Distal Radius Fractures: Reconstruction Approaches, Planning, and Principles

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Abstract

Distal radius fracture (DRF) is a common injury. Treatment options have evolved and now several can be used to address even the most complex fracture patterns. Complex fractures of the distal radius and ulna can be challenging, and specific goals must be kept in mind to achieve definitive anatomical and functional restoration. This article summarizes the concepts, principles, and surgical options regarding complex DRF reconstruction.

Take-Home Points

- Restore proper anatomic parameters; compare to the other side.
- Don't forget about the DRU joint.
- CT can aide in identifying subtle articular depression and severe comminution to change operative management.
- Remember, there still is a role for external fixators; an alternative remains an internal spanning plate.
- Respect the soft tissues, which can aide in reduction, however don't leave the operating room without feeling confident about your fixation.

Distal radius fracture (DRF), a common fracture, accounts for almost one sixth of all emergency department visits.[1] With the advent of emerging technologies and refined technique, treatment options for DRFs have evolved. Although controversy remains regarding nonoperative vs operative treatment of DRFs in the elderly,[2,3] select situations (open injuries, complex high-energy injuries, young age) warrant definitive fixation. Previously, internal fixation options were limited. Current technologies include locked fixed-angle plating, fragment-specific fixation, and locked variable-angle plating. These modalities aid in achieving and maintaining more anatomical fixation. This article summarizes tips, tricks, and planning for definitive external and internal fixation of complex DRFs.

Anatomical Considerations and Classification

The wrist joint, part of the complex articular network that begins at the forearm and ends at the distal interphalangeal joint, is the foundation for fine- and gross-motor skills. Understanding the anatomy of this network can provide a valuable roadmap for operative reconstruction.

At the wrist level, the radius bears most of the weight-bearing, and in some studies exhibits up to 80% of the load.[1,4] The triangular distal radius bears this weight through a biconcave articular surface with facets for the lunate and scaphoid separated by an anteroposterior ridge.[5-7] The radius also articulates with the ulnar head at the sigmoid notch to form the distal radioulnar (DRU) joint. Restoring the relationships of the DRU joint, the triangular fibrocartilage complex, and the ulnar variance is of paramount importance.[1,8,9]

Classical teaching calls for restoration of radial inclination to about 23°, volar tilt to 11° to 12°, and radial length to about 11 mm. Especially regarding volar tilt and radial length, however, cadaveric and clinical studies have found more variance, leading to use of the contralateral extremity as an operative template, particularly when closed reduction thought to be adequate deviates significantly from these parameters.[1,4,7]

DRF classification based on these principles has led to abundant representation in the literature.[10-13] Many authors have focused on fracture lines, comminution degree, articular surface violation, and other anatomical or radiographic characteristics of DRF classification and operative fixation approach.[10-13] In 2001, Fernandez[9] proposed a classification system focused on energy or mechanism of injury. In comparisons,[14] the Fernandez system had the highest interobserver reliability—higher than that of AO (Arbeitsgemeinschaft für Osteosynthesefragen).

Considerations for Operative Treatment: Column Theory

In the restoration of anatomical alignment in complex DRFs, it is important to consider the 3 joints and the 3 columns—radial, intermediate, and ulnar (**Figure 1**). In addition, parallels between the distal radius and the tibial plateau can be considered because of similarities in operative goals. Restoration of mechanical axis, length, alignment, rotation, and articular surfaces is paramount.[15] Considering multiple surgical approaches to address "bicolumnar injuries" and reconstructing the "simpler" columnar injury first are common principles.[16]

The goals of fracture fixation at the wrist are the same as at any other joint: anatomical reduction, stable fixation, and early range of motion (ROM). Column restoration can result in consistent achievement of those goals. Intuitively, there is a close correlation between anatomical alignment and functional results.[17] Rebuilding the structural foundation of the columns with respect to buttressing and restoring the 3 radial articulations with the ulna, scaphoid, and lunate can consistently yield restoration of length, inclination, and tilt (**Figure 2**). Next, we discuss the options available and how to use each to an advantage, individually or in hybrid constructs.

External Fixation: Is There Still a Role?

In the setting of highly comminuted, complex fractures, external fixation with Kirschner wires (K-wires) is a reasonable choice, with restoration of motion and strength within 75% to 80% of the uninjured wrist.[18] In a 2-year study of 113 patients with comminuted metaphyseal DRFs randomly assigned to either external fixation or casting, Kreder and colleagues[19] found a trend toward better clinical, functional, and radiographic outcomes with external fixation with or without K-wire fixation. There was improved restoration of radial length and palmar tilt with external fixation. A study of unstable DRF in patients with osteoporosis found that redisplacement was more common after treatment with a cast than after treatment with an external fixator.[20] Although closed reduction and casting continue to have a role in the treatment of DRF, Kreder and colleagues[19] found that remanipulation was necessary in at least 9% of cases. According to a meta-analysis[21] of the literature on DRF treatment, 4 articles directly address the question of the superiority of external fixation over closed reduction and casting, and 3 of the 4 found more favorable radiographic and functional
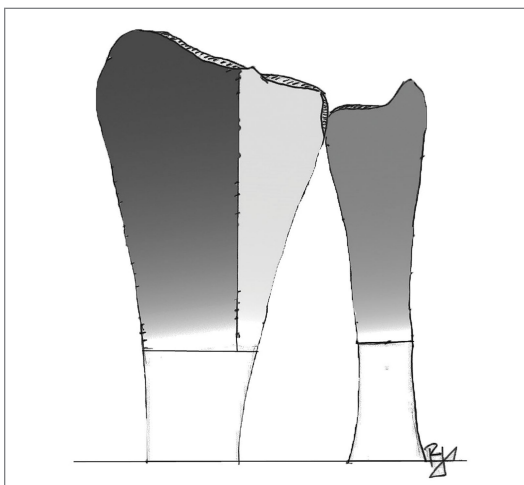

Figure 1. Column theory.

Figure 2. Reconstruction result based on column restoration of the radial and intermediate columns.

outcomes with external fixation.

External fixation is useful in treating complex DRFs with metaphyseal comminution. It can also be effective in the presence of simple articular involvement without depression of the joint surface. External fixation devices can span areas of soft-tissue injury and are useful as manipulation tools in achieving anatomical reduction. Although external fixation is effective, its complications include pin-tract infection, nerve injury, loss of reduction, and loss of digital ROM. In a meta-analysis, Li-hai and colleagues[22] found that external fixators had a complication rate of 30.9%. With this technique, it is important to avoid midcarpal distraction, excessive ulnar deviation, and excessive palmar flexion. Papadonikolakis and colleagues[23] found that dis-
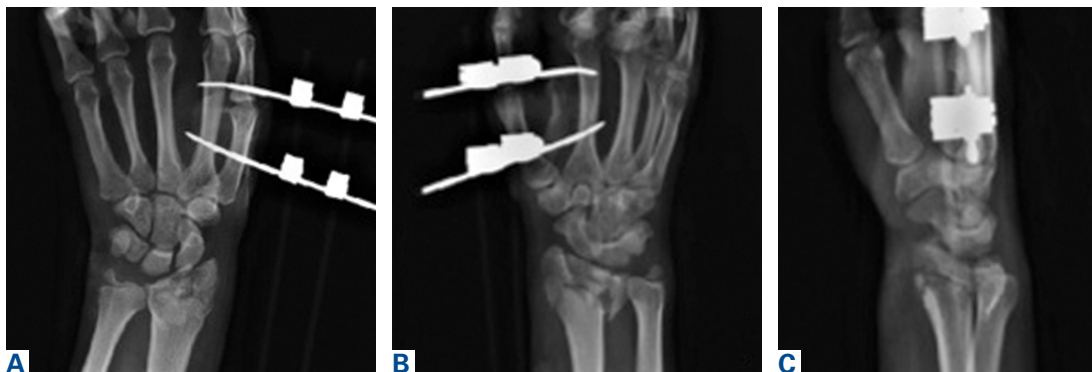
Figure 3. External fixation may not always be the answer. (A) Anteroposterior, (B) oblique, and (C) lateral radiographs of a 19-year-old right-hand-dominant man who presented from an outside institution 4 weeks after injury with loss of reduction.
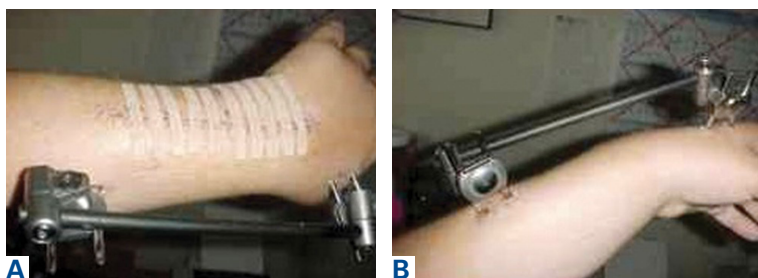

Figure 4. (A) Avoid the "cotton-loader" position, depicted here. (B) Excessive midcarpal distraction, ulnar deviation, and excessive palmar flexion.

traction of as little as 2 mm to 5 mm significantly affected the function of the flexor digitorum superficialis at the metacarpophalangeal joint. Over-distraction in wrist flexion can lead to lengthening of the extensor tendons and loss of full digital ROM. Excessive flexion and ulnar deviation can lead to median nerve compression and associated symptoms, as well as poor extensor and radial tendon length. In addition, prolonged distraction in excessive flexion combined with swelling and inflammation during fracture healing causes digital stiffness and contracture.[23] Biomechanical studies have found that proximal pin placement in the radius, along with distal pin fixation in 6 metacarpal cortices through the second and third metacarpals, helps provide the strongest fixation.[24]

As for technique, pins are placed in the second metacarpal and radial shaft. With respect to the radius, the incision is made just proximal to the edge of the abductor pollicis longus muscle in the "bare area." Ideal pin placement is between the extensor carpi radialis longus and the extensor carpi radialis brevis, with care taken to avoid the radial sensory nerve, which lies between the extensor carpi radialis longus and the brachialis and emerges 9 cm proximal to the radial styloid.[25] Next, a 2.5-cm

to 3-cm incision is made over the palpable edge of the index metacarpal near the base. During drilling, the guide is placed at intersecting 45° angles, and the distal pin is placed 2 cm to 3 cm from the proximal pin. The proximal metacarpal pin is placed at the base of the metacarpal. The second metacarpal pin can also be placed first, with the external fixator used to judge proximal placement of the radial pin within the bare area.

Various supplements to external fixation have positive outcomes. Wolfe and colleagues[18] found that using K-wires with the external fixation construct added stability in flexion/extension, radial/ulnar deviation, and rotational motion. They noted that fixation stability may depend more on the augmentation to fixation than on the external fixator itself. In a prospective, randomized trial, Moroni and colleagues[26,27] found that, compared with standard pins, hydroxyapatite-coated pins had higher extraction torque, which was associated with improved fixation. When combined with external fixation, calcium phosphate cement also provided additional stability, allowing the bone filler to help maintain articular reduction and cortical continuity.[28,29]

External fixation has its disadvantages and complications. It can be bulky, and theoretically it contributes to higher rates of stiffness in the wrist and fingers.[30-32] Higher rates of pin-site infection have been reported, along with hardware failure and associated loss of reduction, in patients treated with external fixation (**Figures 3A-3C**).[31-33] In addition, joint overdistraction can adversely affect the length-tension curve and contribute to potential reflex sympathetic dystrophy, which can be devastating (**Figures 4A, 4B**).[1,21,31,33] Despite these complications, external fixation remains a powerful tool in the treatment of high-energy

DRFs. In many cases, authors who compared open reduction and internal fixation (ORIF) with external fixation found no significant differences in outcome scores or function.[31-34] In a meta-analysis of 917 patients, Margaliot and colleagues[33] found no differences in pain, grip strength, wrist ROM, or radiographic parameters. More recently, in prospective randomized trials, both Egol and colleagues[31] and Grewal and colleagues[34] compared hybrid external fixation with ORIF, and, though early outcomes favored ORIF, 1-year follow-up comparisons were even, and there were no significant differences. These consistently reproducible results reaffirm keeping external fixation in the orthopedic toolbox.

Definitive Reconstruction With ORIF

Early nonlocked dorsal plating options for DRF fixation had unacceptable rates of plate failure, poor cosmesis, and extensor tendon complications.[17,35-37] Subsequent technologic advances—multiple approaches, lower profile plating, and rigid, fragment-specific fixation—have allowed even the most complex fracture patterns to be addressed (**Table**). In malunited fractures, bone graft may not be required if the fracture is extra-articular and treated with a volar locking plate. Other options include corticocancellous autograft from the iliac crest, hydroxyapatite synthetic grafts, and osteoconductive bone graft substitutes, such as bone morphogenic proteins. In addition, healing times are similar in cases, regardless of whether a graft was used.[38]

Involvement of the radial and intermediate columns should be addressed first. Although some may prefer a single volar plate, others may use fragment-specific fixation to buttress a comminuted radial styloid (in orthogonal fashion) and/or a dorsal ulnar fragment to restore the intermediate column and thereby fully restore the radial articular surface.[39,40] Typically, restoring the radial and intermediate columns for radial articular reduction subsequently and simultaneously restores the majority of radial height and length. After the radial and intermediate columns are reduced and stabilized, the need for ulna column fixation can be determined. Important factors in ulna column restoration are severe osteoporosis and ulna head and/or neck comminution. Significant comminution throughout the metaphysis of both the radius and the ulna may also warrant stabilizing the ulna with internal fixation. Finally, any DRU joint instability

Table. Principles and Goals of Treating Complex Distal Radius Fractures

Evaluate all 3 wrist joints
Determine which columns are affected
Start reconstruction with "simple side"
"Think like a tibial plateau"
Consider fragment-specific fixation
Do not forget ulna for mechanical supplementation
Use low-profile dorsal fixation when necessary
In dorsal approach, keep extensor pollicis longus free after approach and repair retinaculum
Always test for stability of distal radioulnar joint at end of procedure
Ask: Are goals achieved? Is patient ready for early range of motion?

noted on examination should also favor fixing the ulnar side.

Assessment of the distal ulna in these complex fractures goes beyond the involvement of an ulnar styloid fracture. Typically, fractures at the base of the ulnar styloid have been reported to have little clinical relevance, including a low incidence of associated DRU joint problems.[41-43] Decisions to address the ulnar column are largely swayed by any instability found on DRU joint testing, as laxity caused by severe comminution can dictate the need for distal ring fixation to provide support. Even in the presence of a high-energy fracture in severely osteoporotic bone, the argument can be made to prevent instability by supporting the ulnar column. Stabilization of the ulnar articular surface can also be made more facile by creating an easier "A" fracture pattern (per AO classification) from a complex "C" to further aid in achieving efficient anatomical reduction. After preoperative planning is completed, depending on which columns need to be addressed, several surgical approaches can be considered to achieve maximum exposure and soft-tissue mobilization in order to successfully complete the operative fixation goals.

Volar Approach

An approach is selected for ideal exposure of a facile environment for definitive fixation. Access to the radial column can be gained with the extended flexor carpi radialis (FCR) approach. This approach allows visualization and removal of the appropriate deforming forces on the radial column to allow for fracture reduction by "opening the book," similar to

that of tibial plateau reconstruction.[44,45] It may be prudent to perform a preincision Allen test as well as a preoperative DRU joint examination for comparison after ORIF is complete. Compared with the classic Henry approach near the distal radius, going through the volar sheath of the FCR avoids many of the perforating radial artery branches. Avoiding stripping the radial artery of its surrounding fat and lymphatics prevents postoperative "cold intolerance." Retracting the FCR ulnarly and then incising the dorsal FCR sheath provide ready access to the pronator quadratus after collective ulnar mobilization of both the FCR and the flexor pollicis longus.[44] In addition, for work near the distal FCR sheath, care must be taken to avoid the branch of the palmar cutaneous nerve that emerges about 5 cm proximal to the wrist flexion crease.[46]

Once at the level of the pronator quadratus, an "L-shape" incision can be made to reflect the muscle off the radius. Care must be taken when working too distal to avoid transection of the inserting volar wrist ligaments.[44] Leaving a cuff for repair of the pronator remains controversial. In a recent case-control series, however, Hershman and colleagues[47] did not find significant differences in function or complication rate in patients with and without repair. After reflection, adequate exposure of the radial column should be achieved. Ready access to the radial styloid for orthogonal plating can be obtained by releasing the brachioradialis, which simultaneously releases one of the primary fracture deforming forces.[44] With this incision and exposure, if needed, dorsal bone grafting can be achieved from the volar side; however, care must be taken to protect the first dorsal compartment.[48] The cutaneous branch of the median nerve may be at risk with this exposure, but avoiding dissection ulnar to the FCR tendon can help to reduce this risk.[49]

Before surgery, if the fracture pattern dictates a more ulnar approach, we prefer the extended carpal tunnel approach. Using the plane between the palmaris longus and the flexor digitorum superficialis medially and the FCR laterally, the extended carpal tunnel approach provides an obvious release of the flexor retinaculum but, more important, allows for extensile access to the sigmoid notch, the DRU joint, and the ulnar column.

Dorsal Approach
The dorsal approach is necessary in a few select cases. With a focus on fragment-specific fixation, presence of a significant dorsal ulnar fragment should warrant a dorsal approach.[50] In addition, in select, rare cases in which volar access is limited or unavailable, dorsal access is the only option.[50] Finally, if direct articular visualization is required, the dorsal approach typically is favored as the stronger radiocarpal ligaments found on the volar side are maintained.

Access should begin with an incision centered over the dorsal distal radius; a safe access point is just ulnar to the Lister tubercle. On incision of the retinaculum through a full-thickness excision, the third dorsal compartment is opened and the extensor pollicis longus (EPL) mobilized, fully exposing the dorsal distal radius. Work can be performed on either side of the EPL between the second and fourth dorsal compartments. Exposure typically is not an issue because of the pliable soft tissue of the dorsum, with ready access from styloid to styloid.[44] Here, low-profile plates and/or mini-fragment-specific plate options should be used to minimize potential tendon damage.[51] Care must also be taken to avoid damaging the radiocarpal or scapholunate ligaments.[49] On closure, the retinaculum is repaired primarily; however, though some proponents advocate relocating the EPL tendon into its groove, we prefer leaving the EPL free within the surrounding soft tissue to reduce tension and promote unhindered excursion. The dorsal approach, though controversial and used inconsistently, should remain an important tool in anatomical restoration, especially in cases of complex fracture patterns.

Conclusion
Controversy still marks the lack of consensus on deciding which DRF treatment is optimal. Some investigators question moving away from external fixation and cite the lack of significantly better data relative to ORIF.[21,52] The same proponents note that the only advantage over external fixation is earlier return to function and cite reports of tendon rupture and complications with both dorsal and volar fixation options.[34,53-58] Other investigators find that operative treatment generally does not provide a significant improvement over nonoperative treatment.[59]

With the advent of lower profile locked plating, fragment-specific fixation, and variable-angle devices, comparative clinical trials are finding it difficult to keep up.[60-64] Results from ongoing prospective randomized trials like ORCHID (Open Reduction and Internal Fixation Versus Casting for Highly Comminuted Intra-Articular Fractures of the Distal Radius; 500 patients >65 years old, 15 centers)

will provide more definitive answers about ideal treatment.[65]

Anatomical restoration involves a versatile array of fragment fixation and reconstruction. Careful preoperative planning and a consistent approach to restoring the radial, intermediate, and ulnar columns, along with a proper surgical approach, are ideal. Many advances in internal fixation have been exceedingly helpful. Use of external fixation, especially in a bridging fashion with or without supplementation, is still valuable in many situations.

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