A Review Paper

Internal Fixation of Distal Radius Fractures

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Abstract

When adequate fracture reduction cannot be achieved with closed techniques, internal fixation can restore anatomy and improve functional outcomes. Volar plating, dorsal plating, and radial plating are well-described techniques that are useful in isolation or in combination, depending on the specific fracture pattern. In this article, we review each of these techniques and provide case examples to illustrate their applicability.

Despite widespread enthusiasm for volar plating, current literature does not demonstrate a clear benefit of plating over external fixation.[1-3] When a fracture is well reduced, either technique can provide similar good results. In contrast, inadequate reduction with residual intra-articular incongruency or carpal translation will provide poor functional results.[4-6] The key to positive outcomes, therefore, is appropriate reduction rather than type of fixation used.

The benefit of internal fixation is the ability to manipulate and control the major fracture fragments in displaced, unstable fractures better than is possible with external fixation or Kirschner wire pinning. Through ligamentotaxis, external fixation with or without supplemental pinning can reduce large fracture fragments, restore radial length and inclination, and prevent subsequent collapse. These maneuvers, with or without dorsal bone grafting, can reliably treat most extra-articular and simple intra-articular fractures. However, in cases of unstable intra-articular fractures, external fixation often cannot control all fracture components. This is especially true with regard to reduction of the lunate facet fragment, which is essential in restoring distal radioulnar joint (DRUJ) congruency.[7] In many instances, external fixation cannot restore articular congruity,[8] in which case internal fixation should be pursued. In addition, the amount of time in the external fixator is limited, and after removal, radial alignment can continue to change with additional subsidence into the metaphyseal void, especially when bone graft or substitutes are not used.

When the fracture pattern is not amenable to external fixation and percutaneous pinning because of inability to adequately reduce fracture components and restore articular congruity, the surgeon must decide which type of internal fixation is most appropriate. Although volar plating is the most common open technique, it may not be optimal or sufficient in certain circumstances. Fixed-angle trajectory screws may not be able to capture the necessary unstable fragments required to achieve a stable reduction. Several next-generation volar plates address this issue by allowing variable-angle screw trajectories. However, angle variability is limited, and volar screws may still be inadequate for capturing certain fracture fragments. In these circumstances, dorsal or radial plating can be applied as a means of primary or secondary fixation. As a basic principle, unstable fragments should be adequately captured and maintained throughout fracture healing and rehabilitation.

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Reduction Parameters

On first presentation, closed reduction should be performed before any operative intervention. After closed reduction is performed, standard anteroposterior (AP), lateral, and oblique wrist plain films should be obtained. Normal radial parameters are radial inclination of 23.6°, radial height of 11.6 mm, and ulnar variance of –0.6 mm.[9] Normal volar tilt is around 11 mm, with a range of 0 mm to 22 mm. However, contralateral wrist plain films should be obtained to account for individual anatomical variability.

On lateral plain films, it is important to assess for carpal translation. In a prospective, randomized study, McQueen and colleagues[5] demonstrated that the main predictor of final functional outcome was carpal malalignment. On AP plain films, it is important to critically assess the ulnar variance and sigmoid notch alignment. Incongruence at the sigmoid notch can result in restricted pronation/supination. Ulnar variance has been shown to reflect fracture instability and radiographic outcome with statistical significance.[10] Restoration of radial height has also been shown to have predictive value in functional outcome analysis.[6]

When one is evaluating plain films, it is important to identify patterns associated with ligament injuries. One arthroscopic series reported scapholunate ligament injuries with instability in 21.5% of intra-articular fractures and 6.7% of extra-articular fractures.[11] This study also reported triangular fibrocartilage complex (TFCC) injuries in 35% of intra-articular fractures and 53% of extra-articular fractures. On plain films, ulnar styloid base fractures and significant radial shortening or dorsal angulation are associated with TFCC injuries.[11,12] Awareness of concomitant ligamentous injuries and careful examination help

Figure 1. **(A,B)** Volar Barton fracture with displaced volar fragment. **(C,D)** Plain films at 4-month follow-up. Note screw capture of the lunate facet fragment and the subchondral position of the distal row of screws. **(E)** Measurements at 4-month follow-up.

Case 1. 4-Month Follow-up

Range of motion	ext: 95% flex: 85% sup: 94% pron: 100%
Grip	92% of uninjured side
DASH	10
Visual Analog Scale score	0.5 cm (0-10 cm)

E

surgeons discern instabilities that require treatment beyond fracture fixation.

Once surgery is indicated, the approach and sequence of reduction maneuvers should be mastered. First, the lunate facet fragment, which is critical, should be reduced and stabilized. This will align the sigmoid notch and maintain carpal alignment, both of which will maximize wrist mobility and allow for postoperative rotatory motion. Also, when fluoroscopy is used to assess reduction and subchondral screw placement during surgery, a 20° lateral projection is more helpful than a standard lateral image. The 20° lateral image, which accounts for the radial inclination, displays the ulnar two-thirds of the articular surface and defines the volar rim of the lunate facet.[9] Last, after fracture fixation, it is important to assess DRUJ stability by examining the amount of translation compared with that in the patient's normal contralateral wrist. DRUJ instability is associated with poor wrist function and increased pain.[13] Consequently, any significant asymmetric DRUJ instability should be addressed.

Volar Plating

Volar plates are ideally suited to buttressing volarly displaced fractures, such as Smith fractures and volar Barton fractures. But volar locking plates can be effectively used for dorsally displaced fractures, as well.[14] The volar approach allows access to the entire distal radius from the radial styloid to the volar lunate facet. Therefore, this is a utilitarian approach for intra-articular fractures with multiple fragments. In terms of fixation, currently available fixed-angle locking plate technology offers stability comparable to that of an intact radius.[15] Locking plates also have the advantages of improving stability in osteoporotic bone and preserving periosteal blood supply.[16-18]

A variety of volar approaches have been described.[19,20] The standard Henry approach is carried out between the radial artery and the flexor carpi radialis. The modified Henry approach is performed through the flexor carpi radialis sheath. The extended carpal tunnel approach develops the interval between the finger flexor tendons and the flexor carpi ulnaris. This last approach allows for improved visualization of the ulnar side of the radius and is useful for reduction of unstable ulnar fragments.

Complications associated with volar plating, like those associated with other plating techniques, include tendon injury, infection, stiffness, pain syndromes, joint penetration, and cartilage injury. The extensor tendon may be injured if a screw is excessively long. It is helpful to keep in mind that on a true lateral image, the most dorsal cortical projection corresponds to the Lister tubercle. Therefore, appropriate-length screws placed ulnar to the third extensor compartment may appear short on a lateral image because of the dorsal projection of the Lister tubercle. Obtaining a 20° inclined lateral view will truly assess screw position.

Case 1: Volar Barton Fracture

Because of the significant volar displacement with carpal translation in this case (Figures 1A, 1B), a volar buttress plate would best serve to reduce and stabilize the fracture. It is important for the plate to be positioned at the extreme medial

Figure 2. (A,B) Dorsal Barton fracture with significant dorsal comminution. (C–E) After reduction, displaced dorsal fragments and evidence of significant dorsal cortical comminution remain. (F,G) Postoperative plain films after dorsal plating and bone grafting, with restoration of normal radial parameters.

margin of the lunate facet, bordering the DRUJ, to prevent lunate escape and retranslation. As already mentioned, stabilization of this piece will maintain joint congruence and radial length and thereby permit full rotation. Depressed fracture fragments should be elevated to restore radial length and tilt. Use of a bone graft or bone graft substitute can aid in maintaining reduction of these fragments before screw purchase. Each volar plate design has a different seating on the volar cortex and different fixed trajectories into the dorsal rim, but every effort should be made to place the screws in a subchondral position to minimize subsidence and to capture the dorsal fracture fragment. Plain films obtained at 4-month follow-up show maintenance of reduction (Figures 1C, 1D). Measurements at 4-month follow-up are depicted in Figure 1E. The patient participates in unrestricted work and sports activities.

Dorsal Plating

Dorsal plates can be used as primary fixation for dorsally displaced fractures. Alternatively, they can be used as secondary fixation when a volar plate cannot capture a displaced dorsal fragment. Facet-specific dorsal plates can also be applied after metaphyseal void bone grafting for dorsal comminution to help support the articular surface. In a retrospective study comparing volar and dorsal plates as a primary mode of fixation, Ruch and Papadonikolakis[21] illustrated that dorsal plates were associated with higher rates of volar collapse and late complications when applied to injuries with significant volar cortex comminution. Interestingly, the 2 groups had equivalent Disabilities of the Arm, Shoulder, and Hand (DASH) scores, and all cases went on to bony union. These results suggest that dorsal plates may be better suited as a secondary means of fixation.

The dorsal approach uses the third extensor compartment with radial transposition of the extensor pollicis longus tendon. This is followed by subperiosteal elevation of the fourth compartment to expose the major fracture pieces. If necessary, the Lister tubercle can be removed to allow for better plate position and a flatter surface for monobloc plating.

Initial experience with dorsal plating was fraught with tendon complications[22-24] apparently stemming from plate

Figure 3. (A,B,C) Preoperative plain films show displacement of the radial column fragment. (D,E) Plain films at 4-month follow-up. (F) Measurements at 4-month follow-up.

Case 3. 4-Month Follow-up

Range of motion	**ext: 83%** **flex: 75%** **sup: 100%** **pron: 100%**
Grip	**78% of uninjured side**
DASH	**3**
Visual Analog Scale score	**1.0 cm (0-10 cm)**

F

design and composition. Early plates were higher profile, between 2.5 and 3.5 mm, which caused tendon irritation and rupture. Also, it has been shown that the initial titanium composition of the plates caused marked soft-tissue inflammation.[25] Newer dorsal plates are lower profile (1.2-1.6 mm) and are either stainless steel or titanium alloy. These plate design improvements have reduced complication rates. The recent literature includes very few cases of associated tendon complications with new low-profile plates.[21,26]

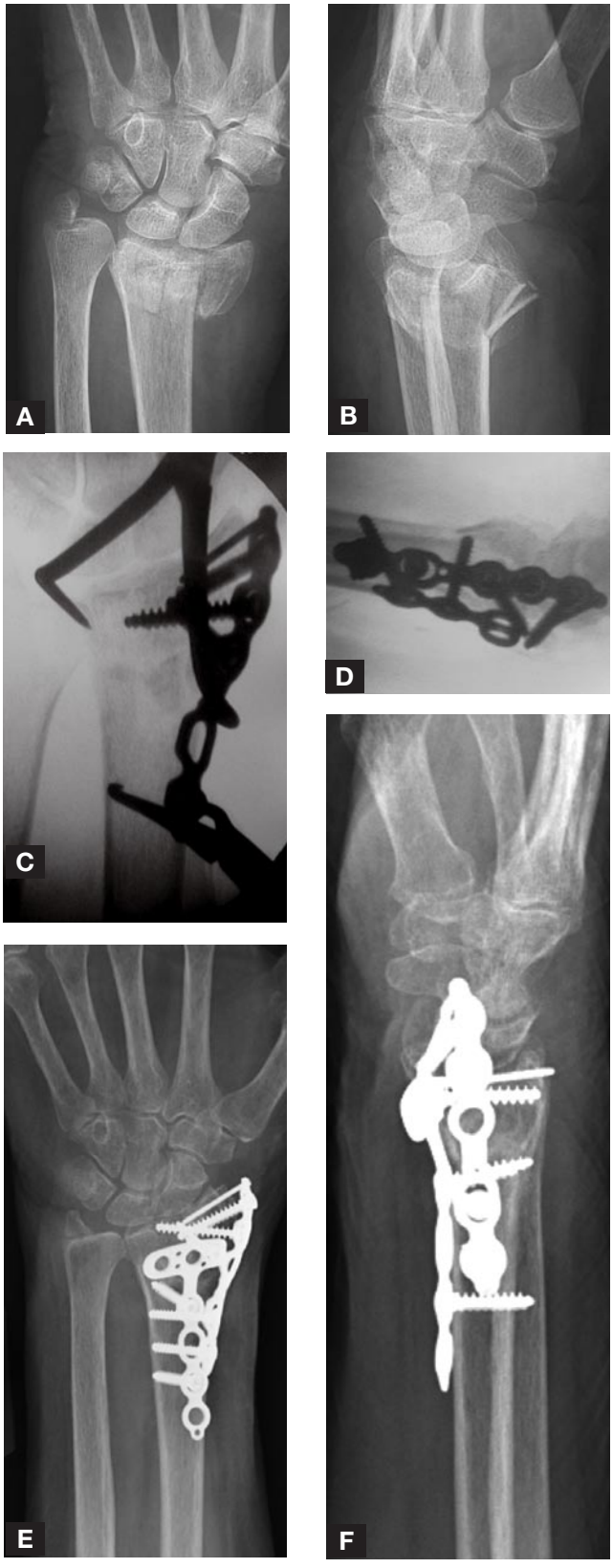
Case 2: Dorsal Barton Fracture With Dorsal Comminution

Preoperative plain films show a dorsally displaced intra-articular distal radius fracture (Figures 2A, 2B). After reduction, there are still displaced dorsal fragments and evidence of significant dorsal cortical comminution (Figures 2C–2E). Therefore, dorsal bone grafting into the metaphyseal void for subchondral support will be needed—followed by stabilization, supplied in this case by a dorsal plate. During surgery, a large dorsal defect was seen after reduction, which was packed with allograft cancellous bone chips. Postoperative plain films show restoration of radial height and tilt parameters (Figures 2F, 2G).

Radial Plating

Radial plates are useful as primary or secondary fixation for fractures with significant radial displacement. This technique can allow greater control by securing both dorsal and volar fracture pieces. Also, less soft-tissue dissection is required, which translates into less operative trauma and potentially fewer soft-tissue complications.[27]

The radial approach is performed through the first dorsal extensor compartment. The superficial radial nerve should be identified and protected throughout the procedure. Fortuitously, the superficial radial nerve divides into dorsal and palmar branches so the dissection and plate application can occur between the branches without excessive retraction. The brachioradialis is elevated for later closure over the plate to the pronator quadratus. The radial capsular ligaments are left intact.



Case 4. 5-Month Follow-up

Range of motion	ext: 30% flex: 20% sup: 100% pron: 100%
Grip	40% of uninjured side
DASH	6
Visual Analog Scale score	0.0 cm (0-10 cm)

G

Figure 4. (A,B) Comminuted intra-articular fracture displacement of the radial column, along with both dorsal and volar displacement of the intermediate column. (C) Reduction of the radial column with application of a radial plate. (D) Application of a volar buttress plate to maintain reduction of the intermediate column. (E,F) Plain films at 5-month follow-up. (G) Measurements at 5-month follow-up.

Case 3: Dorsal Barton Fracture With Radial Displacement

In this case, the distal radial fragment is significantly displaced radially (Figures 3A, 3B, 3C). To restore the normal radial width, height, and inclination dimensions, a radial plate was applied. After the reduction was performed, restoration of the radial inclination resulted in a radial bony defect, which was filled with allograft. The distal screws are directed in divergent sagittal directions to capture both dorsal and volar fragments (Figures 3D, 3E). Four months after surgery, the patient returned to work without restrictions. Measurements at 4-month follow-up are depicted in Figure 3F.

Case 4: Comminuted Intra-Articular Fracture With Multiple Displaced Fragments

Preoperative plain films show significant radial translation of the radial column (Figure 4A). In addition, the lateral x-ray indicates both volar and dorsal displacement of the intermediate column pieces (Figure 4B). To first define the radial boundary of the fracture and to restore the radial height, a radial plate was applied (Figure 4C). Next, to reduce and buttress the ulnar fragments, a secondary volar plate was applied (Figure 4D). Five-month postoperative plain films (Figures 4E, 4F) and measurements (Figure 4G) are provided. The patient has returned to all activities of daily living.

Conclusions

Because of a lack of persuasive randomized clinical trials, there is still active debate as to whether internal fixation is superior to external fixation for distal radius fractures. The debate is more confusing with the concepts and evolution of non–joint-spanning external fixators. Most orthopedic surgeons agree that there are certain intra-articular fracture patterns that are better treated by plating because of the difficulty reassembling the fracture fragments with external fixation alone. Internal fixation can be accomplished safely and effectively through a variety of approaches. Reliability and predictability should guide and inform surgeons' decisions, but the quality of reduction, along with the avoidance of complications, is paramount.

Authors' Disclosure Statement

Dr. Kim reports no actual or potential conflict of interest in relation to this article. Dr. Rosenwasser wishes to note that he has served as a consultant for Biomet, Inc. and Stryker, Inc.

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