Fractures of the distal radius: controversies in treatment, rehabilitation and management of complications
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Fractures of the Dorsal Articular Margin of the Distal Part of the Radius with Dorsal Radiocarpal Subluxation
**ABSTRACT**

**Purpose**
Fractures of the volar articular margin of the distal part of the radius with volar radiocarpal subluxation (Barton fractures) are well recognized, and substantial data are available to guide their treatment. In contrast, fractures of the dorsal articular margin of the distal part of the radius with dorsal radiocarpal subluxation (sometimes referred to as dorsal or reverse Barton fractures) are rarely mentioned, and there are very little data to guide their treatment.

**Methods**
Twenty patients with a fracture of the dorsal articular margin of the distal part of the radius with dorsal radiocarpal subluxation were evaluated. A spectrum of volar injuries was observed: two patients had torn volar ligaments; ten had a displaced, rotated volar marginal lip fracture; six had impaction of the volar aspect of the articular surface; and two had no appreciable volar injury. Fourteen of the twenty patients also had impacted central articular fragments. Eighteen patients underwent surgical reconstruction of the articular surface and application of dorsal buttress plates with use of a variety of surgical approaches. At the time of follow-up, the outcome was assessed radiographically and with use of the modified Mayo wrist score and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire.

**Results**
At an average of thirty months postoperatively, nineteen fractures had healed without substantial loss of alignment and one patient had recurrent dorsal subluxation after plate removal. The final average amount of wrist and forearm motion was 59° of flexion, 56° of extension, 87° of pronation, and 85° of supination. The average grip strength was 85% of that of the contralateral, uninjured hand. The final functional result according to the system of Gartland and Werley was rated as excellent or good for eighteen patients and as fair for two. The average modified Mayo wrist score was 75 points, and the average DASH score was 15 points.

**Conclusions**
Fractures of the dorsal articular margin of the distal part of the radius with dorsal radiocarpal subluxation are accompanied by a spectrum of volar injuries, including
ligament injuries, avulsion fractures, and impaction of the articular surface. Despite the relative complexity of these injuries, satisfactory wrist function can be achieved with operative treatment in most patients.

Level of Evidence
Level 4, therapeutic study

INTRODUCTION

In 1838, John Rhea Barton defined the dorsal marginal fracture of the articular surface of the distal end of the radius with associated dorsal dislocation of the carpus as: “a subluxation of the wrist consequent to a fracture through the articular surface of the carpal extremity of the radius... The fragment... usually is quite small, and is broken from the end of the radius on the dorsal side.” (1) Currently, at least in North America, the eponym Barton fracture is used to refer to the more commonly encountered volar shearing fracture of the distal part of the radius (2-7). Dorsal, or reverse, Barton fractures of the distal part of the radius have been discussed in book chapters and review articles, but very few case series have been published (3,8). We describe the spectrum of associated injuries and the functional and radiographic results of treatment in a series of patients with a fracture of the dorsal articular margin of the distal part of the radius and dorsal radiocarpal subluxation.

MATERIALS AND METHODS

Between 1999 and 2003, one surgeon treated twenty-four patients with a fracture of the dorsal articular margin (the dorsal edge of the articular surface) of the distal end of the radius associated with dorsal radiocarpal subluxation or dislocation. Subluxation was defined as a loss of concentric reduction of the radiocarpal articulation. Patients were asked to return for examination and radiographic evaluation according to a protocol approved by our human research committee. One patient could not be located and three declined to participate, leaving twenty patients available for study. Informed consent was obtained from each patient.

There were fourteen men and six women with an average age of thirty-six years.
(range, twenty to sixty-one years). Nine fractures involved the right wrist and eleven, the left. Fifteen dominant hands were affected. Before the injury, ten patients were employed at desk-based work, eight were laborers, one was a homemaker, and one was a student. Four patients were injured in a motor-vehicle collision; six, in a fall from a standing height; six, in a fall from a greater height; and four, during sports activity. Three patients had multiple injuries, and four others had additional injury involving the ipsilateral upper extremity. None of the distal radial fractures were open. One patient had an associated open elbow fracture, classified as Grade IIIC (disruption of the brachial artery) according to the criteria described by Gustilo and Anderson(9).

According to The Comprehensive Classification of Fractures of Long Bones(10), two patients had a Subtype-B2.1 fracture; three, B2.2; three, B2.3; one, C1.2; and eleven, C3.2. According to the Fernandez classification system(11), eleven patients had a Type-2 fracture and two had a Type-3 fracture. Several fractures overlapped two categories: two were classified as Type 2 or 4 and five, as Type 4 or 5.

Figures 1-A, 1-B, and 1-C. A sixty-one-year-old woman sustained a fracture of the distal part of the radius in a fall from a standing height. (Reprinted with permission of David Ring.) Fig. 1-A The injury was best characterized on a lateral radiograph of the wrist. Note the dorsal marginal shearing fracture, dorsal radiocarpal subluxation, and volar impaction of the majority of the articular surface as a single, large volar fracture fragment. The radial styloid was also fractured. Fig. 1-B Internal fixation was performed, through a dorsal exposure, with use of 2.4mm locking compression plates. Fig. 1-C A radiograph made after implant removal demonstrates a neutral palmar tilt and restoration of the alignment of the hand with the wrist.
Radiographs, computed tomographic scans (of fifteen patients), and operative exposure (in nineteen patients) demonstrated, in addition to the dorsal marginal articular fracture, a radial styloid fracture in eighteen patients, central articular impaction in fourteen, radiocarpal dislocation (rather than just subluxation) in two, and a volar fracture in sixteen. In six patients, the volar metaphyseal cortex was relatively nondisplaced and the fracture displacement consisted of volar tilting of the majority of the articular surface as a single large fragment. Ten patients had a small, widely displaced, and rotated fragment, representing a type of avulsion fracture of the volar radiocarpal ligaments. Two patients had an associated intercarpal injury: one had a rupture of the scapholunate interosseous ligament, and one had a scaphoid fracture. Six patients had an associated fracture of the ulnar styloid process.

*Figures 2-A, 2-B, and 2-C.* A twenty-nine-year-old woman sustained a fracture of the distal part of the radius in a motor-vehicle collision. (Reprinted with permission of David Ring.) Fig. 2-A A lateral radiograph shows a dorsal marginal shearing fracture with dorsal radiocarpal subluxation and a small, widely displaced and rotated volar fracture fragment. Fig. 2-B A combined dorsal and volar exposure was used for internal fixation. The dorsal fragment and the radial styloid were repaired with 2.0-mm plates and screws. The volar fracture fragment was realigned and was secured with a volar wire loop. Fig. 2-C A lateral radiograph made after implant removal shows a relatively neutral alignment of the articular surface and restoration of the alignment of the hand with the wrist.
The injuries were grouped into one of four overall patterns on the basis of the injury characteristics described above.

The volar impaction pattern (observed in six patients) consisted of dorsal angulation of a large volar articular fragment, representing the majority of the radiocarpal articular surface with a relatively well-aligned volar cortical fracture (Figs. 1-A, 1-B, and 1-C).

The displaced, rotated volar fragment pattern (present in ten patients) consisted of a fractured volar fragment, representing the origin of the long and short radiolunate ligaments—an alternative to rupture of these ligaments (Figs. 2-A, 2-B, and 2-C).

The central impaction pattern (observed in two patients) was characterized by central articular impaction in addition to the dorsal marginal shearing fracture, without volar fracture or volar ligament disruption (Figs. 3-A, 3-B, and 3-C).

Figures 3-A, 3-B, and 3-C. A forty-four-year-old man sustained a fracture of the distal part of the radius in a fall from a height. (Reprinted with permission of David Ring.) Fig. 3-A The initial lateral radiograph demonstrated a dorsal marginal shearing fracture, some central articular impaction, and dorsal radiocarpal subluxation. Fig. 3-B Dorsal exposure, realignment and support of the articular surface, and stable internal fixation were achieved with a dorsal pi-shaped plate and replacement of the displaced metaphyseal bone. Fig. 3-C A lateral radiograph made after implant removal shows restoration of good alignment.
Finally, the radiocarpal fracture-dislocation pattern (observed in two patients) consisted of complete dislocation of the lunate from a relatively intact lunate facet of the distal part of the radius (Figs. 4-A and 4-B).

Figures 4-A and 4-B. A thirty-eight-year-old man sustained a fracture of the distal part of the radius in a fall from a height. (Reprinted with permission of David Ring.) Fig. 4-A The radiograph made after the injury shows a dorsal radiocarpal dislocation with a dorsal marginal shearing fracture. Operative exposure demonstrated avulsion of the volar radiocarpal ligaments from the lunate surface of the distal part of the radius. All of the injured structures were repaired with use of a combined dorsal and volar approach. The ulnar styloid was repaired through a separate incision.

Nineteen patients were treated operatively, and one patient declined operative treatment. Of the nineteen patients who received operative treatment, eleven were treated through a dorsal exposure alone, seven were treated through a combined dorsal
and volar exposure, and one was treated through a volar exposure alone.

For dorsal exposure, a longitudinal incision over the distal part of the radius and radiocarpal joint was made in line with the third metacarpal. The extensor pollicis longus was mobilized from the third dorsal compartment, and the tendons of the second and fourth dorsal compartments were mobilized. The dorsal marginal fragments were mobilized along with the dorsal capsule so that they could be reflected distally. In most patients, a small longitudinal capsulotomy between dorsal fragments was made to improve exposure of the radiocarpal articulation.

Fourteen patients had impacted central articular fragments. Relatively small fragments were discarded in four patients, and the impacted articular fragments were retained and realigned in ten patients. In five patients, these fragments were very thin osteochondral wafers with very little subchondral bone. The resulting defects were filled with autogenous cancellous bone graft from the iliac crest in two patients and with local bone that had been displaced in the injury and collected during the operative exposure in the remaining patients. Seven patients had temporary intraoperative distraction with a skeletal distractor or an external fixator. In two patients, the external fixator was left in place for three weeks.

Implants applied to the dorsal surface of the distal part of the radius included twelve stainless-steel pi-shaped plates, two titanium 2.4-mm locking compression plates, and four titanium 2.0-mm T-shaped plates (all made by Synthes, Paoli, Pennsylvania).

Volar exposure was performed with use of a volar Henry exposure. The wrist capsule was not incised; the fracture fragments were occasionally mobilized to enable examination of the articular surface. Implants applied to the volar surface of the distal part of the radius included six titanium 2.4-mm volar plates, one titanium 2.0-mm plate, and two stainless-steel volar wire loops. The postoperative dressing incorporated a volar plaster splint for the seventeen patients without external fixation. The plaster splint was changed to a removable plastic splint at the time of suture removal, and the plastic splint was worn for an additional two to four weeks. Active-assisted exercises of the digits and forearm were initiated on the morning after the surgery. Functional use of the hand for light daily activities was encouraged. Active-assisted exercises of the wrist were initiated when use of the volar splint was discontinued. Strengthening was initiated at six weeks after the operation.

Complications and Additional Surgical Procedures
The patients were advised to have the dorsal plate removed, and only one declined. The
plates were removed between three and nineteen months (average, seven months) after the surgery. One patient had recurrent dorsal subluxation of the radiocarpal joint after removal of the dorsal plate at eight months after the injury.

**Evaluation**

The final evaluation was performed by one of us (S.A.L.-C.) who was not involved in the care of the patients. Each patient completed the DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire (12). Grip strength was measured bilaterally and represented the average of three attempts with a Jamar dynamometer (Asimow Engineering, Los Angeles, California) set at the third station, with the elbow in 90° of flexion and the wrist and forearm in neutral. A final rating was assigned according to the modified Mayo wrist score (13) and the modification of the Gartland and Werley score (14) by Sarmiento et al (15). Digital stiffness was evaluated according to the distance from each fingertips to the distal palmar crease with the digit in maximum flexion.

The radiographic results were evaluated on images made at the time of final follow-up. Radiographic signs of posttraumatic osteoarthrosis were rated according to the system of Knirk and Jupiter (16). With that system, Grade 0 indicates no evidence of arthrosis; Grade I, slight narrowing of the joint space; Grade II, marked narrowing of the joint space and formation of osteophytes; and Grade III, complete loss of the joint space with bone-to-bone contact as well as formation of marginal osteophytes and subchondral cysts.

**Results**

The final evaluation was performed after all additional surgical procedures had been carried out, and at an average of thirty months (range, twelve to sixty months) after the initial surgery. Sixteen patients had mild pain, three had moderate pain, and one had severe pain as rated according to the modified Mayo wrist score. Twelve patients had no pain at rest, and ten had no pain with activity. No patient had pain related to forearm motion. None of the patients, including the one with recurrent dorsal dislocation, had symptoms or signs referable to instability of the wrist or the distal radioulnar joint.

The final average amount of wrist motion was 59° (range, 30° to 85°) of flexion, 56° (range, 35° to 80°) of extension, 31° (range, 15° to 50°) of radial deviation, and 35°
(range, 10° to 50°) of ulnar deviation. The final average amount of forearm motion was 87° (range, 80° to 90°) of pronation and 85° (range, 66° to 90°) of supination. All patients could easily touch each fingertip to the distal palmar crease at the final evaluation. The final grip strength averaged 78 lb (35.4 kg) (range, 18 to 140 lb [8.2 to 63.5 kg]). This represented an average of 85% (range, 50% to 110%) of the grip strength of the contralateral, uninvolved hand.

All fractures healed and there were no loose or broken implants. The final average radiographic measurements were 18° (range, 7° to 28°) of ulnar inclination, 4° (range, 0° to 15°) of dorsal tilt of the articular surface on the lateral radiograph, and 1 mm of ulnar negative variance (the ulna shorter than the radius) (range, 3 mm of ulnar negative variance to 2 mm of ulnar positive variance). One patient had residual dorsal radiocarpal subluxation. Five patients had radiographic signs of arthrosis, which was Grade I in two of them, Grade II in two, and Grade III in one (the patient with residual subluxation).

The average score on the DASH questionnaire was 15 points (range, 0 to 37 points). According to the modification of the Gartland and Werley system (14) by Sarmiento et al (15), six patients (30%) had an excellent result, twelve (60%) had a good result, and two (10%) had a fair result. The average Mayo wrist score was 75 points (range, 55 to 90 points). The categorical ratings according to the Mayo wrist score were excellent (90 to 100 points) for one patient, good (80 to 89 points) for eight patients, fair (65 to 79 points) for ten patients, and poor (<65 points) for one patient.

**DISCUSSION**

There is a paucity of published data regarding fractures of the dorsal articular margin of the distal part of the radius with dorsal radiocarpal subluxation (3,8,17-19). This may be due in part to the relatively low prevalence of fractures with these characteristics (estimated to be between 0.5% and 1.6% of all fractures of the distal part of the radius (17,19,20). It may also be due to the fact that some consider these injuries to be radiocarpal fracture-dislocations or complex articular fractures (21-28). Volar marginal articular fractures (Barton fractures) have a consistent and characteristic appearance that is easily identified. In contrast, dorsal marginal articular fractures occur in association with a variety of volar injuries and a spectrum of radiocarpal subluxation.
As a consequence, they are not as easily identified as belonging to a particular group of fractures. As with all uncommon injuries, scientific inquiry has thus far been limited to retrospective case series, as it was in this paper, and the numerous limitations of this type of study must be kept in mind. In particular, the proposal that these fractures are the result of a primary shearing mechanism \(^\text{(11)}\) seems plausible but remains speculative.

We included these fractures in one group on the basis of the presence of both (1) a fracture of the dorsal articular margin of the distal end of the radius and (2) dorsal radiocarpal subluxation or dislocation. We observed four general patterns of injury that included those two characteristics: (1) impaction of the majority of the distal radial articular surface with a relatively intact volar metaphyseal fracture line; (2) radiocarpal fracture-dislocation with rupture of the radiolunate ligaments (true radiocarpal dislocation); (3) radiocarpal fracture-dislocation with fracture of the volar portion of the lunate facet where the radiolunate ligaments originate; and (4) central articular impaction with relative sparing of the radial styloid and the volar most portion of the lunate facet. These features are not well described in existing classification systems. Many patients with a dorsal marginal articular fracture have a combination of fracture characteristics (dorsal marginal shearing fracture with central articular impaction) that may be better treated with a dorsal exposure and fixation, whereas others have fracture characteristics (a rotated volar lunate facet fragment) that may be better treated with a volar exposure and fixation. The dorsal exposure is useful for direct visualization and manipulation of the articular surface, particularly when there is central impaction, and for buttressing of the dorsal marginal articular fragment. The volar exposure is helpful for realignment and internal fixation of displaced volar fragments. In particular, small avulsion-type fractures of the volar lip of the lunate articular facet can be very challenging to repair, and techniques incorporating small wires or sutures that engage the wrist capsule are useful \(^\text{(29)}\) (Figs. 2-A, 2-B, and 2-C). Some patients in whom the majority of the articular surface is impacted into a dorsally angulated position, with a relatively nondisplaced volar metaphyseal fracture line and no central articular impaction, can be treated through a volar exposure alone. However, in general, it is difficult to treat dorsal shearing fractures of the distal part of the radius without dorsal exposure and fixation.

Dorsal marginal articular fractures are seen in relatively young patients (average age, thirty-six years in the present series) and are high-energy injuries. We have found that the metaphyseal bone is usually fragmented and spread throughout the zone of injury during displacement. If all of this metaphyseal bone is carefully collected during the
exposure of the fracture, it is usually sufficient to place this bone into the metaphyseal defect created by fracture realignment in order to support the articular fragments. Dorsal metaphyseal cortical fragments do not provide much structural support, and they can also be morselized and used to help fill the metaphyseal defect. In our opinion, the potential support of the articular surface provided by implants with multiple fixed-angle (locking) screws may further decrease the need for bone graft or bone-graft substitutes.

As might be expected with this pattern of fracture, relative shortening of the radius with respect to the ulna was not a problem. However, restoration of the normal palmar tilt of the distal part of the radius was extremely challenging. When an attempt was made to restore the alignment of the articular surface and achieve stable internal fixation, it was difficult to also restore palmar tilt, probably as a result of dorsal metaphyseal comminution with relatively intact volar metaphyseal support. Neutral alignment was the goal, which seems reasonable given the results in this series.

The average DASH score in our study was similar to the average DASH score that was observed in a large cohort of consecutive patients with any type of fracture of the distal part of the radius (30). However, the modified Mayo wrist scores, which are based on relatively strict criteria, indicated unsatisfactory results in more than half of the patients. That finding demonstrates the severity of the injury and the permanent impairment that should be anticipated after treatment of these complex injuries.

In conclusion, fractures of the dorsal margin of the articular surface of the distal part of the radius associated with dorsal radiocarpal subluxation or dislocation should be carefully evaluated for the presence of volar ligament injury or volar avulsion fracture, central articular impaction, and impaction of the majority of the articular surface as a large volar fragment. A combined dorsal and volar exposure is often necessary for these injuries because the central articular impaction and the dorsal marginal shearing fracture may be best treated through a dorsal exposure in internal fixation and the volar ligament injuries or avulsion fracture require a volar exposure and fixation. Despite the relative complexity of these injuries, satisfactory wrist function can be achieved in most patients.
REFERENCES


