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Distal Radius Fractures: Strategic Alternatives to Volar Plate Fixation

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Abstract

Volar locking plates have provided surgeons with enhanced capability to reliably repair both simple and complex fractures and avoid the hardware-related complications associated with dorsal plating. However, there have been an increasing number of published reports on the frequency and types of complications and failures associated with volar locked plating of distal radius fractures. An informed, critical assessment of distal radius fracture characteristics will allow surgeons to select an individualized treatment strategy that maximizes the likelihood of a successful outcome. Knowledge of the anatomy, patterns, and characteristics of the diverse types of distal radius fractures and the complications and failures associated with volar locked plating will be helpful to orthopaedic surgeons who treat patients with these injuries.

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Fractures of the distal radius are common, and the incidence of these injuries continues to increase.[1] A broad range of individuals are affected, from young patients with high-energy injuries to elderly patients with osteoporotic fragility fractures. Treatment strategies have evolved along with an understanding of these injuries, with recent epidemiologic studies indicating the growing use of internal fixation.[2,3] Volar locking plates have provided surgeons with enhanced capability to reliably repair both simple and complex fractures while avoiding the hardware-related complications associated with dorsal plating.[4] However, there is a growing body of literature reporting the frequency and types of complications and failures associated with distal radius fracture fixation with volar locking plates.[5] An assessment of fracture characteristics will allow the surgeon to select an individualized treatment strategy that maximizes the chances of success.

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Table 1
Complications of Volar Plate Fixation

Study (Year)	Number of Patients	Reported Complications
Extensor tendon-related		
Arora et al[20] (2007)	141	2 EPL ruptures 4 extensor tenosynovitis
Rampoldi and Marsico[22] (2007)	90	3 extensor tendon irritations or ruptures
Soong et al[23] (2011)	321	1 extensor tendon irritation
Flexor tendon-related		
Arora et al[20] (2007)	141	2 FPL ruptures 9 flexor tendon irritations
Rampoldi and Marsico[22] (2007)	90	2 flexor tendon irritations
Soong et al[23] (2011)	321	13 flexor tendon irritations
Loss of volar tilt		
Rozental and Blazar[21] (2006)	41	2 cases
Loss of lunate facet fixation		
Rozental and Blazar[21] (2006)	41	2 cases
Rampoldi and Marsico[22] (2007)	90	1 case
Harness et al[37] (2004)	NA (case report series)	7 cases

EPL = extensor pollicis longus, FPL = flexor pollicis longus, NA = not available.

Anatomic and Biomechanical Considerations

Current approaches to the management of distal radius fractures are based on the principle that restoration of normal anatomy will facilitate an expeditious return to function.[6,7] Careful consideration of the anatomy and biomechanics of the injury will help the surgeon choose a treatment strategy to restore the normal stability and load-bearing characteristics of the wrist.

The three-column theory of the distal radius and ulna is particularly helpful in understanding the biomechanical rationale for treating distal radius fractures.[8,9] The lateral (radial) column, composed of the radial styloid and the scaphoid fossa, provides radiocarpal stability through the styloid's osseous buttress and the origin of the palmar radiocarpal ligaments. Restoring the intermediate column, composed of the lunate fossa and sigmoid notch, reestablishes the primary load-bearing surface of the radiocarpal joint.[9] Reducing the articular surface of the sigmoid notch provides congruity to the distal radioulnar joint (DRUJ) and tensions its soft-tissue attachments.[10,11] Restoring the volar lunate facet provides radiocarpal stability via a bony buttress (the teardrop or critical corner) and the ligamentous support of the short radiolunate ligament.[12] Restoring the integrity of the medial (or ulnar) column, composed of the distal ulna and triangular fibrocartilage complex (TFCC), allows it to serve as a fulcrum for rotating the radius and share in load transmission from the carpus.[9]

The optimal management of a distal radius fracture will ensure restoration of each column. The radial and intermediate columns are anatomically reduced and rigidly fixed, and the medial column is stabilized as necessary through bony fixation, TFCC repair, and/or immobilization.[8] During preoperative planning, careful attention should be paid to fractures that are particularly prone to radiocarpal instability (such as articular shearing fractures),[13] loss of fixation (such as lunate facet fractures), and fractures that may require direct articular visualization and reconstruction (such as extensively impacted articular fractures). Each of these fracture characteristics should alert the surgeon that adequate fracture fixation may not be possible using only volar plating; however, the fracture can be successfully managed if these characteristics are recognized preoperatively or intraoperatively.[14,15]

Complications Associated With Volar Locking Plates

Since their introduction, volar locking plates have been reliably used to treat displaced distal radius fractures.[16,17] The fixed-angle construct minimizes the load transmitted to the often-comminuted metaphysis while decreasing the risks of screw loosening and loss of reduction.[18] Successful reports of fixation with volar plating were contemporaneous with the increasing frequency of hardware-related complications from dorsal plating, leading to the rapid adoption of volar plating to fix dorsally angulated fractures.[4,19]

Although volar plates are increasingly used to manage many injury patterns, complications are associated with these implants. These complications can be divided into two main categories: tendon-related and loss of fixation (**Table 1**). Other complications, including complex regional pain syndrome and neurologic injury, occur less frequently and are less directly related to the hardware.[5,20,21]

Tendon-Related Complications

Extensor Tendons

Although avoidance of extensor tendon irritation was seen as a key advantage of volar locking plate fixation for dorsally displaced fractures, damage to the extensor tendons still occurs from drill tips, prominent screws, and displaced bony fragments (**Figure 1**). Arora et al[20] reported 2 ruptures of the extensor pollicis longus and 4 patients with extensor tenosynovitis in a series of 141 consecutive patients with dorsally displaced distal radius fractures treated with a volar locking plate. In a study of 90 patients with distal radius fractures treated with volar plate fixation, Rampoldi and Marisco[22] reported 3 extensor tendon irritations or ruptures.[22] In the largest series of patients followed for complications after volar plating, Soong et al[23] reported that 1 of 321 patients had plate-related extensor tendon irritation.

Despite its relative rarity, this chapter's authors attempt to prevent intraoperative extensor tendon damage and postoperative extensor tendon irritation by drilling only the volar cortex and inserting unicortical locked screws that are slightly shorter than the measured amount, particularly in the setting of dorsal comminution. Alternatively, if the fracture necessitates bicortical fixation, full-length smooth pegs are preferred. This practice is substantiated by a biomechanical study by Wall et al[24] that reported no difference in axial or sagittal stiffness force among full-length bicortical screws, unicortical screws (full length, 75% length, and 50% length), and unicortical pegs in an osteoporotic distal radius model.

Flexor Tendons

The placement of hardware within the volar concavity of the distal radius minimizes the risk of flexor tendon irritation. This innate advantage is present only if the plate is positioned proximal to the transverse ridge at the distal extent of the pronator fossa (the so-called watershed line).[25] Placing the plate distal to the ridge allows greater capability in securing distal subchondral fragments but leaves the plate and screw heads in close proximity to the flexor tendons and at increased risk for postoperative flexor tendon rupture[26] (**Figure 2, A**). Distal plate placement does not allow the hardware to be fully covered by the pronator quadratus (**Figure 2, B**). Arora et al[20] reported 2 flexor pollicis longus ruptures and 9 cases of flexor tendon tenosynovitis in their study of 141 patients with unstable distal radius fractures treated with a fixed-angle plate. Two cases of

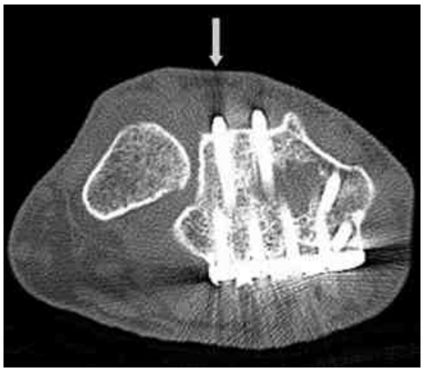

Figure 1 CT scan showing the risk of injury to extensor tendons (arrow) from prominent locking screws. (Courtesy of Philip E. Blazar, MD, Boston, MA.)

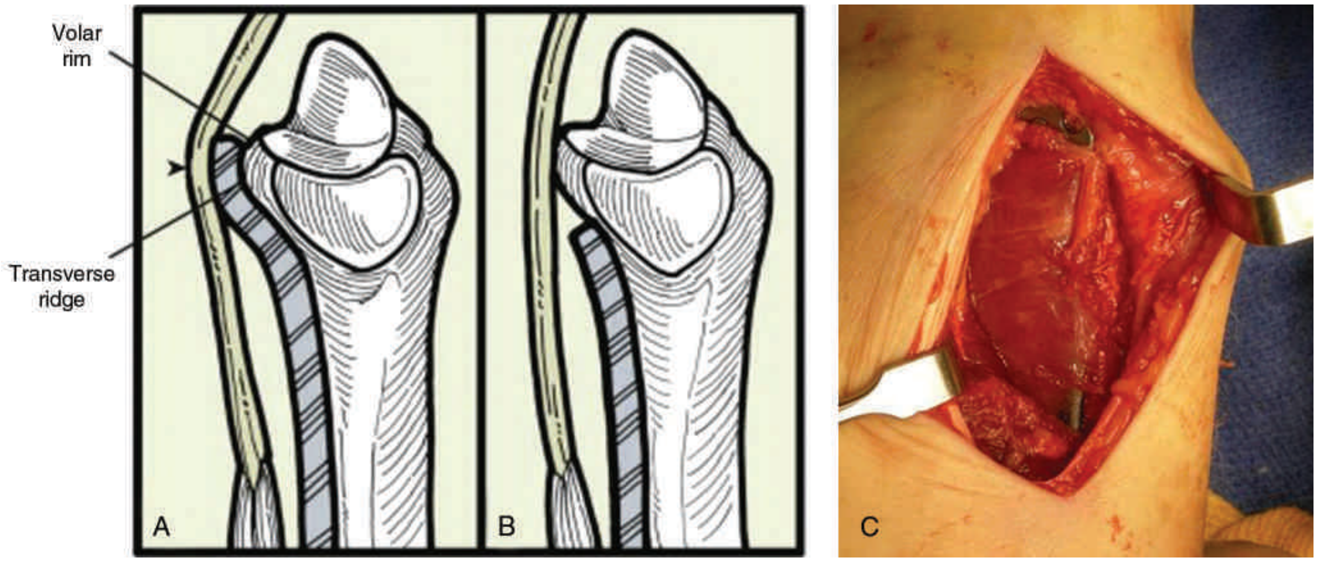

Figure 2 Distal placement of a volar locking plate puts the hardware in close proximity to the flexor tendons. **A,** In this illustration, the position of the volar plate is too distal, placing the flexor tendons at increased risk for irritation from the hardware. **B,** Illustration showing the appropriate position of the volar plate within the concavity of the distal radius. (Reproduced with permission from Wolfe SW: Distal radius fractures, in Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH, eds: *Green's Operative Hand Surgery*, ed 6. Philadelphia, PA, Elsevier, 2010, pp 561-638.) **C,** Distal placement of a volar locking plate does not allow the hardware to be fully covered by closure of the pronator quadratus. (Courtesy of Philip E. Blazar, MD, Boston, MA.)

flexor tendon irritation in 90 patients were reported by Rampoldi and Marsico,[22] and 13 cases of plate-related flexor tendon irritation were reported in 321 patients by Soong et al.[23] Given that delayed flexor tendon rupture has been reported up to 5 years after volar plating,[27] there should be a low threshold of consideration for hardware removal if there is concern about flexor tendon irritation. Ultrasound or MRI can be useful in identifying synovitis or attritional changes in at-risk flexor tendons. Retained drilling guides from screw insertion and loosening of improperly engaged locking screws have been reported as mechanisms for flexor tendon irritation after volar plating.[20,28]

Loss of Fixation After Volar Plating

Loss of Volar Tilt

The restoration of radiocarpal alignment in the sagittal plane substantially influences functional outcomes and grip strength after distal radius fracture treatment.[29] After achieving intraoperative reduction of anatomic sagittal tilt, the volar fixed-angle construct can be used to secure reduction without applying an implant to the dorsal surface. However, long-term clinical success has been correlated with maintenance of sagittal collinearity of the radius and the carpus.[29] The biomechanical stability of the construct is contingent on the distance of the distal screws from subchondral bone, with the highest resistance to metaphyseal settling seen with screws inserted as close to subchondral bone as possible.[30] Because fractures with extensive dorsal comminution are believed to be at greatest risk for loss of volar tilt, multiple fluoroscopic views should be used to maximize subchondral screw purchase distal to the zone of comminution.[21,31]

Loss of Fixation in the Lunate Facet

The importance of the volar lunate facet as the cornerstone of stability for the radiocarpal joint and the DRUJ was reported by Melone.[10] The effects of this fragment on radiocarpal instability have been emphasized, and awareness of its importance for DRUJ stability is increasing.[32-35] The volar aspect of the lunate facet contains a radiographic prominence (teardrop) that provides stability against volar subluxation by serving as a bony buttress at the origin of the short radiolunate ligament.[12,36] Loss of fixation of the volar lunate facet has been widely recognized as a mechanism of failure after volar plating.[21,22,37] Because the teardrop is less than 5 mm wide and has a relatively steep volar slope, it is difficult for the ulnar limb of volar locking plates to provide adequate stabilization.[37,38] This chapter's authors believe that at least two points of fixation are needed within this critical corner of the intermediate column. The newest volar locking plates feature two distal rows of multiaxial locking screws, providing the potential to achieve additional screw purchase within the volar lunate facet.[39] However, it is unlikely that the additional proximal row of screws provides sufficient distal capture for this small fragment, and distal placement of the entire plate comes at the expense of potential flexor tendon irritation. Given this risk, alternate methods of fixation are often preferred to secure the volar lunate facet fragment. Plating of the intermediate column can be accomplished through a volar-ulnar incision using a buttress pin, a mini plate-and-screw construct, or a tension banding technique.[14,34,40,41] These fixation techniques can be used as part of a multicolumn internal fixation approach or an approach augmented by external fixation.[8,34]

What Cannot Be Fixed With a Volar Plate?

Dorsal Ulnar Fragment

The displaced dorsal ulnar fragment is particularly challenging to control with a volar implant. Although not all dorsal ulnar fragments require stabilization, it is important to recognize that this fragment comprises a portion of both the radiolunate and radioulnar articular surfaces, and displacement of larger fragments can lead to instability of either joint. The inability to secure the dorsal ulnar fragment, depending on its size, can prevent the maintenance of adequate sagittal radiocarpal alignment and predispose the fracture to dorsal collapse. Although dorsal comminution and articular impaction can be addressed using an extended flexor carpi radialis approach,[42] this technique relies on indirect articular reduction and gaining adequate indirect purchase of the dorsal fragments with volarly to dorsally placed screws. A dorsal approach provides the surgeon with the advantage of visualizing and directly reducing the articular surface, often through a limited and targeted approach. The application of a dorsally based implant also provides a buttress against dorsal fragment displacement, which decreases the risk of secondary collapse.

As previously mentioned, the frequency of hardware-related irritation of the extensor tendons was a major limitation of conventional dorsally applied implants. This prompted the development of low-profile dorsal plates; however, these plates had inherently less material strength. In recognizing the need to strategically apply these smaller plates, Rikli and Regazzoni[8] introduced the concept of multicolumn fixation. They achieved stable fixation and promising clinical results using 2.0-mm plates positioned on the lateral and intermediate columns at 50° to 70° from each other.[8,43] Biomechanical studies supported the multicolumn strategy, with superior stiffness compared with both augmented external fixation and conventional dorsal plates.[44,45] Because of persistent implant irritation, a system of even lower-profile pin-plates and wireforms was developed.[40,43,46] This fragment-specific implant system allows the surgeon greater versatility in selecting implants for challenging fracture patterns, such as those that include a dorsal ulnar fragment. Using a pin-plate to secure the dorsal ulnar corner allows buttressing of the deformity while minimizing the risk of soft-tissue irritation. Multicolumn fixation with fragment-specific implants has been used with good to excellent results and no reported extensor tendon ruptures.[40,47,48]

The specific utility of multicolumn fixation for stabilizing the dorsal ulnar fragment is substantiated by biomechanical testing. During loads expected in the rehabilitation phase, the dorsal ulnar pin-plate provided a buttress effect against dorsal closure of the osteotomy that was not provided by the volar locking plate.[49] A biomechanical evaluation by Taylor et al[50] demonstrated that a multicolumn approach using a dorsal ulnar pin-plate provided greater stiffness for the ulnar-sided fracture fragment than a volar locking plate. When viewed in conjunction, these studies indicate that multicolumn plating provides an advantage over volar locking plates in securing the intermediate column and opposing dorsal fracture collapse.

Volar Ulnar Fragment

As previously mentioned, the volar ulnar fragment is regarded as the cornerstone of the radiocarpal joint and the DRUJ because it plays critical roles in maintaining sagittal alignment, transmitting the load from the carpus, and providing sigmoid notch congruity.[9,10,37] The challenges of securing the volar ulnar fragment with a volar locking plate mainly arise from the small size and sloping morphology of the fragment.[38] Given the contour of currently available volar locking plates, it is difficult to achieve multiple points of fixation within the volar ulnar fragment. Moving the plate more distally puts the flexor tendons at increased risk for irritation, whereas using a multiaxial guide to obtain more distal and ulnar screw trajectories increases the risk of screw placement within the radiocarpal joint or the DRUJ. The shortcomings of using volar locking plate fixation in this situation have been recognized along with the need for smaller implants that can be placed more distally.[21,37] It has been reported that Kirschner wires, tension-band wiring, and miniplates provide adequate fixation of the volar ulnar corner.[34,41] The volar buttress pin has been reported to provide rapid and secure fixation of small critical corner fragments.[14,15,40] Provisional fixation of the fragment is performed with a Kirschner wire, and sagittal radiocarpal alignment and stability are carefully assessed. The buttress pin has two prongs that provide fixed-angle support within the subchondral bone (**Figure 3**). The proximal aspect of the volar buttress pin implant is secured to the intact diaphysis with 2.0-mm screws and washers. Although the implant can be applied through the standard volar approach, a limited approach between the flexor tendons and the ulnar neurovascular bundle is helpful when performing multicolumn fixation with multiple incisions.[14,15] Care must be taken to avoid traction on the median nerve and the palmar cutaneous branch if applying an ulnar-sided implant through a standard Henry approach.

Marginal Articular Shear Fractures

Marginal shearing fractures (Fernandez type II) are difficult to treat with volar locking plates for many of the same reasons described for dorsal and volar ulnar fragments[13] (**Figure 4**). Dorsal shearing fractures (reverse Barton fractures) are associated with radiocarpal subluxation or dislocation. These fractures are relatively uncommon; are usually caused by high-energy mechanisms; and often have a spectrum of associated volar injuries, including carpal ligament tears, articular impaction, and volar marginal shearing.[51] Because of the direction of the associated radiocarpal instability, these injuries are often best approached from the dorsal side. Articular impaction can be directly assessed from this approach, and bone grafting is often helpful to provide subchondral support. The fracture is then buttressed with a dorsally based implant to minimize the risk of recurrent instability.[51] Low-profile implants of various sizes, ranging from 2.0-mm to 3.5-mm dorsal plates to fragment-specific pin-plates or wireforms can be used (**Figure 4**). The surgeon chooses the implant based on the fracture characteristics and the soft-tissue coverage capability. Volar shearing fractures (and the treatment of volar injuries associated with dorsal marginal shearing fractures) require an analogous approach. Larger fragments can be stabilized with volar locking plates; however, marginal shear fragments typically require the use of low-profile, distally positioned implants to buttress the articular surface.

Unstable Radial Styloid

The radial styloid plays a critical role in radiocarpal stability, providing both an osseous buttress and the ligamentous origin of the stout palmar radiocarpal ligaments.[9] Reduction of the ra-

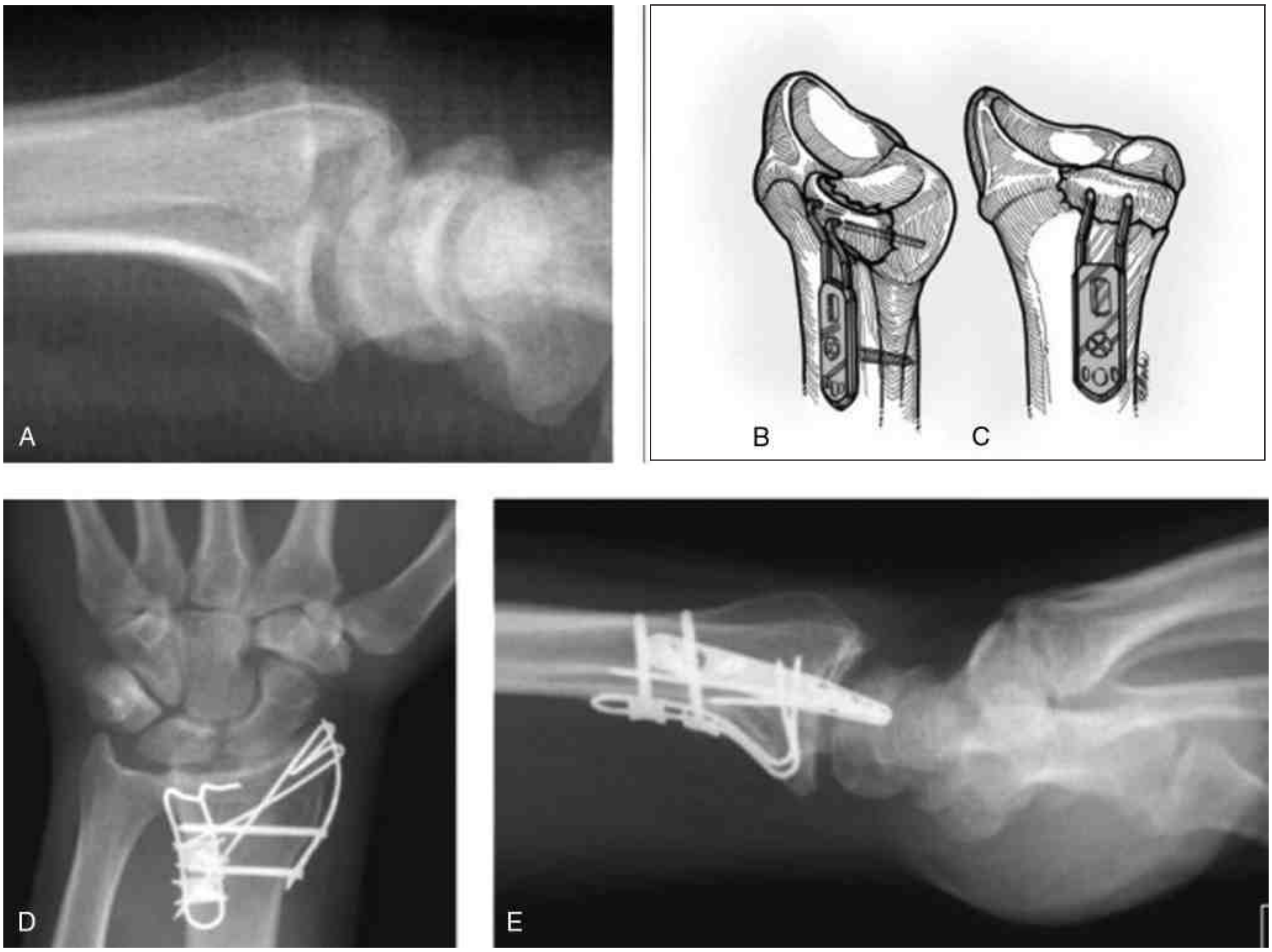

Figure 3 A volar buttress pin can be used to secure the volar ulnar corner of the distal radius. **A,** Radiograph showing volar subluxation of the carpus. Oblique view (**B**) and frontal view (**C**) of a volar buttress pin applied to secure the volar-ulnar corner. AP (**D**) and lateral (**E**) intraoperative radiographs of multicolumn fixation, including a volar buttress pin. (Reproduced with permission from Wolfe SW: Distal radius fractures, in Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH, eds: *Green's Operative Hand Surgery*, ed 6. Philadelphia, PA, Elsevier, 2010, pp 561-638.)

dial styloid is essential to ensure appropriate restoration of radial inclination and the length and congruity of the radioscaphoid articulation. Two or more points of fixation can usually be obtained for large radial styloid fragments within the radial-sided distal screws of the volar locking plate. However, if anatomic reduction and solid fixation of the radial styloid cannot be confidently obtained because of comminution, small fragment size, or instability from shearing, the application of a 2.0-mm plate should be considered along the radial column.[8,40] The plate provides additional coronal plane compression to close articular gaps and aids in supporting a comminuted articular surface (**Figure 5**). This plate can be used in combination with a volar locking plate or intermediate column-specific, low-profile implants.[40,52,53] Mechanical studies support the addition of a radial column plate to enhance the stability of a volar locking plate for comminuted articular fractures.[54]

Central Impaction

The dorsal approach provides a distinct advantage if there is substantial central impaction of the articular surface. Because of the volar radiocarpal ligaments, the volar approach requires indirect visualization and reduction techniques. Alternatively, an extended Henry approach allows visualization but entails considerable periosteal stripping.[42] Using a targeted dorsal approach, the articular surface is directly reduced and reconstructed. Bone graft may be used to fill subchondral and metaphyseal voids to aid in supporting small impacted articular fragments. If the subchondral bone has sufficient integrity, a dorsal plate is applied for

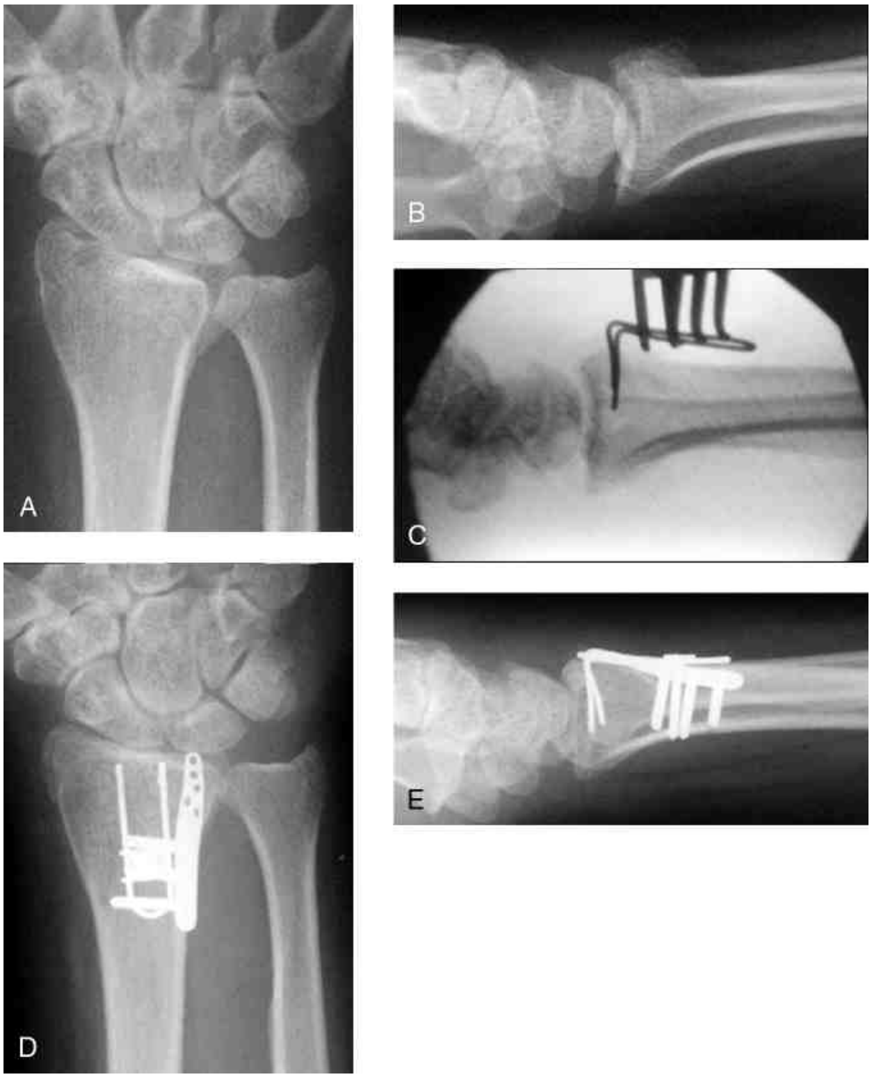

Figure 4 Preoperative (**A**) and lateral (**B**) radiographs of a dorsal marginal shear fracture. **C,** Intraoperative lateral fluoroscopic view. The fracture was reduced and secured with dorsal wireform implants. AP (**D**) and lateral (**E**) radiographs taken 1 month postoperatively.

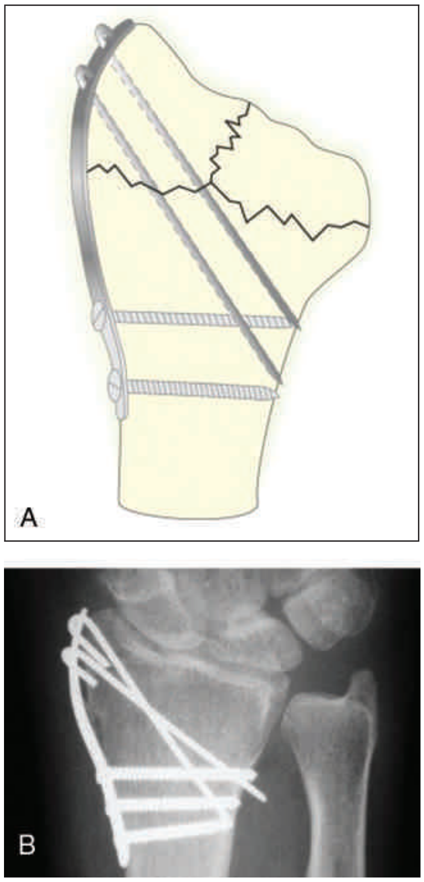

Figure 5 Illustration (**A**) and radiograph (**B**) of a radial styloid plate used to stabilize an unstable radial styloid fracture and to close an articular gap. (Panel 5A reproduced with permission from Wolfe SW: Distal radius fractures, in Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH, eds: *Green's Operative Hand Surgery*, ed 6. Philadelphia, PA, Elsevier, 2010, pp 561-638. Panel 5B copyright Scott Wolfe, MD, New York, NY.)

fracture fixation. If bone stock is severely compromised from a high-energy injury, a spanning dorsal plate can be used in a bridging fashion to neutralize the compressive forces on the articular surface[55,56] (**Figure 6**). The plate, which essentially serves as an internally placed external fixator, is placed along the dorsal wrist and beneath the extensor retinaculum. Fixation screws are placed far from the zone of injury, in the radial diaphysis and the metacarpal, to increase the rigidity of the construct.[57] Different plates and hardware positions have been reported, with the original description of a 3.5-mm plate applied under the fourth dorsal compartment.[58] Hanel et al[59] described the use of a 2.4- to 2.7-mm combiplate applied under the second dorsal compartment. Three screws each are placed on the distal and proximal sides using a combination of locking and cortical screws.[60] In addition to its use for centrally impacted articular injuries, this technique is useful in the polytrauma setting (limited surgical time, bilateral fractures, and fractures with severe comminution or osteoporosis).[56,59,61] Consolidation of the fracture typically occurs at a mean of 110 days; the distraction plate can be removed shortly thereafter.[56] The clinical results are comparable to other fixation techniques. The complication profile is safe, with the need for staged plate removal being the major limitation.[62]

Figure 6 AP (**A**) and lateral (**B**) radiographic views of a spanning plate used to bridge a comminuted articular surface. Fixation points are placed far from the zone of injury. (Reproduced with permission from Ruch DS, Ginn TA, Yang CC, Smith BP, Rushing J, Hanel DP: Use of a distraction plate for distal radial fractures with metaphyseal and diaphyseal comminution. *J Bone Joint Surg Am* 2005;87(5):945-954.)

DRUJ Instability

Volar plating alone cannot treat DRUJ instability. Stabilization of the intermediate column may help improve DRUJ stability in two ways: by (1) restoring articular congruency of the sigmoid notch to provide a seat for the distal ulna and (2) tensioning the TFCC and the surrounding soft-tissue stabilizers of the DRUJ. In each instance, stability of the ulnar column should be assessed immediately after the lateral and intermediate columns have been stabilized. Injury patterns with TFCC avulsions or basilar styloid fractures or fractures with proximal extension are at highest risk for DRUJ instability.[35] If the DRUJ is unstable, forearm rotation should be examined to find a position of stability for postoperative immobilization. Ten to 14 days of above-elbow immobilization is generally sufficient to achieve adequate stability to begin active forearm rotation exercises. If a stable position cannot be identified, TFCC repair and/or open reduction and internal fixation of the basilar styloid or ulnar head fracture should be performed using Kirschner wires or styloid-specific plates. In the setting of persistent instability, dual 0.062-inch Kirschner wire fixation can be used to temporarily fix the radius and the ulna in supination.

Summary

Although most distal radius fractures can be treated reliably with volar locking plates, each fracture should be carefully assessed to ensure that alternative strategies are not needed. When using volar locking plates, the risk of tendon-related complications can be minimized by drilling in a unicortical fashion, inserting less than full-length distal locking screws, and avoiding distal positioning of the plate. The importance of the intermediate column, specifically the volar and dorsal ulnar fragments of the distal radius, cannot be overemphasized. Inadequate fixation of these fragments can have adverse implications on radiocarpal alignment, radioulnar stability, and functional outcome. Marginal shearing fractures are difficult to secure with volar locking plates. Multicolumn fixation techniques can be used to fix volar and dorsal ulnar fragments and buttress marginal shearing fractures. Dorsal approaches can be useful in reconstructing impacted articular fractures, with dorsal plating or distraction plating used for definitive fixation. The ulnar column needs to be assessed after osteosynthesis of the distal radius is complete, with stabilization if necessary via styloid plating, TFCC repair, or supine immobilization. Adherence to these principles will maximize the opportunity for the restoration of normal anatomy and function after a distal radius fracture.

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