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Original article

What happens to the posterior comminution in extra-articular fractures of the distal radius treated with volar locking plates?

Que devient la comminution postérieure dans les fractures extra-articulaires de l'extrémité distale du radius traitées par plaques antérieures verrouillées ?

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ABSTRACT

Extra-articular fractures of the distal radius with posterior displacement are typically treated with volar locking plates. However, this fixation method does not address the posterior comminution, which seems to have no impact on the final result. The purpose of this study was to determine the fate of the posterior comminution. This was a retrospective study of 22 patients over 50 years old with a distal radius fracture. A preoperative computed tomography (CT) scan was performed to evaluate the comminution. All fractures were fixed with a volar locking plate. All patients underwent a bone density scan. Patients were reviewed at 6 months post-operative to determine their clinical, radiological and functional outcomes. The CT scan was performed again to determine the fate of the comminution. At 6 months post-operative, 82% of patients had an oval metaphyseal defect. The mean volume of this defect was 1.86 mL. The contents of this defect most closely resembled fat. There was no statistical link between the defect's volume and the various parameters studied. On the other hand, the defect's density was positively related to the functional outcome and negatively related to the patients' body mass index. Because of the compression experienced by the cancellous bone, a distal metaphyseal defect often persists after consolidation in dorsally displaced distal radius fractures. The posterior comminution is ultimately of little consequence.

Mots clés :
Fracture
Poignet
Comminution postérieure
Défect osseux

RÉSUMÉ

Les fractures extra-articulaires de l'extrémité distale du radius à déplacement postérieur sont traitées par plaques antérieures verrouillées. Ce mode d'ostéosynthèse néglige la comminution postérieure. La comminution postérieure semble ne pas avoir de répercussion sur le résultat final. Cette étude avait pour but d'étudier le devenir de cette comminution. Il s'agit d'une étude rétrospective portant sur des patients de plus de 50 ans. Un scanner préopératoire avait été réalisé pour évaluer la comminution. Toutes les fractures étaient ostéosynthésées par une plaque antérieure verrouillée. Une ostéodensitométrie avait été pratiquée chez tous les patients. Les patients étaient revus à 6 mois pour une évaluation clinique, radiologique et fonctionnelle. Un scanner était alors réalisé pour évaluer le devenir de la comminution. Vingt-deux patients ont été inclus. À 6 mois postopératoires, il a été trouvé chez 82 % des patients un défect métaphysaire ovalaire. Le volume moyen de ce défect était de 1,86 mL. Le contenu de ce défect avait une tonalité proche de celle de la graisse. Il n'a pas été mis en évidence de lien statistique entre le volume du défect et les différents paramètres étudiés. Par contre, la densité du défect était liée négativement à l'Indice de Masse Corporelle et

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positivement aux résultats fonctionnels.Dans les fractures de l'extrémité distale du radius à déplacement postérieur, persiste après la consolidation un défect métaphysaire distal lié à la compression de l'os spongieux. La comminution postérieure a finalement peu de conséquence.

1. Introduction

More than 89% of distal radius fractures are displaced dorsally. Metaphyseal comminution is related to the injury mechanism and the compressive loading during the injury event. It most often affects the posterior cortex, which is thinner and weaker than the anterior cortex [1]. Many authors have recommended using autografts, allografts, bone cement or bone substitutes, alone or in combination with fracture fixation to provide architectural support to the fractured radius and prevent it from shortening [2]. Volar plate fixation with epiphyseal locking screws is the most commonly used technique [3–6]. This is the only fixation method that maintains the height of the radius – even in cases of circumferential metaphyseal comminution [4] – and allows early mobilization. Placing locking screws in the epiphysis ensures stable fracture alignment but does not address the posterior comminution. With this type of fixation, the degree of comminution does not appear to impact the clinical and radiological outcomes.

The aim of this study was to evaluate the fate of the posterior comminution in extra-articular distal radius fractures.

2. Patients and methods

2.1. Patients

This was a retrospective study of patients over 50 years of age who suffered an extra-articular wrist fracture with posterior tilt, corresponding to stages of 23-A2 and 23-A3 in the AO classification.

2.2. Methods

2.2.1. Inclusion and surgical treatment

The diagnosis was made based on X-rays including AP and lateral views. All the included patients also underwent a preoperative CT scan to accurately classify the fracture on the AO classification, to look for associated lesions and to evaluate the degree of comminution in the posterior cortex. The comminution was characterized by its height – measured on sagittal CT slices – and its location.

All fractures were fixed with a locked volar plate (VariAx 2 Distal Radius Plating System, Stryker®) and another X-ray was taken postoperatively. All the procedures were performed under regional anesthesia.

2.2.2. Outcomes

The patient outcomes were evaluated at 6 months post-operative. We evaluated the pain at rest and during activity based on a visual analog scale, joint motion in flexion, extension, ulnar deviation, radial deviation, supination and pronation using a goniometer, grip strength using a Jamar® dynamometer by comparing the injured side to the healthy contralateral side (in %). The functional outcomes were based on the QuickDASH score (Disabilities of the Arm, Shoulder and Hand) and the Mayo Wrist Score.

Another set of AP and lateral X-rays were taken during this follow-up visit. These were used to assess bone healing and to look for secondary displacement. Secondary displacement was defined arbitrarily as loss of the radial slope measured on an AP view or the radial anteversion measured on a lateral view of more than 5 ° between the immediate post-operative and follow-up X-rays.

All patients underwent a bone density scan within 6 months after the surgical procedure. Osteopenia (low bone mass) was defined as a *T*-Score between −1.0 and −2.5 at the femoral neck or lumbar spine. A *T*-score of −2.5 or lower was indicative of osteoporosis.

2.2.3. Fate of the posterior comminution

A follow-up CT scan was done in all patients at 6 months post-operative. The aim of this exam was to confirm the healing of the fracture site and to determine the fate of the posterior comminution.

2.2.4. Characterization of metaphyseal defect

When a distal metaphyseal defect was found, it was characterized by its volume, its density in Hounsfield units (HU) and its location relative to the articular surface. The metaphyseal defect was compared to an ellipsoid whose volume was calculated using the formula: V = 4/3 Pi a b c, where a, b and c correspond to the defect's diameter in three planes in space (height, width, thickness). The height, width and thickness of the defects were measured in a standardized and reproducible manner. The axial slices were used to measure the width and thickness, the sagittal slices were used to measure the height and thickness and the coronal slices were used to measure the height and width. This resulted in two measurements of each diameter being taken. The average of these two measurements was used to calculate the volume (Fig. 1).

The density (in HU) was calculated on the axial slices (Fig. 2). Measurements were made on the proximal, middle and distal parts of the defect and these three measurements were averaged.

2.3. Statistical analysis

The quantitative variables were summarized by their mean, standard deviation, maximum and minimum values, while the qualitative variables were summarized by percentages. The normality of the distribution of the numerical variables was analyzed using the Shapiro-Wilk test. Correlations between numerical variables were determined using Pearson's correlation test while correlations between quantitative and qualitative variables were determined using Spearman's correlation test. The height of the preoperative comminution was correlated to the 6-month outcomes of pain, range of motion, grip strength and functional scores. The volume of the metaphyseal defect was correlated to the height of the comminution, patient age, bone mass index (BMI), bone density scan results, pain levels, joint range of motion, grip strength and functional scores. Lastly, the defect's density was correlated to patient age, BMI, bone density scan results, pain levels, joint range of motion, grip strength and functional scores. The threshold for statistical significance was set at 5%.

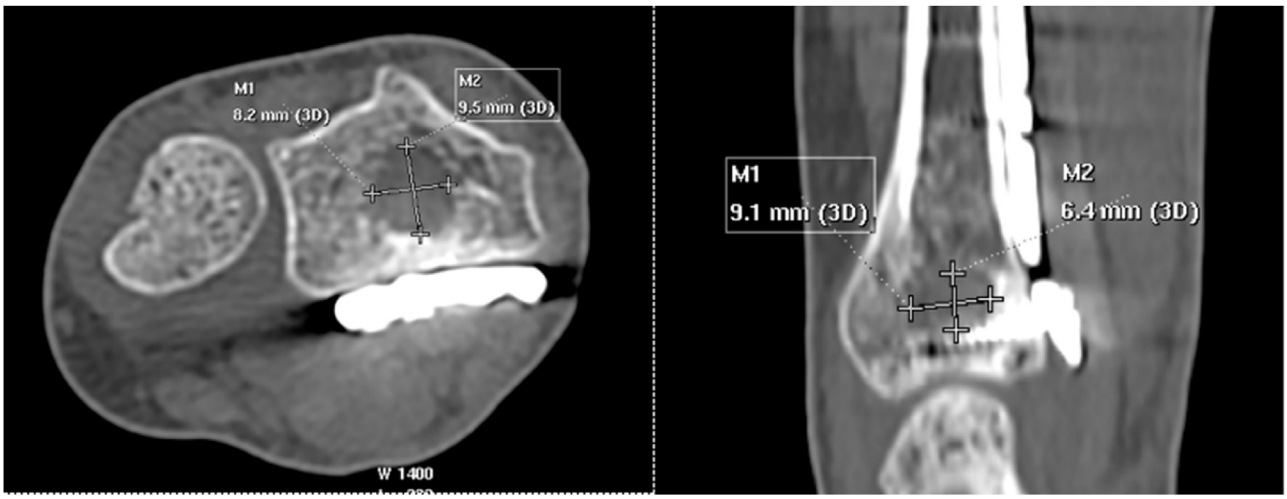

Fig. 1. Example of the measurements done on the axial slices (left) and sagittal slices (right) to calculate the volume of the residual metaphyseal defect on the CT scan at 6 months post-operative. On the axial slice (left image), this defect was 8.2 mm wide and 9.5 mm thick. On the sagittal slice (right image), this defect was 6.4 mm tall and 9.1 mm wide.

3. Results

3.1. Patients

Twenty-two patients were included in the study: 3 men (14%) and 19 women (86%). The mean age at the time of the fracture was 70 years (52–89). The mean BMI was 24.0 (± 5.6; 17.6–43.1). Of the 22 fractures, 14 (64%) were in the right wrist and 8 (36%) were in the left wrist. The dominant wrist was injured in 15 patients (68%).

3.2. Preoperative work-up

All fractures were type 23-A3 in the AO classification, thus all had posterior comminution. The distal end of the ulna was also fractured in 17 patients (77.3%). The fracture was in the styloid in 9 patients (52.9%), base of the styloid in 6 patients (35.3%) and ulnar neck in 2 patients (11.8%). There were no intracarpal lesions.

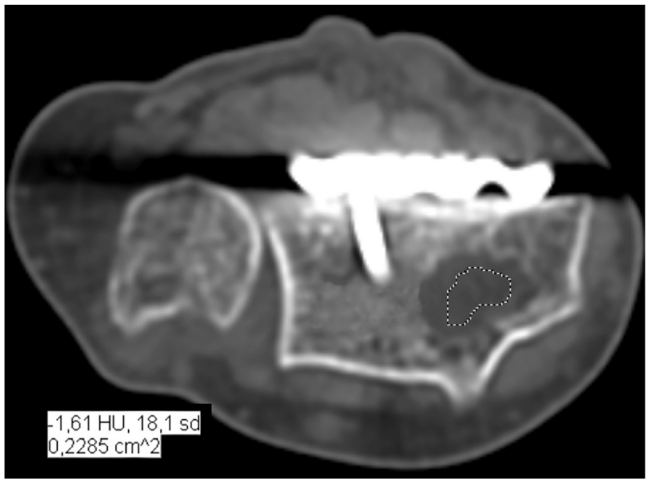

Fig. 2. Example of the density measurement performed on the CT scan images of the metaphyseal defect. Here, the defect had a measured density of −1.61 UH. This same measurement was done on three slices in the proximal, middle and distal part of the defect to calculate the average value.

3.3. Characterization of posterior comminution

The mean height of the posterior comminution was 8.66 mm (± 1.56; 6.0–12.1) (Fig. 3). In 72% of cases, the comminution affected the entire posterior cortex. It was limited to the postero-ulnar cortex in 10.5% of cases and the posteroradial cortex in 7% of cases. For the other 10.5%, the comminution extended toward the anterior cortex but was not circumferential.

3.4. Bone density scan

Thirteen patients (59%) had osteopenia and seven patients (32%) had osteoporosis at the femoral neck. Ten patients (45%) had osteopenia and three patients (14%) had osteoporosis at the lumbar spine.

3.5. Clinical and functional outcomes

At 6 months post-operative, the pain level was 0.68 (0–5) at rest and 2 (0–6) during activity (Table 1). The mean joint amplitude was 68 ° (± 11; 35–80) in flexion, 52° (± 10; 30–75) in extension, 38 ° (± 10; 15–60) in ulnar deviation, 18 ° (± 8; 5–35) in radial deviation, 84 ° (± 1; 80–85) in pronation and 85° (± 11; 45–90) in supination. The grip strength on the injured side was 86% on average (50–150) of the healthy contralateral side. The mean QuickDASH was 23.55 (0–68). The mean Mayo Wrist Score was 72 (55–95). The Mayo Wrist Score was qualified as good or excellent in 9 cases (41%), mediocre in 8 cases (36%) and poor in 5 cases (23%).

3.6. Radiological results

All fractures had healed at the 6-month follow-up visit. There was one case of secondary displacement, which occurred in an 88-year-old woman who had a 10° increase in the posterior tilt.

3.7. Metaphyseal defect

On the 6-month post-operative CT scan, a distal metaphyseal defect was found in 82% of patients (18 patients) over the preoperative posterior comminution. The mean volume of this defect was 1859 mm^3 or 1.86 mL (± 1.57; 0–5.83) (Fig. 4). The mean density of this defect was −3.85 UH (± 59.90; −87.91–122.21). This

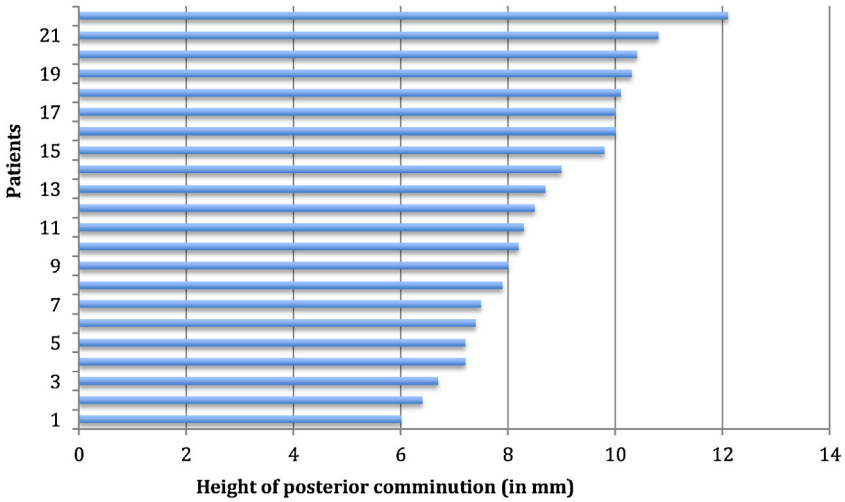

Fig. 3. Height of the posterior comminution on each patients' preoperative CT scan.

Table 1
Clinical outcomes at 6 months post-operative.

Patient	Pain at rest (VAS)	Pain with activity (VAS)	QuickDASH	Mayo clinic score	Flex	Ext	UD	RD	Pro	Sup	Strength (healthy)	Strength (injured)
1	0	0	56.82	70	75	40	40	30	85	45	18	15
2	0	2	31.82	60	55	60	45	15	85	90	28	16
3	0	0	9.09	65	65	50	40	10	85	90	28	18
4	0	0	0	90	80	60	60	30	85	90	24	23
5	0	2	68.18	65	55	45	35	20	85	90	16	8
6	0	0	0	80	40	50	15	10	85	80	12	18
7	4	6	29.55	55	70	50	40	20	85	90	19	12
8	3	4	25	70	55	45	35	10	85	90	26	13
9	0	0	47.73	70	65	55	50	10	85	85	14	13
10	1	4	47.73	65	35	55	30	10	85	90	13	11
11	0	3	13.64	80	75	75	50	30	85	90	23	18
12	0	0	0	90	65	60	45	25	85	90	38	34
13	0	0	0	80	70	30	35	15	85	90	20	18
14	0	0	50	80	60	60	30	15	85	90	11	9
15	0	3	11.36	60	70	35	40	25	85	90	25	15
16	0	0	9.09	80	55	65	55	35	85	90	28	22
17	5	6	65.91	60	45	50	25	25	85	55	8	8
18	0	3	18.18	95	55	70	40	10	85	90	10	12
19	0	5	11.36	75	70	45	35	20	85	85	8	12
20	2	4	9.09	60	45	50	20	10	85	90	14	8
21	0	2	13.64	70	60	55	45	25	85	90	30	30
22	0	0	0	80	55	45	35	5	85	90	14	13

VAS: visual analog scale; Flex: flexion (in degrees); Ext: extension; UD: ulnar deviation; RD: radial deviation; Pro: pronation; Sup: supination strength (healthy): grip strength (in kg) on healthy side; Strength (injured):grip strength (in kg) on injured side.

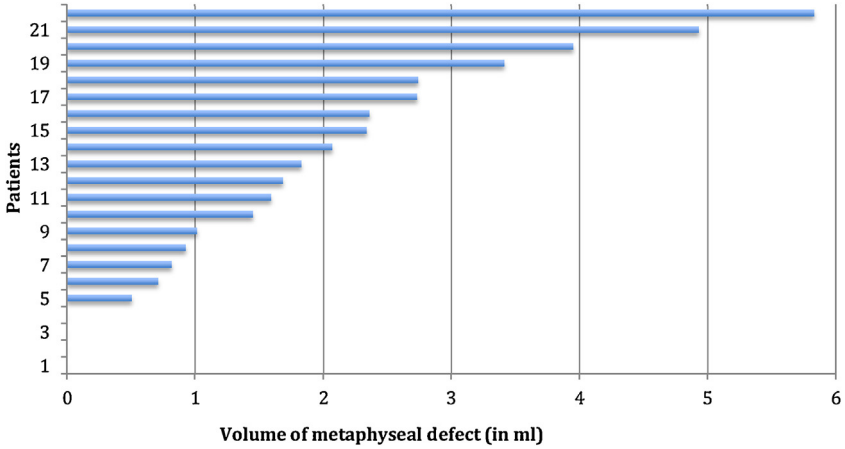

Fig. 4. Volume of each patients' metaphyseal defect at 6 months post-operative.

density most resembled that of fat tissue. The most distal portion of the metaphyseal defect was located an average of 5.5 mm (3–12) from the radiocarpal joint line.

3.8. Correlations

The height of the posterior comminution and its location did not impact the pain levels, joint amplitude, grip strength or functional scores. There was no correlation between the volume of the metaphyseal defect and the height of the preoperative comminution, patient age, BMI, bone density scan results, pain levels, joint amplitude, grip strength or functional scores. The density of the defect was negatively correlated with the BMI ($P = 0.0039$) and positively correlated with the QuickDASH ($P = 0.0010$) and the Mayo Wrist Score ($P = 0.0063$) In patients with a higher BMI, the density of the defect was lower, whereas a higher density defect was correlated with better functionality outcomes.

4. Discussion

Before the introduction of locking volar plates, various authors were interested in the metaphyseal defect created by bone impaction, since they were aware that maintaining the reduction requires this defect to be filled. The early studies compared cementoplasty only to conservative treatment, with cementoplasty having better outcomes [2]. Later on, metaphyseal defect filling was combined with fracture site pinning [7,8]. In a prospective study of 52 post-menopausal women with a distal radius fracture, Zimmerman et al. showed that injectable calcium phosphate cement combined with percutaneous pinning led to better strength, range of motion and functional outcomes. Filling the metaphyseal defect is not a trivial procedure and is associated with certain complications: use of an autograft results in donor site morbidity, allografts have a risk of disease transmission, while bone substitutes can migrate into soft tissues or even into the joint [8]. In recent years, indications for metaphyseal filling combined with fracture pinning have become less common in parallel with the development of volar locked plates.

In our study, one patient suffered a secondary displacement. This complication has also been reported in other published studies. Lattamann et al. reported two cases of secondary displacement (1%) in a cohort of 228 patients [9]. How can this complication be prevented? In an experimental study, Liverneaux showed that the mechanical strength of the radius could be doubled by a percutaneous injection of calcium phosphate cement in the metaphysis [10]. Some authors have proposed filling the metaphyseal void in addition to volar plate fixation [11]. Comparative studies have found no significant differences in the outcomes and secondary displacement rate. Thus, their use is not justified in the treatment of extra-articular fractures, especially since they increase the cost and morbidity of the procedure.

The degree of posterior comminution due to the initial injury event had no impact on our patients' pain, range of motion, grip strength and functional outcomes. Nevertheless, we found that 82% of our patients had a persistent metaphyseal defect at 6 months post-operative that had a mean volume of 1.86 mL.

Few studies have looked into the fate of the metaphyseal impaction created by the injury event. In a histomorphometry study, Lutz et al. showed that the volar and dorsal bone microarchitecture parameters were significantly different once bone union had been achieved [12]. This observation is consistent with our findings: the dorsal metaphyseal cancellous bone had been impacted during the injury event and did not regain its original architecture, even after bone union. Other studies in animal models have shown that bone can regenerate in small defects but that larger volume defects are filled with fibrous tissue and lower-quality cancellous bone [13,14].

We found no statistical relationship between the volume of the metaphyseal defect at 6 months post-operative and the bone density scan results. It would be logical to think that the largest defects would occur in osteoporotic patients. The bone architecture of the distal radius changes with age; in osteoporotic patients, it is responsible for a reduction in the trabecular bone [15].

The density of the metaphyseal defect was positively correlated with the functional outcomes. The highest density defects likely contained tissue resembling cancellous bone, while the lower density defects likely contained lower strength fibrous tissue. Thus, better bone regeneration seems to contribute to better functional outcomes. We did not identify any parameters that predict bone regeneration, since neither the clinical or bone density data were related to the defect's density. While we have no proof that a persistent metaphyseal defects makes the distal radius weaker, we believe that the presence of a defect should make us think carefully about removing the fracture fixation hardware.

It has been shown that fracture fixation is more stable when the epiphyseal screws are placed in subchondral bone [16]. In our study, the mean distance between the metaphyseal defect and the joint space was 5.5 mm, which confirms the need to position the epiphyseal screws as distally as feasible to achieve the best possible hold and reduce the risk of secondary displacement. The "target window" of epiphyseal screws is very small, thus there is a risk of the screws protruding in the radiocarpal joint. This risk can be reduced by using arthroscopy, now a popular indication for treating intra-articular fractures, which also has a place in extra-articular fractures, particularly for diagnosing ligament damage [17] This ligament damage, which was not evaluated in our study, is likely under-estimated. Lamraski et al. reported abnormal findings on 57% of arthrography scans, all types of fractures pooled [18].

5. Conclusion

Extra-articular, dorsally displaced distal radius fractures very often occur in combination with posterior cortical comminution and crushing of the trabecular bone in the distal metaphysis of the radius. At 6 months post-operative, we found a persistent metaphyseal defect in the majority of our patients, a defect filled by low-density tissue instead of metaphyseal cancellous bone, with unknown mechanical properties.

We could not identify any relationship between the degree of initial posterior comminution and the clinical and radiological outcomes at 6 months post-operative. Nevertheless, the higher the density of the metaphyseal defect, the better the functional outcome scores. None of the other criteria that we studied were correlated with the defect's density. Out study did not allow us to associate increased fragility of the distal radius with the presence of this metaphyseal defect. It would be interesting to follow the evolution of this defect over the longer term and to analyze it with histology.

Disclosure of interest

The authors declare that they have no competing interest.

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