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**Publisher Information**  
The Journal of Bone and Joint Surgery  
20 Pickering Street, Needham, MA 02492-3157  
www.jbjs.org
Loss of Fixation of the Volar Lunate Facet Fragment in Fractures of the Distal Part of the Radius

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Investigation performed at the Department of Orthopaedic Surgery, Massachusetts General Hospital, Boston, Massachusetts; Miami Hand Center, Miami, Florida; Department of Orthopaedic Surgery, New York University-Hospital for Joint Diseases, New York City; and Department of Orthopaedic Surgery, Lindenhofspital, Bern, Switzerland

Background: The purpose of the present study is to report on a cohort of patients with a volar shearing fracture of the distal end of the radius in whom the unique anatomy of the distal cortical rim of the radius led to failure of support of a volar ulnar lunate facet fracture fragment.

Methods: Seven patients with a volar shearing fracture of the distal part of the radius who lost fixation of a volar lunate facet fragment with subsequent carpal displacement after open reduction and internal fixation were evaluated at an average of twenty-four months after surgery. One fracture was classified as B3.2 and six were classified as B3.3 according to the AO comprehensive classification system. All seven fractures initially were deemed to have an adequate reduction and internal fixation. Four patients required repeat open reduction and internal fixation, and one underwent a radiocarpal arthrodesis. At the time of the final follow-up, all patients were assessed with regard to their self-reported level of functioning and with use of Sarmiento’s modification of the system of Gartland and Werley.

Results: At a mean of two years after the injury, six patients had returned to their previous level of function. The result was considered to be excellent for one patient, good for four, and fair for two. The average wrist extension was 48°, or 75% of that of the uninjured extremity. The average wrist flexion was 37°, or 64% of that of the uninjured extremity. The one patient who underwent radiocarpal arthrodesis had achievement of a solid union. The four patients who underwent repeat internal fixation had maintenance of reduction of the lunate facet fragment. The two patients who declined additional operative intervention had persistent dislocation of the carpus with the volar lunate facet fragment.

Conclusions: The stability of comminuted fractures of the distal part of the radius with volar fragmentation is determined not only by the reduction of the major fragments but also by the reduction of the small volar lunate fragment. The unique anatomy of this region may prevent standard fixation devices for distal radial fractures from supporting the entire volar surface effectively. It is preferable to recognize the complexity of the injury prior to the initial surgical intervention and to plan accordingly.

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

Displaced intra-articular fractures of the distal end of the radius represent complex injuries because of the small size of the fracture fragments and their interrelationship with radiocarpal and radioulnar kinematics. While the morphology of the articular disruption may vary widely, it has become apparent that fractures involving the volar lunate facet articular fragment, as emphasized initially by Melone, are among the more difficult articular injuries to treat effectively. This difficulty is due, in part, to the normal anatomy of the volar aspect of the distal part of the radius. The volar surface of the distal part of the radius is relatively flat, except for the very distal margin, which slopes volarly to form a ridge from which the volar radiocarpal ligaments originate (Fig. 1). When viewed in the axial plane in cross-section, it is apparent that the distal cortical margin slopes volarly from radial to ulnar (Fig. 2). This, in turn, may prevent a volar-based fixation plate from providing equal support of both the scaphoid and lunate volar cortical margins.

The volar lunate fragment has been difficult to maintain in a reduced position when treated as an isolated fracture with a cast or splint and when treated as part of a comminuted distal radial fracture. To our knowledge, no
reports have documented loss of fixation of the lunate facet fragment after internal fixation of a volarly displaced shearing fracture of the distal part of the radius. The present report describes a series of seven patients who had a volar shearing fracture of the distal part of the radius that was characterized by two or more articular fragments and in whom standard volarly applied plates failed to support the realignment of a marginal lunate facet fracture fragment. This experience illustrates that, because of the unique anatomy of the very distal aspect of the volar part of the radius, standard distal radial implants may not support both the scaphoid and lunate facets equally well.

Materials and Methods

Over a ten-year period, in the combined practices of the authors, seven patients with a volar shearing fracture of the distal part of the radius that had been treated operatively with volar plate fixation demonstrated loss of reduction of a volar ulnar lunate facet fragment. The data on the patients were obtained by means of a retrospective review of the charts and plain radiographs under a protocol approved by the human research committee (Table I). The patients included four men and three women with an average age of 51.4 years (range, thirty-eight to seventy-one years). In four patients, the injury involved the dominant limb. Six patients were actively employed (as a chiropractor, gardener, lawyer, engineer, secretary, and interior decorator), and one was retired. Associated medical comorbidities included hypertension in three patients and rheumatoid arthritis in one.

Five fractures resulted from a fall from a standing height, one resulted from a sports-related injury, and one resulted from a motorcycle accident. Six fractures were classified as type B3.3 and one was classified as type B3.2 according to the AO comprehensive classification system. Three patients had an associated ulnar styloid fracture, one of which was associated with a high-energy injury mechanism (a motorcycle accident). None of the patients with an ulnar styloid fracture had instability of the distal radioulnar joint. All of the fractures were closed.

The indication for the initial operation was unacceptable closed reduction with volar displacement of the radiocarpal articulation. A standard AO/ASIF volar distal radius T-plate (Synthes, Paoli, Pennsylvania) was used in five patients, and a volar DVR locking plate (Hand Innovations, Miami, Florida) was used in two. In one patient, supplemental radial styloid fixation was obtained with a cancellous screw. None of the ulnar styloid fractures were treated operatively.

A retrospective review of the initial postoperative
radiographs revealed an anatomic reduction of the volarly displaced fragments and radiocarpal articulation in each patient. In addition, there was acceptable placement of the implant volarly, with the distal part of the limb in line with the radial inclination of the distal part of the radius, in each patient. No patient was managed with a cast, and all patients began active motion within two weeks after surgery. Follow-up radiographs revealed loss of reduction of the volar lunate facet fragment in all seven patients and associated radiocarpal subluxation in four patients (Cases 1, 2, 4, and 5). While operative treatment was offered to all seven patients, two (Cases 1 and 2) declined additional intervention because they were relatively pain-free and did not object to the visible wrist deformity.

Five patients elected to undergo repeat surgery. The interval between the initial operative procedure and the reoperation varied widely, reflecting the fact that four of these patients were treated at an outside institution. The average time to reoperation was sixty days (range, nine to 146 days). By virtue of the duration of the time before presentation as well as associated findings at the time of surgery, a variety of reconstructive procedures were required. In four patients (Cases 3, 4, 5, and 7) the displaced lunate facet fragment could be reduced and supported with a new volarly applied plate or
screw. In two of these patients (Cases 5 and 7), a scapholunate dissociation also was noted and was treated operatively with direct ligament repair. In one patient (Case 4), additional external fixation was applied for eight weeks.

The last patient who was treated operatively (Case 6) had articular incongruity and an inability to maintain reduction of the radiocarpal articulation, which led to the decision to perform a radioscapholunate arthrodesis. One patient (Case 5) required removal of percutaneous Kirschner wires at eight weeks postoperatively, one patient (Case 6) required hardware removal after healing at the site of a radioscapholunate arthrodesis, and one patient (Case 7) underwent removal

<table>
<thead>
<tr>
<th>Case</th>
<th>Modified Gartland-Werley Score*</th>
<th>Clinical Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 (Good)</td>
<td>Works 40 hr/wk</td>
</tr>
<tr>
<td>2</td>
<td>8 (Good)</td>
<td>Occasional scar sensitivity, works without pain</td>
</tr>
<tr>
<td>3</td>
<td>2 (Excellent)</td>
<td>Occasional pain with exertion</td>
</tr>
<tr>
<td>4</td>
<td>7 (Good)</td>
<td>Same as preoperative status</td>
</tr>
<tr>
<td>5</td>
<td>16 (Fair)</td>
<td>Same as preoperative status</td>
</tr>
<tr>
<td>6</td>
<td>18 (Fair)</td>
<td>Daily activities/no chiropractic manipulations</td>
</tr>
<tr>
<td>7</td>
<td>8 (Good)</td>
<td>Full activities</td>
</tr>
</tbody>
</table>

*The score is given, in points, according to Sarmiento’s modification\(^{17}\) of the system of Gartland and Werley\(^{18}\). The corresponding rating of the score is given in parentheses.
of a scapholunate screw four months after repair of the scapholunate interval. There were no infections or episodes of nerve dysfunction.

**Evaluation**

The final functional result was rated by the physician according to Sarmiento's modification\(^{17}\) of the system described by Gartland and Werley\(^{18}\). The grip strength on the involved side was measured as the average of three attempts at maximal grip with a Jamar dynamometer (Asimow Engineering, Los Angeles, California) and was expressed as a percentage of that on the contralateral, uninjured side. The final radiographs were evaluated by a single observer according to Sarmiento's modification\(^{19}\) of the system of Lidstrom\(^{20}\). Radiographic signs of arthrosis were rated, according to the system of Knirk and Jupiter\(^1\), as grade 0 (no arthritis), grade 1 (slight joint-space narrowing), grade 2 (marked joint-space narrowing, osteophyte formation), and grade 3 (bone-on-bone contact, osteophyte formation, cyst formation). Articular congruity was assessed according to the method of Knirk and Jupiter\(^1\). Step-off was classified as grade 0 (0 to 1 mm), grade 1 (1 to 2 mm), grade 2 (2 to 3 mm), or grade 3 (>3 mm).

**Results**

The average duration of follow-up was 24.4 months (range, five to seventy-two months). Six patients returned to their self-reported preoperative level of function. All patients but one returned to their previous level of employment and exercise capacity. One patient (Case 2) complained of occasional scar sensitivity but worked without pain. Another (Case 3) complained of occasional pain with heavy exertion. One patient (Case 6) who worked as a chiropractor did not have a return to full use of the wrist for manipulations after radioscapoholunate arthrodesis.

**Clinical Evaluation**

The average wrist extension was 48° (range, 35° to 65°), or 75% of that of the uninjured extremity. The average wrist flexion was 37° (range, 20° to 50°), or 64% of that of the uninjured extremity. The average supination and pronation were 75° (range, 70° to 80°) and 75° (range, 65° to 80°), respectively. The average radial and ulnar deviation were 14° (range, 5° to 20°) and 15° (range, 5° to 30°), respectively.

The average grip strength was 29 kg (range, 18 to 40 kg) on the injured side, compared with 40 kg (range, 23 to 65 kg) on the uninjured side. The grip strength on the injured side...
was an average of 77% (range, 62% to 96%) of that on the un-
injured side.

When the five patients who underwent repeat internal fix-
ation were compared with the two who were treated nonopera-
tively, no considerable difference was noted with regard to the
range of motion of the wrist. In fact, the average flexion-exten-
sion arc for the two patients with persistent volar dislocation of
the carpus was equal to the average arc for the entire group of
patients. The grip strength, expressed as a percentage of that
on the uninjured side, was 88% for these two patients com-
pared with 71% for the patients who were treated operatively.

According to Sarmiento’s modification\textsuperscript{17} of the system of
Gartland and Werley\textsuperscript{18}, the result was considered to be excel-
lent for one patient, good for four, and fair for two (Cases 5
and 6). One of the fair results was in the patient (Case 6) who
was managed with radiocarpal arthrodesis. In four other patients (Cases 3, 4, 5,
and 7) reduction of the lunate facet fragment was maintained
after repeat reduction and internal fixation. According to
Sarmiento’s modification\textsuperscript{19} of the system of Lidstrom\textsuperscript{20},
the radiographic result was rated as excellent in three patients, good
in one, and fair in two. According to the system of Knirk and
Jupiter\textsuperscript{3}, radiographic signs of arthrosis were rated as grade 0
in one patient, grade 1 in three, and grade 2 in two. According
to the method of Knirk and Jupiter\textsuperscript{3}, the articular congruity
was classified as grade 0 (0 to 1 mm of step-off) in four pa-
tients (Cases 3, 4, 5, and 7) and as grade 1 (1-2 mm step-off)
in two patients (Cases 1 and 2). One patient (Case 6) was not
assessed with regard to the radiographic outcome because of
the performance of a radiocarpal arthrodesis.

**Illustrative Case Report**

Case 4. A fifty-four-year-old man sustained a type-B3.2 volar

 inclination averaged 21° (range, 18° to 25°), and ulnar variance
 averaged −0.4 mm (range, 3 to −3 mm). Two patients (Cases 1
 and 2) who declined a second procedure had persistent disloca-
tion and articulation of the carpus with the volar lunate facet
fragment as well as the volar rim of the distal part of the radius.

In one patient (Case 6), union was achieved after radiocap-
 radiolunate arthrodesis. In four other patients (Cases 3, 4, 5,
 and 7) reduction of the lunate facet fragment was maintained
after repeat reduction and internal fixation. According to
Sarmiento’s modification\textsuperscript{17} of the system of Lidstrom\textsuperscript{20}, the
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Jupiter\textsuperscript{3}, radiographic signs of arthrosis were rated as grade 0
in one patient, grade 1 in three, and grade 2 in two. According
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in two patients (Cases 1 and 2). One patient (Case 6) was not
assessed with regard to the radiographic outcome because of
the performance of a radiocarpal arthrodesis.

**Illustrative Case Report**

Case 4. A fifty-four-year-old man sustained a type-B3.2 volar
shearing injury with an associated ulnar styloid fracture (Figs. 3-A and 3-B). The fracture was stabilized with a volar DVR locking plate (Figs. 3-C and 3-D). After an apparently adequate initial reduction and fixation as determined on the basis of c-arm images made during the operation, the fixation of the volar lunate facet fragment was subsequently lost (Figs. 3-E and 3-F). The carpus dislocated with the fragment volar to the plate. The patient was managed, through a volar approach, with repeat reduction of the volar lunate facet fragment, application of a standard AO/ASIF volar distal radial plate, and placement of a bridging external fixator for additional stability (Figs. 3-G and 3-H). The external fixator was removed after eight weeks, and a good reduction was subsequently maintained (Figs. 3-I and 3-J). After thirteen months of follow-up, the modified Gartland and Werley rating was good and the radiographic score was excellent.

Discussion
The experience described in the present report brings attention to the fact that, while the distal metaphyseal flare of the radius is flat and accommodates standard implants effectively, the very distal cortical margin is not the same when viewed in axial projections. The ulnar volar margin of the lunate facet slopes volarly as viewed from proximal to distal and may not be effectively supported by standard implants. In addition, the volar rim of the distal part of the radius is not straight but slopes volarly from radial to ulnar. This makes fractures of the volar margin of the distal part of the radius a challenge to treat.

On the basis of anatomic and radiographic studies, Mekhail et al. described the profile of the volar margin of the distal part of the radius in the coronal plane as smooth, with a “lazy S” appearance. They found that the ulnar aspect of the volar rim of the radius is convex distally, forming a palmar prominence of the lunate facet. Paley et al. attempted to accurately define the dorsal and volar edges of the distal part of the radius with use of anatomic and radiographic methods. They found that the volar rim of the distal part of the radius is more prominent toward the ulnar side at the volar prominence of the lunate facet and then it tapers off more radially. The volar lunate facet thus extends more distally than one would expect, which may make it more difficult to achieve adequate support with standard volar plate fixation. In addition, the volar aspect of the lunate fossa bears more load than the scaphoid fossa does when the wrist is in a position of function. This force transmission across the volar margin of
the lunate fossa may make it more difficult to control volar lunate fracture fragments with a volarly applied plate.

Anatomical studies by Berger and Landsmeer\(^2\) demonstrated that the short radiolunate ligament originates from the volar margin of the lunate facet and attaches to the volar surface of the lunate. Based on its thickness, this ligament may play a key role in maintaining stability of the radiolunate articulation. A volar shearing fracture with comminution creates a functional radiolunate ligament avulsion, which may lead to instability.

In a previous study, two of us (J.B.J. and D.L.F.) and colleagues\(^6\) demonstrated that the vast majority of volar shearing fractures have two or more articular components. The involvement of the ulnar marginal aspect of the lunate facet may not always be readily apparent on standard preoperative radiographs. Furthermore, the standard operative approach to these fractures has been through the distal limb of the Henry approach\(^6\), which may limit adequate exposure to this region of the distal part of the radius. The deforming forces of the volar distal radioulnar ligament and ulnar radiocarpal ligaments, which attach to the ulnar volar lunate facet fragment, add to the risk of displacement if the fragment is not adequately supported.

The ability to effectively treat the fracture with realignment and stable fixation appears to be predicated on a number of factors. The amount of time that has transpired between the time of recognition and the time of repeat surgery will certainly be a factor. In addition, the size of the displaced fragment may require more than just support with the ulnar end of a T-shaped plate. Consideration should be given to additional support of the fragment with a tension-wire technique as described by Chin and Jupiter\(^8\), with Kirschner wires left flush with the cortical rim and prominent on the dorsal side for later retrieval, with a radiolunate Kirschner wire, or with an external fixator\(^21\).

In conclusion, when evaluating volar shearing fractures, one should heed the presence of a small ulnar lunate facet fragment. When standard radiographs reveal the possibility of such a fragment, two-dimensional and even three-dimensional computed tomographic scans may well provide important additional information preoperatively. Second, when faced with a more complex volar shearing fracture, the surgeon might consider an ulnarily-based incision between the ulnar artery and nerve and the flexor tendons to allow direct access to the volar ulnar corner of the radius\(^11\). Finally, adjuvant fixation of the fragment with a smaller implant placed more distally, or temporary external fixation, may prevent displacement of the volar lunate facet fragment.

References


