Dorsal Lunate Facet Fracture Reduction Using a Bone Reduction Forceps

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Abstract

Background The dorsal lunate facet fragment represents part of a complex articular injury of the distal radius and is challenging to reduce through a standard volar approach. We propose reduction through a standard volar approach and intraoperative dorsal lunate facet reduction using a bone forceps. To evaluate the postoperative reduction, we used computed tomography (CT) scan.

Methods We retrospectively included 60 patients with a median follow-up of 44 weeks. Fracture reduction was evaluated using pre- and direct postoperative CT scans of the wrist, measuring the articular gap and step of the sigmoid notch. The range of motion was evaluated clinically by the treating physician. Bivariate analysis was performed to compare pre- and postoperative radiographic measurements and to compare wrist range of motion.

Results When comparing the injured with the uninjured wrist, there was a significant difference in flexion, extension, pronation, and supination. In 87% of the patients, there was complete radiographic reduction of the fracture.

Conclusion This study shows that dorsal ulnar lunate facet fracture fragments in distal radius fractures can be reduced through a standard volar approach with the help of an intraoperative bone reduction forceps. Using wrist CT, we showed that 87% of the patients with a dorsal ulnar lunate facet fragment had a postoperative articular step or gap of <1 mm.

Level of Evidence: This is a level IV, therapeutic study.

Keywords
- radiographic evaluation
- radius fracture
- volar plate fixation

Intra-articular fractures of the distal radius involving the lunate facet threaten the normal function of both radiocarpal and radioulnar articulations.[1–10] Failure to restore normal or near-normal articular anatomy can lead to distal radioulnar (DRU) joint instability or arthrosis, as well as incongruity and dysfunction of the radiolunate joint.

When faced with a widely displaced dorsal lunate facet fracture, several options exist to achieve both surgical access and stable internal fixation. Among these include the volar approach described by Orbay, which involves pronation of the radial shaft exposing the dorsal articular fragments and allowing for direct reduction; combined volar and dorsal surgical approaches; and a standard or modified volar approach with manual manipulation and reduction of the dorsal lunate facet.[3,11–23]

The aim of this study is to demonstrate that an acceptable reduction of a displaced dorsal lunate facet fracture can be achieved using a standard flexor carpi radialis (FCR) approach,

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anatomically shaped volar distal radius plate, and a bone reduction forceps.[24–26] The anatomical realignment of this new approach was confirmed using both preoperative and postoperative computed tomography (CT).

Materials and Methods

Study Population

After the approval of our Institutional Review Board, we retrospectively evaluated all patients with distal radius fracture with a dorsal ulnar corner fragment undergoing operative treatment. They were identified through an ongoing procedure database kept by the traumatology department that collects patient and treatment data prospectively. Indication for operative treatment was distal radius fractures requiring closed manipulation to achieve an acceptable anatomical position. Open fractures were excluded. From 2007 to 2015, 61 skeletally mature patients visited an urban hospital that fulfilled these criteria. All fractures were operated by a single surgeon within 10 days after injury. This was done by open reduction and fixation with a 2.4-mm Variable Angle LCP (VA-LCP) Volar Distal Radius Plate (Depuy-Synthes, West Chester, PA) and intraoperative dorsal lunate facet fragment reduction with a bone reduction forceps. We included patients who had pre- and postoperative wrist radiographs and CT scans to evaluate fracture characteristics, reduction adequacy, and fracture healing. We excluded one patient who had a CT scan at an outside hospital. Fourteen males and 46 females with a median age of 60 years (interquartile range [IQR]: 42–70) were included in this study (►**Table 1**). The fractures were classified according to the Müller Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification of the long bone.[27] Nine patients had a type B fracture and the remainder had type C fractures (12 type C1, 25 type C2, and 16 type C3). Ulnar styloid fractures accompanied the distal radius fracture in 29 of the patients. At final follow-up, active wrist function of the injured wrist was compared with that of the uninjured wrist by the treating surgeon. During the follow-up period, no patient had a secondary surgery. A final pain score was obtained using the numeric pain rating scale in 54 patients. The median follow-up period was 44 weeks (IQR: 28–27).

Table 1 Patient characteristics with dorsal ulnar corner fracture

Variable	$n = 60$
Age, median (IQR), y	60 (42–70)
Male sex, *n* (%)	14 (23.3)
Right, *n* (%)	27 (45)
AO classification, *n* (%)	
B2	9 (15)
C1	21 (35)
C2	19 (31.7)
C3	11 (18.3)
Articular gap, mean (SD), mm	2.4 (1.9)
Articular step-off, mean (SD), mm	0.8 (1.2)
Ulnar styloid fracture, *n* (%)	29 (48.3)
Intraoperative bone graft, *n* (%)	0
Secondary surgery, *n* (%)	0

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen; IQR, interquartile range; SD, standard deviation.

Radiological Assessment

The wrist radiographs and CT scans were acquired preoperatively and directly postoperatively. All measurements were performed by one of the authors, a final year orthopaedic resident. Conventional radiographs were used to assess the postoperative fracture healing. Using a CT scan (SOMATOM Emotion 16, Siemens Healthcare, Malvern, PA), the articular gap and step between dorsal lunate facet fracture and sigmoid notch in the axial plane were measured using the methods described by Rozental et al.[4] In one patient, initial measurements could not be performed because of severe fracture dislocation. The volar tilt and radial height were determined in the postoperative radiographs. We considered a fracture to be adequately reduced when there was a postoperative articular step or gap of <1 mm.

DRU joint subluxation was calculated using the radioulnar ratio (RUR).[28] We chose this ratio over the Mino criteria or epicenter method because it identifies DRU joint subluxation in earlier stages.[29–31] The RUR was calculated by identifying the ulnar center with the use of concentric circles. From the ulnar center point, a perpendicular line to a line through the dorsal and volar margins of the sigmoid notch is drawn (►**Fig. 1**). The ratio between the dorsal and volar sigmoid notch lines and the distance from the volar sigmoid rim to the intersection point are calculated. No subluxation of the DRU joint was defined using the normal RUR range (42–58%) described by Lo et al.[2,29]

All preoperative and postoperative conventional and CT scans can be accessed through the ICUC Database (http://www.icuc.net/), along with intraoperative photographs and fluoroscopy images/photographs of the final range of motion.

Fig. 1 Postoperative measurement of the radioulnar ratio using computed tomography scan of the wrist.

Surgical Techniques

After having the tourniquet on the arm, we used the conventional volar longitudinal approach in between the FCR tendon and the radial neurovascular bundle. Volar fragments were reduced by manipulation under radiographic visualization using a C-arm, whereas dorsal fragments including the dorsal lunate facet fragment were reduced indirectly through ligamentotaxis. However, adequate anatomical reduction of the dorsal lunate facet fragment was achieved using a bone reduction forceps (Depuy-Synthes) over the volar plate to relocate the fragments, again under radiographic visualization (►**Fig. 2**). Bone reduction forceps is an externally used device comprising a tongue that is placed over the dorsal wrist to press the dorsal distal radius while the other pinpoint tongue is placed onto the VA-LCP to create compression across the fracture (►**Fig. 2**). Provisional fixation was achieved with Kirschner wires inserted through the most distal holes of the VA-LCP, and definite fixation was achieved using locking screws; no attempt was made to specifically catch the dorsal lunate facet fragment. Bone grafting or a carpal tunnel release was not performed. Postoperatively patients were immobilized in a volar splint for 3 to 7 days, and a removable splint was worn for 3 to 4 weeks. Patients were encouraged to pursue pronation and supination of the wrist and finger motions as tolerated from day 1 after surgery. Wrist flexion and extension exercise was started from the first week.

Statistical Analysis

Descriptive statistics were performed, presenting categorical variables as absolute numbers and percentages and continuous variables as mean with standard deviation or as median with interquartile range (IQR) depending on normality. Postoperative wrist motion was represented as percentage of the uninjured wrist. We compared the wrist function in the injured wrist with that in the uninjured wrist using a linear regression for parametric continuous variables and Spearman's rank correlation coefficient for nonparametric continuous variables. We compared the difference in pre- and postoperative articular step or gap using a Wilcoxon signed rank test. Significance was set at the $p < 0.05$ level.

Results

At final follow-up, the flexion, extension, pronation, and supination were 92.1, 96.4, 99.7, and 99.3%, respectively, in the unaffected side ($p < 0.01$) (►**Table 2**). Postoperatively, 48 (80%) patients had no articular gap or step, 4 (6.7%) had an articular step or gap of <1 mm, 6 (10%) had an articular gap or step of 1 to 2 mm, and 2 had an articular step or gap of >3 mm (►**Table 3**). The median preoperative articular gap was 2 mm (IQR: 1.1–3.2 mm), and the postoperative articular gap was 0 mm (IQR: 0–0.7 mm) ($p < 0.01$). The median preoperative articular step was 0 mm (IQR: 0–1.6 mm), and the median postoperative articular step was 0 mm (IQR: 0–0 mm) ($p < 0.01$). The average RUR was $51 \pm 11.6\%$, with 80% of the patients having a RUR ranging between 38 and 68%. In total, 33 (54.1%) patients had no radiographic ulnar subluxation. The average postoperatively achieved volar tilt was -3.9 ± 6.9 degrees; 36.1% of the patients had a volar tilt that was 0 degrees or positive. The average postoperative radial height was 12 ± 3.2 mm. The numeric pain score was 0 in 46 patients, 2 in 7 patients, and 4 in one patient.

Discussion

This study used CT scans to evaluate the reduction of dorsal lunate facet fragment fixation using a standard volar approach with the aid of a bone forceps (►**Fig. 3**). We showed that adequate radiographic reduction is achieved in 87%, without ulnar subluxation in more than half of the patients. Fractures that had an articular gap or step of >1 mm were C2 or C3 fractures in 9 of 12 patients. Furthermore, patients had a good range of motion and few patients had postoperative pain.

However, we need to interpret these results in respect to its strengths and limitations. First, we did not compare patients treated with a bone forceps with those treated without a bone forceps. Second, we only evaluated direct postoperative reduction using CT scans, without evaluating if long-term reduction was maintained. Third, the use of CT scans in all patients to detect dorsal lunate fractures may have overdiagnosed patients.[1,4,32] Fourth, all the measurements were performed by one investigator. Finally, our follow-up limits conclusions

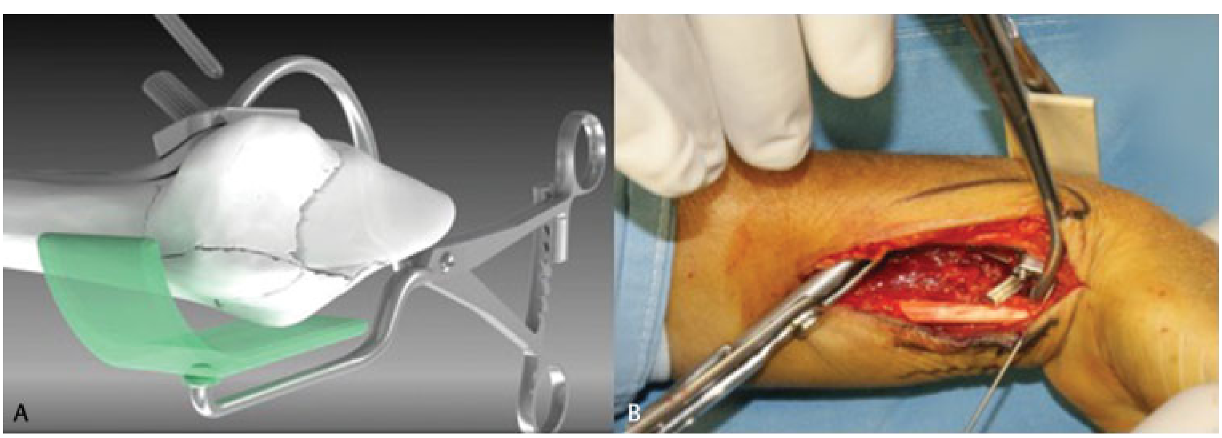

Fig. 2 (**A**) Bone reduction forceps. (**B**) Intraoperative use of a bone reduction forceps.

Table 2 Functional outcomes at final follow-up after surgery

Variable	All patients ($n = 60$)		p-Value	Percentage of uninjured wrist
	Affected wrist	Unaffected wrist		
Wrist extension, mean (SD), degrees	74 (10.7)	77.3 (8.6)	<0.01[a]	96.4
Wrist flexion, mean (SD), degrees	71.5 (15.5)	78.8 (15.5)	<0.01[a]	92.1
Wrist supination, mean (SD), degrees	93.7 (7.4)	94.4 (6.7)	<0.01[b]	99.3
Wrist pronation, mean (SD), degrees	92.7 (8.4)	93.1 (8)	<0.01[b]	99.7

Abbreviation: SD, standard deviation.
[a]Using linear regression.
[b]Using Spearman's correlation.

Table 3 Radiological results

	Prereduction	Postreduction	p-Value
Ulnar subluxation,[a] mean (SD), %	–	51 (11.6)	–
Articular gap, median (IQR), mm	2 (1.1–3.2)	0 (0–0.7)	<0.01[b]
Articular step, median (IQR), mm	0 (0–1.6)	0 (0–0)	<0.01[b]
Volar tilt, mean (SD), degrees	–	–3.9 (6.9)	–
	–		
Radial height, mean (SD), mm	–	12 (3.2)	–

Abbreviations: IQR, interquartile range; SD, standard deviation.
[a]$n = 59$; one patient had prior ulna resection.
[b]Using Wilcoxon's signed rank test.

regarding osteoarthritic changes of the radiocarpal and DRU joint.

In intra-articular distal radius fractures, dorsal lunate facet fragments can be difficult to anatomically reduce.[33] Patients with these fragments tend to have a higher grade of DRU joint osteoarthritis and poorer functional outcomes.[5,34] Vitale et al[5] and Porter and Tillman[35] reported that patients postoperative articular step-off of >1 mm have poorer functional scores at long-term follow-up. Knirk and Jupiter reported that all patients with a gap of >2 mm develop osteoarthritis.[36] However, others showed that the dorsal rim fragments do not influence outcome.[37] Nonetheless, if these fragments are not adequately repaired, it can lead to carpal collapse.[38,39]

Fixation of the dorsal lunate fragments remains challenging. In this study, we used a bone forceps to reduce the dorsal lunate facet fragment with success. Previously, Orbay et al have described an extended volar approach technique to expose the articular surface.[16,40] The standard FCR approach is extended by releasing the radial septum and subperiosteal release of the

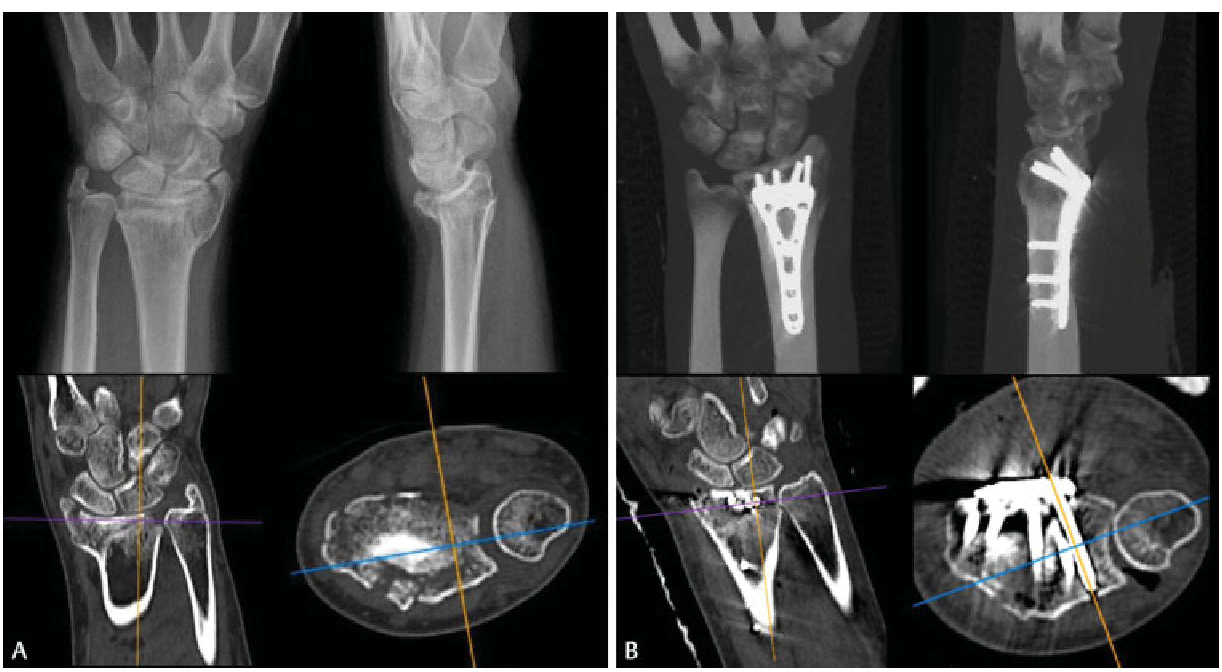

Fig. 3 (A) Preoperative computed tomography showing a distal radius fracture. (B) Postoperative CT showing distal radius fracture reduction.

proximal radial fragment. Then, by pronating the radial shaft, the articular surface is exposed. Another technique to reduce the dorsal ulnar corner has been described by Tsuchiya et al in two patients with B2 fractures. They used a fenestration within the volar radius to reduce the fragment with an elevator. Other proposed approaches using a volar and dorsal approach have also been described.[14,18,38,39,41] The advantage of our technique is that no additional soft tissue or an additional dorsal approach is often not needed. However, if there is dorsal carpal subluxation on intra-operative fluoroscopy after fracture reduction with the volar plate, an additional dorsal approach is often needed.

The use of dorsal plates has a higher risk of extensor tendon rupture or irritation in up to 11%.[3,17,19,26,41–43] Additionally, dorsal plates often require additional plate removal up to 75% compared with 34% after volar plating.[18,19,44] Wei et al confirmed that patients with a dorsal plate had a decreased risk of neuropathy but a higher risk of tendon irritation.[12] The reported clinical and radiographic outcomes were similar to volar plate fixation. A study by Rozental et al reported complications in 75% of the patients treated with pi-plates; these findings confirm reports by Ring et al.[45,46]

In conclusion, volar plate fixation has become the standard treatment of intra-articular fracture fragments with good clinical outcomes.[47–49] Adding a bone forceps to the surgical technique will allow adequate reduction of the dorsal lunate facet fragment without additional morbidity. Further comparisons in outcomes between our proposed technique and other fixation approaches are required, emphasizing the need of fixation of the dorsal lunate facet fragment, along with the safety and efficacy to do so with a full-length screw.

Note
This work was performed at the Department of Orthopedic Surgery, Hand and Upper Extremity Service, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts, United States, in collaboration with the Department of Traumatology, British Hospital, Montevideo, Uruguay.

Authors' Contributions
J. L., J. A., A. K., S. O., and J. B. J. contributed to the study design, J. A., J. L., and A. K. contributed to data assembly, J. A., J. L., and S. O. contributed to data analysis, J. L., J. A., S. O., and J. B. J. contributed to the initial draft, and J. L., J. A., A. K., S. O., and J. B. J. contributed to the final approval of manuscript.

Conflict of Interest
None declared.

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