# Volar Marginal Rim Fractures of the Distal Radius Have a Higher Rate of Associated Carpal Injuries—A Comparative Cohort Study

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## Abstract

**Background** Volar marginal rim distal radius fractures can be challenging due to volar instability of the carpus. The associated carpal injuries, however, have not previously been reported.

**Purpose** The aim of this study was to compare volar marginal rim fractures to other distal radius fractures to determine if there is any association with other carpal injuries. If so, do these injuries lead to further instability and fixation failure?

**Materials and Methods** A retrospective radiological review of 25 volar marginal rim fractures was conducted. This was compared with a comparison cohort of 25 consecutive intra-articular distal radius fractures not involving the volar marginal rim. All radiographs were reviewed for associated carpal injuries, including carpal and ulnar styloid fractures, scapholunate instability, and carpal translocation.

**Results** Volar marginal rim fractures had a significantly higher incidence of associated carpal injuries per patient (2.52 vs. 1.64), scapholunate diastasis (36 vs. 12%), and carpal dislocation (80 vs. 48%). The fixation chosen was more likely to involve a volar rim-specific plate (44 vs. 0%). Following surgical fixation, the volar marginal rim fractures had a significantly higher incidence of carpal instability (56 vs. 24%), failure of fixation (24 vs. 0%), and revision surgery (12 vs. 0%).

**Conclusions** Volar marginal rim fractures have significantly more carpal injuries, scapholunate instability, and volar carpal instability, compared with other distal radius fractures. Despite the use of volar rim-specific plating, volar marginal rim fractures have a significantly higher incidence of persistent carpal instability, including scapholunate instability, ulnar translocation, volar subluxation, failure of fixation ,and revision surgery.

**Level of Evidence** This is a level III, retrospective review.

**Keywords**
- distal radius fractures
- lunate facet
- volar rim
- carpal injury

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Fractures involving the volar marginal rim are a complex subset of distal radius intra-articular fractures. Volar marginal rim fractures are uncommon, only making up a minority (1–11%) of all distal radius fractures.[1]

The lunate has been described as the keystone to the carpus and is supported by the lunate facet. The lunate facet owes its importance to its load-bearing function as well as the attachment of the radiolunate ligaments, which prevent volar subluxation and ulnar translocation of the carpus.[2] In addition, the volar marginal rim is part of the both the radiocarpal (RC) joint and the distal radioulnar joint (DRUJ).[3] Fractures of the volar marginal rim disrupt the lunate facet and its attachments, and may compromise stability to the entire carpus (►**Fig. 1**).

The aim of treatment of these specific fractures is to provide durable and stable fixation of the volar ulnar corner. Consequently, congruency at the RC joint and DRUJ is maintained, and the lunate "keystone" is supported. Traditionally, this has been performed with a volar buttress plate, and more recently with locking screws. However, some devastating complications have been reported leading to an evolution of fixation methods used to stabilize the volar marginal rim.[4] One such way is the use of specific volar rim plates designed to be positioned distal to the watershed line of the radius.[4]

At our institution, we have noticed several associated carpal injuries in treating these fracture subtypes and, despite advanced plating technology, multiple cases of fixation failure. We hypothesize that fractures of the volar marginal rim of the distal radius are associated with more complex carpal injuries. The aim of this study was to compare volar marginal rim fractures to other distal radius fractures to:

- Determine whether there is an association with other carpal injuries.
- Determine whether this fracture subset has a higher rate of complications such as carpal instability or fixation failure.

## Materials and Methods

This study was reviewed and supported by our institution's Human Research Ethics Committee prior to commencement.

We identified all distal radius fractures requiring operative fixation in our level 1 trauma center in a multiple-surgeon series. All fractures had surgery and follow-up at the same center.

Inclusion criteria for the study group included patients who had an intra-articular distal radius fracture involving the volar marginal rim that was treated with open reduction and internal fixation. All patients were 18 years or older at time of surgery. All patients were included who had suitable preoperative and postoperative electronic radiographs for comparison. All patients had radiographic follow-up at 6 weeks and a minimum follow-up of 12 months. Pathological fractures were excluded.

A comparison cohort was identified of an identical number of other intra-articular distal radius fractures not involving the volar marginal rim. They were matched for demographic data. Other intra-articular distal radius fractures included any other injury where an isolated volar marginal rim fragment did not exist. This could involve fracture line propagation to both lunate facet and scaphoid fossa. Patients older than 18 years of age with the same imaging criteria were included. These fractures were taken sequentially in the same time frame as the volar marginal rim cohort.

Demographics collected included gender, age, mechanism of injury, and fixation method. From the picture archiving and communication system, preoperative, intraoperative, and postoperative images were assessed. Separate pre- and postoperative observations were made by two independent observers with the mean result taken. This was repeated 6 months after initial recording to confirm inter- and intra-observer reliability. Postop immobilization involved 6 weeks in a short arm cast for volar marginal rim fractures. In the

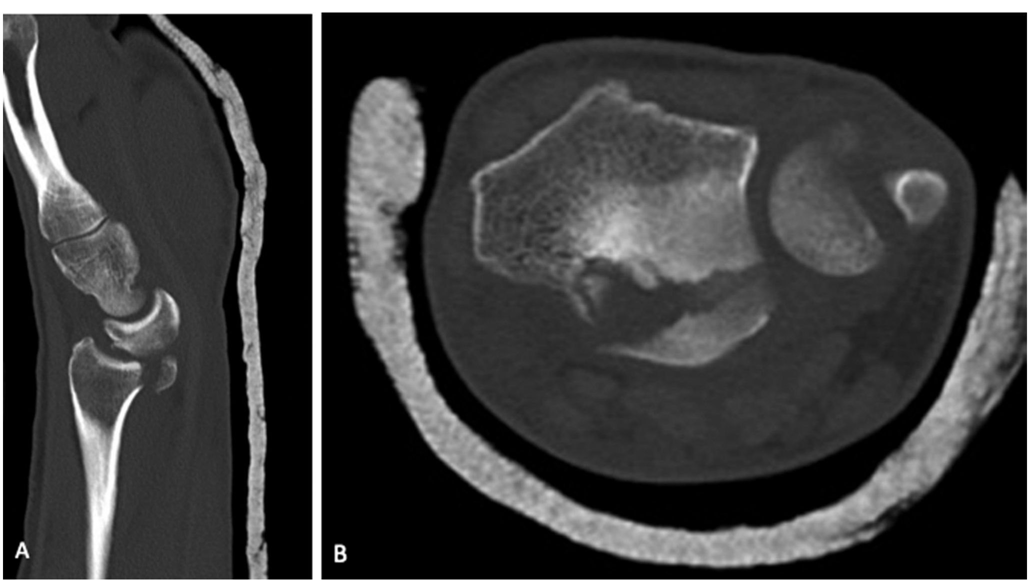


**Fig. 1** (A, B) Example of volar marginal rim fracture of the distal radius with resulting volar subluxation of the carpus.

 

other intra-articular distal radius fracture group, if fixation was deemed rigid enough, a gentle range of motion with a removable splint was allowed at 2 weeks postop. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines in the presentation of our data.

### Carpal Measurements

The radiological methods used to define and measure carpal injuries included;

### Scapholunate Joint

Scapholunate distance was measured both proximally and distally at the joint as the ulnar-most point of scaphoid cortex to the radial-most point of the lunate.[5] A scapholunate distance of over 3 mm was considered abnormal and recorded as diastasis. The scapholunate angle was measured at an intersecting line between the axis of the lunate through midpoints of convex proximal and concave distal joint surfaces and the axis of the scaphoid. It can best identified by finding the perpendicular to a line joining the distal palmar and dorsal borders of the bone.[6] A scapholunate angle over 70° was noted as increased and suggestive of a dorsal intercalated segmental instability (DISI) deformity.[7]

### Reduction of the Lunate Facet

The teardrop angle was used to assess adequacy of fracture reduction measured by the "arc method."[8] A circle was drawn to match an arc of the articular surface of the volar lunate facet fragment. A line tangent to the circle was drawn, passing through the volar margin of the subchondral bone. The teardrop angle was the angle formed between a line tangent to the circle and a line extended from the central axis of the radius.[8]

### Carpal Translocation

There is debate as to the most accurate method of measuring carpal translocation. Therefore, we used three methods to compare interobserver reliability of these methods and to improve accuracy of diagnosis. The relation of the lunate or capitate to the distal radius or the lunate facet of the distal radius can be measured. However, measurement using the position of the capitate includes the status of the midcarpal joint, whereas the measurement of ulnar translocation of the lunate incorporates the scapholunate and RC ligaments.

Bouman et al defined the ulnar translocation ratio as the distance from the radial styloid to the ulnar-most aspect of the distal radial articular surface divided by the distance to the ulnar-most aspect of the lunate.[9] A normal Bouman ratio is $0.87 \pm 0.04$.[9]

The method described by Gilula and Weeks utilizes a ratio of the uncovered lunate (distance between the ulnar-most point of the lunate to a line at the ulnar-most point of the lunate facet) compared with the full width of the lunate as a percentage.[10] Carpal translocation was defined as a ratio >44% in a posteroanterior neutral view.[11]

The Schuind method used perpendicular lines brought from the proximal radial edge and the ulnar-most edge of the lunate. Parallel to these lines, another line was drawn on the ulnar-most aspect of the radius. All lines were placed parallel to the radius long axis.[12] It was noted postoperatively if these were performed in a neutral or radially deviated position as this is known to affect the measurements. Carpal translocation was defined as a ratio >47%.[11]

### Other Injuries

Other injuries noted included ulnar styloid fracture (tip or base), DRUJ incongruence, radio-lunate subluxation or dislocation postoperatively, and any other injuries found on computed tomography (CT) or magnetic resonance imaging (if performed). Any other associated carpal injuries were identified and documented.

"Failure" was defined as loss of fixation of the fragments, or loss of position of the carpus on postoperative imaging.

### Statistical Analysis

Categorical data were analyzed using the Chi-squared test. Intragroup continuous data were analyzed using paired *t*-test and intergroup continuous data were analyzed using unpaired *t*-test. All *p*-values $<0.05$ were considered significant. Intraclass correlation coefficient was 0.860 (95% confidence interval: 0.724–0.932), suggesting excellent agreement between observers.

## Results

### Demographics

There were 25 distal radius fractures that were eligible for inclusion in the volar marginal rim group. This was compared with a comparison group of 25 intra-articular distal radius fractures undergoing operative fixation at the same institution during the timeframe. The two groups had no significant difference in mean age, gender, or mechanism of injury. Full demographics are presented in ►**Table 1**. The preoperative and 6-week postoperative radiographs were used for measurement of angles and distances. The mean follow-up was 41 months in both groups (31–48 months).

For the volar marginal rim group, the surgeon was more likely to use the volar rim specific plate (44 vs. 0%, $p < 0.001$) or a bridging plate (8 vs. 0%). Two patients also had external fixation and one had wrist arthroscopy as part of the assessment.

### Preoperative Results

Preoperative results are presented in ►**Table 2**. A higher incidence of scapholunate diastasis ($p = 0.047$) and greater mean scapholunate interval ($p = 0.027$) were seen in the volar marginal rim group; however, there were no significant differences in scapholunate angle or DISI deformity (►**Table 2**). Significantly more associated carpal injuries were seen in the volar marginal rim group (2.52/patient), compared with the nonvolar marginal rim group (1.64/patient) ($p = 0.0048$). There was a similar presence of ulnar styloid fracture and DRUJ incongruence. There was significantly more preoperative carpal dislocation ($p = 0.018$) associated with the volar marginal rim fracture group (80 vs.



 

**Table 1** Demographic data of volar marginal rim and nonvolar marginal rim fracture groups

| | Volar marginal rim group ($n = 25$) | Nonvolar marginal rim group ($n = 25$) | *p*-Value |
|---|---|---|---|
| Mean age (range), y | 53.7 (23–86) | 55.4 (18–84) | |
| Gender, % female | 40 | 68 | 0.89 |
| Mechanism of injury, % low impact | 48 | 68 | 0.15 |
| AO/OTA classification, % type 2R3B3.3 | 84 | 76 | 0.48 |
| Treatment, *n* | | | |
| Fixed angle volar plate | 7 | 10 | 0.37 |
| Variable angle volar plate | 5 | 15 | **0.003** |
| Volar rim specific plate | 11 | 0 | <**0.001** |
| Bridging plate | 2 | 0 | 0.52 |

Note: Significant *p*-values are in bold.

48%). No associated scaphoid fractures or perilunate dislocations were noted.

### Postoperative Results

Postoperative results are presented in ►**Table 3**. There was a significantly greater incidence of carpal instability in the volar marginal rim group (56 vs. 24%, $p = 0.02$). There was a significantly greater scapholunate interval in the volar marginal rim group ($p = 0.039$). There was a higher incidence of scapholunate diastasis (24 vs. 8%), ulnar translocation (28 vs. 16%) (►**Fig. 2**), and volar subluxation (4 vs. 0%); however, these differences were not significant.

The mean teardrop angle between the groups was similar ($p = 0.255$); however, both were below normal values quoted in the literature.

### Fixation Failures

There was a significantly higher rate of fixation failure in the volar marginal rim group (24 vs. 0%, $p = 0.009$). This was not dependent on specific volar marginal rim plate usage ($p = 0.54$). Four of the six fixation failures occurred within the first 2 weeks following surgery. Fixation failure involved escape of the volar marginal rim fragment after fixation in four cases, one case of articular collapse, and one case with broken wires, recurrent scapholunate diastasis and ulnar carpal translocation following scapholunate ligament fixation. All four cases with volar marginal rim fragment escape were plated with standard variable angle locking plates with escape of the fracture either distally over the plate or around the ulnar side of the plate. ►**Fig. 3** shows an example of volar marginal rim fragment escape following fixation.

**Table 2** Preoperative radiological results

| Measurement | Volar marginal rim group ($n = 25$) | Nonvolar marginal rim group ($n = 25$) | *p*-Value |
|---|---|---|---|
| Scapholunate injury | | | |
| SL interval (mm), mean (SD) | 2.97 (1.09) | 2.31 (1.02) | **0.027** |
| SL diastasis (>3 mm), *n* (%) | 9 (36%) | 3 (12%) | **0.047** |
| SL angle, mean (SD) | 64.8° (16.6) | 60.0° (10.2) | 0.225 |
| DISI deformity, *n* (%) | 13 (52%) | 9 (36%) | 0.254 |
| Instability | | | |
| DRUJ incongruence, *n* (%) | 1 (4%) | 0 (0%) | 0.312 |
| Carpal dislocation, *n* (%) | 20 (80%) | 12 (48%) | **0.018** |
| Ulnar styloid fractures | | | |
| Tip, *n* (%) | 12 (48%) | 12 (48%) | 0.333 |
| Base, *n* (%) | 8 (32%) | 9 (36%) | |
| Total carpal injuries, *n* (injuries/case) | 63 (2.52) | 41 (1.64) | **0.005** |

Abbreviations: DISI, distal intercalated segmental instability; DRUJ, distal radioulnar joint; SD, standard deviation; SL, scapholunate.
Note: Significant *p*-values are in bold.

**Table 3** Postoperative radiological results

| Measurement | Volar marginal rim group ($n = 25$) | Nonvolar marginal rim group ($n = 25$) | *p*-Value |
|---|---|---|---|
| Scapholunate injury | | | |
| SL interval (mm), mean (SD) | 2.51 (1.02) | 1.97 (0.76) | **0.039** |
| SL diastasis (>3 mm), *n* (%) | 6 (24%) | 2 (8%) | 0.123 |
| SL angle, mean (SD) | 61.6° (17.0) | 63.2° (10.4) | 0.683 |
| DISI deformity, *n* (%) | 10 (40%) | 11 (44%) | 0.775 |
| Ulnar translocation | | | |
| Bouman ratio, mean (SD) | 0.91 (0.06) | 0.89 (0.04) | 0.157 |
| Gilula and Weeks ratio, mean (SD) | 0.34 (0.17) | 0.37 (0.13) | 0.446 |
| Schuind ratio, mean (SD) | 0.33 (0.16) | 0.37 (0.13) | 0.323 |
| Total ulnar translocated, *n* (%) | 7 (28%) | 4 (16%) | 0.306 |
| Tear drop angle, mean (SD) | 54.7 ± 14.5 | 50.8 ± 9.2 | 0.255 |
| Complications | | | |
| Carpal subluxation, *n* (%) | 1 (4%) | 0 (0%) | 0.312 |
| Carpal instability, *n* (%) | 14 (56%) | 6 (24%) | **0.02** |
| Revision surgery, *n* (%) | 3 (12%) | 0 (0%) | **0.074** |
| Fixation failure, *n* (%) | 6 (24%) | 0 (0%) | **0.009** |

Abbreviations: SD, standard deviation; SL, scapholunate.
Note: Significant *p*-values are in bold.

## Discussion

In this study we have identified that volar marginal rim fractures have significantly more carpal injuries when compared with other intra-articular distal radius fractures, with an increase in the association of scapholunate instability and volar carpal instability. There were differences in the methods of fixation, with the more common use of volar rim-specific plates and bridging plates. The volar rim group had significantly higher incidence of persistent carpal instability, failure of fixation, and need for revision surgery.

There were nine cases of scapholunate diastasis in the volar marginal rim cohort compared with three in the comparison cohort. We believe this to be a clinically significant finding of pathology. The fact that only two patients had scapholunate repair could signify the lack of identification of carpal injury or the controversy in the management of scapholunate injury in the setting of distal radius fracture.[13,14] The best way to confirm acute scapholunate injury in the context of volar rim fracture is with arthroscopy at the time of fixation. Following the review of our series, it is the author's preferred practice to perform arthroscopy in these cases, and if acute injury is present, then proceed to repair the scapholunate ligament.

The majority of our fixation failures (66%) were early (<2 weeks postoperatively) with the remainder failing at 6 to 8 weeks. On critical retrospective review of our four cases of volar marginal rim escape, it could be argued that the plate could be placed either more distal or more ulnar to sufficiently capture all of the small volar marginal rim fragments. A limitation of our study was that we cannot decisively say whether the higher rate of fixation failure is due to a failure of surgical technique and fixation rather than pathology. Regardless, this high rate of fixation failure has led to an important discovery and one crucial point for its management: this uncommon injury pattern is not identified properly, and failure to do so and manage it differently to a standard intra-articular distal radius fracture can lead to devastating results. It has previously been presented that the volar marginal fragment is avascular with a variable retrograde blood flow through distal capsular vessels.[15] Therefore, even though fixation may be adequate at the time of operation, fragment healing is unsatisfactory or delayed which leads to collapse and then fixation failure. Multiple methods of fixation have been attempted to provide strong fixation of the lunate fragment, including specific volar plates, dual plating, K wire fixation, and external fixators with relative success; however, there are published reports of reduction failures and revision surgery in numerous occasions.[1,3,4,15,16]

These failures of fixation all have a similar point of failure relating to inadequate fixation of the volar marginal rim fragment. We believe that for this reason, after identification of a separate volar marginal rim fragment, CT imaging for fracture planning and early involvement with a specialist with an interest in distal radius fractures should be undertaken. Intraoperatively, a specific volar rim fixation device should be utilized, with intraoperative examination through a full range of motion to confirm stability of the fracture fragment and a low threshold to supplement fixation with an



 


**Fig. 2** Example of postoperative ulnar translocation of the carpus.

**Fig. 3** Example of fixation failure of the volar marginal rim fragment over and around the variable angle standard volar plate.

external fixator or dorsal bridging plate. A stress examination under fluoroscopy can be performed involving posterior–anterior force to elicit volar subluxation and a radial–ulnar force to assess for ulnar translocation. Due to the high rate of early failure, we believe these fracture pattern should be followed closely with weekly radiographs until 4 weeks and include longer follow-up than standard distal radius fractures. ►**Fig. 4** shows our suggested algorithm for management of volar marginal rim fractures.

Our study did have a few limitations. We had relatively small patient numbers; however, this injury is rare and larger numbers would only be possible with a multicenter trial. We were able to demonstrate that scapholunate diastasis and ulnar translocation of the carpus were more prevalent in the volar marginal rim group, and the lack of statistical significance is likely due to low patient numbers and type II error. In addition, no functional outcomes were recorded; however, this was not the primary aim of this study. We are only able to conclude about fixation failures in the short term, and this study did not have long-term outcome measures to identify how associated carpal injuries or fixation of this fracture pattern may lead to poor prognostic long-term complications such as degenerative changes, stiffness, pain, or vocational change. This is a retrospective study, with multiple surgeons, perhaps altering the technical results of fixation failure, but this does reflect the community service provided.

The primary aim of the study was to identify the associated carpal injuries with volar marginal rim fractures of the distal radius, and this was shown in much more alarming numbers than first thought prior to data collection. We propose that the volar marginal rim distal radius fracture is a component of a more complex radiocarpal injury, involving the ulnar styloid, scapholunate ligament, and the volar short carpal ligaments. In addition, the volar RC ligaments may act as a secondary stabilizer and compromise of these will unmask other carpal injuries. This is further supported by the significance of increased associated carpal injuries and both the scapholunate diastasis and preoperative carpal dislocation in comparison with the nonvolar marginal rim fracture group. The actual fracture of the volar

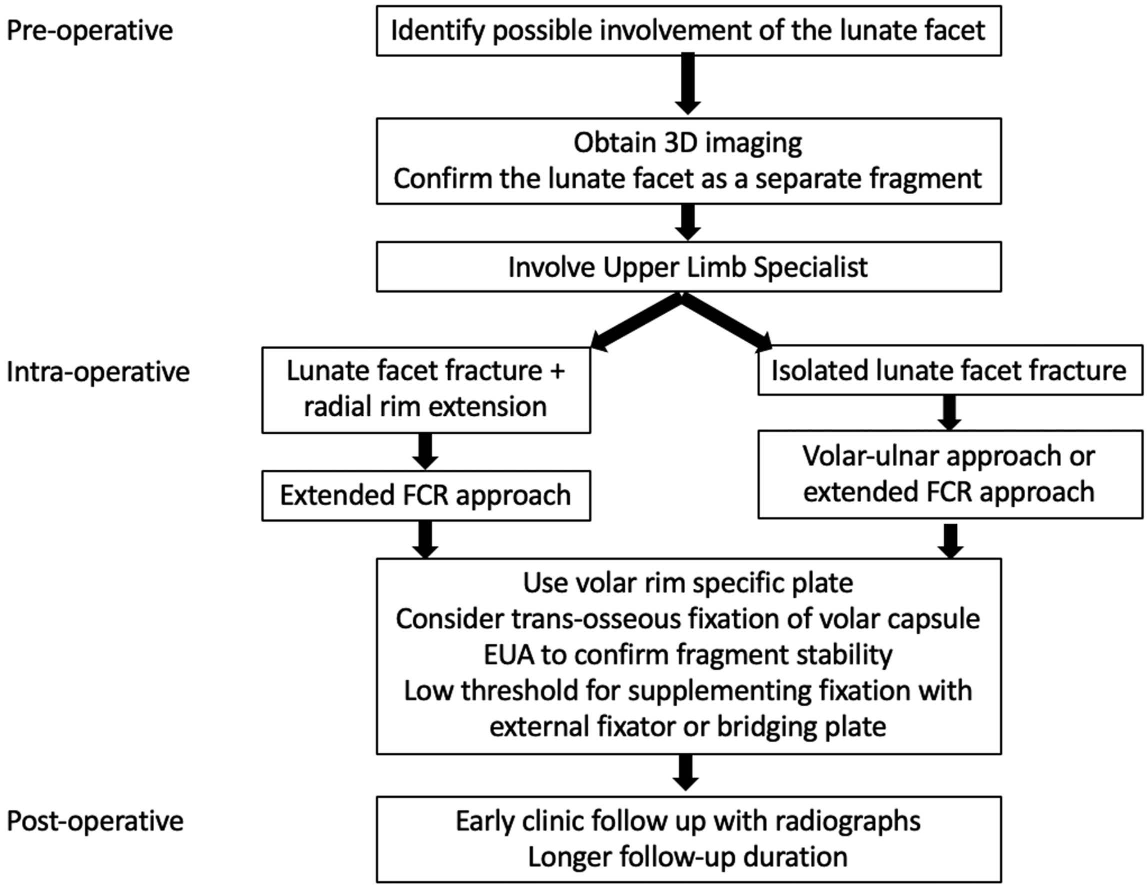


**Fig. 4** Treatment algorithm for volar marginal rim fractures.



marginal rim of the distal radius may just be the tip of the iceberg to a larger more complex carpal issue.

### Ethical Approval

This study was reviewed and supported by our institution's Human Research Ethics Committee prior to commencement.

### Conflict of Interest

G.I.B. mentions payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing, or educational events from IBRA Foundation, and AO Foundation, as well as leadership or fiduciary role in other board, society, committee or advocacy group, unpaid from Australian Hand Surgery Society, Asia Pacific Wrist Association, and International Wrist Arthroscopy Association. The remaining authors do not report any conflict of interest related with the article.

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