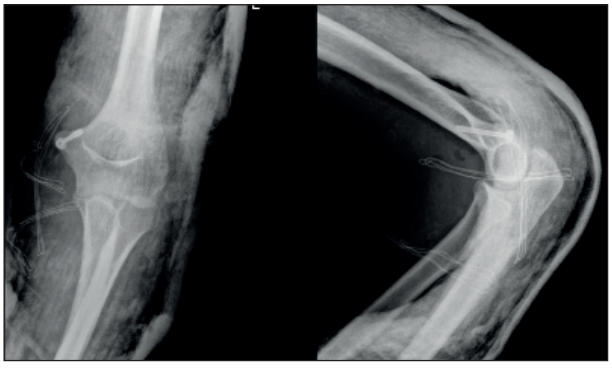

Figure 5. Postoperative radiographs.

Table 1. Flexion and extension of both elbows.

	Right (healthy)	Left (operated)
Flexion	40°	43°
Extention	180°	175°

Discussion

The medial epicondyle is the anatomic origin of the flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, palmaris longus, part of the pronator teres, and the ulnar collateral ligament; it is constantly solicited during elbow movements by the powerful epicondylar muscles and the medial collateral ligament. All these structures, thus including capsule, are considered the key of elbow stability.

The medial epicondyle is the last ossification centre to fuse to the distal humerus. Fusion usually occurs after 15 years of age (12).

Medial epicondyle fractures of the humerus account for 11–20% of all elbow injuries in children and in 30–55% of cases they are associated with an elbow dislocation (3,4).

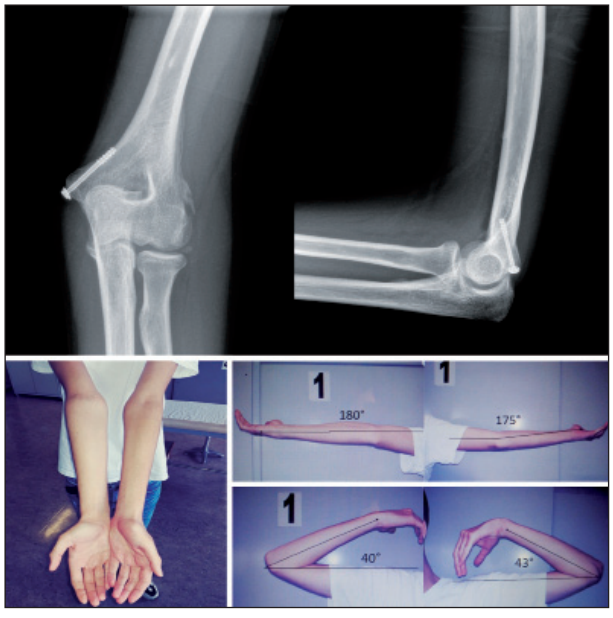

Figure 6. X-rays and clinical evaluation 90 days after surgery.

There are 3 theories about the mechanism of acute medial epicondylar apophyseal injuries: a direct blow, an isolated avulsion mechanism, and an association with elbow dislocation (13,14).

The literature is controversial regarding the management of these paediatric fractures: disagreement lies particularly in identifying the correct treatment for lesions with considerable displacement (≥5 mm) (6).

There is a consensus that fractures displaced <2 mm should be treated conservatively with a plaster cast; instead those with displacement ≥5 mm should be treated surgically.

Most common treatments include kirschner wires and cannulated screw fixation (15).

Kirschenr wires should be preferred, in younger patients who still have open physis (and therefore growth potential), because this approach minimizes the risk of developing cubitus varus deformity due to a screw across the growing apophysis. Instead, cannulated screws with or without a washer should be used in adolescent near skeletal maturity, where the possible complications mentioned above are minimal (16). Furthermore, operative treatment with ORIF has a crucial role in avoiding the painful nonunion and minimizing the risk of symptomatic valgus instability.

In this type of injuries not only bone has to be considered. Fracture often reflects significant damage to «invisible» soft tissue. The capsular, ligamentous and muscular injuries are often underestimated and a high degree of instability may be masked in an undisplaced or minimally displaced fracture (17).

For all these reasons Authors decided to fix the epicondyle with ORIF. Outcomes confirmed that this decision was indicated.

Conclusions

Results confirm that all patients, with medial epicondyle avulsion with displacement ≥5 mm, with or without elbow dislocation should be surgically treated. ORIF with screws is preferred in adolescent near skeletal maturity, thus diminishing non-union, residual valgus instability and elbow stiffness rate.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. Wilkins KE, Chambers HG. Fractures involving the medial epicondylar apophysis. In: Rockwood CA Jr, Wilkins KE, Beaty JH, editors. Fracture in children 4. Philadelphia: Lippincott-Raven; 1996; 4: 801-19.
2. Schwab GH, Bennet JB, Wood GW, Tullos HS. Biomechanics of elbow instability: the role of the medial collateral ligament. Clin Orthop Relat Res 1980; 146: 42-52.
3. Fahey JJ. Fractures of the elbow in children. AAOS Inst Course Lect 1960; 17: 13-46.
4. Rang M. Children's fractures 2nd Edn. Philadelphia, J B Lippincott Lippincott, 1983: 9.
5. Kilfoyle RM. Fracture of the medial condyle and epicondyle of the elbow in children. Clin Orthop Relat Res 1965; 41: 43-50.
6. Kamath AF, Baldwin K, Horneff J, Hosalkar HS. Operative versus non-operative management of pediatric medial epicondyle fractures: a systematic review. J Child Orthop 2009; 3: 345-57.
7. Josefsson PO, Danielsson LG. Epicondylar elbow fracture in children: 35-year follow-up of 56 unreduced cases. Acta Orthopaedica Scandinavica 1986; 57: 313-15.
8. Lee HH, Shen HC, Chang JH, Lee CH, Wu SS. Operative treatment of displaced medial epicondyle fractures in children and adolescents. J Shoulder Elbow Surg 2005; 14:178-85.
9. Duun PS, Ravn P, Hansen LB, Buron B. Osteosynthesis of medial humeral epicondyle fractures in children: 8-year follow-up of 33 cases. Acta Orthop Scandinavica 1994; 65: 439-41.
10. Pathy R, Dodwell ER Medial epicondyle fractures in children. Curr Opin Pediatr 2015; 27: 58-66.
11. Patel NM, Ganley TJ. Medial epicondyle fractures of the humerus: how to evaluate and when to operate. J Pediatr Orthop 2012; 32: S10–3.
12. Wilkins KE. Fractures of the medial epicondyle in children. Instr Course Lect 1991; 40: 3-10.
13. Smith FM. Medial epicondyle injuries. JAMA 1950; 142:3 96-402.
14. Watson-Jones R. Primary nerve lesions in injuries of the elbow and wrist. J Bone Joint Surg 1930; 12: 121-40.
15. Wilkins KE. Fractures involving the medial epicondylar apophysis. In: Rockwood CA Jr, Wilkins KE, King RE, editors. Fractures in children. 3rd ed. Philadelphia: JB Lippincott 1991; 509-828.
16. Ergin ÖN, Demirel M, entürk F, Bayram S, Bilgili F. Long-term comparative study of internal fixation with Kirschner wires or cannulated screws for displaced medial epicondyle fractures of the humerus in children: A 10-year

follow-up of 42 cases. Ulus Travma Acil Cerrahi Derg. 2020 Jan;26(1):137-143.
17. Louahem DM, Bourelle S, Buscayret F et al Displaced medial epicondyle fractures of the humerus: surgical treatment and results. A report of 139 cases. Arch Orthop Trauma Surg 2010; 130: 649-55.

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Case report

A 2-free-end flexor carpi radialis tendon graft for treating a complex index finger extensor tendon injury

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Summary. *Background:* Volar plating has increasingly become the most used technique for the treatment of unstable distal radius fractures due to the low soft-tissue disturbance and its biomechanical reliability, which allows the early mobilization of the wrist. One of the main goals of the volar locking compression plates design is to avoid those soft tissue complications historically associated to the dorsal plating. However, extensor tendon complications can not be completely excluded. *Method:* The authors report the case of a patient with a complete rupture of the index finger extensor tendons after volar plate fixation of the distal radius. Due to the presence of a severe tendons retraction with a 4-centimeter gap and the neighbouring soft tissues damage, it was decided to fill the gap with a 2-free-end autograft harvested from the Flexor Carpi Radialis (FCR) tendon, using the volar surgical approach performed to remove the plate. *Results:* At the 2-month follow-up, the patient showed the complete recovery of the flexion-extension movements. *Conclusions:* Even though the 2-free-end FCR tendon graft is not commonly reported for the reconstruction of extensor tendons defects, we assume it deserves to be considered as an adequate technique whenever the neighbouring tendons are critically compromised. (www.actabiomedica.it)

Key words: Distal Radius Volar Plating, Extensor Tendon Injuries, FCR tendon Graft

Introduction

Distal radius fractures account for approximately one third of all fractures in the elderly with an incidence rate of 190-200 per 100,000 person-years (1). Surgical fixation of distal radius fractures has become more popular because of innovations in implant technology, such as low-profile implants with locking fixation. The overall symptomatic complication rate following open reduction and internal fixation has been reported to be as high as 28 percent (2). One of the main goals of the volar locking compression plates design is to avoid those soft tissue complications associated to the dorsal plating. Although nowadays the volar plate fixation is the most used surgical technique for the treatment of distal radius fractures, extensor tendon damages can not be completely excluded.

Among the complications reported in literature, they need to be mentioned: tenosynovitis of the extensor tendons, rupture of Extensor Pollicis Longus (EPL), rupture of Extensor Digitorum Communis, screw penetration of the radiocarpal joint (3). These complications can be less likely to occur with an appropriate pre-operative planning (4). In literature, Lister's tubercle has been described to hide the screw protrusion through distal locking plate holes, where the EPL tendon is most vulnerable to injury, and often goes undetected with standard lateral views (5). The screws need to be long enough to support the dorsal surface of the distal radius. However, penetration

of the extensor compartment when choosing longer screws is plausible. Surgeons need to confirm the screw length using the intra-operative fluoroscopy, to avoid the dorsal cortex penetration. Hill et al. (2015) recommended the intra-operative use of the Dorsal Tangential View (DTV) to best detect dorsal screw penetration after volar plating, based on a cadaveric study (6). Several fluoroscopic views have been described to enhance the ability to detect dorsal cortex screw penetration. The Skyline view and the Carpal Shoot-Through view have been developed to increase the visibility of the dorsal cortex. Both the Skyline and the Carpal-Shoot-Through views place the arm in supination with an elbow flexion of approximately 70-75 degrees and an inclination of 15-20 degrees on the vertical plane. Nevertheless, they differ from each other in the position of the wrist. Namely, in the Skyline view the wrist is placed in full palmar flexion position, whereas in the Carpal-Shoot-Through view is placed in full dorsal flexion position (7, 8).

Case Report

A 58-year-old woman was admitted to our Department with a sudden inability to extend the second finger of her left hand (Fig. 1). No recent trauma was reported. One year earlier she suffered a displaced fracture of the distal radius - 23 C2 according to the AO/OTA classification. Internal fixation by volar plate was performed, using the flexor carpi radialis–radial artery interval (Henry's approach). The right positioning of the plate, the screws length, as well as the restoration of the volar tilt were intraoperatively assessed by fluoroscopic images. The 4-week x-ray follow-up showed early signs of fracture healing. However, the screws seemed overlong with respect to the dorsal cortical surface in the lateral view (Fig. 2). No extensor tendons functional deficit was found. 12 months later, the patient came back with a complete functional deficit of the index finger extension. Yet, the metacarpo-phalangeal (MCF) and proximal inter-phalangeal (PIP) joint examination proved no stiffness, and the full passive extension was noticed. The Ultrasound Examination suggested an incomplete rupture of the extensor tendon mechanism of the index finger, confirmed by the MRI examination. A second surgery was recommended, consisting in the plate removal and reconstruction of the extensor tendon mechanism, with end-to-end suture or tendon graft in case of a massive tendon defect. The patient rejected the surgery. However, she came back 6 weeks later due to the unacceptable disability and with the result of a chronic lesion. In agreement with the patient it was decided to proceed to the surgical treatment. It was decided to perform a combined dorsal and volar approach, in order to remove the plate and repair the extensor tendon injury. Starting from the dorsal approach, we confirmed the complete rupture of the extensor tendon mechanism of the second finger, the incomplete rupture of the extensor tendon mechanism of the fourth and fifth fingers, and the presence of a widespread tenosynovitis involving the whole extensor tendons apparatus and the retinaculum. The dorsal prominence of the screws was also confirmed. The index finger extensor tendon showed a severe retraction with a 4-centimeter gap, which did not allow its end-to-end suture. A tendon graft using the Palmaris Longus was not taken into consideration due to its congenital absence in our patient. There-

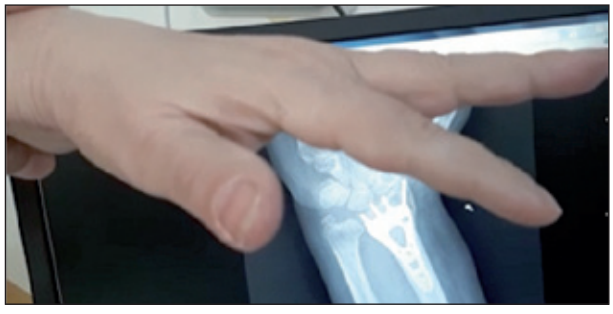

Figure 1. Patient inability to extend the second finger of the left hand

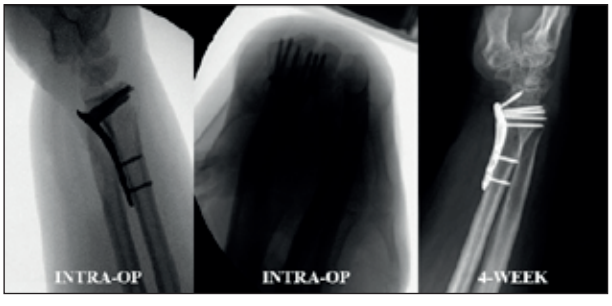

Figure 2. Intra-operative and 4-week follow-up x-ray

fore, it was decided to use a strip harvested from the FCR using the volar surgical approach performed to remove the plate. The graft was used to fill the index finger tendon gap, obtaining a good flexion-extension balance (Fig. 3). The end-to-end suture for the fourth and fifth extensor tendon mechanism was performed. The latter was reinforced by the tenodesis between the Extensor Digiti Minimi and the branch for the fifth finger of the Extensor Digitorum Communis. The tendon sutures were protected by a short hand-wrist splint for 4 weeks. At the splint removal, the patient was discharged to the Rehabilitation Unit to start a targeted rehabilitation program. No post-operative complications occurred. At the 2-month follow-up, a complete recovery of the flexion-extension movements of all the fingers of the left hand was obtained (Fig. 4).

Discussion

Tendon rupture following dorsal plating of distal radius fractures is a well-documented complication.

Figure 3. FCR tendon graft used to fill the index finger extensor tendon gap

Figure 4. Clinical outcome at the 2-month follow-up

Surgeons have more recently adopted volar plating to minimize the tendon issues usually seen with dorsal plating. Although, a number of extensor tendon injuries are still noted. Al-Rashid M. et al. (2006) published a series which reported a 4.4% to 8.6% incidence of extensor tendon rupture following volar plating (9). There is no consensus regarding the optimal technique to manage tendon injuries following volar plating of the distal radius. Tendon transfers appear to be a reliable option, as they were commonly described to treat both flexor and extensor ruptures. Namely, the Extensor Indicis Proprius (EIP) to EPL tendon transfer is a good and reproducible option. Lemmen et al. demonstrated that the EIP has an appropriate caliber, expendable to treat EPL lesions (10). In addition to tendon transfers, primary repairs, interphalangeal arthrodeses, and tendon graftings were all techniques used to manage these kind of complications. Palmaris Longus tendon interpositional reconstruction is most frequently used to overcome the tendon defects in 4-5 Verdan's extensor zones. In patients with a skin and tendon defect, composite venous flaps and Palmaris Longus tendon reconstruction could be an alternative procedure to fix the gap formation in zones 4 and 5. Another feasible option, described for zones 4 and 5, is the tendon allograft from a cadaveric donor (11). Where applicable, an easier valuable solution to overcome an extensor tendon defect in these zones, is to suture the distal end of the defective tendon to a neighbouring tendon in a side-to-side fashion, in order to obtain motor strength from the neighbouring intact tendon. It is also reported by Al-Qattan MM a two-stage reconstruction using a silicone rod for significant tissue defects with a massive tendon gap. This technique prescribes the application of a tendon rod to the extensor tendon gap. Secondary to that procedure, the gap area is later reconstructed using a tendon graft that can be harvested from any donor area, and the silicone rod is removed with two small incisions at the distal and proximal area of the gap. After the rod is removed, the tendon graft is inserted in its place (12). As far as our patient is concerned, the end-to-end suture was not applicable for the treatment of the index finger injury, due to a chronic lesion, which led to a relevant tendon gap. It was feasible only for the fourth and fifth fingers. The fifth extensor tendon suture was

ensured with the tenodesis between the Extensor Digiti Minimi and the branch for the fifth finger of the Extensor Digitorum Communis, to enhance the motor strength. The Palmaris Longus tendon graft was not possible due to its absence. The allograft from a cadaveric donor was refused from our patient, so it was not considered. For this reason, as valid alternative, it was decided to harvest a 2-free-end graft from the FCR for filling the gap . FCR arises from the medial epicondyle of the humerus along with the other flexor muscles of the forearm. It runs on the radial side of the forearm and finally attaches mainly to the base of the second metacarpal bone and also to the third metacarpal bone by a small slip (13). Its tendon is described in literature as one of the most used grafts for hand and wrist tendon reconstruction. It may be used to stabilize the base of the first metacarpal bone in trapeziectomy, to reconstruct the scapholunate and lunotriquetral interosseous ligaments in advanced Kien-böck's disease, to reconstruct the scapho-lunate ligament linkage in the Brunelli's Technique (14, 15).

In conclusion, even though the 2-free-end FCR tendon graft is not commonly reported for the reconstruction of extensor tendon defects, we assume it deserves to be considered as an adequate technique whenever the neighbouring tendons are critically compromised and the Palmaris Longus transfer is not applicable.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. C. M. Court-Brown and B. Caesar, "Epidemiology of adult fractures: A review," *Injury* 2006; 37: 691–697.
2. R. Arora, M. Lutz, A. Hennerbichler, D. Krappinger, D. Espen, and M. Gabl, "Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate," *J. Orthop. Trauma* 2007; 21: 316–322.
3. L. M. Berglund and T. M. Messer, "Complications of volar plate fixation for managing distal radius fractures," *Journal of the American Academy of Orthopaedic Surgeons* 2009; 17: 369-77.
4. Y. Totoki, Y. Yoshii, T. Kusakabe, K. Akita, and T. Ishii, "Screw Length Optimization of a Volar Locking Plate Using Three Dimensional Preoperative Planning in Distal Radius Fractures," *J. hand Surg. Asian-Pacific Vol.* 2018; 23: 520-527.
5. D. Dolce, D. Goodwin, M. Ludwig, and S. Edwards, "Intraoperative evaluation of dorsal screw prominence after polyaxial volar plate fixation of distal radius fractures utilizing the Hoya view: a cadaveric study," *Hand* 2014; 9: 511–515.
6. B. W. Hill, I. Shakir, and L. K. Cannada, "Dorsal screw penetration with the use of volar plating of distal radius fractures: How can you best detect?," *J. Orthop. Trauma* 2015; 29: 408–413.
7. D. Marsland, C. M. Hobbs, and P. S. Sauvé, "Volar locking plate fixation of distal radius fractures: use of an intra-operative 'carpal shoot through' view to identify dorsal compartment and distal radioulnar joint screw penetration," *Hand* 2014; 9: 516-21.
8. A. P. Riddick, B. Hickey, and S. P. White, "Accuracy of the skyline view for detecting dorsal cortical penetration during volar distal radius fixation," *J. Hand Surg. Eur. Vol.* 2012; 37: 407–411.
9. M. Al-Rashid, K. Theivendran, and M. A. C. Craigen, "Delayed ruptures of the extensor tendon secondary to the use of volar locking compression plates for distal radial fractures," *J. Bone Jt. Surg. - Ser. Br* 2006; 88: 1610-2.
10. M. H. M. Lemmen, T. A. R. Schreuders, H. J. Stam, and S. E. R. Hovius, "Evaluation of restoration of extensor pollicis function by transfer of the extensor indicis," *J. Hand Surg. Eur. Vol.* 1999; 24: 46-9.
11. T. Türker, K. Hassan, and N. Capdarest-Arest, "Extensor tendon gap reconstruction: A review," *Journal of Plastic Surgery and Hand Surgery* 2016; 50: 1-6 .
12. M. M. Al-Qattan, "Two-staged extensor tendon reconstruction for zone 6 extensor tendon loss of the fingers: Indications, technique and results," *J. Hand Surg. Eur. Vol.* 2015; 40: 276-8.
13. B. K. Potu, V. Kumar, S. Annam, and S. R. Sirasanagandla, "A morphometric study on flexor carpi radialis muscle of the forearm: A cadaveric study," *Morphologie* 2016; 100: 12-6.
14. M. Henry, "Outcomes assessment of lunate replacement arthroplasty with intrinsic carpal ligament reconstruction in Kienböck's disease," *Hand* 2014; 9: 364-9.
15. G. A. Brunelli and G. R. Brunelli, "A new technique to correct carpal instability with scaphoid rotary subluxation: A preliminary report," *J. Hand Surg. Am.* 1995; 20: 82-5.

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1. Anthony I, Bell SW, Blyth M, Jones B et al. Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty. J Bone Joint Surg Am. 2016;98-A(8):627-35.
2. Illgen, R, Bukowski, B, Abiola, R, Anderson, P, Chughtai, M, Khlopas, A, Mont, M. Robotic-assisted total hip arthroplasty: Outcomes at minimum two year follow up. Surgical Technology International. 2017 July 25; 30:365-372.
3. Mahoney O, Kinsey T, Mont M, Hozack W, Orozco F, Chen A. Can computer generated 3D bone models improve the accuracy of total knee component placement compared to manual instrumentation: a prospective multi-center evaluation? XXXII convegno annuale della International Society for Technology in Arthroplasty (società internazionale per la tecnologia nell'artroplastica). Toronto, Canada. 2-5 ottobre 2019.
4. Suarez-Ahedo, C; Gui, C; Martin, T; Chandrasekaran, S; Domb, B. Robotic arm assisted total hip arthroplasty results in smaller acetabular cup size in relation to the femoral head size: A Matched-Pair Controlled Study. Hip Int. 2017; 27 (2): 147-152.
5. Haddad, F.S, et al. Iatrogenic Bone and Soft Tissue Trauma in Robotic-Arm Assisted Total Knee Arthroplasty Compared With Conventional Jig-Based Total Knee Arthroplasty: A Prospective Cohort Study and Validation of a New Classification System. J Arthroplasty. Ago 2018;33(8):2496-2501. Pubblicazione elettronica 27 mar 2018.
6. Hozack, W, Chen, A, Khlopas, A, Mahoney, O, Mont, M, Murray, T, Orozco, F, Higuera Rueda, C, Stearns, K. Multicenter Analysis of Outcomes after Robotic-Arm Assisted Total Knee Arthroplasty. Convegno annuale della American Academy of Orthopedic Surgeons (accademia americana dei chirurghi ortopedici). Las Vegas, NV, USA. 12-16 marzo 2019.
7. Banks, Scott A, PhD. Haptic Robotics Enable a Systems Approach to Design of a Minimally Invasive Modular Knee Arthroplasty. Am J Orthop. 2009;38(2 suppl): 23-27. February 2009.

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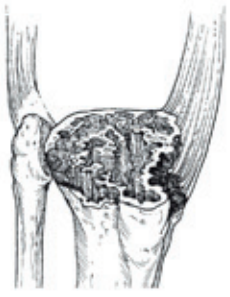

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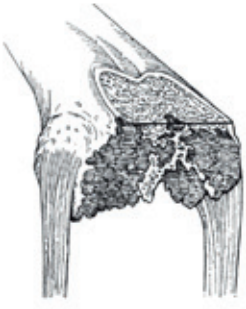

F_{2B}

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AORI defects as illustrated by Pecora, et al.[25]

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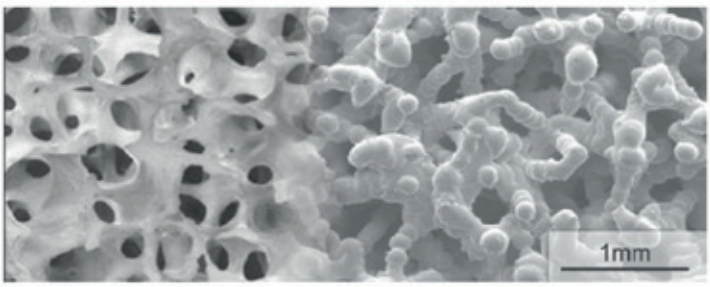

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