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ORIGINAL ARTICLE • UPPER LIMB - WRIST - ARTHROSCOPY

Does arthroscopic assistance improve reduction in distal articular radius fracture? A retrospective comparative study using a blind CT assessment

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Abstract

Introduction The objective of this study was to compare the articular reduction in two groups of patients with a distal articular radius fracture who underwent surgery with versus without arthroscopic assistance. The initial hypothesis of this study is that arthroscopic assistance does not improve reduction in distal articular radius fractures.

Methods The study was retrospective (1/04/2014–01/04/2017) and included 41 patients: 23 had arthroscopically assisted osteosynthesis, and 18 had not. All patients included had CT before and 3 months after surgery. All radiographic and CT measurements were retrospectively taken by an independent radiologist who did not know which operative technique was performed. Secondary judgement criteria were clinical analysis at 1-year follow-up and tourniquet time. We also reported all soft tissue injuries diagnosed and repaired and postoperative complications.

Results At the third month, articular step was 0.91 ± 1.25 mm (arthroscopy) and 1.41 ± 1.68 mm (no arthroscopy), without statistical difference ($p = 0.3756$). No difference was found for articular gap between the two groups [arthroscopy (0.55 ± 1.04 mm), (no arthroscopy (0.82 ± 1.54 mm)] ($p = 0.8574$). Except for the tourniquet time, clinical results at 1-year follow-up were not different. One patient of each group had a scapholunate pinning, and 6 patients of the arthroscopy group had a TFCC 1B injury, which was repaired.

Conclusion This study did not demonstrate that arthroscopic assistance improves step and gap reduction of articular distal radius fracture, confirming initial hypothesis and recent literature data.

Level of evidence Retrospective, III.

Keywords Wrist fracture · Computed tomography · Wrist arthroscopy · Articular step · Articular gap

Introduction

In the past two decades, publications about arthroscopic assistance in the surgery of wrist injuries increased.

Many publications were about two facets of wrist arthroscopy: assisted reduction in distal articular and extra articular radius fractures [1–8] and treatment of acute intra-carpal ligamentous injuries [9–13].

Benefits of arthroscopic assistance in the treatment of ligamentous injuries of the wrist seem to find a positive consensus [10, 11]. However, its contribution in improving articular gap and step in articular distal radius fracture remains controversial [5]. Besides, many publications are cohort studies, and few are controlled randomized trials [2, 5]. These cohort studies cannot bring out an improvement of radiologic parameters after arthroscopic assisted surgery in comparison with conventional surgery [1, 4, 14]. The main

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limit of evaluating the quality of reduction is inherent in radiographic measurements that come under inter- and intra-observer variability and the difficulty to precisely measure parameters like articular gap and step. Indeed, a good reduction is defined by a step < 1 mm [15]. To our knowledge, two studies used preoperative and postoperative CT to compare the quality of reduction after surgery of articular distal radius fracture with versus without arthroscopic assistance [16, 17]. Burnier et al. [16] assessed arthroscopic assistance by comparing reduction of the carpal surface and the sigmoid notch of the radius. Their study found an improvement in the step reduction of the carpal surface for the arthroscopically assisted reduction group (20 patients) and not for the fluoroscopic group of their study (20 patients). Christiaens et al. [17] compared step and gap reduction in distal articular radius fractures, between two groups of 20 patients using CT measurement. They found a significant improvement in step and gap reduction in the arthroscopic group of their study. No studies in the literature have used blind assessment of articular gap and step, emphasizing the interest of this study.

The main purpose of this study was to compare with a CT measurement the quality of articular step reduction and articular gap, 3 months after surgery between two groups of patients with an articular distal radius fracture treated by osteosynthesis. One group had an arthroscopically assisted reduction, and the other group only had fluoroscopic control of the reduction. The main judgement criteria were quantitative and millimetric. Secondary judgement criteria were clinical assessment at 1-year follow-up, tourniquet time and immobilization time. We also reported all soft tissue injuries diagnosed and repaired and all complications that occurred during or immediately after surgery. The hypothesis of this study was that there was no difference in the quality of the reduction between the two groups.

Materials and methods

Study

It was a retrospective comparative single-center study. The institution gave its approval for this study. To perform this study, all data related to patients admitted in the emergency unit for intra-articular radius fracture from January 1 of 2014 to April 1 of 2017 were collected.

Inclusion criteria were patients aged between 18 and 65 years admitted to emergency unit for wrist trauma and with a diagnostic of distal articular radius fracture who gave oral and written consent for surgery. A CT scan should be made before and 3 months after surgery.

Exclusion criteria were patient aged below 18 and above 65 years or if they were unable to give oral and written consent for surgery. Polytraumatized patients and patient with another homolateral fracture of the upper limb or neurovascular deficit were not included. Also, patients under tutorship and pregnant women were not included.

Patients

According to the inclusion and exclusion criteria, 41 patients were included in this study and two groups of patients were individualized: the "no-arthroscopy" group who had a fluoroscopically assisted osteosynthesis ($N = 23$) and the "arthroscopy" group who had an arthroscopically assisted osteosynthesis ($N = 18$). The mean age in the "no-arthroscopy" group was 47.5 (± 15) years and 41 (± 16) years in the "arthroscopy" group. The "no-arthroscopy" group included 12 men and 11 women, and the "arthroscopy" group included 11 men and 7 women.

Prior to surgery, preoperative CT was made in order to assess all articular fragments and to evaluate comminution of the fracture. All fractures were AO type-C fractures [18].

Operative techniques

All patients had osteosynthesis with a Variax® (Stryker™, Michigan, USA) anterior locking plate with a standard Henry's approach.

In the "arthroscopy" group, all surgeries were made by a senior orthopedic surgeon, experienced in wrist arthroscopy.

In the "no-arthroscopy" group, all surgeries were made by a senior orthopedic surgeon.

For the « arthroscopy » group, the reduction in the fracture was assessed with a 2.7-mm arthroscope inclined at 30° and with a probe of 1.5 mm diameter. The probe was used to search and assess interfragmentary gap and step.

Before arthroscopic time, the anterior plate was placed and fixed with one cortical screw.

A standard arthroscopic approach was made, using a 3–4 portal for the arthroscope and a 6R portal for the probe [19]. After removing hemarthrosis, radiocarpal exploration allowed the study of the articular surface of the radius and then visualized articular fracture lines and evaluated interfragmentary step and gap. Also, scapholunate ligament and TFCC injuries were searched.

Then, the reduction in the fracture was performed. The probe held fragments in place, and epiphyseal locking screws were positioned (Fig. 1). The arthroscope allowed a direct visibility on the reduction. If necessary, additional pinning was made in order to help in the reduction in the fragments before positioning epiphyseal screws. Pins could be left in place to stabilize osteosynthesis.

When a scapholunate injury was diagnosed, it was classed according to Geissler's classification [15] and a scapholunate pinning was made for grade 3 or 4. All pins were removed at the sixth week.

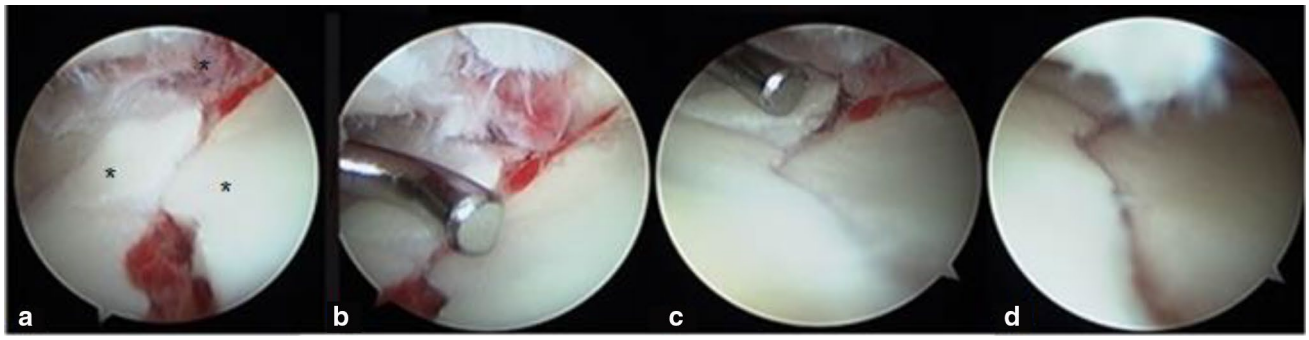

Fig. 1 Arthroscopically assisted 3 fragment fractures (view from 6R portal). **a** View of the fracture before reduction (asterisks for each fragment). **b** The probe in 3–4 portal is used to align the 2 dorsal fragments and reduce the step, and osteosynthesis is then made with direct visualization of the reduction. **c** To reduce the third anterior fragment, the same technique is used with the probe pushing on the fragment to align it with the 2 others, allowing osteosynthesis of the well-positioned fragment. **d** Final view of the reduction

When a TFCC injury was diagnosed, it was classed according to Palmer's classification [20]. Peripheral 1B lesions were repaired by direct inside-out suture [21].

An anteroposterior and lateral fluoroscopic control was made after final proximal cortical fixation.

For the « no-arthroscopy » group, osteosynthesis technique only differed by the articular reduction of the fracture that was only controlled fluoroscopically. With standard anteroposterior and lateral views, we searched for any step and gap higher than 1 mm on the articular surface of the radius. If so, osteosynthesis was modified to improve reduction. Scapholunate ligament disruption was then searched by performing radial and ulnar inclination after osteosynthesis. An additional scapholunate pinning was made if radiological signs of scapholunate dissociation were found (i.e., DISI, ring sign, scapholunate diastasis, step in Gilula's arcs).

Judgement criteria

The main judgement criteria were the comparison of interfragmentary step and gap on the carpal surface of the radius between the two groups of patients with CT measurement (in millimeters), 3 months after surgery.

A senior radiologist was asked to retrospectively measure postoperative interfragmentary gap and step on CT. To do so, he had to evaluate the most displaced fragments one frontal and sagittal line on postoperative CT and measure interfragmentary step and gap.

Measurement was taken by drawing a tangent line at each edge of the most displaced fragments and by measuring the difference in step (Fig. 2) and gap (Fig. 3) between these lines.

To allow a blinded analysis, CT measurements were realized by the same senior radiologist who did not know which surgical technique was used (arthroscopic assistance or not).

Secondary judgement criteria were the comparison of clinical results at 1-year follow-up. All patients are reviewed after distal radius fracture 1-year after surgery, which is a common practice in our institution. For this study, we collected all data concerning wrist motion measured with a goniometer: flexion–extension, pronation–supination, and pain measured with visual analog scale and Mayo Clinic score [22] and QuickDASH score [23].

We collected all data concerning complications that occurred during or immediately after surgery and all intra-articular soft tissue injuries diagnosed and repaired and tourniquet time (in min) in the two groups.

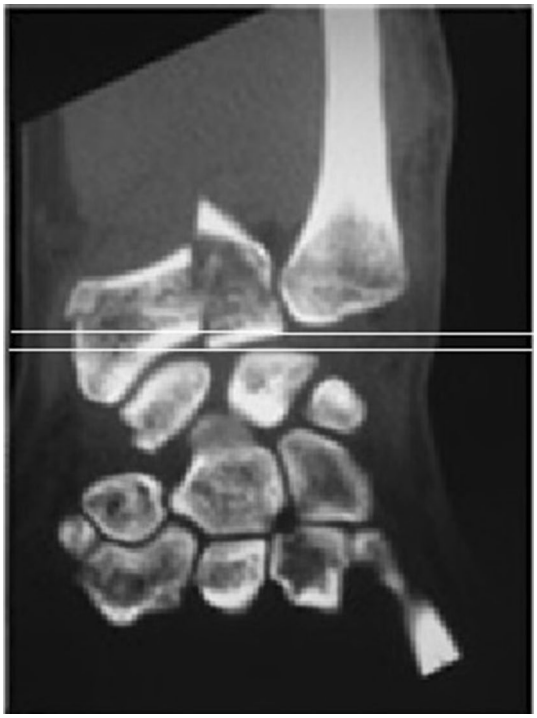

Fig. 2 Step measurement

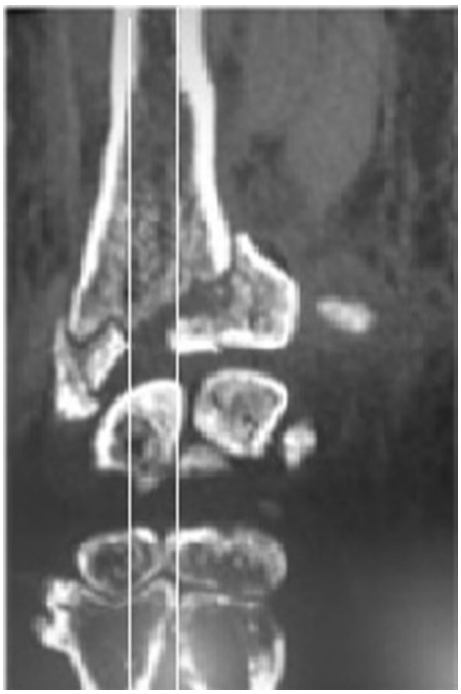

Fig. 3 Gap measurement

Lastly, we collected data from the third-month CT concerning diagnostic of non-union and the presence of articular hardware in the two groups.

Statistical analysis

Qualitative parameters are expressed in frequencies and percentage. Quantitative parameters are expressed in terms of mean and standard deviation (±). Normality of distributions was checked graphically and using the Shapiro–Wilk test.

Qualitative parameters were compared between the two groups by Chi-squared test. Quantitative parameters were compared by Student's *t* test or Mann–Whitney *U* test according to the distribution.

For the main judgment criteria, a Mann–Whitney *U* test was used to compare interfragmentary step and gap between the two groups.

Statistical analysis was done at the two-tailed alpha risk level of 0.05, and data were analyzed using the SAS software package, release 9.3 (SAS Institute, Cary, NC).

There was no statistical difference between the two groups of this study in terms of patients' characteristics, fracture type and gravity. Radiographic (radial inclination, palmar tilt and ulnar variance) and preoperative CT step, gap and number of fragments were not different between the two groups.

The radiologist took all preoperative CT measurements using the same technique as postoperative measurement (Table 1).

Results

At the third-month CT, mean interfragmentary step was lower than 1 mm for the « arthroscopy » group, whereas it was higher than 1 mm in the « no-arthroscopy » group. However, there was no statistical difference between the two groups.

The mean interfragmentary gap was not statistically different between the two groups (Table 2).

Secondary judgement criteria

All patients came to the 1-year consultation.

At 1-year follow-up, there was no statistical difference between the two groups in regard to mean VAS, wrist motion and functional scores (Table 3).

Table 1 Comparison between the two groups

Criteria	No arthroscopy ($n=23$ patients)	Arthroscopy ($n=18$ patients)	p
Age (years)	47.5 (±15)	41 (±16)	0.1919
Gender	Men 12 (52%) Women 11 (48%)	Men 11 (61%) Women 7 (39%)	0.0934
Side of wrist fracture	Right 8 (35%) Left 15 (65%)	Right 22 (58%) Left 16 (42%)	0.3136
AO type fracture	C 23 (100%)	C 18 (100%)	1
Preoperative radial inclination (°)	16.8° (±7.3°)	19.1° (±6.5°)	0.3098
Preoperative radial palmar tilt (°)	−7.43° (±21.4°)	−8° (±17.5°)	0.9282
Ulnar variance (mm)	1.4 (±2.8)	0.4 (±2)	0.2924
Preoperative CT step (mm)	2.15 (±1.79)	1.96 (±1.71)	0.7907
Preoperative CT gap (mm)	3.12 (±1.82)	3.74 (±1.60)	0.2989
CT number of fragments	5.30 (±1.84)	5.22 (±1.48)	0.946

Table 2 Main criteria comparison

Group	No arthroscopy	Arthroscopy	*p*
Step at 3-month CT (mm)	1.41 (± 1.68)	0.91 (± 1.25)	0.3756
Gap at 3-month CT (mm)	0.82 (± 1.84)	0.55 (± 1.04)	0.8574

Table 3 Clinical results at 1-year follow-up

Group	No arthroscopy	Arthroscopy	*p*
VAS	1.05 (± 1.4)	0.6 (± 1.9)	0.1324
Flexion (°)[a]	70 (± 11°)	74 (± 5°)	0.3975
Extension (°)[a]	74 (± 9°)	80 (± 6°)	0.1311
Pronation (°)[a]	86 (± 7°)	86 (± 6°)	0.9803
Supination (°)[a]	83 (± 10°)	83 (± 9°)	0.9282
Mayo Clinic	90 (± 9)	86 (± 16)	0.8227
QuickDASH	3.6 (± 4.75)	9.7 (± 22.04)	0.9288

[a]Values in degrees rounded to the nearest integer

Tourniquet time was longer ($p < 0.0001$) for the « arthroscopy » group (91 ± 25 min) than for the « no-arthroscopy » group (54 ± 20 min).

No complications during or immediately after surgery were reported.

All fractures had been consolidated at the third-month CT assessment, and no intra-articular material has been diagnosed.

Three patients from the « no-arthroscopy » group and seven from the « arthroscopy » group had an additional pinning.

One patient from the no-arthroscopy group had a scapholunate diastasis more than 4 mm with a ring sign during testing, and one from the arthroscopy group had a Geissler's grade 3 scapholunate disruption. Both had scapholunate pinning. All pins were removed at the sixth week after surgery.

Six patients had a TFCC–1B injury, and an inside-out suture was made.

Discussion

The objective of this study was to compare the quality of reduction in articular radius fracture with or without using arthroscopic assistance and with a blind CT assessment.

This study did not bring to light any statistical difference in terms of quality of step and gap reduction between the two groups, confirming the initial hypothesis of this study.

Our study has some limitations. The study population was low, but this was inherent to inclusion criteria (CT before and 3 months after surgery). So, the study could not find statistical difference between the two groups due to a lack of power. Moreover, the number of patients included does not differ from studies using CT assessment to compare reduction in distal radius fracture with or without arthroscopic assistance [16, 17].

Besides, it was a non-randomized retrospective study, exposing it to selection bias. However, the two groups were similar in all comparative criteria searched in this study, and notably all preoperative radiographic and CT measurements were not statistically different. Lastly, the follow-up time was short, but this duration was sufficient to assess the main judgement criteria and is in line with follow-up time of studies in the literature [1, 4, 5].

In the literature, two studies used CT measurement to compare quality of reduction in distal articular radius fractures [16, 17].

Burnier et al. [16] found an improvement in the step reduction of the carpal surface for the arthroscopically assisted reduction group and not for the fluoroscopic group of their study. This difference between Burnier et al.'s results and ours can be explained by the design of Burnier et al. study. In their study, the difference between step was compared before and after surgery in the same group, whereas our study compared the arthroscopy group versus the no-arthroscopy group. Considering that there was a significative difference in measurements for their arthroscopic group and not for their fluoroscopic group, they concluded that arthroscopic assistance is useful to improve reduction in distal articular radius fracture. Christiaens et al. [17] compared step and gap reduction between two groups of 20 patients using CT measurement. They found a significant improvement in step and gap reduction in the arthroscopic group of their study although, unlike this study, they did not use a blind CT assessment which could have led to measurement bias.

Arthroscopic assistance to control the reduction in articular distal radius fracture remains a controversial subject. Hardy et al. [1] published a study supporting arthroscopic assistance. In their population of 18 young adults with a distal articular radius fracture, 11 had a step below 1 mm. In 2008, the study of Varitimidis et al. [2] also supported arthroscopic assistance. They published a randomized comparative study of 40 patients, divided into two groups: A group had osteosynthesis with external fixator with fluoroscopic control, and the other had a supplementary arthroscopic assistance. At 12- and 24-month follow-ups, the reduction in the radiographic step was better in their « arthroscopy » group. In our study, we also found a mean step below 1 mm in our « arthroscopy » group, but without statistical difference with the « no-arthroscopy » group. In 2016, the study published by Thiart et al. [6] seems to go along with the fact that arthroscopic assistance did not permit a better reduction, considering that in their study, reduction is often sufficient in order to limit

wrist osteoarthritis. By not finding a better reduction with arthroscopic assistance, our study is in line with this recent publication.

The use of CT is a strength of this study, taking its precision into consideration [24–26]. Moreover, CT assessment made by an independent radiologist who did not know which operative technique was used, strengthens the objectivity and avoids measurement bias.

Arora et al. [24] realized a prospective study on 120 articular distal radius fractures on which preoperative radiographs and CT were made. CT assessment of the articular fracture led to the adaptation of the osteosynthesis in 23% of the fractures, underlining the major role of CT analysis before articular wrist trauma surgery. For Heo et al. [27], CT was better than radiographs to detect fracture line in the sigmoid notch, which can lead to DRUJ secondary osteoarthritis. This study included 121 articular distal radius fractures. Radiographic assessment found a fracture line in the DRUJ in 81 cases versus 99 for CT assessment.

The secondary objective of this study was clinical comparison between two groups at 1-year follow-up, without statistical difference. Only tourniquet time was statistically different and was higher in the « arthroscopy » group, showing the high skill level requested for an arthroscopic assistance in this surgery. No complication during or immediately after surgery was reported.

The literature provided divergent results on clinical outcomes. Many studies did not exceed 12 months of follow-up [1, 4–6, 28, 29]. Most of these studies are cohort studies that reported good follow-up results [1, 6, 14]. However, for Levy et al. [4], there appeared to be an absence of anatomo-clinical parallelism between the quality of articular reduction and functional scores at 1-year follow-up. The series included 35 patients with a mean age of 78 years treated with pinning. At 6 weeks at the time of the removal of the pins, an arthroscopy was performed to assess the quality of the reduction. Only 2 of 35 patients had a step greater than 1 mm, and 9 of 35 patients had an interfragmentary gap greater than 1 mm. They concluded in a practical way by recommending that joint reduction under arthroscopic assistance should be limited to young patients.

Yamazaki et al. [5] were not in favor of arthroscopic assistance. In their study, the technique did not improve neither joint congruence nor functional scores in articular distal radius fractures with an anterior plate osteosynthesis. Their study was a randomized controlled trial between two groups with a total of 74 patients. One group only had fluoroscopic assistance, and the other had both fluoroscopic and arthroscopic assistance. At six- and 48-week follow-ups, they did not find any statistical difference in radiographic assessment (step and gap) and functional scores. We have to underline that in their study, mean patient age was 64. In a population aged higher than 65 years, anatomical reduction of the articular surface does not seem to be correlated with better functional outcome at long time follow-up [30].

Among these studies, some studies concluded that arthroscopic assistance has the advantage of allowing a less invasive surgery. The study of Lebailly et al. [31] reported a mean incision length of 16.1 mm with good functional scores by using a mini-invasive approach and arthroscopically assisted reduction in distal radius fracture. Abe et al. [3] reported a pre-positioning anterior plate technique in adjunction to arthroscopy for osteosynthesis of distal radius fractures that could allow a less invasive surgery.

Conclusion

With a blind CT assessment of step and gap reduction performed by an independent radiologist, our study did not confirm that arthroscopic assistance improves the reduction in articular distal radius fracture.

Author contribution MS: Main author—acquisiton of data and manuscript writing. PEW: Secondary author—acquisition of data. VM: Analysis of data. EG: Interpretation of data, revision of manuscript. CC: revision of manuscript, study conception. ME: Data interpretation, critical revision, study conception. TB: Data interpretation, study conception.

Compliance with ethical standards

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Ethical approval All procedures performed in this study, involving human participants, were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

References

1. Hardy P, Gomes N, Chebil M, Bauer T (2006) Wrist arthroscopy and intra-articular fractures of the distal radius in young adults. Knee Surg Sports Traumatol Arthrosc 14:1225–1230. https://doi.org/10.1007/s00167-006-0123-9
2. Varitimidis SE, Basdekis GK, Dailiana ZH, Hantes ME, Bargiotas K, Malizos K (2008) Treatment of intra-articular fractures of the distal radius: fluoroscopic or arthroscopic reduction? J Bone Joint Surg Br 90:778–785. https://doi.org/10.1302/0301-620X.90B6.19809
3. Abe Y, Tsubone T, Tominaga Y (2008) Plate presetting arthroscopic reduction technique for the distal radius fractures. Tech Hand Up Extrem Surg 12:136–143. https://doi.org/10.1097/BTH.0b013e3181670fe3
4. Levy S, Saddiki R, Normand J, Dehoux E, Harisboure A (2011) Arthroscopic assessment of articular fractures of distal radius osteosyntheses by percutaneous pins. Chir Main 30:218–223. https://doi.org/10.1016/j.main.2011.04.004

5. Yamazaki H, Uchiyama S, Komatsu M, Hashimoto S, Kobayashi Y, Sakurai T, Kato H (2015) Arthroscopic assistance does not improve the functional or radiographic outcome of unstable intra-articular distal radial fractures treated with a volar locking plate: a randomised controlled trial. Bone Joint J 97-B:957–962. https://doi.org/10.1302/0301-620x.97b7.35354
6. Thiart M, Ikram A, Lamberts RP (2016) How well can step-off and gap distances be reduced when treating intra-articular distal radius fractures with fragment specific fixation when using fluoroscopy. Orthop Traumatol Surg Res 102:1001–1004. https://doi.org/10.1016/j.otsr.2016.09.005
7. Liverneaux P, Ichihara S, Facca S, Hidalgo Diaz J (2016) Résultats de l'ostéosynthèse par plaque antérieure et abord mini-invasif (MIPO) des fractures de l'extrémité distale du radius: mise au point. Hand Surg Rehabil 35S:S80–S85
8. Igeta Y, Vernet P, Facca S, Naroura I, Diaz JJH, Liverneaux PA (2018) The minimally invasive flexor carpi radialis approach: a new perspective for distal radius fractures. Eur J Orthop Surg Traumatol. https://doi.org/10.1007/s00590-018-2124-z
9. Mathoulin C, Sbihi A, Panciera P (2001) Interest in wrist arthroscopy for treatment of articular fractures of the distal radius: report of 27 cases. Chir Main 20:342–350
10. Forward DP, Lindau TR, Melsom DS (2007) Intercarpal ligament injuries associated with fractures of the distal part of the radius. J Bone Joint Surg Am 89:2334–2340. https://doi.org/10.2106/JBJS.F.01537
11. Hohendorff B, Eck M, Mühldorfer M, Fodor S, Schmitt R, Prommersberger K-J (2009) Palmar wrist arthroscopy for evaluation of concomitant carpal lesions in operative treatment of distal intraarticular radius fractures. Handchir Mikrochir Plast Chir 41:295–299. https://doi.org/10.1055/s-0029-1238309
12. Lindau T (2017) Arthroscopic evaluation of associated soft tissue injuries in distal radius fractures. Hand Clin 33:651–658. https://doi.org/10.1016/j.hcl.2017.07.015
13. Fontès D (2016) Pathology of the triangular fibrocartilaginous complex in distal radius fractures. Hand Surg Rehabil 35S:S60–S68. https://doi.org/10.1016/j.hansur.2016.01.009
14. Khanchandani P, Badia A (2013) Functional outcome of arthroscopic assisted fixation of distal radius fractures. Indian J Orthop 47:288–294. https://doi.org/10.4103/0019-5413.109872
15. Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL (1996) Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am 78:357–365
16. Burnier M, Herzberg G, Izem Y, Joulie S (2013) Traitement des fractures articulaires du radius distal sous arthroscopie: le but anatomique est-il atteint? Revue de Chirurgie Orthopédique et Traumatologique 99:e22. https://doi.org/10.1016/j.rcot.2013.10.061
17. Christiaens N, Nedellec G, Guerre E, Guillou J, Demondion X, Fontaine C, Chantelot C (2017) Contribution of arthroscopy to the treatment of intraarticular fracture of the distal radius: retrospective study of 40 cases. Hand Surg Rehabil. https://doi.org/10.1016/j.hansur.2017.03.003
18. Müller ME, Nazarian S, Koch P (1987) Part 2: Classification AO des Fractures: Tome I: les os Longs, 1st edn. Springer, Berlin
19. Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M (2006) Set-up, portals and normal exploration in wrist arthroscopy. Chir Main 25S1:S131–S144. https://doi.org/10.1016/j.main.2006.07.029
20. Palmer AK (1989) Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am 14:594–606
21. Bain GI, Munt J, Turner PC (2008) New advances in wrist arthroscopy. Arthroscopy 24:355–367. https://doi.org/10.1016/j.arthro.2007.11.002
22. Cooney WP, Bussey R, Dobyns JH, Linscheid RL (1987) Difficult wrist fractures. Perilunate fracture-dislocations of the wrist. Clin Orthop Relat Res 214:136–147
23. Hudak PL, Amadio PC, Bombardier C (1996) Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med 29:602–608. https://doi.org/10.1002/(SICI)1097-0274(199606)29:6%3c602:AID-AJIM4%3e3.0.CO;2-L
24. Arora S, Grover SB, Batra S, Sharma VK (2010) Comparative evaluation of postreduction intra-articular distal radial fractures by radiographs and multidetector computed tomography. J Bone Joint Surg Am 92:2523–2532. https://doi.org/10.2106/JBJS.I.01617
25. Cole RJ, Bindra RR, Evanoff BA, Gilula LA, Yamaguchi K, Gelberman RH (1997) Radiographic evaluation of osseous displacement following intra-articular fractures of the distal radius: reliability of plain radiography versus computed tomography. J Hand Surg Am 22:792–800
26. Hunt JJ, Lumsdaine W, Attia J, Balogh ZJ (2013) AO type-C distal radius fractures: the influence of computed tomography on surgeon's decision-making. ANZ J Surg 83:676–678. https://doi.org/10.1111/j.1445-2197.2012.06311.x
27. Heo YM, Roh J-Y, Kim S-B, Yi JW, Kim KK, Oh BH, Oh H-T (2012) Evaluation of the sigmoid notch involvement in the intra-articular distal radius fractures: the efficacy of computed tomography compared with plain X-ray. Clin Orthop Surg 4:83–90. https://doi.org/10.4055/cios.2012.4.1.83
28. Zemirline A, Taleb C, Facca S, Liverneaux P (2014) Minimally invasive surgery of distal radius fractures: a series of 20 cases using a 15 mm anterior approach and arthroscopy. Chir Main 33:263–271. https://doi.org/10.1016/j.main.2014.04.007
29. Swart E, Tang P (2017) The effect of ligament injuries on outcomes of operatively treated distal radius fractures. Am J Orthop 46:E41–E46
30. Gehrmann SV, Windolf J, Kaufmann RA (2008) Distal radius fracture management in elderly patients: a literature review. J Hand Surg 33:421–429. https://doi.org/10.1016/j.jhsa.2007.12.016
31. Lebailly F, Zemirline A, Facca S, Gouzou S, Liverneaux P (2014) Distal radius fixation through a mini-invasive approach of 15 mm. PART 1: a series of 144 cases. Eur J Orthop Surg Traumatol 24:877–890. https://doi.org/10.1007/s00590-013-1363-2