Prevent Collapse and Salvage Failures of the Volar Rim of the Distal Radius

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J Wrist Surg 2016;5:17–21.

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Abstract

Background Articular fractures of the distal radius may include a small fragment from the volar margin of the lunate fossa: volar marginal fragments (VMFs); these fragments are prone to loss of fixation and avascular necrosis, and often result in wrist subluxation. We present our experience managing acute and delayed VMFs. The first is treated using a hook plate extension to a volar locking plate and the latter using a volar opening wedge osteotomy to redistribute loads on the remaining articular surface.

Materials and Methods We retrospectively reviewed the records of all patients treated at our facility with a hook plate extension for a VMF and for patients treated with a volar opening wedge osteotomy. Medical charts were examined for complications and functional results.

Technique A hook plate extension was used to fix the VMF when plate buttressing was insufficient. For patients who presented a collapsed and reabsorbed VMF, a volar opening wedge osteotomy was used to reorient the articular surface, restoring joint stability.

Results The hook plate extension was successful in managing 19 of the 21 acute VMFs. The volar opening wedge osteotomy provided concentric reduction and improved pain and motion in all treated patients.

Conclusion We demonstrated that hook plate fixation of the VMF is an effective means of fixing the acute VMF and that a volar opening wedge osteotomy can be used to salvage a distal radius fracture with a collapsed VMF.

Keywords
- volar rim
- distal radius fracture
- volar marginal fragment
- opening wedge osteotomy
- wrist surgery

Distal radius fractures (DRFs) can occur from a low-energy fall or high-energy trauma when excessive forces are transmitted across the wrist. Specific fracture patterns are determined by the quality of the bone, orientation of the wrist during injury, and magnitude and rate of force application.[1] The radius fractures in predictable patterns, sometimes with multiple articular fragments.[2] Generally, articular fractures present a fracture plane separating the lunate fossa from the scaphoid fossa. More often than not, a coronal fracture plane also divides the lunate fossa into posteromedial and anteromedial (volar ulnar) fragments.[3] Typically, the anteromedial fragment can be successfully stabilized through open reduction and internal fixation (ORIF) using a volar plate with sufficient buttressing surface. When the fragment is too small and therefore the fracture line too distal, the plate may be unable to buttress it. An anteromedial fragment too small to be buttressed by the plate is called a volar marginal fragment (VMF). While rare, they prove problematic.

The volar rim of the lunate fossa is the only sector of the articular surface responsible for preventing volar carpal translation.[4–6] In addition, the volar margin of the lunate facet is the anchorage point for the short radiolunate ligament important in carpal stability.[7] Following fracture, if a VMF is not properly stabilized, joint subluxation in a volar direction often occurs.[8] If a VMF is present, it requires stable fixation to assure proper healing. This fragment is often avascular as its blood supply is variable and retrograde through its distal capsular attachments. A fragment-specific extension of the

received
December 4, 2015
accepted
December 8, 2015
published online
January 11, 2016

DOI http://dx.doi.org/10.1055/s-0035-1570745.
ISSN 2163-3916.

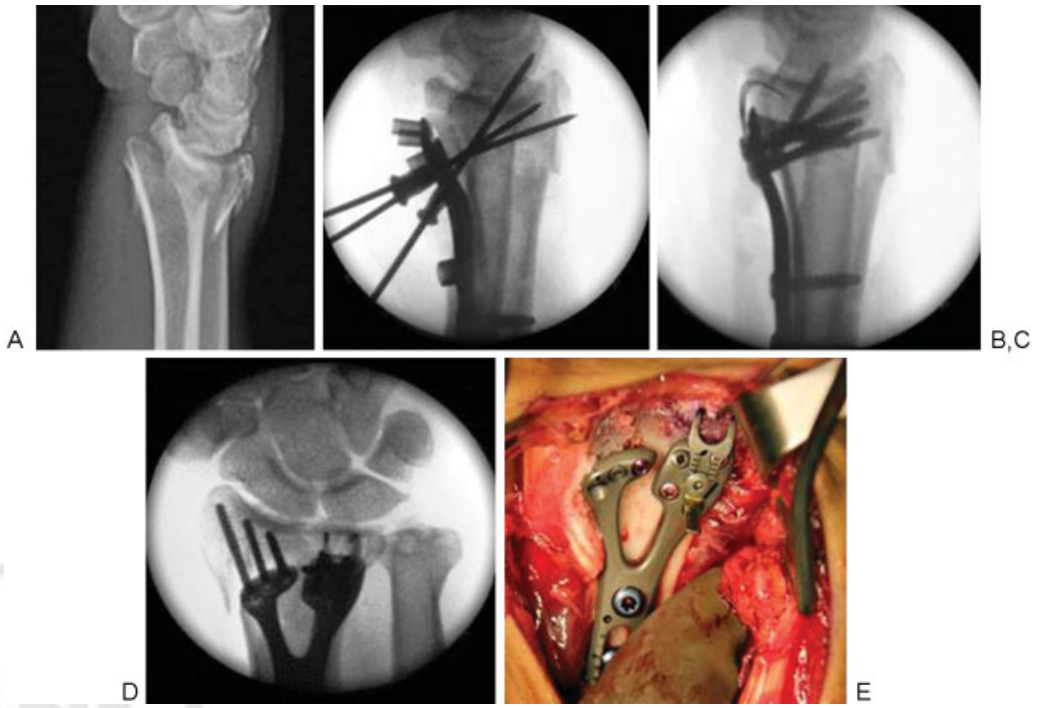

Fig. 1 (**A**) Preoperative X-ray showing an intra-articular radial fracture with a volar marginal fragment. (**B**) Intraoperative radiograph showing volar fracture line distal to distal plate edge. (**C, D**) Intraoperative fluoroscopy after hook plate application. (**E**) Intraoperative photograph of the radius, with hook plate securing the volar marginal fragment.

buttress plate or hook plate may be used to acutely stabilize the VMF (►**Fig. 1**).

We present our experience using a hook plate extension to capture the VMF in 21 patients treated at our facility over the past 3 years. We use the extended flexor carpi radialis (FCR) approach to manage most DRFs in need of operative treatment. It allows us to adequately access the volar rim of the lunate fossa to identify and treat the VMF.[9] However, if the VMF is not addressed or improperly fixed, collapse and reabsorption of the VMF may result. When this occurs, salvage is difficult and simply fixing the VMF often proves insufficient treatment. In these cases, a volar opening wedge osteotomy may be used to redistribute the joint loads to the remaining intact articular surface and restore joint stability to salvage the wrist (►**Fig. 2**). We present our experience using a volar opening wedge osteotomy in three patients treated at our facility over the past 10 years.

Fig. 2 (**A**) An X-ray of a dorsally displaced fracture with undetected VMF. (**B**) Immediate postoperative X-ray with wire suture fixation of VMF attempted. (**C**) 4 weeks postoperative X-ray, collapse commencing.

Fig. 2 (*Continued*) (**D**) 16 weeks postoperative; volar tilt of 27 degrees; carpal subluxation and ulnar plus wrist demonstrated. (**E**) X-ray postosteotomy correction, neutral tilt, concentric reduction, and restoration of radial length.

Methods

Hook Plate Extension Study

We retrospectively reviewed the records of all patients treated at our facility with a volar hook plate extension for management of a VMF during ORIF of a DRF. Medical charts were examined for complications and for functional results.

Opening Wedge Osteotomy Study

We retrospectively reviewed the records of all patients treated at our facility with a volar opening wedge osteotomy for the management of a collapsed VMF after volar plating a DRF (minimum follow-up time of 1 year). Medical charts, X-rays, and therapy notes were investigated and all patients were contacted for a final evaluation. The charts were examined for the presence of complications and for functional results. The surgical procedure consisted of a volar opening wedge osteotomy to decrease volar tilt to provide volar support to the carpus and restore radial length. Proximal ulna cancellous autograft bone was used in all cases.

Surgical Technique

Hook Plate Extension Technique

We utilize the extended FCR approach.[9] Distal release of the FCR tendon to the level of the trapezium provides sufficient access to manage VMFs. Reduction of fracture fragments and plate application was done in standard fashion. After plate application, the relation of the anteromedial fragment proximal fracture plane to the distal edge of the plate was examined to decide if sufficient buttress fixation was provided. When insufficient stability was noted, the hook plate was used. A reduction tool and drill guide instrument is used to facilitate application of the hook plate extension.[10] The hook plate is secured to the volar plate with a set screw. Closure was performed in a standard fashion.

Opening Wedge Osteotomy Technique

In our delayed cases with reabsorption of the VMF and carpal subluxation, all other DRF fragments had healed by the third month. An opening wedge osteotomy was used to redirect the joint forces into the dorsal aspect of the radial articular surface and therefore unload the volar lunate facet. Through a volar approach, a K-wire was inserted parallel to the articular surface in the lateral view using the image intensifier and served as a guide for the sagittal plane correction. A small sagittal saw was used to cut the distal radius transversely and parallel to the K-wire, leaving a dorsal cortical hinge to rotate the distal fragment into extension. The goal of correction in the sagittal plane was to achieve at least neutral volar tilt of the residual lunate fossa surface; slight dorsal tilt is the preferred correction. Radial inclination was addressed simultaneously and restoration of radial length was also considered a priority. Using the plate benders, a volar plate was shaped to reduce its inherent volar tilt and allow the plate to sit flush against the volar cortex to avoid flexor tendon irritation. After plate application, cancellous autograft was harvested from the proximal ulna and inserted into the defect created on the radius (►**Fig. 3**). Rehabilitation consisted of immediate finger motion and the wrist was protected with a removable splint for 8 weeks.

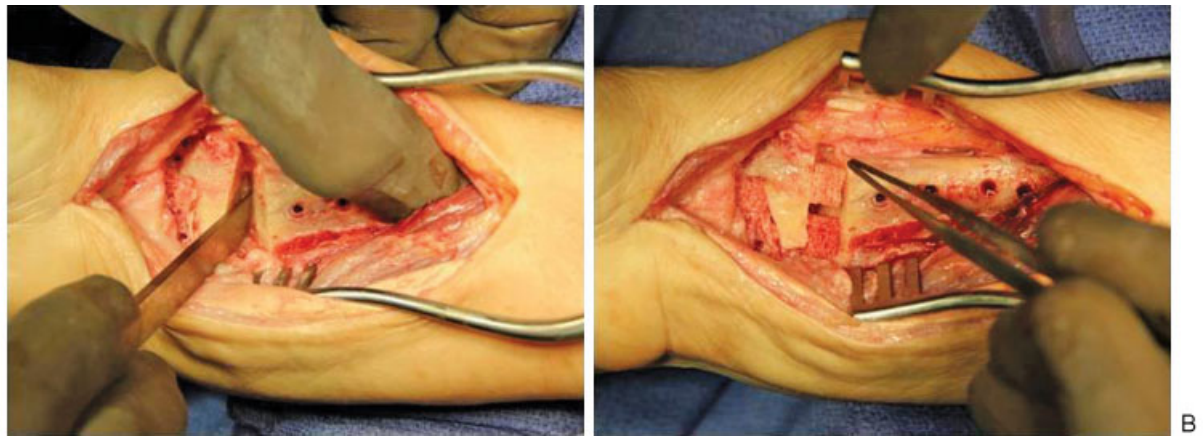

Fig. 3 (**A**) Volar opening wedge osteotomy of the radius to create the correct volar tilt. (**B**) Inserting allograft wedges during an osteotomy to maintain corrected tilt prior to plate application.

Results

Hook Plate Extension Study

We treated 21 patients, 14 females and 7 males (ages 38–87 years; average 68.6 ± 11.9 years), with a volar hook plate extension for management of a VMF (15 left wrists and 6 right wrists). Fracture fixation was obtained using the Geminus volar distal radius plate system (Skeletal Dynamics, Miami, FL). The hook plate attachment is a modular part of this system. Medical charts were examined for complications and for functional results. Of the 21 patients treated, 17 used the hook plate extension during the primary reduction (first surgery; 81.0%), and 4 used the hook plate extension during a secondary procedure for a failed VMF (19.0 %). The hook plate extension was successful in reducing the VMF and maintaining reduction through final follow-up in 19 of the 21 patients treated in this manner (90.5%). Of note, the two cases where the hook plate did not maintain reduction were secondary revisions of failed VMFs.

In the first case, an 87-year-old woman underwent primary conventional volar plate fixation of a volar shear fracture. On postoperative follow-up, volar translation of a previously unrecognized VMF was found. She underwent revision of fixation, with subsequent nonunion and redisplacement of the VMF. She declined further surgery, as she had returned to her preinjury low-demand function with minimal residual wrist pain.

In the second case, a 65-year-old man also experienced loss of volar fragment fixation after primary conventional volar plating. He was treated with revision fixation and application of a hook plate. The VMF did not heal and redisplaced postoperatively. He was treated with an opening wedge osteotomy and temporary spanning internal fixation.

Table 1 Demographic information on the opening wedge osteotomy patients

	Age (y)	Dominance	Revision surgery (time post-ORIF)
1	47	Dominant	3 mo
2	70	Nondominant	10 mo
3	63	Nondominant	4 mo

Abbreviation: ORIF, open reduction and internal fixation.

Table 2 Results of the opening wedge osteotomy study

	Follow-up time period (y)	VAS score	DASH score	Grip (% contralateral)
1	4.5	0	6.8	102%
2	2.5	0	4.5	65%
3	10	0	11	83%
Average	5.7	0	7.4	83.3

Abbreviations: DASH, Disabilities of the Arm, Shoulder and Hand; VAS, visual analog scale.

Opening Wedge Osteotomy Study

We treated three patients, all female (ages 47–70 years), with a collapsed VMF after primary conventional volar plating 3 to 5 months postindex ORIF (►**Table 1**). Cast immobilization failed to prevent progression in these cases. All patients presented before the third month post-op with either radiographic evidence of failure of initial reduction or poor clinical progress after the initial surgical treatment. Symptoms included unexpected pain and failure to recover forearm supination. Radiologic findings progressed from collapse of the VMF to volar subluxation of the carpus and reabsorption of the VMF. All three patients underwent a volar opening wedge osteotomy with proximal ulna cancellous autograft. Cancellous allograft chips were also utilized, particularly to maintain correction intraoperatively.

Within 2 months postosteotomy, all three patients had decreased pain and improved pain and motion. Follow-up X-rays revealed concentric joint reduction in all cases. At final follow-up (►**Table 2**), patient's passive and active visual analog scale scores were 0; their QuickDASH scores were 4.5 to 11.

Discussion

The VMF is the Achilles heel of DRF fixation. Biomechanical studies have demonstrated that the centroid of force application is located palmarly on the lunate fossa, and because the lunate fossa is offset in a palmar direction relative to the radial shaft, the VMF carries high loads and is difficult to stabilize. Carpal instability may result from an unstable VMF as the short radiolunate ligament originates from the volar rim of the lunate fossa. These small fragments are more often present in volar fractures but can also occur in dorsal injuries. Particular attention must be paid to the volar shear fracture pattern, as this pattern is most commonly associated with the presence of a nondisplaced VMF, which becomes displaced postoperatively after fixation of the larger volar shear fragment with volar plate fixation.

There have been numerous reports regarding the seriousness of this problem and the need to identify and manage these fragments. Often, VMFs are missed in pre-op X-rays, and if proper exposure is not achieved, they can also be missed during surgery. Unfortunately, the other fracture fragments are often reduced easily and fixation seems initially stable. Because VMF are often avascular, they fail to heal and are then resorbed. When this happens, the wrist subluxates palmarly, assuring an unsatisfactory clinical result.

Primary stable fixation of VMFs is essential, as rigid stability will allow for revascularization and clinical success. On the contrary, once avascular necrosis and resorption has occurred, secondary fixation cannot provide good outcomes. This was reflected in our experience with the use of the hook plate extension. It proved successful in every case of primary VMF fixation but failed in half of the cases when it was used for a secondary procedure.

We used the hook plate in VMFs that could not be stabilized by buttressing with the volar plate. Volar plate fixation is limited to 2 mm proximal to the watershed line to prevent flexor tendon

impingement. Since the watershed line is ~3 mm proximal to the joint line, the total length of volar lunate facet that must remain uncovered is 5 mm. Anteromedial fracture fragments of approximately this size or less were considered to be VMFs and all were stabilized with the hook plate. In our cases treated with the hook plate, we did not detect any flexor tendon complication despite its crossing the watershed line. This may be due to its low profile and smooth surface. Regardless, it is important to be on the lookout for flexor tendon irritation. If such irritation were to develop, removal of the hook plate after fragment healing must be performed.

For the failed VMF, only salvage procedures may prove effective. Total wrist fusion and proximal row-to-radius fusion can be utilized as salvage options but these procedures inherently limit final wrist function. Even in the case of a limited flexion-extension arc, the preservation of any amount of sagittal plane wrist motion improves hand function. For this reason, we favored the volar opening wedge osteotomy, as it maintains motion on both radiocarpal and intercarpal joints. The volar opening wedge osteotomy will correct volar subluxation by creating a compensatory dorsal deformity and also address restoration of radial length. A major clinical finding in cases of failed VMFs is the loss of forearm rotation, particularly of supination. Restoration of an ulnar neutral wrist may be most important in restoring this function. Our experience with autograft harvest from the proximal ulna has been encouraging, although care must be taken to minimize the potential risk of olecranon fracture. However, this source offers the benefits of being better tolerated by ambulatory patients, as the donor site is included in the operative field of the corrective osteotomy.

Conflict of Interest

J.L.O. and F.R. are consultants for Skeletal Dynamics. L.V. is an employee of Skeletal Dynamics. J.L.O. is the first inventor on the Geminus Volar Plating System patent. The authors certify that they may receive payments or benefits from Skeletal Dynamics related to this work.

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