

# Clinical, functional and radiological outcomes of the use of fixed angle volar locking plates in corrective distal radius osteotomy for fracture malunion

Valerio Pace<sup>1</sup>, Pasquale Sessa<sup>2</sup>, Matteo Guzzini<sup>3</sup>, Marco Spoliti<sup>2</sup>, Alessandro Carcangiu<sup>3</sup>, Natale Criseo<sup>3</sup>, Alessio Gaii Via<sup>2</sup>, Luigi Meccariello<sup>4</sup>, Auro Caraffa<sup>1</sup>, Riccardo Maria Lanzetti<sup>2</sup>

<sup>1</sup>Department of Trauma & Orthopaedics, University of Perugia, Perugia, Italy; <sup>2</sup>Department of Emergency and Acceptance, Orthopaedics and Traumatology Unit, San Camillo - Forlanini Hospital, Rome, Italy; <sup>3</sup>Department of Trauma and Orthopaedics, Sant'Andrea Hospital, University of Rome "La Sapienza", Rome, Italy; <sup>4</sup>Department of Trauma and Orthopaedics, "Vito Fazzi" Hospital, Lecce, Italy

**Abstract.** *Background and aim:* Fractures of the distal radius are a common injury and mal-union can occur in those managed non-operatively. This can cause significant functional limitations along with pain. A corrective osteotomy with the use of a volar locking plate aims to restore articular surface congruency and improve outcomes. We present our local experience with clinical, functional and radiological outcomes of corrective osteotomy using a fixed angle volar locking plate and bone graft for management of distal radius mal-union. *Methods:* Retrospective study. All adult patients. Both pre and post operatively clinical range of motion was recorded. Post operative PROMS was measure by DASH, MAYO and SF-12 and pain by means of a VAS measured from 0-10. Mean follow up period was at 15 months. *Results:* 32 patients underwent the studied procedure. 24F-8F. Mean age: 56. Radiological union of corrective osteotomy: 28 (88%) of patients. 4 patients required further operative treatment to achieve corrective union. No other reported complications post-op. Post-operatively flexion improved by 24 and extension 20. Pronation was improved by 24 and supination 22. Pain was improved from an average VAS pre-operative of 5.6 to 1.6 post-operatively. Mean DASH scored improved from 57.8 to 16.2 post-operatively and MAYO 38.5 to 58.6. The mean post-operative SF-12 score was 46.2 from 31. *Conclusions:* In this series of 32 patients (the biggest reported in the literature in our knowledge) a corrective osteotomy with fixed-angle volar locking plate for mal-united distal radius has shown to improve both clinical-radiological and patient reported outcomes and provide good results of the very few complications' treatments. ([www.actabiomedica.it](http://www.actabiomedica.it))

**Key words:** Distal radius fractures, distal radius mal-union, corrective osteotomy, fixed-angle locking volar plate, hand rehabilitation.

## Background

Fractures of the distal radius are extremely common injuries, which are steadily becoming a public health issue. Malunion is a very common complication of distal radius fractures with a previously reported

rate as high as 17% in distal radius fractures managed conservatively (1-4). Several studies have shown that distal radius fracture malunion complications could cause physiological and biomechanical modifications which could consequently cause significant anatomical and functional alterations and predispose to early

osteoarthritis, with consequent significant functional and social negative implications for the patients. For these reasons an appropriate correction of anatomical and biomechanical alterations seems to be essential for good definitive results (1-4).

Several radiographic parameters can be used to assess this pattern of fracture and decide the most appropriate management. These parameters need to be restored to obtain good functional outcome in distal radius fractures. It has been shown that the ulnar variance and volar tilt are the most important ones, whilst small variations of other radiographic parameters seem to not affect the final outcome, but they must still be taken into account (such as radial inclination, radial height and articular step off and gap) (5).

Different approaches and surgical techniques have been proposed and described in the literature to treat malunion of distal radius. The use of volar locking plates in corrective osteotomy for the treatment of acute distal radius fractures has been progressively a quite common surgical treatment options. As for acute injuries, similar volar techniques and fixations have now been started to become advocated for distal radius malunion. Being a relatively recent practice, few are the studies reporting either short or long-term results. Therefore doubts and room for further research still exist (1-4).

Moreover ambiguous results have been obtained on the need to associate bone grafting to the osteotomy and plating procedure (6). Among the Authors supporting the use of bone graft, further various results were obtained among the use of autologous corticocancellous, heterologous and synthetic bone graft (6-8).

The purpose of this study was to assess the clinical, functional and radiological outcomes of corrective osteotomy using a fixed angle volar locking plate with bone graft for management of distal radius malunion.

## Materials and methods

Retrospective study on patients undergoing corrective osteotomy, fixed angle volar locking plate fixation and bone graft (autologous or synthetic) for the treatment of distal radius malunion after failure of conservative treatment. We included in the study all

patients treated in the set time-frame of 10 years at two linked specialist centres. Two teams performed all procedures utilising the same technique. Indications for surgery: significant deformity and/or reduction of ROMs (range of motion), persistent pain, radiological evidence of malunion (which occurs when the fracture heals with improper alignment, incorrect length, articular incongruity, or a combination of these factors). In practice distal radius malunion includes an alteration of radiographic parameters such as volar tilt, ulnar variance, radial inclination, radial height and articular step off and gap) (6).

The use of autologous or synthetic bone graft was taken depending on Institution availability and surgeons' preference.

Inclusion criteria: definitive diagnosis of distal radius malunion in adult patients initially treated conservatively for distal radius fractures; surgical treatment with osteotomy and fixed angle volar locking plate at least 6 weeks after initial trauma; absence of comorbidities or other factors able to modify the initial conservative management and the subsequent surgical treatment for malunion (e.g. congenital skeletal malformations, hemiparesis, and tumours); availability of standardised clinical and radiological follow up pre and post-surgery.

Exclusion criteria: surgical treatment performed within 6 weeks from injury; patients with open physis; previous surgery of the same wrist; any comorbidities or previous injury able to modify management decisions.

Surgical technique: all surgeries were performed using the "Modified Henry approach" (9, 10), with patients positioned supine after regional anaesthesia of the brachial plexus and injured arm positioned on the arm-table. In all cases, the arm was exsanguinated and a tourniquet was applied after administration of a dose of endovenous prophylactic antibiotic. In keeping with the "Modified Henry Approach", a longitudinal volar skin incision was made along the flexor carpi radialis tendon, starting proximally to the wrist crease. Soft tissues were dissected, the tendon retracted radially, all neurovascular structures and the flexor pollicis longus (retracted ulnarly) were protected throughout. This was followed by longitudinal incision of the pronator quadratus along its radial

border, and distal release of the brachioradialis and dorsal periosteum. A good exposure of the malunion site was achieved at this point. Under image intensifier guidance, a dedicated plate (DVR® Crosslock Distal Radius Plating System, Zimmer-Biomet) was used to aid the osteotomy first, and to achieve stabilization after. The plate was positioned over the palmar aspect of the distal radius and a bolster used to maintain the good position. A K-wire was then placed 2-3 mm proximal to the articular surface, parallel to the joint, through the K-wire hole on the distal plate row. After having removed the plate, the corrective osteotomy was then performed, following a plane parallel to the K-wire left in situ. The plate is then slid back over the K-wire (which has provisionally assured volar tilt restoration) and fixed to the distal fragment (utilizing the watershed line as a guide for correct positioning) with locking screws. Once distal fixation is complete, the plate is fixed to the proximal fragment with cortical screws. Small dedicated guides were positioned before hand on all screw holes before drilling and screw insertion. These guides helped the surgeons in performing a correct drilling by stabilizing the drill and assuring the most appropriate direction to the drill, and consequently providing an appropriate screw insertion. Final image intensifier checks confirmed good final achievement of correction of alignment, length, angulation, translation, rotation and articular surface.

Bone graft was then used in order to fill the bone gap. This The graft was taken (after local anaesthetic infiltration) from the contralateral iliac crest (following appropriate prepping and draping of the donor site) through a small oblique incision parallel to the iliac crest and the harvest of corticocancellous bone. Alternatively synthetic bone graft was used. After satisfactory final fluoroscopy checks, wounds were closed in layers and dressed. A below elbow back slab was applied to the operated arm.

For clinical, functional and radiological evaluation the authors used: initial and post-reductions and casting plain radiographs, pre and post-op plain radiographs, pattern of fracture, displacement-angulation-inclination of fractures, radial height, ulnar-variance, grade of osteoarthritis using the “Knirk and Jupiter osteoarthritis grading” (11), ROMs, DASH (The

disabilities of the arm, shoulder and hand), VAS (Visual Analogue Scale), MAYO, SF-12 (12 items short form survey) scores.

A postoperative follow up was planned and carried out and findings recorded. All patients were seen postoperatively at 2 weeks for wound check, removal of sutures and clinical assessment and again with xray on arrival (antero-posterior and lateral views) at 6 weeks, 3 months and 12 months for clinical assessment.

Rehabilitation protocol: A below elbow back slab was left in situ for 2 weeks after surgery and removed at the removal of sutures follow up appointment. Elevation and ROM exercises in the digits through both passive assisted and active exercises during this initial 2 weeks were recommended. ROM exercises of elbow and shoulder were also advised in order to prevent joint stiffness. Gradually progressive strengthening and dexterity exercises were recommended between the 6th and 12th post-op week, till return to heavy lifting and manual work 12 weeks after surgery if radiological evidence of fracture healing and pain control were achieved.

The study protocol was approved by the hospital's Ethical Review Board and it was conducted in accordance with the principles of the Declaration of Helsinki and its amendments. We fully informed all the subjects about the characteristics of the study and they gave their consent.

Statistical analysis: Statistical analysis was performed with SPSS (version 22). Continuous variables were compared using the Student t-test. Results were analysed, and the study groups were compared with each other. Continuous variables were described using the mean  $\pm$  sd. The level of significance was set as  $p=0.05$ .

## Results

32 patients were finally included and treated in the set time-frame. 24 were women and 8 were men. The mean follow up was 15 months (range: 12-25 months). The mean time between initial trauma and surgery for diagnosis of malunion was 40 weeks. The mean age was 56 (range 20-76). No significant early complications were recorded after surgery.

Radiological evidence of fracture consolidation achieved in 28 patients (88%), on average after 12.1 weeks from surgery. Bone graft was used in 100% of the cases: autologous bone graft was used in 28 cases and synthetic graft for the remaining 4 cases (Table 1). Autologous bone graft was always considered the first choice of treatment, but synthetic bone graft needed to be used in the 4 aforementioned cases due to lack of sufficient autologous graft or when in presence of poor quality of the graft.

A significant improvement of radiographic and functional parameters was recorded in all patients.

All patients showed improvement of radial inclination, radial height and correction of angulation on post-operative radiographs ( $p < 0.05$ ).

At final follow up: mean tilt  $7.2^\circ$  (mean  $5.3^\circ$ - $8.1^\circ$ ); ulnar-variance  $< 2$ mm on average (range 1-5); mean shortening of 2mm (range 1-4) mm; average improvement of extension was  $20.2^\circ$  (range  $18.5^\circ$ - $22.4^\circ$ ); average improvement of flexion was  $24.8^\circ$  (range  $22.9^\circ$ - $26.5^\circ$ ); average improvement of pronation was  $23.9^\circ$  (range  $21.6^\circ$ - $24.8^\circ$ ); average improvement of supination was  $22.4^\circ$  (range  $20.9^\circ$ - $24.1^\circ$ ) ( $p < 0.05$ ) (Table 2).

A grade not higher than 0 or 1 of osteoarthritis was recorded for all patients at final follow up. Mean pre-op DASH: 57.8. Mean post-op DASH: 16.2. Mean pre-op VAS: 5.6. Mean post-op VAS: 1.6. Mean pre-op MAYO: 38.5. Mean post-op MAYO: 58.6. Mean pre-op SF-12: 31.2. Mean post-op SF-12: 46.2 ( $p < 0.05$ ) (Table 3).

The 4 patients who were diagnosed with non-union were reoperated and achieved results at the final follow up (12 months after the second surgery)

in keeping with the results achieved after 12 months (from the first procedure) by the other 28 patients successfully treated by the initial operation. A scientifically proved reason for the failure of the initial surgical procedure was not identified.

No significant differences in terms of results and outcomes were found between the autologous bone graft cases versus synthetic bone graft cases.

## Discussion

Distal radius fractures are reported to be common injuries. Both conservative and surgical strategies are available and well accepted internationally (depending on the pattern of the fracture and loss of reduction, together with patient related factors). Acceptable results are frequently obtained with both strategies, if appropriate indications are followed (1, 2, 4, 9).

Unfortunately a small percentage of surgically treated fractures and a quite significant percentage of conservatively treated fracture could progress to symptomatic malunion. Deformities can be observed

in all three planes with displacement in dorsal or palmar tilt, translation, shortening and axial rotation. Malunion complications are reported as frequent as 20-25% of the distal radius fractures treated conservatively. This is becoming a relevant economic burden for healthcare systems and represent a significant part of overall workload for the orthopaedic teams (1, 2, 4, 12).

The most common treatment option for such cases is an osteotomy and plating procedure, with or without bone grafting. In rare cases a simultaneous ulnar-sided

**Table 1.** Characteristic of the population

Number of patients	32
Gender	24 F – 8 M
Mean follow up	15 (12-25)
Age	56 (20-76)
Mean time from injury to surgery	40 weeks
Radiological evidence of fracture consolidation at final follow up	28 (88%)
Early complications	0
Late complications	4 (non-union)

**Table 2.** Final radiological and functional results

Mean tilt	$7.2^\circ$ ( $5.3^\circ$ - $8.1^\circ$ )
Ulnar variance	$< 2$ mm (1-5)
Mean shortening	2mm (1-4)
Improvement of extension	$20.2^\circ$ ( $18.5^\circ$ - $22.4^\circ$ )
Improvement of flexion	$24.8^\circ$ ( $22.9^\circ$ - $26.5^\circ$ )
Improvement of pronation	$23.9^\circ$ ( $21.6^\circ$ - $24.8^\circ$ )
Improvement of supination	$2.4^\circ$ ( $20.9^\circ$ - $24.1^\circ$ )
Knirk and Jupiter osteoarthritis grading	0 to 1

**Table 3.** Pre and post-op scores

Score	Pre-op (mean)	Post-op (mean)
DASH	57.8	16.2
VAS	5.6	1.6
MAYO	38.5	58.6
SF-12	31.2	46.2

procedure or soft tissue release procedures might be needed. In the worst scenario wrist fusion or other salvage treatments might be taken into account (4, 12).

The surgical management aims at correcting anatomical, functional and biomechanical alterations. In fact radius malunion could lead to consequences affecting the radiocarpal and distal radio-ulnar joints and the carpus. Particularly, biomechanical consequences include changes in pressure forces on the distal radius and ulna, and displacement of the centers of rotation. These alterations cause progressive reduction of function and degenerative changes, along with pain. The degree of clinical acceptance is patient specific, depending on several factors (age, work, comorbidities, etc...). However it is thought that the functional outcome is closely correlated with anatomical reduction of the fracture and proper stabilization. Limits of radiological acceptance should be defined at 20 degrees of dorsal tilt, 5 degrees of radial inclination, and a - 4 mm distal radio-ulnar index (12, 13).

Both dorsal and volar approaches have been studied and proposed, and different plates (anatomical or fixed-angle ones) have also been studied for the treatment of radius malunion. Correction with 3D-printed patient-specific plates or other utilizations of 3D technology have been recently presented. However results of all these options are contradictive and certainly still debated. Similarly outcomes of bone grafting against procedures without bone grafting are heterogeneous (14-17).

Good results are reported in the literature with osteotomy and fixed-angle volar plates. However the majority of these studies are characterised by low level of evidence and very little cohorts. Other studies do not specifically present results related to the technique presented in our work. Data in support of this technique highlights that fixed-angle plates have significant strong advantages over dorsal plating and that his use is advantageous in elderly osteopenic patients and

for high-energy comminuted fractures and malunions requiring osteotomy (2, 4, 12, 18).

In this scenario we present the very good outcomes obtained in a significant number of patients treated with osteotomy and fixed-angle volar plating for distal radius malunion following initial conservative treatment of the fracture. Bone graft (autologous or synthetic) was also used by the operating surgeons to fill up the gaps.

Our series of cases is thought to include the biggest cohort on this specific topic, in the best of our knowledge. It highlights that good clinical, functional and radiological results could be achieved with the use of the studied surgical technique for the treatment of distal radius malunion. Our results corroborate what has been already proposed in the literature, showing that the use of fixed-angle volar locking plates together with osteotomy could allow good anatomical restoration and good correction of functional and radiological parameters (19-23).

Therefore the chosen type of plate was found to be very effective by the operating surgeons, as it provided a guide (through the use of the K-wire placed initially in the distal row) for the execution of the corrective osteotomy. Moreover the inserted distal row K-wire was used as a landmark and guide for correct plate positioning, avoiding too distal positioning of the plate and consequent intra-articular placement of distal locking screws.

The dedicated screw hole guides were found to be an easy but very effective aid which guaranteed appropriate drill direction and screw insertion.

The achievement of good results with the studied technique was strongly supported by the outcomes obtained at final follow up (Table 2, 3). Level of pain, ROMs and scores' values showed at the final follow up results comparable with those obtainable in the healthy population. This achievement can be considered as excellent given the significant initial anatomical and functional alterations caused by the malunion. The absence of significant early complications makes the studied procedure safe and feasible. This acquires particular value for patients such those described in our cohort as the final aim of the studied procedure was to correct a complex type of deformity with significant disruption of the anatomy, biomechanics and function.



Looking at the records of non-union cases after the studied procedure, we suggest the use of autologous bone grafting in distal radius malunion treated with corrective distal radius osteotomy instead of synthetic graft. We do not have enough data to fully support this hypothesis with appropriate evidence, but our results suggest that autologous bone graft gives the patients more chances to achieve union, with the contemporary advantage of reducing costs for the institutions. On the other hand the use of synthetic bone graft spare patients from another surgical incision and procedure, which however has revealed to be very safe (no complications) and well tolerated by the patients.

It seemed very relevant to the Authors that an appropriate and carefully dissection (particularly the release of the pronator quadratus and brachioradialis, and the protection of the radial artery, median nerve and flexor tendons particularly) and exposure of the malunion site were essential for a correct osteotomy and plate positioning, nevertheless for the avoidance of complications and a better healing process (9, 10, 12). In fact no metalwork failure or infection were recorded, and none of the patients required the plate to be removed, meaning that no soft-tissue irritation was caused by the plate and screws.

We believe that our strong encouragement to the patients to strictly follow our standardized rehabilitation protocol was one of the key points allowing the achievement of the final functional results. In fact only an appropriate rehabilitation protocol providing a gradual return to strength and manual activities, together with early passive and active mobilization to reduce joint stiffness not just at the hand-wrist but also at shoulder and elbow, can allow an appropriate return to pre-injury function and dexterity (24, 25).

**Limitations:** We were not able to present a study with higher level of evidence. However the size of our cohort gives to the results strong significance, particularly comparing our study to the other works already presented. Therefore we advocate a more powered study with higher level of evidence and a control-group.

A more standardised decisional approach to the use or not use of bone graft should be studied and put in place, so that only objective data and results are obtained and analysed. Moreover further evidence on

the superiority of autologous corticocancellous bone graft against synthetic bone graft in terms of percentage of success in fracture consolidation is needed.

Our follow up is relatively short, but the obtainment of excellent functional results at final follow up (almost in keeping with pre-injury function) did not advocate the need for any longer follow up.

We conclude that the use of the studied fixed angle volar locking plate in corrective distal radius osteotomy for fracture malunion, together with autologous bone graft, is an effective, feasible and safe surgical option which provides very good clinical, functional and radiological outcomes in our experience.

**Acknowledgments:** We truly and sincerely thank Prof. Caraffa and our Institutions for their support and guidance throughout the entire research process.

**Conflicts of interest/Competing interests:** All Authors disclose any financial and personal relationships with other people or organisations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

“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”

**Ethics approval - Consent to participate - Consent for publication:** All patients were informed in a clear and comprehensive way of the two type of treatments and other possible surgical and conservative alternatives. Patients were treated according to the ethical standards of the Helsinki Declaration, and were invited to read, understand, and sign the informed consent form.

**Availability of data and material:** we presented our main data in the manuscript. Data files are available for scrutiny if necessary on request.

**Authors' contributions:** VP, PS, MG, MS, AC, NC, LM, AG, AC and RL designed the study and selected the cases. VP, PS, MG, MS, AC, NC collected and analysed the data. VP, PS, MG, MS, AC, NC, LM, AC and RL discussed the results and compared data

with the literature. VP, RL, and AC wrote the article and the bibliography. VP, PS, MG, MS, AC, NC, LM, AC and RL reviewed the article and approved his submission.

## References

- Adams BD. Effects of radial deformity on distal radioulnar joint mechanics. *J Hand Surg Am* 1993 May; 18(3): 492-8.
- Bushnell BD, Bynum DK. Malunion of the distal radius. *J Am Acad Orthop Surg* 2007 Jan; 15(1): 27-40.
- Koh S, Morris RP, Patterson RM, Kearney JP, Buford WL Jr, Viegas SF. Volar fixation for dorsally angulated extra-articular fractures of the distal radius: a biomechanical study. *J Hand Surg Am* 2006 May-Jun; 31(5): 771-9.
- Prommersberger K-J, Pillukat T, Mühldorfer M, van Schoonhoven J. Malunion of the distal radius. *Arch Orthop Trauma Surg* 2012 May; 132(5): 693-702.
- Perugia D, Guzzini M, Civitenga C, et al. Is it really necessary to restore radial anatomic parameters after distal radius fractures? *Injury* 2014 Dec; 45 Suppl 6: S21-6.
- Mahmoud M, El Shafie S, Kamal M. Correction of dorsally-malunited extra-articular distal radial fractures using volar locked plates without bone grafting. *J Bone Joint Surg Br* 2012 Aug; 94(8): 1090-6.
- Ekrol I, Hajducka C, Court-Brown C, McQueen MM. A comparison of RhBMP-7 (OP-1) and autogenous graft for metaphyseal defects after osteotomy of the distal radius. *Injury* 2008 Sep; 39 Suppl 2: S73-82.
- Winge MI, Røkkum M. CaP cement is equivalent to iliac bone graft in filling of large metaphyseal defects: 2 year prospective randomised study on distal radius osteotomies. *Injury* 2018 Mar; 49(3): 636-643.
- Conti Mica MA, Bindra R, Moran SL. Anatomic considerations when performing the modified Henry approach for exposure of distal radius fractures. *J Orthop* 2016 Nov; 14(1): 104-107.
- Ilyas AM. Surgical approaches to the distal radius. *Hand (N Y)* 2011 Mar; 6(1): 8-17.
- Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am* 1986 Jun; 68(5): 647-59.
- Voche P, Merle M, Dautel G. Non-articular malunions of the distal radius: evaluation and techniques of correction. *Rev Chir Orthop Reparatrice Appar Mot* 2001 May; 87(3): 263-75.
- Krimmer H, Schandl R, Wolters R. Corrective osteotomy after malunited distal radius fractures. *Arch Orthop Trauma Surg* 2020 May; 140(5): 675-680.
- Raad F, Schep NWL. Malunion of the distal radius: correction with a 3D-printed patient-specific plate. *Ned Tijdschr Geneesk* 2020 Jun 25; 164: D4617.
- Shintani K, Kazuki K, Yoneda M, et al. Computer-Assisted Three-Dimensional Corrective Osteotomy for Malunited Fractures of the Distal Radius Using Prefabricated Bone Graft Substitute. *J Hand Surg Asian Pac Vol* 2018 Dec; 23(4): 479-486.
- Byrne A-M, Impelmans B, Bertrand V, Van Haver A, Verstreken F. Corrective Osteotomy for Malunited Diaphyseal Forearm Fractures Using Preoperative 3-Dimensional Planning and Patient-Specific Surgical Guides and Implants. *J Hand Surg Am* 2017 Oct; 42(10): 836.e1-836.e12.
- Mugnai R, Tarallo L, Lancellotti E, et al. Corrective osteotomies of the radius: Grafting or not? *World J Orthop* 2016 Feb 18; 7(2): 128-35.
- Smith DW, Henry MH. Volar fixed-angle plating of the distal radius. *J Am Acad Orthop Surg* 2005 Jan-Feb; 13(1): 28-36.
- Malone KJ, Magnell TD, Freeman DC, Boyer MI, Placzek JD. Surgical correction of dorsally angulated distal radius malunions with fixed angle volar plating: a case series. *J Hand Surg Am* 2006 Mar; 31(3): 366-72.
- Smith DW, Henry MH. Volar fixed-angle plating of the distal radius. *J Am Acad Orthop Surg* 2005 Jan-Feb; 13(1): 28-36.
- Voche P, Merle M, Dautel G. Non-articular malunions of the distal radius: evaluation and techniques of correction. *Rev Chir Orthop Reparatrice Appar Mot* 2001 May; 87(3): 263-75.
- Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report *J Hand Surg Am* 2002 Jan; 27(2): 205-215.
- Prommersberger KJ, Lanz UB. Corrective osteotomy of the distal radius through volar approach *Tech Hand Up Extrem Surg* 2004 Jun; 8(2): 70-77.
- Lanzetti RM, Astone A, Pace V, et al. Neurolysis versus anterior transposition of the ulnar nerve in cubital tunnel syndrome: a 12 years single secondary specialist centre experience. *Musculoskelet Surg* 2020 Feb 8.
- Rollo G, Bisaccia M, Cervera Irimia J, et al. The Advantages of Type III Scaphoid Nonunion Advanced Collapse (SNAC) Treatment With Partial Carpal Arthrodesis in the Dominant Hand: Results of 5-year Follow-up. *Med Arch* 2018 Oct; 72(4): 253-256.

### Correspondence:

Received: 23 January 2021

Accepted: 20 February 2021

Matteo Guzzini, PhD

Department of Trauma and Orthopaedics,

Sant'Andrea Hospital, University of Rome "La Sapienza"

Via di Grottarossa 1053

00100 Rome Italy

Phone: 06-33775818

E-mail: [matteo.guzzini@uniroma1.it](mailto:matteo.guzzini@uniroma1.it)