Volar Marginal Rim Fracture Fixation With Volar Fragment-Specific Hook Plate Fixation

Maureen A. O'Shaughnessy, MD,* Alexander Y. Shin, MD,* Sanjeev Kakar, MD*

Purpose To review the outcomes of patients treated with a volar hook plate specifically designed to capture volar marginal rim fractures.

Methods A retrospective study was performed over 18 months of patients treated with a volar hook plate in the management of AO type B or C distal radius fractures with a volar marginal rim fragment. Clinical and radiographic outcomes were evaluated.

Results The series included 26 wrists in 25 patients, average age 55 years. Average follow-up was 9 months (range, 3–30 mo). Twenty patients had AO type C fractures and 6 had AO type B fractures. All 6 AO type B were B3 fractures. Of the AO type C, 1 had C1, 7 had C2, and 12 had C3. No patients had loss of fixation of the critical volar ulnar corner and there was no evidence of carpal subluxation. Five patients required hardware removal. Four patients experienced hardware irritation requiring removal of all hardware including the volar hook plate. One patient required partial hardware removal that did not include the volar hook plate. All patients with volar hardware irritation had hook plates that were of second-generation design that had a prominent bend, which has since been modified. There were no cases of tendon rupture.

Conclusions Volar marginal rim fragments of intra-articular distal radius fractures are not amenable to standard volar plate fixation. Fragment-specific fixation using a volar hook plate designed specifically for these fragments allowed for stable fixation when combined with other fragment-specific fixation techniques. There was no loss of fixation of the critical corner in this series. Although hardware irritation can occur, fully seated hooks and subsequent modification of the design of the hook bend has diminished this complication. *(J Hand Surg Am. 2015;40(8):1563–1570. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Distal radius fracture, fragment-specific fixation, lunate facet.

THE RESTORATION OF ARTICULAR congruity in the management of intra-articular distal radius fractures is necessary to optimize outcomes.[1,2] A subset of intra-articular fractures involves the volar marginal rim, also known as the volar ulnar corner or the critical corner. When this fragment is not appropriately stabilized, devastating carpal subluxation or malunion may occur.[3]

Recent focus on the volar lunate facet articular fragment has emphasized that this fracture pattern can be among the most difficult articular injuries to treat owing to its unique anatomy.[3] The distal extent of the radius is flat except at its very distal lip, which slopes volarly to form the volar lunate facet. The slope renders the standard fixed contour volar plate fixation unable to capture both scaphoid and lunate volar cortical margins adequately, leaving the volar marginal rim fragment inadequately supported.[3] Fracture fragments are often small and distal to the watershed line. Standard volar plates have a relatively thick profile in relation to the unique anatomical dimensions of the lunate facet.

From the *Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN.

Received for publication October 3, 2014; accepted in revised form April 20, 2015.

A.Y.S. receives royalties from Mayo Medical Ventures/TriMed Orthopaedics. S.K. is a consultant for Arthrex and Skeletal Dynamics.

Corresponding author: Sanjeev Kakar, MD, Department of Orthopedic Surgery, Mayo Clinic, 200 First Street SW, Rochester, MN 55905; e-mail: Kakar.sanjeev@mayo.edu.

0363-5023/15/4008-0006$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2015.04.021

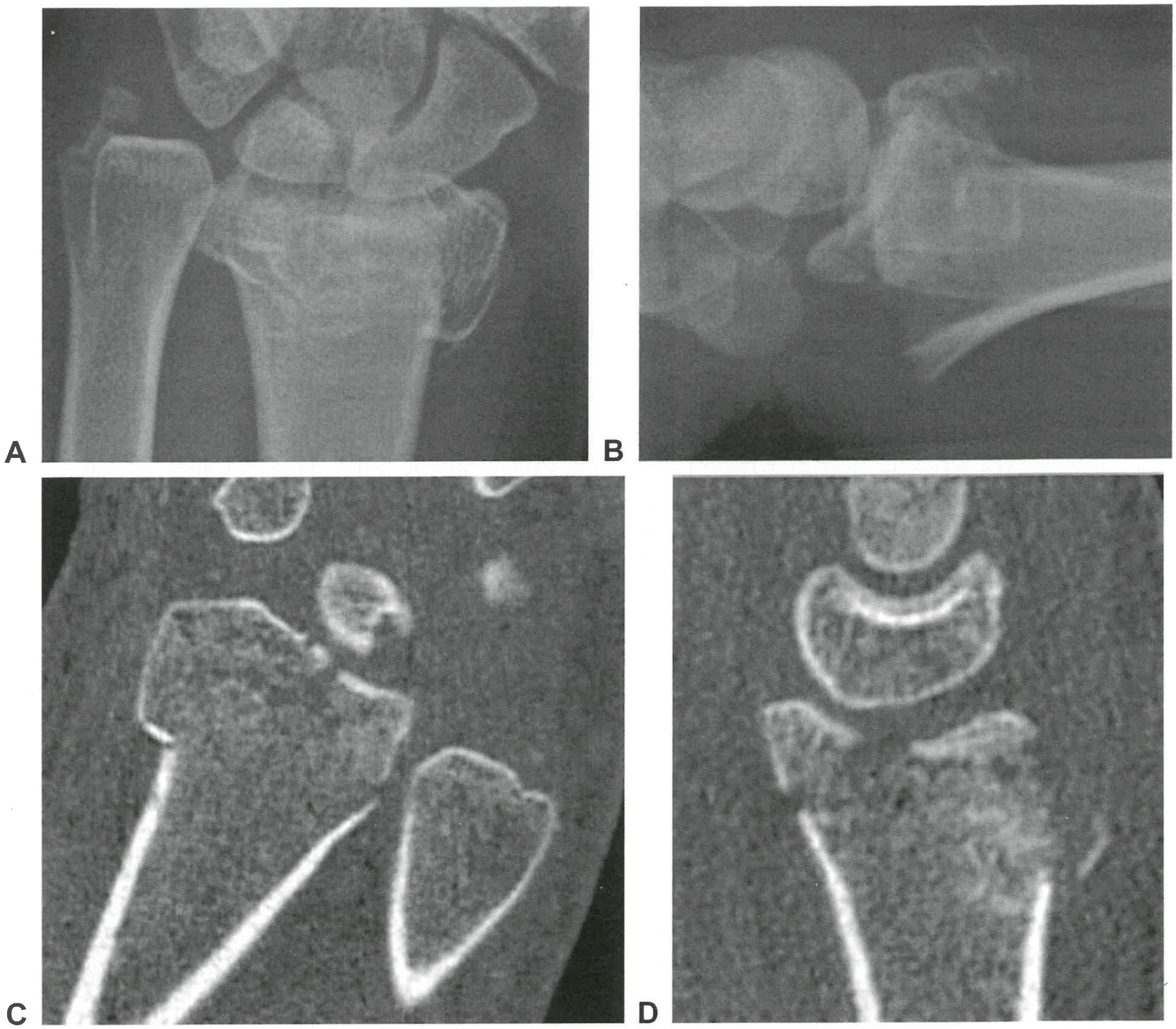

FIGURE 1: The injury radiographs **A, B** and computed tomographic images **C, D** show comminution and a distal volar ulnar fragment.

A standard plate placed distally to capture these fragments may lead to flexor tendon rupture or inadvertent intra-articular screw penetration because of its placement distal to the watershed line.[4]

Andermahr et al[5] evaluated the volar lunate facet using computed tomography and found that the facet is on average 19 mm in diameter and projects 3 mm anterior to the volar cortical surface of the shaft of the distal radius. The small fragment, which supports the volar lunate, is at risk for inadequate fixation in addition to unfavorable biomechanical shear forces.[5] Anatomically, the important short radiolunate ligament originates from the volar rim of the lunate facet. Fixation of this facet is integral to prevent volar subluxation of the carpus.[6] Finally, the volar ulnar corner is part of the radiocarpal as well as the distal radioulnar joint. Failure to adequately reduce and stabilize this fragment can lead to incongruity and instability at these joint surfaces.

Fixation options for the volar lunate facet include temporary Kirschner wire fixation, ulnar end of a t-plate, tension-wire technique, wire form fixation, wire loop, and headless compression screw fixation.[3,6–11] Arthroscopically aided reduction and visualization have also been described.[8] The various techniques described are technically difficult to perform. Certain patients, such as those with osteoporosis, may not be suitable for these techniques.[7]

The key to managing the volar ulnar corner is proper reduction techniques that allow stable, durable fixation. Bakker and Shin[12] introduced the volar hook plate (TriMed Orthopedics, Santa Clarita, CA) that was designed to address the volar marginal rim fracture in conjunction with fragment-specific fixation techniques. This implant is designed to be placed distal to the watershed line and allow for stable fixation of the volar ulnar corner.

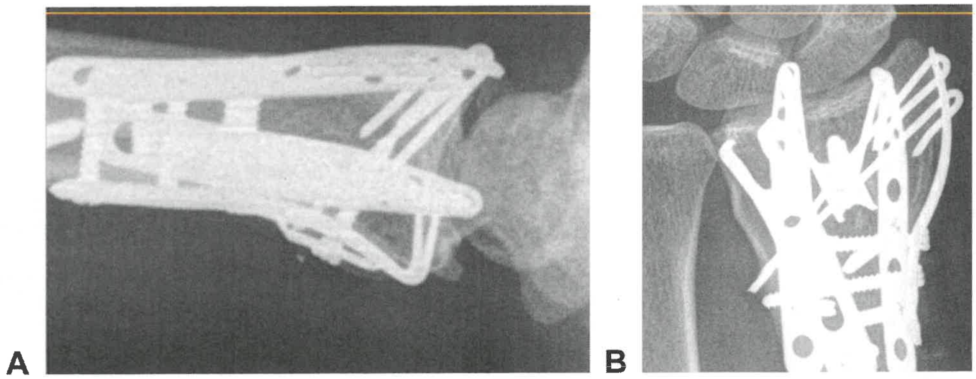

FIGURE 2: Postoperative radiographs (**A** lateral, **B** posteroanterior) show maintenance of articular congruity and stabilization of the volar ulnar fragment.

The purpose of this study was to evaluate the radiographic and clinical outcomes of patients who had complex intra-articular fractures with a volar ulnar corner fracture treated with this hook plate.

MATERIALS AND METHODS

We undertook an institutional review board–approved retrospective review of all patients who had a comminuted intra-articular distal radius fracture with a volar ulnar corner fragment and who underwent fixation that included a volar hook plate between January 2012 and July 2013.

Inclusion criteria were patients aged over 18 years with AO type B or C fractures with involvement of the volar ulnar corner treated with fragment-specific fixation and a volar ulnar corner hook plate.[13] Patients were excluded if the injury was, or if the fracture was not, an AO type B or C distal radius fracture. Patients were also excluded if they had an external fixator, bridge plate, or other means of fixation of the volar ulnar corner.

Range of motion of the operative and contralateral wrist was measured at follow-up visits. Data were recorded as the total degrees of flexion-extension arc and the average arc compared with the contralateral side. Grip strength was measured as the average of 3 consecutive attempts at maximal grip using the dynamometer (Jamar Hand Dynamometer, Sammons Preston Rolyan, Bolingbrook, IL) and was reported as a percentage of the contralateral side. Latest radiographs were evaluated and recorded and include articular congruity, radial inclination, volar tilt, radial height, and volar tear drop angle. We recorded radiographic measurements according to accepted standard techniques.[14,15] The first author (M.A.O.), who was not blinded to the study protocol, made measurements. Adequate reduction was defined as less than 1 mm of articular incongruity and less than 10° dorsal tilt. Loss of fixation was defined as evidence of plate or screw loosening, carpal translation, or carpal collapse. Complications, including the necessity for hardware removal of the hook plate, were recorded.

Hook plate surgical technique

The indication for the use of the volar hook plates was a volar ulnar fracture fragment of the distal radius that was minimally 5 mm long, 7 mm wide, and 4 to 5 mm in anterior-posterior dimensions. Fragments smaller than 5 mm are difficult to control with this technique and alternative techniques are recommended for fragments of this size or smaller. All hook plates were placed distal to the watershed line. The plates included 3 generations of volar hook plates (Trimed, Inc, Santa Clarita, CA). The first-generation plates were custom bent by the surgeon. The second-generation plate was prebent but was noted not to seat fully. The third-generation plate was prebent and thinned at the level of the hook bend to address the concern of prominence in the prior generation. The narrow plate allows for a wide degree of placement possibilities, and its distally fixed-angle hooks permit distal purchase of the cortex while residing just distal to the watershed line.[12]

An extended flexor carpi radialis volar approach to the distal radius is made that allows one to get as distal as needed to visualize the cortical rim of the distal radius. First, the volar ulnar corner is reduced anatomically while keeping the volar carpal ligaments intact. Using a specifically designed guide, the distal hook path is predrilled with the volar ulnar corner reduced. The plate is inserted and proximal screws are placed. The volar radial fragment, if present, is reduced in a similar fashion. After this reduction, a dorsal incision and capsulotomy is performed to address the dorsal

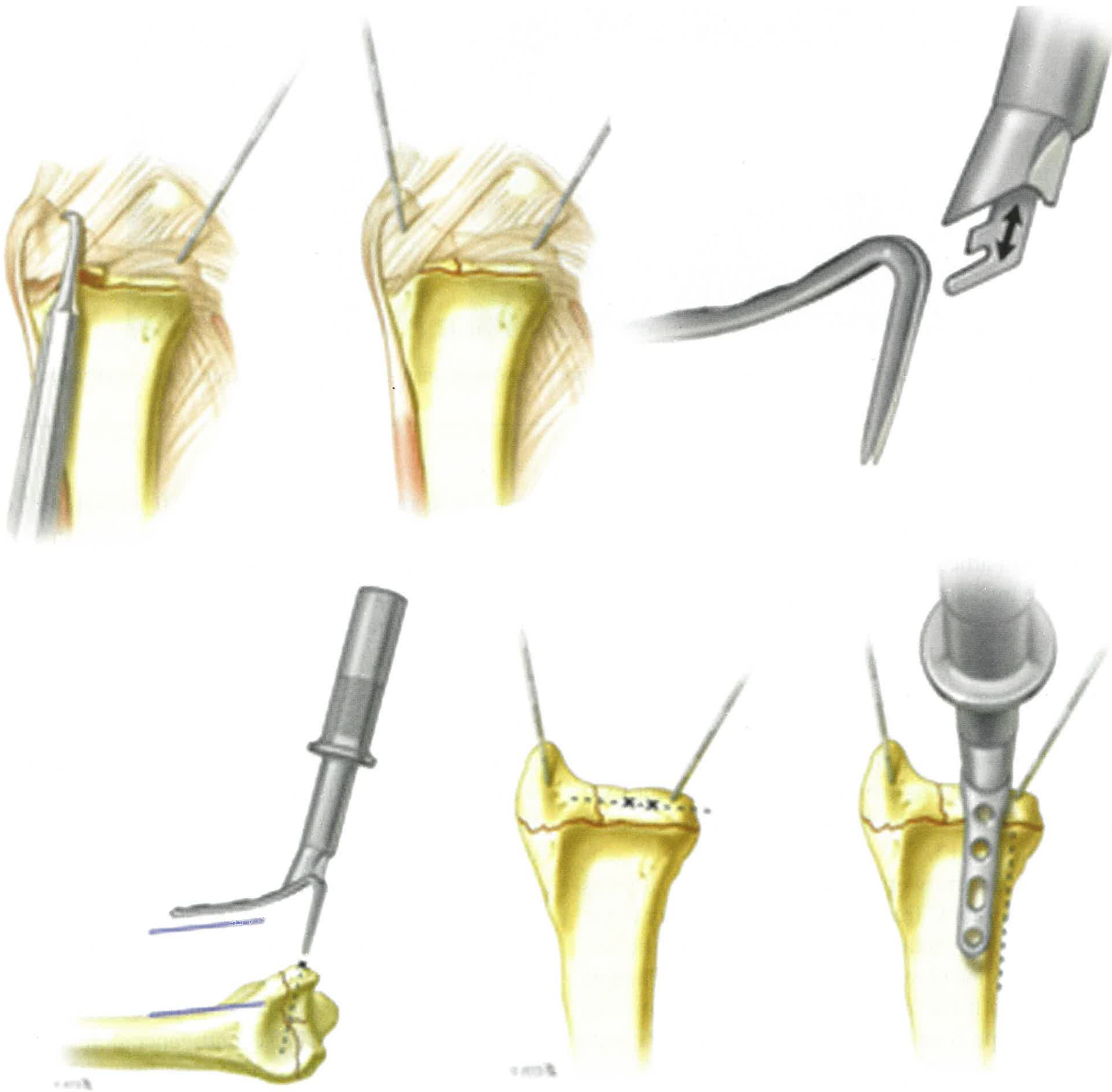

FIGURE 3: Volar hook plate operative technique. (Illustration with permission of A. Y. Shin. Copyright © 2013.) The volar ulnar corner is first reduced anatomically. The volar radial fragment, if present, is reduced in a similar fashion. The volar hook plate is then appropriately positioned, taking care to remain colinear with the volar cortex and that the tines are placed extra-articularly. The hook plate insertion points are marked and predrilled. Using the insertion guide, the hook plate is seated in the volar lunate facet fragment and secured using the shaft screws.

ulnar fragment and visualize the articular surface and confirm anatomic reduction if indicated. Once the dorsal ulnar and volar ulnar fragments are reduced and stabilized with fragment-specific fixation techniques, the radial column is reduced and fixed (Fig. 1). Allograft bone graft is used as necessary to fill voids and assist in fracture fragment reductions. Details of the surgical technique have been previously described.[12] Figures 2 and 3 show the final placement of the volar hook plate.

RESULTS

Demographics

Overall, 26 wrists in 25 patients (7 male and 18 female) were included. Fractures involved the dominant side in 13 patients (50%). Average age at time of injury was 55 years (range, 21–89 y). Mechanism of injury was motor vehicle accident (3), fall from a standing height (19), fall from a ladder (2), and sporting accident (2). A total of 18% (5) were laborers and 8% (2) were smokers. No patients had a diagnosis of inflammatory arthritis. There were 20 AO type C fractures and 6 AO type B fractures. All 6 AO type B were B3 fractures. Of the AO type C, 1 was C1, 7 were C2, and 12 were C3. Figures 4 and 5 demonstrate the injury and follow-up films of one such patient.

Surgical intervention consisted of fixation using volar hook plate in all patients in the series. Figure 5 shows an example. Bone graft was used in 20 of 26 cases for support after articular collapse had been disimpacted. When dorsal fixation was required (19 of 20 C type fractures), a dorsal capsulotomy was made for direct visualization of the articular reduction. The B type fractures did not require dorsal capsulotomy. All patients had an FCR volar approach with volar hook plate. Other fixation used the fragment-specific implants with additional approaches (20 radial and 19 dorsal incisions). Additional hardware included radial pin plates (11), dorsal pin plates (29), radial styloid plates (8), volar radial hook plate (16), and dorsal column buttress plate (3). The average number of plates used per patient was 3.7 (range, 2−6 plates).

Patients showed adequate return of function based on clinical range of motion and grip strength. Average follow-up time for clinical evaluation was 13 months (range, 3−30 mo). Follow-up was between 3 and 6 months for 5 wrists, 6 to 12 months for 2 wrists, and 12 months or more for 19 wrists. Postoperatively, patients were immobilized an average of 5.9 weeks. Average flexion-extension arc was 94° on the affected extremity compared with 131° of the contralateral extremity (when available). Grip strength was 22 versus 30 kg on the contralateral side, giving average grip strength of 84% of the unaffected extremity.

Radiographic assessment

Review of postoperative radiographs showed satisfactory reduction and realignment. All patients had adequate initial fracture reduction and maintained adequate reductions at final follow-up. Average final measurements were radial inclination 20°, radial height 9.9 mm, volar tilt 3°, and tear drop angle 55°. All wrists had preservation of articular congruity. No loss of reduction or fixation was noted.

COMPLICATIONS

Five of 26 patients (19%) required removal of hardware, of whom 4 patients required volar hardware removal because of prominent hardware seen on radiographs and concern for possible flexor tendon irritation. All volar hardware removals were for second-generation plates. One patient had dorsal and radial hardware removed because of a pin backing out. The volar hardware (including hook plate) was not problematic and was left in place. Average time to repeat surgery was 8 months (range, 3−14 mo). After hardware removal of the volar hook plates, no subsequent complications occurred.

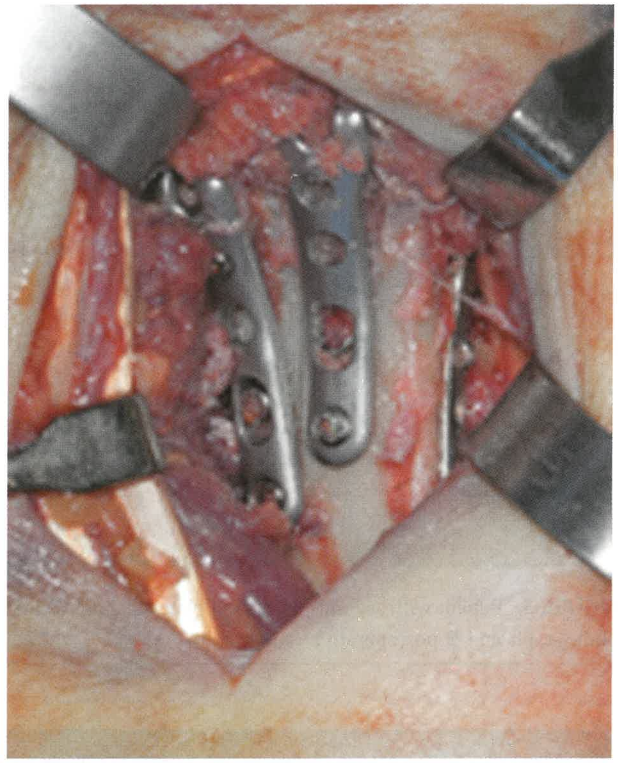

FIGURE 4: Photograph of intraoperative volar hook placement.

No patients had loss of reduction or articular height and there were no returns to the operating room for repeat fixation. There were no cases of tendon rupture, infection, or dehiscence.

DISCUSSION

The problem of fixation of the lunate facet has become well-defined, leading to increased awareness of the management options and clinical and radiographic outcomes of patients with this intra-articular fragment.[3,6−12,16−19] Various techniques have been described for fixation of the fragments, including temporary Kirschner wire fixation, a combination of volar plate and external fixation, ulnar end of a t-plate, tension-wire technique, wire form fixation, wire loop, and headless compression screw fixation.[3,6−11]

Indication for use of the hook plate are volar ulnar fracture fragments minimally 5 mm long, 7 mm wide, and 4 to 5 mm in anterior-posterior dimensions. This technique is not suitable for fractures with dimensions below this minimum requirement. These fractures may be better treated with suture or wire form fixation.[9]

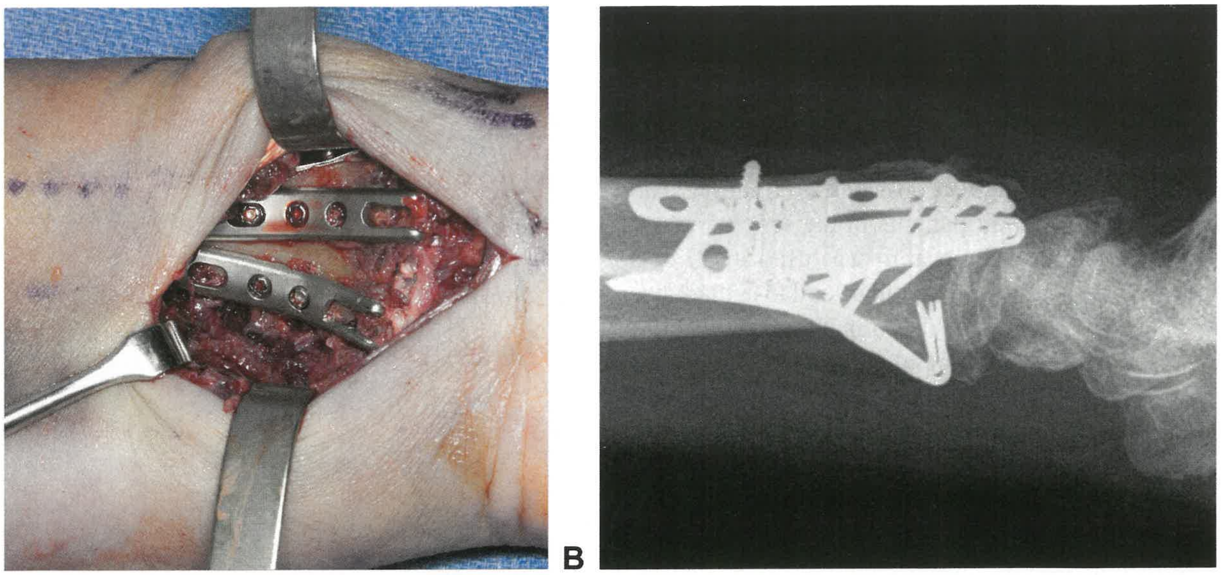

FIGURE 5: Patient with second-generation plates that are well-seated with tines flush with the volar cortex noted in this **A** intraoperative photograph and **B** postoperative radiograph.

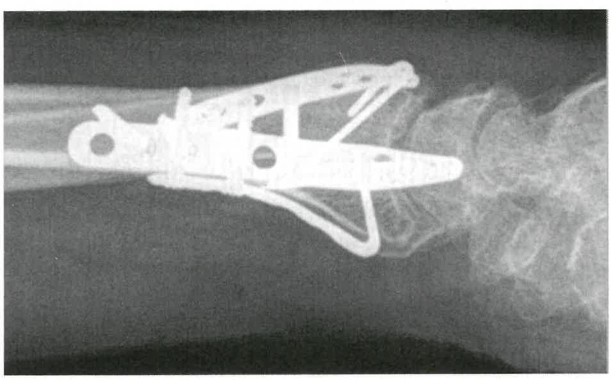

FIGURE 6: Radiograph showing a third-generation plate with a thinner profile at the hook bend.

Previous studies have described cases of fixation failure including articular collapse, malunion, nonunion, carpal subluxation or dislocation, and wrist dysfunction.[2,10,16,19] A retrospective review of all AO B3.3 fractures treated with standard volar plate found a 28% failure incidence (7 of 45 patients).[16] These authors found that statistically significant risk factors for loss of fixation were AO B3.3 classification, less than 15 mm of volar cortex available for fixation, and initial lunate subsidence of greater than 5 mm.[16] Ruch et al[10] and Harness et al[3] describe series of 13 and 7 patients, respectively, who developed loss of fixation and carpal subluxation after initial fixation. However, these series were not matched with patients who did not develop failure, so the incidence cannot be calculated from their studies. The fractures in our series were varied in subtype, with 20 AO type C fractures and 6 AO type B3 fractures. No patients in our series developed failure of fixation or carpal subluxation.

The incidence of complication in the literature is varied. One study reviewing 4 young males treated with wire loop fixation reported no complications at 24-month follow-up.[7] Bakker and Shin[12] reviewed 6 patients treated with the volar hook plate, with no complications noted at short-term follow-up. Another series of 21 patients treated with a combination of volar plate and external fixator observed for 24 months found pin track infections in 9% and flexor tenosynovitis requiring removal of hardware in 5%.[10] In a large series of 49 patients observed for an average of 51 months, the incidence of complications was 41%.[17] Most of those patients were treated with t-plate alone; supplemental Kirschner wires or screws were used in 11, and 2 had adjunctive external fixator placed. Complications were noted in 20 patients, including removal of hardware, tenosynovitis treated with synovectomy, and extensor pollicis longus rupture treated with tendon transfer. Another series reviewing patients undergoing revision for loss of fixation had a 43% incidence of prominent hardware requiring removal.[3]

We noted complications in 5 of 26 patients; 4 were related to volar hardware prominence. Of the 4 cases requiring volar hook plate removal, all had second-generation hook plates that were of greater thickness, and these plates had a bend of the tines that were thicker than the first- and third-generation plates. The second-generation hook plate has been replaced with a thinner and lower-profile bend of the tines (Fig. 6). One patient who required hook plate removal had inadequately seated hooks. Pre-drilling with a guide specific for the volar ulnar corner has addressed this complication. The surgeon should take care at the time of surgery to evaluate for plate prominence on lateral and tilt lateral views to ensure appropriate positioning. If the plate is unable to be seated fully, it should be removed and repositioned or bent to allow flush seating on the volar cortex. In addition, if there is a dorsal ulnar corner fragment, it needs to be stabilized to prevent dorsal drift of the ulnar-sided fragments. Careful postoperative evaluation and radiographic evaluation can assist the surgeon in determining the need for hook plate removal. The surgeon should be aware of the risk of symptomatic hardware after fragment-specific fixation and pay close attention to any flexor or extensor tenosynovitis at follow-up. With this device the latest complication was noted at 13 months postoperatively. As with any new implant or surgical technique, continued surveillance is indicated postoperatively and patients should be appropriately counseled regarding signs and symptoms of tendon irritation or rupture.

Radiographic outcomes reported in matched studies are varied. Ruch et al[11] reported 100% maintenance of reduction at 24 months' average follow-up. Jupiter et al[17] reported that 29% of patients had articular incongruity and 10% had reversal of volar tilt. Bakker and Shin[12] reported 100% maintenance of reduction in a series of 6 patients. In our series, radiographic outcomes revealed no loss of fixation and complete articular restoration for all patients.

Failure to recognize and adequately secure this volar-ulnar fragment can be devastating and often results in radiocarpal subluxation that necessitates complex reconstructive or salvage procedures. Harness et al[3] reported on 7 patients who failed primary fixation. These patients were managed with repeat reduction and internal fixation with a volar t-plate, radioscapholunate arthrodesis (1), scapholunate repair (2), and nonsurgical management (2). A recent case report described the use of osteochondral autograft from the knee to replace a symptomatic cartilage defect of the lunate facet.[19] Ruch et al[10] described 13 patients who developed lunate facet malunion and carpal subluxation at an average of 5 months. They were treated with juxta-articular corrective osteotomy and fixation using volar plates. Publications on revision surgeries in failed lunate facet management underscore the need to address this fragment adequately with primary fixation techniques.

We recognize the limitations and biases inherent in retrospective studies that include limited numbers of patients and difficulties with follow-up. In our series, 5 patients had 3- to 6-month follow-up and 2 had 6- to 12-month follow-up; as such, they would need to be observed longer to determine whether they developed any hardware-related complications. The radiographic observer was not blinded to the study protocol, which could have allowed for bias. We used fixation with fragment-specific techniques in all of our cases; however, the number and type of plates varied in each case, and therefore results may not be entirely related to the volar hook device alone. These limitations notwithstanding, all patients in this study were followed past fracture union and had a standardized physical examination at follow-up.

REFERENCES

1. Fernandez JJ, Gruen GS, Herndon JH. Outcome of distal radius fractures using the short form 36 health survey. *Clin Orthop Related Res.* 1997;(341):36–41.
2. Melone CP. Articular fractures of the distal radius. *Orthop Clin North Am.* 1984;15(2):217–236.
3. Harness NG, Jupiter JB, Orbay JL, Raskin KB, Fernandez DL. Loss of fixation of the volar lunate facet fragment in fractures of the distal part of the radius. *J Bone Joint Surg Am.* 2004;86(9):1900–1908.
4. Soong M, Earp BE, Bishop G, Leung A, Blazar P. Volar locking plate implant prominence and flexor tendon rupture. *J Bone Joint Surg Am.* 2011;93(4):1328–1335.
5. Andermahr J, Lozano-Calderon S, Trafton T, Crisco JJ, Ring D. The volar extension of the lunate facet of the distal radius: a quantitative anatomic study. *J Hand Surg Am.* 2006;31(6):892–895.
6. Waters MJ, Ruchelsman DE, Belsky MR, Leibman MI. Headless bone screw fixation for combined volar lunate facet distal radius fracture and capitate fracture: case report. *J Hand Surg Am.* 2014;39(8): 1489–1493.
7. Chin KR, Jupiter JB. Wire-loop fixation of volar displaced osteochondral fractures of the distal radius. *J Hand Surg Am.* 1999;24(3): 525–533.
8. Wiesler ER, Chloros GD, Lucas RM, Kuzma GR. Arthroscopic management of volar lunate facet fractures of the distal radius. *Tech Hand Upper Extrem Surg.* 2006;10(3):139–144.
9. Moore AM, Dennison DG. Distal radius fractures and the volar lunate facet fragment: Kirschner wire fixation in addition to volar-locked plating. *Hand.* 2014;9(2):230–236.
10. Ruch DS, Wray WH III, Papadonikolakis A, Richard MJ, Leversedge FJ, Goldner RD. Corrective osteotomy for isolated malunion of the palmar lunate facet in distal radius fractures. *J Hand Surg Am.* 2010;35(11):1779–1786.
11. Ruch DS, Yang C, Smith BP. Results of palmar plating of the lunate facet combined with external fixation for the treatment of high-energy compression fractures of the distal radius. *J Orthop Trauma.* 2004;18(1):28–33.
12. Bakker AJ, Shin AY. Fragment-specific volar hook plate for volar marginal rim fractures. *Tech Hand Upper Extrem Surg.* 2014;18(1): 56–60.
13. Kreder HJ, Hanel DP, McKee M, Jupiter J, McGillivary G, Swiontkowski MF. Consistency of AO fracture classification for the distal radius. *J Bone Joint Surg Br.* 1996;78(5):726–731.
14. Kreder HJ, Hanel DP, McKee M, Jupiter J, McGillivary G, Swiontkowski MF. X-ray film measurements for healed distal radius fractures. *J Hand Surg Am.* 1996;21(1):31–39.
15. Medoff RJ. Essential radiographic evaluation for distal radius fractures. *Hand Clin.* 2005;21(3):279–288.

16. Beck JD, Harness NG, Spencer HT. Volar plate fixation failure for volar shearing distal radius fractures with small lunate facet fragments. *J Hand Surg Am.* 2014;39(4):670–678.
17. Jupiter JB, Fernandez DL, Toh CL, Fellman T, Ring D. Operative treatment of volar intra-articular fractures of the distal end of the radius. *J Bone Joint Surg Am.* 1996;78(12):1817–1828.
18. Jupiter JB, Ring D. A comparison of early and late reconstruction of malunited fractures of the distal end of the radius. *J Bone Joint Surg Am.* 1996;78(5):739–748.
19. Mall NA, Rubin DA, Brophy RH, Goldfarb CA. Cartilage defect of lunate facet of distal radius after fracture treated with osteochondral autograft from knee. *Am J Orthop.* 2013;42(7):331–334.