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Original article

Femoroacetabular impingement: biomechanical and dynamic considerations

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Abstract. Femoroacetabular impingement (F.A.I.) is a pathologic process caused by an abnormal shape of the acetabulum, of the femoral head, or both. F.A.I., often referred to as idiopathic, may be secondary to slipped capital femoral epiphysis, congenital hypoplasia of the femur, Legg-Calvé Perthes disease, post-traumatic mal-union and protrusio acetabuli. From 2009 to 2012 we studied 21 patients (14 males), with a mean age of 52 (33 y - 75 y), affected by idiopathic F.A.I. Every patient underwent pelvic and hip joint X-rays and CT scan with 3D reconstructions, in order to evaluate the morphology of the pelvis and the hip joint and the torsion of the lower limbs (Femoroacetabular ante-retroversion). Our results show an average femoral ante-version angle of 12,4° (15°-20° physiological range) in patients affected by CAM impingement and an average acetabular ante-version angle of 13,5° (15°-20° physiological range) for those with PINCER impingement. These values, in patients affected by F.A.I., are probably related to morphologic and biomechanical features that may lead to the onset of idiopathic femoroacetabular impingement. In the literature, other studies partially support our findings, suggesting a more critical approach to a patient with idiopathic F.A.I. extending evaluations to nearby articulations. (www.actabiomedica.it)

Key words: femoroacetabular impingement (F.A.I.), CAM, PINCER, CT scan, hip arthroscopy, femoroacetabular ante-retroversion

Introduction

Femoroacetabular impingement (F.A.I.) is a term that indicates anatomopathological situations characterised by morphological anomalies of the femoral epiphysis and of the acetabular cavity. Articular movement is altered with appearance of degenerative phenomena that progressively lead to coxathrosis (1-3). One can distinguish two forms of FAI: PINCER and CAM: these can occur on their own or, as is often the case, together (4).

CAM impingement is characterised by a morphological anomaly at the level of the femoral head-neck joint with loss of roundness and offset (5, 6). This situation leads to a mechanical limitation of movement due to the presence of a prominent area in flexo-intrarotation and in abduction/extrarotation that enters into conflict with the underlying rim and cartilage (7-10).

As far as the characteristics of the PINCER impingement are concerned, there is an excess of localised (acetabular retroversion) or global (coxa profunda and protrusion acetabuli) acetabular coverage (1, 12).

The ethiopathogenetic classification divides FAI into primitive, idiopathic, or secondary. Secondary FAI is present in patients with congenital acetabular retroversion, epiphysiolysis (8, 13, 14), hip dysplasia,

Legg-Calve Perthes disease (15, 16), recurrent consolidation of femoral neck fractures (17-19), an elliptical femoral epiphysis, coxa profunda and protrusion acetabuli.

Epidemiological studies have highlighted the presence of geographical factors with a major prevalence in the Western world and of genetic factors with an increased relative risk within the same family nucleus (20, 21).

Despite the majority of FAI cases being due to a known cause, the presence of patients with a negative anamnesis as far as the above mentioned causes are concerned has been recorded (22).

Recent studies indicate that the primum movens in cases of idiopathic FAI could be a subclinical morphological bone predisposition associated to particularly intense physical activities or intense active range of motion. The aim of this study was to understand how the interaction between the femur and the acetabulum contributes to the development of idiopathic FAI evaluating the respective orientation between the acetabulum and the femoral head through CT scans of patients that did not present with risk factors or known causes.

Materials and methods

In our study carried out at the Orthopaedic and Traumatology Clinic of the University of Verona, between November 2009 and July 2012, we evaluated 21 candidate patients (14 males) for hip arthroscopy following coxalgy due to FAI with unknown causes.

At the time of surgery, the mean patient age was of 52 years (range 33-75). 13 cases were diagnosed with CAM impingement, 2 with Pincer impingement

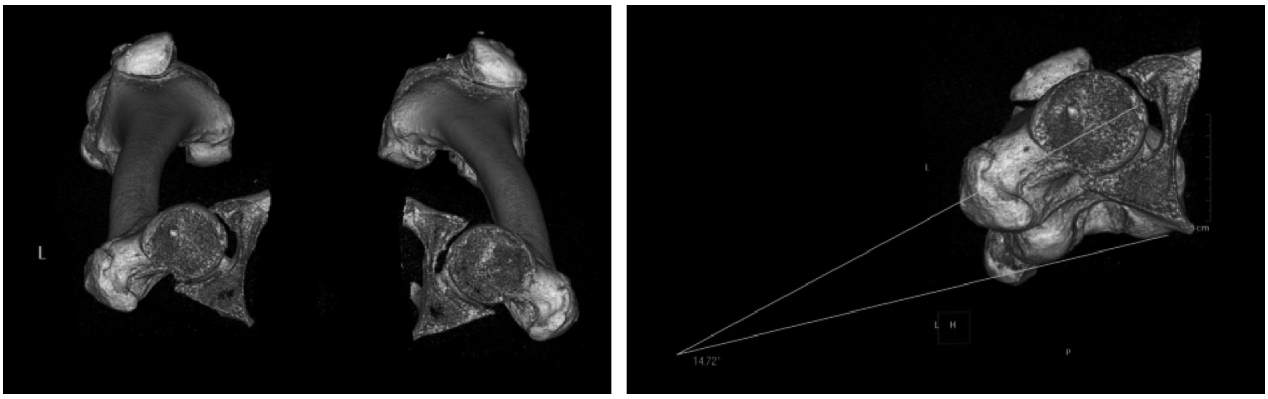

Figure 1. CT study with 3D reconstruction for the measurement of femoral anteversion

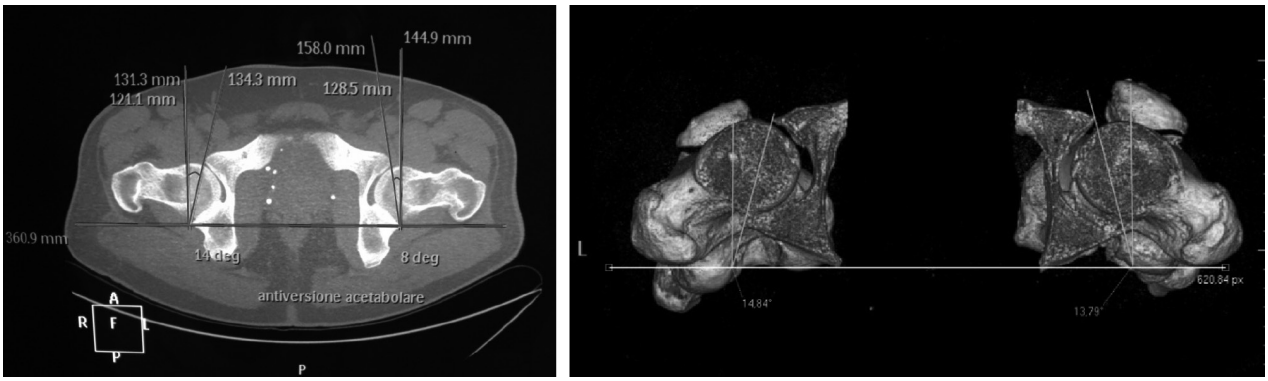

Figure 2. Measurement of acetabular anteversion

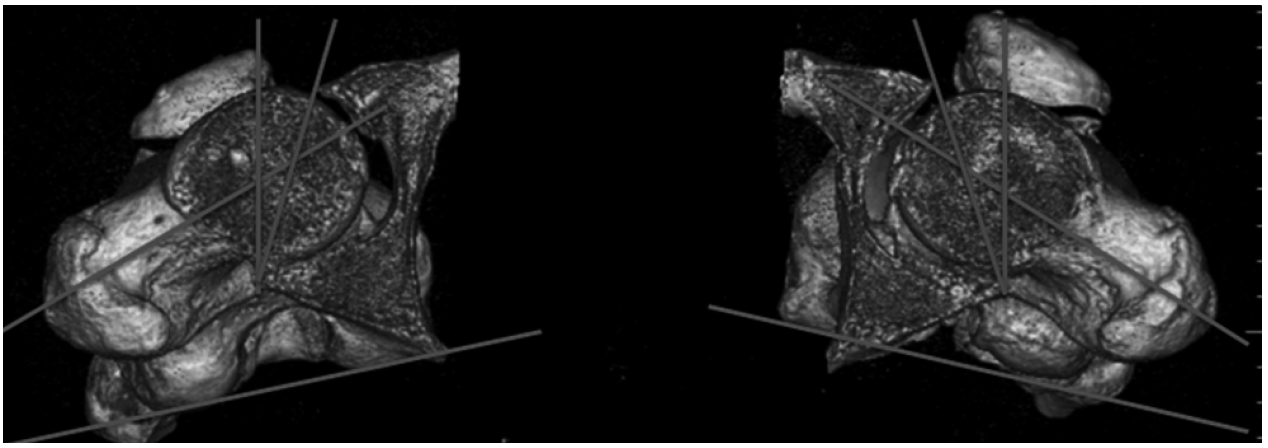

Figure 3. Measurement of the Mc Kibbin index

and in 8 cases, there was an association of both types of FAI (2 cases of bilateral FAI).

Patients presented reduced articular mobility, in particular during flexion and internal rotation and pain especially in the inguinal area and in the trochanteric region.

By carrying out CT scans we were able to study the femoral (Fig. 1) and acetabular (Fig. 2) anteversion and the Mc Kibbin index (Fig. 3) via measurements obtained with software and relate them to the type of FAI: Cam, Pincer or mixed.

Results

The results obtained from the patients studied with CT scans were the following: as far as patients with Cam FAI were concerned, the mean femoral anteversion was of 12.4° (range 7°-15°) and the acetabular anteversion was of 16.4° (range 6°-27°). As far as the patients with Pincer FAI were concerned, the mean femoral anteversion was of 19° (range 18°-20°) and the acetabular anteversion was of 13,5° (range 11°-16°). As far as the patients with mixed FAI were concerned, the mean femoral anteversion was of 15° (range 10°-19°) whilst the acetabular anteversion was of 16,5° (range 8°-23°). The Mc Kibbin index was of 32,9° (range 21°-42°), corresponding to the range of 30-40°, a value corresponding to the lowest probability of coxathrosis (Tab. 1).

Discussion

Our results show that patients with CAM FAI presented lower values (12, 4°) compared to the normal femoral anteversion range (v. n.15°-20°). Studies available in the literature such as the study by Sutter et al. published in 2012 investigated the possibility of a correlation between the values of femoral and acetabular anteversion and development of FAI. The conclusions highlight that the femoral anteversion values that differ from mean values are not directly correlated to the development of FAI (24).

Recent biomechanical studies (25) carried out in asymptomatic patients have demonstrated on the basis of cartilaginous degeneration that the physiologically anteversed hip joint works in retroversion due to the action of dynamic forces. In fact, the areas that present the greatest degeneration correspond to the postero-superior areas of the joint.

This seems to represent an interesting aspect considering that if patients with CAM impingement present less femoral anteversion, the functional retroversion will push the hip into excessive retroversion and therefore, probably due to repeated conflict during movement lead to the formation of a bump.

Other considerations on these results can be made on the basis of a gait analysis carried out by the Department of Physical Therapy and Rehabilitation of the University of Verona on 28 patients (17 males) with an age between 52 and 64, presenting an advanced stage

Table 1. Clinical and instrumental characteristics of the studied patients

	Patient	Age	Gender	Acetab. FAI	Femoral antevers.	McKibbin antevers.	Index
1	Z.L.	75	F	Left Cam	27°	10°	37°
2	B.M.	44	M	Left Cam	14°	7°	21°
3	D.S.S.P.	33	M	Left Cam	13°	15°	28°
4	G.S.	44	M	Left mixed FAI	23°	13°	36°
5	R.V.	61	M	Cam dx	23°	8°	31°
6	C.G	43	M	Right mixed FAI	14°	10°	24°
7	B.M.	56	F	Right mixed FAI	8°	15°	23°
8	D.B.P.	58	F	Right Pincer	16°	18°	34°
9	P. F.	61	M	Right Pincer	11°	20°	31°
10	P. E.	59	F	Right Cam	8,1°	13°	21,1°
11	B.S.	50	M	Right Cam	6°	15°	21°
12	T.L.	45	M	Right Cam	13°	13°	26°
13	A.F.	52	M	Right mixed FAI	15°	17°	32°
14	D.C.	59	M	Left Cam	16°	12°	28°
15	Z.G.	56	M	Left mixed FAI Right mixed FAI	12° 23°	13° 19°	25° 42°
16	C.N.	45	M	Right Cam	11,1°	15°	26,1°
17	B.M.	55	M	Left Cam	24,6°	15°	39,6°
18	F.F.	62	M	Right mixed FAI	20,8°	18°	38,8°
19	F.S.	52	F	Right Cam	20°	14°	34°
20	P. D.	52	F	Left Cam right Cam	15° 22°	11° 13°	26° 35°
21	D.R.	47	F	Right mixed FAI	16°	15°	31°

of coxathrosis. Walking patterns were evaluated during the month prior to hip replacement surgery. The aim of this study was to analyse changes in the walking patterns before and after surgery.

From this study, it emerged that patients with coxathrosis walk opening the angle between their feet, with their hip inclined forwards and especially with an extra-rotation of their leg.

This data, even if statistically insignificant, due to the scarceness and non-homogeneity of the sample, provides us with interesting hypotheses on the functional modifications of the arthrosic hip joint. Walking with an extra-rotated leg and, consequently, with the femoral head in anteversion, there could be an attempt to exit the articular region with cartilage damage, therefore reducing pain. Therefore, in patients with particular anatomical characteristics, among which reduced femoral anteversion due to repeated impingement between the femoral neck and the acetabulum, both working under disadvantageous conditions which lead to a mechanical conflict, CAM FAI develops. The hip could react functionally to this mechanical-pathological phenomenon by working in extra-rotation and exploiting less worn areas from a cartilaginous point of view.

As far as acetabular anteversion is concerned (v. n. 15-20°), we observed that the lowest values (13, 5°) corresponded to patients with Pincer FAI. In the literature, acetabular retroversion was traditionally associated to Pincer FAI representing a pre-arthrosic pathological stage (1, 26, 27). However, Cobb et al. demonstrated that acetabular retroversion is present both in individuals with FAI and in asymptomatic patients suggesting that it is not a sufficient condition for the development of FAI (28).

The results obtained from the measurements of the Mc Kibbin index that recorded for all patients val-

ues within the range of lowest arthrosic risk, indicated that femoral and acetabular retroversion are often associated and of similar degree in our patients. Other recent publications have demonstrated a correlation between femoral and acetabular retroversion. Buller et al. analysed 115 patients and concluded that in asymptomatic patients, femoral and acetabular retroversion compensate each other as if functionally, the femoral retroversion were an adjustment moving the femoral head backwards from the anterior wall that excessively covers the retroverted acetabulum (29).

Conclusions

The anatomical structure of the hip joint and its morphological variations depend on the dynamic interactions between the acetabulum and the proximal femur. Many recent investigations have been carried out into the relation between the bone architecture of the hip and the mechanical loads to which it is subjected. FAI seems to be the result of these complex interactions (30, 31). From our study, it emerged that a vicious orientation of both the acetabulum and the femoral head can play a major role in the genesis of "idiopathic" FAI. This premise is only a starting point that aims to suggest a critical analysis of the patient presenting FAI, considering not only an interaction between the acetabulum and the femoral head, but interpreting it in the light of relations with nearby structures (back bone, knee and foot) (30).

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