Review Article

Adult Distal Radius Fracture Management

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ABSTRACT

Distal radius fractures (DRFs) are some of the most commonly encountered fractures, and the incidence is increasing. Optimal treatment remains controversial. Critical evaluation of the initial imaging is necessary to recognize fracture characteristics and stability. The fracture pattern, injury mechanism, soft-tissue injury, patient characteristics, and surgeon preference are generally taken into consideration when choosing the most appropriate modality. Volar plating has become the workhorse of surgical DRF management but is not without complications. The surgeon should be comfortable using a wide variety of techniques to customize the fixation to the fracture pattern. Recognition of potential dangers and use of intraoperative imaging techniques can mitigate complications. Goals of rehabilitation after the initial treatment of DRF include regaining motion, strength, and ultimately function while managing pain.

Distal radius fractures (DRFs) are some of the most commonly encountered fractures. In the United States, DRF accounts for nearly 17% of all fractures seen in the emergency department with increasing incidence over the past few decades.[1] Optimal treatment is controversial. Here, we present a thorough review of the current literature regarding the management of DRFs.

Initial Imaging

Management of DRFs is fundamentally guided by radiographs. Radiographic parameters to measure include radial height, radial inclination, volar tilt, ulnar variance, and the teardrop angle; other radiographic factors to assess include intra-articular extension, articular step-off, dorsal comminution, and associated ulnar fracture (Figure 1).[2] The surgeon's recognition of these features guides treatment by gaining a more thorough understanding of the injury pattern, thereby predicting fracture stability.

CT can be used as an additional tool in preoperative evaluation. Because of the cost and radiation associated with its usage, CT scans are typically recommended to evaluate surgical candidates for the extent of joint comminution, gapping, or depression, especially when these factors are not clear with appropriate radiographs (Figure 2). Ideally, CT scans are obtained after initial closed reduction and immobilization to better define the radiographic

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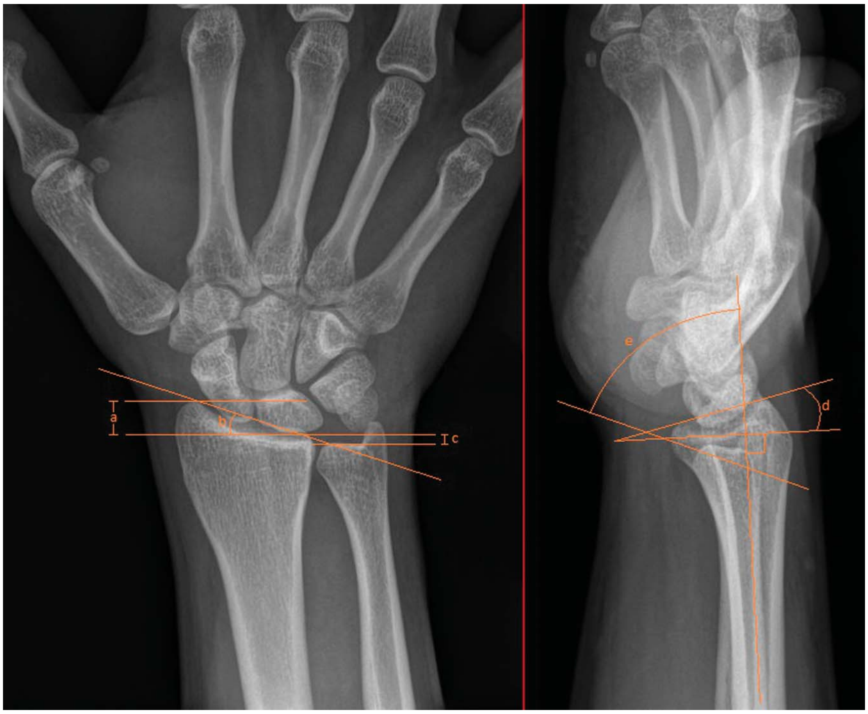
Figure 1



PA and lateral radiographs showing measurements of radial height (**A**), radial inclination (**B**), ulnar variance (**C**), volar tilt (**D**), and teardrop angle (**E**).

features. Although CT scans can identify articular step-offs and gapping better than plain radiography, their influence in decision-making and patient outcomes is unclear.[3]

Treatment

A wide variety of nonsurgical and surgical treatment options exist for DRF. Nonsurgical techniques include closed reduction with initial splint or cast immobilization. Surgical techniques include closed reduction with percutaneous pinning; external fixation; dorsal bridge plating; and open reduction with internal fixation (ORIF) using volar, dorsal, or "fragment-specific" fixation. The fracture pattern, injury mechanism, soft-tissue injury, patient characteristics, and surgeon preference are generally taken into consideration when choosing the most appropriate modality.

One systematic approach is to separate the wrist into the radial, intermediate, and ulnar columns, as described by Rikli and Regazzoni.[4] Rhee et al described a treatment algorithm through the assessment of these individual columns and the pedestal, the metadiaphyseal distal radius, which supports the radial and intermediate columns. For complex DRF, their sequence of wrist construction is anatomic reduction, fixation of the intermediate column to the pedestal, restoration of the radial column, and any necessary management of ulnar column injuries to stabilize the distal radioulnar joint (DRUJ).[5]

Closed Management

A common initial practice with DRFs is obtaining reduction through closed manipulation and immobilization. For displaced fractures, recreation of the fracture mechanism with axial traction often leads to acceptable alignment. Two primary methods for closed reduction exist and have been evaluated in the literature: manual traction and finger trap traction. Both methods assist the provider to manipulate and reduce the fracture appropriately by restoring the radial length. Sosborg-Wurtz et al[6] conducted a recent systematic review of the two methods and noted that reduction by manual traction may better correct volar tilt while finger trap traction may better restore radial length, although these results were not found to be clinically significant. Furthermore, finger trap traction may result in a lower incidence of complex regional pain syndrome (CRPS) and carpal tunnel syndrome and cause less pain during reduction. No consensus exists in the choice of analgesia during reduction as well. A recent meta-analysis found that

Figure 2

A, PA and lateral radiographs showing intra-articular distal radius fractures. **B**, CT scan better revealing intra-articular displacement.

hematoma blocks provide improved postreduction pain relief compared with procedural sedation and analgesia but did not find a difference in pain during reduction or reduction failure.[7] Fernandez[8] investigated the goal radiographic parameters after conducting closed reduction and proposed accepting the following to avoid symptomatic malunion: dorsal tilt ≤10°, radial shortening ≤2 mm, radial inclination ≥15°, ≤2 mm articular step-off, congruent DRUJ, and absence of carpal malalignment. A close follow-up of these patients is important to ensure that they maintain acceptable alignment, with patients usually being seen weekly for the first month after their injury.

Radiographic parameters and patient factors need to be considered to determine the fracture's stability, which is defined as its ability to maintain the radiographic position after acceptable closed reduction and immobilization. One of the most frequently discussed studies regarding criteria to evaluate fracture stability was by Lafontaine et al.[9] They retrospectively reviewed a cohort of 167 DRFs and found that the presence of three or more of the following factors was associated with fracture instability and secondary displacement: dorsal tilt >20°, dorsal comminution, intra-articular radiocarpal fracture, associated ulnar fracture, and older than 60 years. The significance of these variables continues to be scrutinized in more recent literature. A more recent review emphasized dorsal comminution, female sex, and older than 60 years as increased risk factors of secondary displacement.[10] Another prospective study of 157 patients found that loss of radial height, loss of radial inclination, and older than 52 years were the most important factors in predicting fracture instability.[11] The AAOS adopted appropriate use criteria in 2013 that identified unacceptable reduction criteria as radial shortening greater than 3 mm, dorsal tilt greater than 10°, and articular displacement greater than 2 mm.[12] However, without higher levels of evidence, there will likely be no consensus agreement among surgeons for criteria of treatment.

Insufficient evidence exists for the ideal type of immobilization, duration of immobilization, and initiation of therapy with closed management. Although a sugar tong splint to prevent forearm pronation/supination is the most common method of immobilization, this has been challenged. Splints and casts below the elbow are better tolerated by patients but may sacrifice protection against loss of reduction in unstable fractures. Bong et al[13] found similar performance in reduction maintenance between sugar tong and short arm radial gutter splints in a randomized controlled trial of unstable and stable displaced DRFs. Park et al randomly assigned patients older than 55 years with stable DRFs to short arm and long arm casts. Although they found a notable difference in volar tilt at 3 and 6 months, they found no notable difference in functional outcome scores and found more shoulder pain with long arm casts.[14] Regardless of the type of immobilization, shoulder and finger range-of-motion exercise programs should be initiated immediately after immobilization to minimize stiffness and shoulder pain. Immobilization for 4 to 8 weeks is most common despite insufficient evidence. Early cessation of wrist immobilization risks loss of reduction while attempting to minimize stiffness. In the elderly, stiffness seems to be more common after surgical treatment.[15]

Special consideration is given to the elderly patient with osteoporosis. Although older age has been shown to be a predictor of malunion and instability, patients in this age range seem to have acceptable functional outcomes and satisfaction, regardless of malalignment or loss of reduction radiographically.[16] DeGeorge et al[15] found that nonsurgical management was associated with a notable decrease in 1-year complications for patients in this cohort. Therefore, this cohort may require separate guidelines for acceptable radiographic alignment and surgical indications. Kodama et al evaluated 52 active and healthy patients specifically of 60 years or older treated with closed management. They found that volar tilt and ulnar variance were the most notable radiographic parameters affecting clinical outcomes in this cohort.[17]

Closed Reduction and Percutaneous Pinning

Percutaneous pinning can be a useful tool in the fixation of DRFs. Because Kirschner wire fixation is not load-bearing and offers minimal protection against shortening, its use is limited to assisting with initial reduction, unstable DRFs without significant intra-articular involvement, or in conjunction with other modes of fixation that maintain length.

Kapandji[18] first described intrafocal pinning of extra-articular DRFs in 1976, where two Kirschner wires were directed into the fracture site to lever displaced DRFs to improve alignment and maintained to create a buttress effect. Although Kapandji advocated for no additional immobilization postoperatively, this method is typically augmented with additional forms of stability, such as an addition of another wire, or postoperative plaster, or cast immobilization. The ideal duration of postoperative immobilization after percutaneous pinning is unclear.

Percutaneous fixation and ORIF do not seem to have a notable difference in pain or function in the long term. However, when acceptable alignment cannot be achieved through closed or minimal open manipulation, open reduction and internal fixation should be pursued. Although it remains a cost-effective procedure for treating unstable DRF, a recent meta-analysis found that compared with volar plating, closed reduction with percutaneous pinning had a markedly higher incidence of superficial wound (pin tract) infections and CRPS while having lower outcome scores.[19] The technique of burying pins may reduce pin tract infections, although this method may necessitate return to the operating room for wire removal.

Arthroscopy-assisted Fixation

The use of arthroscopy and its effect on patient outcomes have been debated to supplement the previously mentioned fixation strategies. It can be used to identify suspected associated ligamentous injury, assist with anatomic reduction of intra-articular fractures, and remove intra-articular fracture hematoma and debris. Yamazaki et al[20] found in their randomized controlled trial of 74 patients that arthroscopic assistance did not improve functional outcomes or radiographic outcomes for unstable intra-articular DRF. Selles et al[21] conducted a randomized controlled trial of 57 patients and found that arthroscopy to remove intra-articular hematoma and debris did not lead to better outcomes with the 1-year follow-up. They also found soft-tissue injuries to the TFCC, SL ligament, and Lister tubercle (LT) ligament injuries in all their patients, but these ligamentous injuries diagnosed on arthroscopy did not require additional treatment in their study. Although arthroscopy remains the benchmark for the diagnosis of SL, LT, and TFCC ligamentous injuries, their treatment after DRF also remains controversial.

External Fixation

External fixation has long been used in the setting of orthopaedic trauma as a means of both temporary and definitive fixation. The placement of wrist spanning external fixators uses the bare area between the brachioradialis and extensor carpi radialis longus on the forearm and the dorsolateral aspect of the second metacarpal in the hand. Although its use in the treatment of DRF has been mostly supplanted with the introduction of internal fixation techniques, it remains a useful tool for intra-articular DRF with notable comminution and soft-tissue injury, especially in patients who do not require accelerated functional outcome. External fixation can maintain length in the setting of notable comminution through ligamentotaxis but has a small effect on fragment reduction and requires subsequent removal. External fixators can also be used as an adjunct to percutaneous pinning or Kapandji intrafocal pinning for unstable extra-articular DRF.[22] A biomechanical study by Wolfe et al[23] noted that the rigidity of the external fixator can be markedly increased with an augmentation using a single transfixion Kirschner wire.

Complications with external fixation include neuropathies, pin tract infections, pin loosening, nonunion, and malunion. Damage to branches of the superficial sensory radial nerve and lateral antebrachial cutaneous nerves can be avoided with good visualization techniques. The avoidance of pin tract infections requires pin-site care and monitoring, although no pin-site care protocol has been shown to be markedly better than another.[24]

Dorsal Bridge Plating

Dorsal bridge plating techniques are used in cases of severe comminution, soft-tissue injury, osteoporosis, radiocarpal fracture-dislocation, or in the polytraumatized patient because it provides rigid fixation and distraction across the wrist with earlier ability for weight-bearing through the extremity (Figure 3).[25] This technique provides the following multiple advantages: it facilitates reduction, prevents radial shortening, permits the soft-tissue envelope to mature, and preserves radiocarpal and radioulnar joint stability. Its popularity has grown especially in preference to external fixation with a similar complication and outcome profile to other treatment methods.[26] Bridge plating can also assist in the salvage of DRF nonunions or malunions. However, widespread adoption of this technique has been stifled by the need for subsequent implant removal surgery and concern for postoperative stiffness. Lauder et al showed a decrease in wrist flexion, wrist extension, and grip strength in dorsal bridge plating of the nondominant extremity, whereas seeing only a loss of wrist flexion in dorsal bridge plating of the dominant extremity.[27] This suggests that rehabilitation and use of the extremity after plate removal may recover some of the lost function.

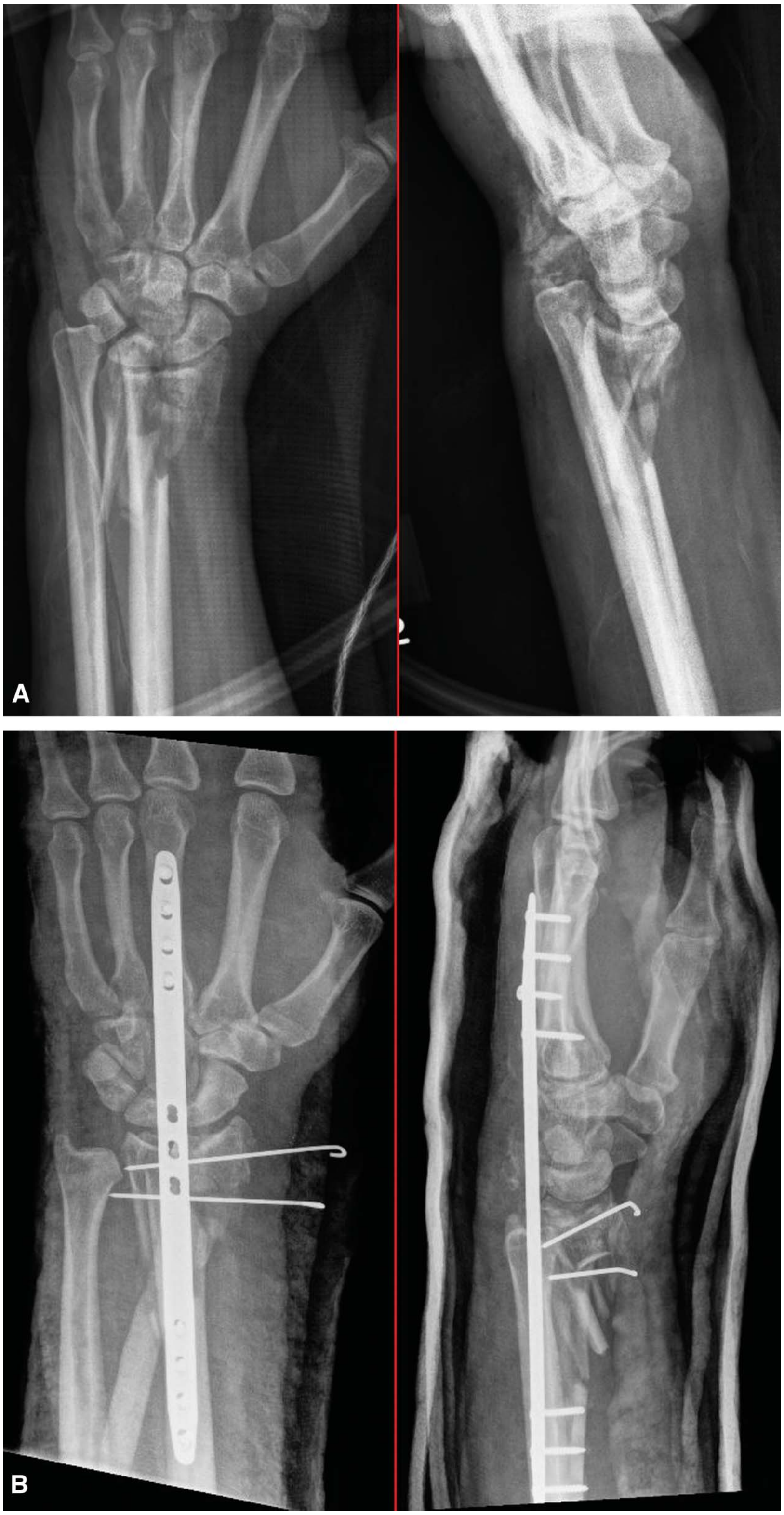
Dorsal Fixation

The greatest advantage of dorsal plating is the ability to buttress a dorsally displaced DRF. It may also be useful in dorsal shear fractures and dorsal die-punch fractures. However, compared with other methods of DRF fixation, dorsal plating has fallen out of favor because of its association with subsequent extensor tendon irritation or rupture due to direct contact over the implant, with the extensor pollicis longus (EPL) most commonly affected. This may be mitigated by the removal of implant after fracture healing or use of newer generation plates, which are "low profile" with a thickness roughly half of the original dorsal plates. Using the extensor retinaculum or other biomaterial to cover the dorsal implant has been reported to decrease the occurrence of extensor tendon dysfunction.[28] Should tendon rupture occur, primary repair is usually not possible because of substance atrophy, retraction, or fraying of the tendon ends. The extensor indicis pollicis remains the most commonly used for tendon transfer to the EPL in these situations.

Volar Fixation

Volar plating has become the most common surgical fixation method preferred by clinicians for its lower complication rate compared with other modalities.[29] Volar locking plates are suitable for unstable extra-articular, basic intra-articular fractures, and osteoporotic individuals, affording early motion and relatively low complication rates (Figure 4). Furthermore, the volar incision can be extended distally to just proximal to the wrist crease, as described by Tannan et al,[30] for a

Figure 3



A, PA and lateral radiographs showing comminuted distal radius fractures. **B**, Open reduction with internal fixation using dorsal bridge plating and percutaneous pinning.

Figure 4

A, PA and lateral radiographs showing dorsally displaced distal radius fractures. **B**, Internal fixation using volar plate fixation.

concurrent carpal tunnel release. This method provides the following advantages: no need for incisions over the palm or nerve, no nerve manipulation, reduced retractor–related trauma, and improved exposure to the volar radius. However, the volar approach is not without its limitations.

Volar fixation may not be the best technique for unstable volar rim/shear fractures, fractures with notable articular comminution, or DRFs with DRUJ instability. The improper use of volar plating can lead to iatrogenic tendon injuries, loss of reduction, inadequate fixation, intra-articular screw placement, neurovascular complications, and implant failure.[31-38]

Mehling et al noted in their biomechanical study that the greatest construct stability, highest stiffness under axial compression, and highest load to failure were noted when filling locking screws in all distal plate holes in the distal fragment within 3 mm of the subchondral bone. They recommended at least four screws in the distal fragment with at least two of them in the distal row of the plate.[39] Beck et al[33] found an association with volar plate failure and less than 15 mm of volar cortex available for fixation. This is of specific concern during volar plating for the volar rim or shear fractures because this can lead to excessively distal plate placement leading to iatrogenic tendon injury.

Mechanical and vascular compromise secondary to the surgical repair can lead to tendon irritation, adhesion formation, tenosynovitis, and rupture. For example, flexor tendon irritation can occur with plate placement distal to the "watershed line," the transverse ridge proximal to the articular surface, and distal to the pronator quadratus. This irritation can ultimately lead to attritional rupture, most commonly of the flexor pollicis longus.[27] In a case series by Drobetz and Kutscha-Lissberg of 50 DRFs treated by the volar locking screw plate system, flexor pollicis longus rupture was noted in 12% of patients at a mean of 10 months postoperatively. They further noted that some of their tendon ruptures could be attributed to improper seating of the locking screw heads, leading to prominence and abrasion of the tendon.[40] Patient education to recognize symptoms and continued follow-ups are important because these complications can occur weeks to months after undergoing ORIF. However, the best way to avoid these complications is with careful placement of volar locking plates with completely flush screw heads proximal to the watershed line. Other strategies to prevent tendon compromise include repair of the pronator quadratus, although no notable advantage has been found in the literature. Using shorter unicortical screws or smooth pegs, ≥75% of the measured length may also limit complications to extensor tendons.[41] These potential issues should be identified before leaving the operating room by the use of fluoroscopy as outlined in the imaging section. If symptomatic tendinitis occurs, implant removal can resolve symptoms in patients who have gone on to union and prevent tendon rupture.

Fragment-specific Fixation

Fragment-specific fixation, first described by Medoff and Kopylov in 1998, uses low-profile implants to provide the surgeon with an individualized approach to DRF management. Although more technically demanding, fragment-specific fixation can be a useful tool for a wide range of fracture patterns, including volar rim/shear, ulnar corner, dorsal wall, radial styloid, and free intra-articular fragments (Figure 5). Fragment-specific fixation requires identification of these DRF implants, followed by independent fixation with semielastic fixation mechanisms to restore articular anatomy without the need for effective thread purchase in small articular fragments.[42] This creates a load-sharing construct with a theoretical advantage to permit earlier range of motion. A biomechanical study by Taylor et al[43] revealed no notable difference in the stiffness of the constructs between fragment-specific fixation and fixed-angle volar plating, implying that they would do similarly with an early range-of-motion protocol. When compared with volar plating for outcomes, Sammer et al found fragment-specific fixation to be less stable and have worse outcomes at 6 months with similar outcomes at 12 months. They found higher complication and revision surgery rates with fragment-specific fixation, although their study was limited by selection bias.[44] A more recent randomized study by Landgren et al[45] of 50 DRFs revealed no statistical difference in patient-reported outcomes between volar plating and fragment-specific fixation at 12 months but found a markedly higher complication rate in the fragment-specific fixation group. Careful patient selection with fragment-specific fixation is important because this technique often requires multiple incisions and plates, which may cause issues with tendon irritation.

Intraoperative Imaging

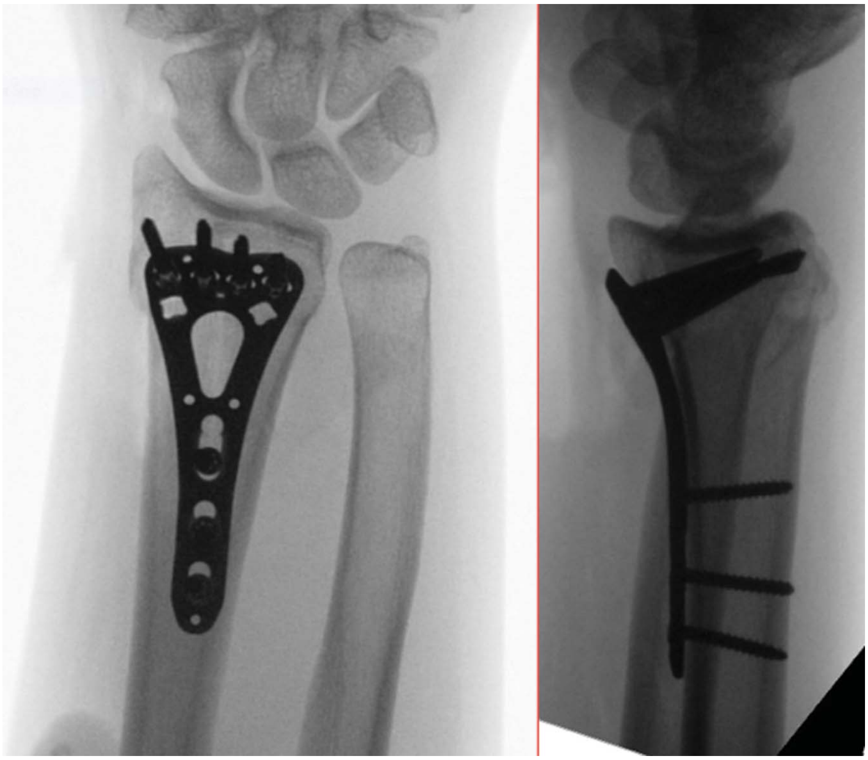
In the surgical setting, the ability to recognize potential problems and ensuring adequate reduction using imaging is paramount. PA and lateral views will provide the

Figure 5

A, PA and lateral radiographs showing a multifragmentary distal radius fracture about the radial, intermediate, and ulnar columns. **B**, Fragment-specific fixation to capture and stabilize the individual pieces.

standard overview of the alignment, length, and volar tilt while exposing the anatomic landmarks for ideal plate placement. Oblique radiographic views can be helpful in the detection of implant complications. The anatomic wrist PA view, obtained with 11° of volar tilt with the wrist neutral, and the anatomic tilt lateral view,

Figure 6



A, Intraoperative fluoro images of the anatomic PA and anatomic lateral views showing no intra-articular screw penetration.

obtained with 15° to 30° radial tilt with the wrist in a neutral position, allow the surgeon to visualize potential intra-articular screw penetration in both dorsal and volar plating techniques (Figure 6). In combination, both of these views provide an improved assessment of intra-articular screw penetration compared with the standard PA and lateral views. A 45° pronated oblique image can be used to visualize both the lunate and scaphoid facets. The dorsal tangential view identifies dorsal screw penetration in volar plating techniques, which can affect extensor tendons. The view is obtained with the wrist in near full flexion and using fluoroscopy to visualize the full height of LT, thereby identifying the greatest distance between LT and EPL groove (Figure 7).

Figure 7

A, Intraoperative fluoro image showing no dorsal screw penetration.

If implant complications cannot be excluded with standard and oblique imaging, consider "live" fluoroscopic imaging or arthroscopic assistance.

Goals of rehabilitation after the initial treatment of DRF include regaining motion, strength, and ultimately function while managing pain. Postoperative rehabilitation of DRFs may be divided into the following three stages: initial immobilization for pain control and early wound healing, mobilization, and strengthening.[46]

Understanding of the optimal length of immobilization after initial DRF management continues to evolve. Shorter postoperative immobilization times have been found to improve range of motion in the early postoperative period without leading to increased complications.[47,48] Furthermore, an accelerated rehabilitation protocol allowing "immediate" gentle range of motion may be safe and allow for early return to function.[48] However, there is a paucity of literature demonstrating durable benefits to early mobilization.

Whether a home exercise program or supervised therapy after surgical fixation of DRF is more effective is also debated. A prospective randomized study found that formal occupational therapy was comparable with or slightly inferior to physician-directed independent home exercise programs for range of motion and grip strength after volar plating of DRF.[49] Valdes et al found no difference between those in a home exercise program or clinic-based therapy in patients who underwent uncomplicated volar plating. However, in patients with postoperative complications (such as finger stiffness, CRPS, and carpal tunnel syndrome) or with comorbidities (such as osteoarthritis or advanced age), clinic-based therapy may be advantageous.[50]

Summary

Successful outcomes of treating DRF are multifaceted. It is necessary to achieve appropriate reduction and restoration of native anatomy for the goal of return to mobility, function, work, and/or sport within a reasonable timeframe. Understanding all available modalities and their potential complications will lead to improved success in treatment of each patient's fracture.

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