Distal Radius Fractures: Current Concepts

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Despite the frequency of distal radius fractures, the optimal treatment remains without consensus opinion. A trend toward increased distal radius fracture open reduction and internal fixation has been identified, with biomechanical and clinical studies suggesting treatment advantages of certain fixation methods over others. Well-controlled patient trials are still missing to lend objective findings to management algorithms. This article reviews the literature over the past 5 years to guide our management regarding this common upper-extremity injury. *(J Hand Surg 2012;37A:1718–1725. Copyright © 2012 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Distal, radius, fracture, surgical, fixation.

CME Continuing Medical Education

TREATMENT OVERVIEW

The goal of distal radius fracture treatment is to restore an upper extremity that has both acceptable mobility and durability. Although these fractures are common and often reviewed, there remains little evidence in support of different treatment options. A recent Cochrane Review[1] revealed insufficient literature support for any one method of surgical fixation; an evidence-based clinical practice guideline was unable to recommend one form of treatment over another.[2]

Despite a lack of consensus, a rise in internal fixation of distal radius fractures has been observed within the United States. Europe is witnessing a similar trend, as evidenced in a nationwide registry review of all surgically treated distal radius fractures in Finland from 1998 to 2008.[3] In a country that has universal public health coverage ensuring insurance-unbiased findings, a doubling incidence of surgical treatment for distal radius fractures and a more than 13-fold increase in the incidence of open reduction and plate fixation were observed. The causes of this global increase may be related to greater need or perhaps improved surgical training. Patients treated by members of the American Society for Surgery of the Hand received internal fixation substantially more often than patients treated by surgeons who were not members (33% vs 16%; $P < .001$). Factors such as number of years in practice, practice type, and the particular type of training received contributed most heavily to whether the fracture received internal fixation.[4]

As the incidence of surgical treatment has increased, the cost of different methods has been explored. To accomplish this, health care intervention cost analysis may be employed that determines a treatment's cost per quality-adjusted life-year (QALY) and compares it with societal norms. The current, widely accepted cost limit per QALY is $50,000, a figure derived from the incremental cost-utility ratio of renal transplantation over dialysis for end-stage renal failure. In patients older than age 65, utility values derived from a decision tree model determined that although casting is the least expensive, internal fixation adds an incremental cost of only $15,330 per QALY, far less than the limit of $50,000, rendering it cost effective for these fractures.[5]

IMAGING

Plain radiographs remain the mainstay in diagnostics of distal radius fractures. The posteroanterior (PA) view obtained in neutral variance as well as a lateral view

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with a beam that is inclined 20° will assess ulnar variance and effectively visualize the articular surface. A 45° pronated oblique view is helpful in that it profiles the dorsal ulnar cortex and lends insight into this biomechanically important region. At times, improved fracture visualization through computed tomography scanning is valuable. This is particularly important when nonoperative treatment is being considered and it must be ensured that acceptable articular alignment is present. Computed tomography has demonstrated the ability to better characterize what radiographically may appear as an extra-articular injury. A high percentage of distal radius fractures, classified as extra-articular by standard radiographs, are revealed as intra-articular injuries. Axial views are helpful in visualizing the distal radioulnar joint (DRUJ) and can identify subluxation or frank dislocation in addition to bony fragments suggestive of radioulnar ligament avulsions. Magnetic resonance imaging is reserved for cases in which the mere existence of a fracture is called into question, and also to help identify concomitant soft tissue pathology.

EDUCATIONAL OBJECTIVES

- State the trend with regard to the surgical treatment of distal radius fractures.
- Discuss the cost per quality-adjusted life year method of assessing treatment.
- List the cumulative risk factors for the loss of reduction in a distal radius fracture.
- Describe the AO Classification of distal radius fractures.
- List the advantages and disadvantages of dorsal plate fixation for distal radius fracture pain.
- Summarize the differences between external fixation in combination with percutaneous pinning versus open reduction and internal fixation using a plate/screw construct.

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CLASSIFICATION

A multitude of classification systems exist, and a recent evaluation of 5 common systems (Fernandez, AO, Frykman, Melone, and Universal Classification Systems) concluded that all exhibited high interobserver and intra-observer unreliability. A more user-friendly and reliable method incorporating a 3-dimensional assessment was advocated.[6] The Melone Classification is clinically useful in that it often influences the operative approach. It emphasizes the importance of the radiolunate articulation and categorizes fractures into 5 groups based on the parts involved: shaft, styloid, dorsal medial facet, volar medial facet, and severely comminuted fractures. The AO Classification divides intra-articular involvement into 3 broad groups that can be subdivided into 27 distinct fracture patterns. Type A describes an extra-articular fracture, type B involves a partial disruption of the articular surface, and type C represents a complete separation of multiple articular fragments from the shaft.

CLOSED REDUCTION AND IMMOBILIZATION

Closed reduction and immobilization in a plaster cast remains an accepted method of treatment for most stable distal radius fractures. A stable fracture is one that is acceptably aligned after reduction effort and where the likelihood of displacement is small. Cumulative risk factors for the loss of reduction have been identified as age over 60, greater than 20° dorsal angulation, 5 mm radial shortening, dorsal comminution, ulna fracture, and intra-articular radiocarpal involvement.[7] In elderly patients, decreased bone mineral density may cause distal radius fracture instability, resulting in a 30% to 50% risk for secondary displacement after closed reduction and splinting, with redisplacement severity correlated with increasing age.[7] If closed treatment is considered appropriate, a splint is usually used for the first few days to accommodate for appropriate swelling. A cast or removable splint is worn thereafter. Radiographs obtained at initial presentation and then at weekly intervals for the first 3 weeks and at 6 weeks status posttrauma will monitor fracture alignment.

If the decision for operative intervention is made, a multitude of stabilization options exist. Factors that must be considered include the biomechanical characteristics of each fixation method, the procedure's associated difficulty, and the soft tissue morbidity.

CLOSED REDUCTION AND PINNING

Closed reduction and percutaneous pin fixation are best suited for fractures without articular involvement and also without substantial metaphyseal comminution. A variety of pinning methods have been described; the most popular is oblique radial styloid to proximal ulnar cortex, as well as placement of the pins through the fracture site. Wires are usually removed 4 weeks after placement to minimize the risk of infection. The decision to use percutaneous pin fixation should be considered with care, because a prospective, randomized trial encountered markedly inferior clinical and radiological results for percutaneous pinning compared with locked volar plating, even for extra-articular distal radius fractures.[8] A new fixation technique that uses threaded

FIGURE 1: Radiographs of a distal radius fracture **A** preoperatively and **B** after fixation with threaded pins.

variable-length cannulated pins (T-Pin; Union Surgical, Philadelphia, PA) may improve bony purchase and yield superior clinical results compared with smooth pins (Fig. 1).

EXTERNAL FIXATION

Bridging external fracture fixation refers to a surgical effort that bridges the radius fracture and gains purchase distal to the radiocarpal joint. It employs ligamentotaxis to improve the length and alignment of the fracture. Intra-articular displacement may be corrected through the placement of percutaneous pins. A prospective, randomized trial compared external fixation in combination with percutaneous pinning to open reduction and internal fixation (ORIF) using a volar or dorsal plate. There was significantly less pain and disability in the ORIF group at early follow-up, with the differences diminishing over time. There were no significant differences in the Disabilities of the Arm, Shoulder, and Hand score, and only a trend for better wrist extension, supination, and grip strength in the ORIF group at 3 months. There were no significant differences between initial postoperative alignment, except for a slightly greater restoration of volar tilt in the ORIF group. The incidence of complications was similar in both groups, although greater tendon complications were seen with internal fixation and more infections were identified with external fixation.[9] These findings are consistent with what other studies have shown. Pin track infection coupled with unsightly scars and superficial radial nerve traction that may lead to complex regional pain syndrome contribute to a trend away from its use.

Nonbridging external fixation uses pins in the distal radial fragment and pins proximal to the fracture without bridging the radiocarpal joint. In this instance, fragments are reduced by direct manipulation. The nonbridging method requires a sizeable extra-articular distal fracture fragment, yet offers less risk of radial shortening and dorsal angulation compared with bridging external fixation.[10]

INDIVIDUAL FRAGMENT FIXATION

Fracture fragment-specific fixation uses a series of low-profile plates and clips to individually supply rigid, low-profile fixation to fracture fragments. Restoration of radial column integrity is followed by fixation efforts to address additional displaced fragments. The fracture fragment specific plates are sufficiently low-profile so as to allow implant placement to match the individual fracture pattern. The fracture fixation usually begins with a radial-sided incision through which the radial and volar plates can be applied. Dorsal and sometimes volar incisions are also required. A prospective cohort study reviewed radiograph and clinical outcomes to compare volar plating with fragment-specific fixation methods. Whereas the radiographic parameters were

FIGURE 2: **A** Coronal, **B** sagittal, and **C** axial computed tomography views of a comminuted distal radius fracture, and **D** PA and **E** lateral radiographs after fragment-specific fixation.

superior with volar locked plating and the complication rate was higher with fragment-specific fixation, no significant clinical difference was seen.[11] Understanding how to employ fracture fragment-specific fixation methods requires considerable expertise and experience, yet proves invaluable when the surgeon is occasionally faced with a comminuted fracture for which no other method will suffice (Fig. 2).

DORSAL PLATES

Radius fractures with metaphyseal comminution typically collapse in a dorsal direction and a dorsal approach will provide excellent articular surface visualization and allow for buttressing of these fragments. Disadvantages are that the plate is placed under the extensor tendons, which may lead to extensor tendon irritation and rupture. Late-generation, low-profile plates that are designed to not cause tendon irritation tackle this major source of complications. Distal fragments may become devitalized once exposed adequately, and achieving adequate purchase is another drawback given that the native volar tilt of 10° may preclude distal enough placement of the plate in a fixed-angle device. Dorsal plates that allow variable-angle screw fixation would not have this problem. A retrospective study on complications of low-profile dorsal and volar locked plating did not identify major differences in tendon irritation or rupture for either of the techniques, and found a higher rate of neuropathic complications with the volar approach.[12] The use of dorsal plates may increase if the concern about tendon irritation that plagued previous design generations proves to be less frequent with newer implants.

VOLAR FIXED-ANGLE PLATES

The volar plate is an evolution of the blade plate as it transfers forces from the subchondral bone away from the dorsal metaphysis and toward the volar cortex. A longitudinal volar scar and the creation of a rigid biomechanical construct that offers the possibility of near-

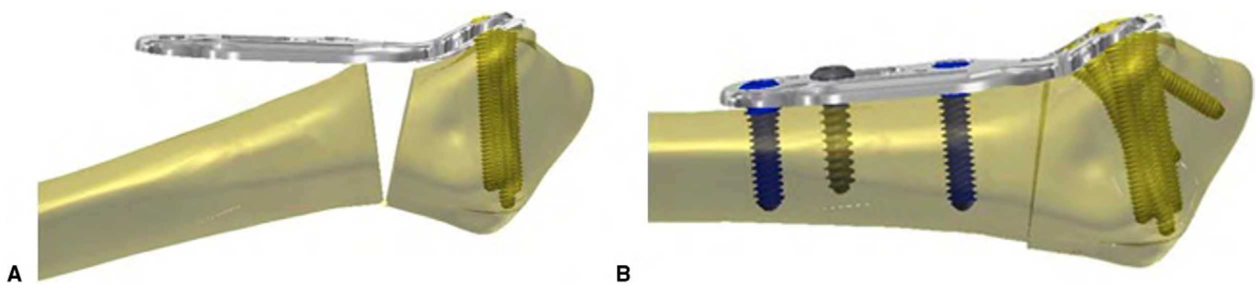

FIGURE 3: The lift-off technique employs distal fixation into the dorsally unstable fracture fragment **A** before fracture reduction and **B** proximal plate fixation.

immediate functional wrist loading are considered benefits. Depending on the plate design, distal screws can lock at a predetermined angle, facilitating the lift-off technique, or can be placed at variable angles relative to the plate. The lift-off method places the distal screws first and then uses the plate to correct the dorsal malalignment of the fracture (Fig. 3). A more traditional approach involves proximal plate fixation before the fracture is reduced, and the distal screws are subsequently placed to maintain the reduction effort. Having screws that can be positioned at a variable angle is advantageous for the latter method. Regardless of technique, the distal screws or pegs are placed immediately subchondral, which a 45° pronated oblique view can help visualize. Volar fixation leverages the intact extensor compartment structural framework that contains and even reduces dorsal fracture comminution. However, dorsal cortical penetration of the screws may lead to extensor tendon rupture. Because lateral and oblique radiographic views have a relatively low sensitivity for detecting dorsal cortical penetration, a study evaluated the sensitivity, specificity, and accuracy of the skyline view in detecting penetration by 1 mm compared with standard radiographs. The skyline view was the most sensitive and accurate for detection of dorsal cortical penetration. The sensitivity, specificity, and accuracy of this view were all 83%. The pronated oblique and lateral views were less accurate, registering 77% and 51%, respectively.[13]

A volar plate has the potential to be subsequently covered by repairing the pronator quadratus, which may reduce the likelihood of tendon interference. The flexor pollicis longus tendon can be at risk for irritation and potential rupture, however, and a cadaver model evaluated the influence of distal radius plate position on contact pressure between it and the distal edge of the locking plate. Contact pressure considerably increased when the distal plate edge was placed distal to the watershed line.[14]

The question of whether using pegs or screws results in important biomechanical differences has been addressed in a cadaveric study. Although there were no statistically significant differences in torsional or axial stiffness at the beginning of loading, after 1,000 cycles, pegs failed by loosening, most often at the peg–plate interface. Screw fixation provided a more stable construct.[15]

Volar plate fixation appears to be used with fewer complications compared with external fixation. A total of 115 patients were reviewed with comminuted intrarticular distal radius fractures. Of those patients, 59 were treated with bridging external fixation, and 56 with volar locking plate fixation. Volar plate fixation had an overall decreased incidence of complications and significantly better motion compared with external fixation. Volar plate fixation also resulted in less radial shortening than the external fixation group, as well as less pain, improved functional outcomes, and grip strength.[16]

INTRAMEDULLARY-BASED DEVICES

Intramedullary radius fracture fixation using subchondral screws that lock to a stem has the theoretical advantages of less surgical dissection and decreased tendon irritation. As one of the available devices, the Micronail (Wright Medical Technology, Inc., Arlington, TN) is inserted through a radial styloid portal and contains 3 fixed-angle distal locking screws and 2 self-tapping, bicortical screws for proximal fixation through an attached outrigger guide. Use of the implant, indicated for extra-articular or simple intra-articular fractures, was reported in 29 consecutive patients whose functional and radiographic outcomes at 12 months demonstrated 9 good and 20 excellent functional results, according to the Mayo wrist score, with almost completely restored range of motion and grip strength. Loss of reduction was seen in 2 patients.[17] Although clinical reports presenting encouraging results are emerging, larger studies with long-term follow-up are necessary to support its use.

ARTHROSCOPY

Most likely because of its logistical and technical demands, arthroscopic assistance during reduction of intra-articular radius fractures has not gained widespread acceptance. A stepwise algorithm for dry wrist arthroscopy presented technical tips on how to handle airflow, suction, and surgical technique. Salient features included initial fixation of the plate with proximal screws; then, the radius fracture is visualized through a 6R portal, and reduced. Provisional K-wires are employed to maintain the fracture alignment while the fragments are reduced arthroscopically. These fragments are then held in proper alignment via screws placed iteratively as the K-wires are replaced.[18]

A study comparing arthroscopic to fluoroscopic reduction for the treatment of AO type C fractures with a stepoff greater than 2 mm underscored the value of direct fracture visualization. After performing reduction and external fixation of the fracture under fluoroscopy, arthroscopy was performed in 1 group, which mandated a revision pinning effort in 45% of patients. Radiographically, the mean stepoff was significantly lower for the arthroscopy group compared with those who had fluoroscopy alone. In the near and midterm follow-up, Mayo wrist scores as well as range of motion were significantly better for the arthroscopy group than the control group.[19]

BRIDGE PLATING

High-energy comminuted distal radius fractures represent unique treatment challenges. In particular, 1 group of patients—those with multiple injuries that require load bearing through the injured wrist to assist with mobilization—may benefit from bridge plating. This device acts as an internal fixator and depends on ligamentotaxis for fracture reduction. The technique may be performed easily, is associated with few complications, and achieves the goals of fracture reduction maintenance while allowing weightbearing through the injured extremity. The latter attribute places it securely in the armamentarium of a surgeon treating complex upper-extremity trauma.

SOFT TISSUE INJURIES

When treating distal radius fractures, a high level of suspicion should be maintained for associated soft tissue injuries to the intrinsic wrist ligaments. Preoperative diagnostic studies as well as intraoperative instability assessment may be valuable. In younger patients, maintaining a high index of suspicion for scapholunate ligament injury is imperative. Prompt diagnosis and treatment in the acute setting may achieve primary ligament healing and avoid a reconstructive or salvage procedure.

DRUJ radioulnar joint instability

Distal radioulnar joint instability is commonly associated with a radius fracture. It was noted as early as 1814, when Abraham Colles stated, "If the surgeon proceeds to investigate the nature of this injury, he will find that the end of the ulna admits of being readily moved backwards and forwards." This high association is likely related to the bony architecture of this joint, which accounts for only 20% of stability, and thus places the mechanical integrity burden on the soft tissue attachments. The bony contact between the radius and ulna is reduced at the extremes of forearm rotation, further reducing bony constraints, thus increasing the risk of DRUJ injury when the forearm is maximally pronated or supinated. The primary stabilizer of the DRUJ is the triangular fibrocartilage complex (TFCC). Additional stabilizers such as the ulnocarpal ligaments, extensor carpi ulnaris subsheath, and interosseous membrane have a secondary role.

Studies examining the incidence of TFCC injuries associated with distal radius fractures have noted an incidence of 45% to 65%. Radial shortening of 5 to 7 mm can stretch the dorsal and palmar radioulnar ligaments and result in ligament tears. Distal radius fracture angulation also affects the biomechanics of the DRUJ. More than 20° dorsal angulation has also been associated with incongruency of the DRUJ in addition to altered TFCC kinematics, leading to tearing at its peripheral attachments. As the amount of displacement and angulation increases, secondary constraints to joint stability are injured as well, such as the ulnocarpal ligaments, extensor carpi ulnaris subsheath, and interosseous membrane.

Prereduction radiographic findings may help to increase the surgeon's suspicion for injury to the DRUJ. Additional findings that may herald problems include an ulnar styloid base fracture, widening of the DRUJ interval on PA radiographs, and dislocation of the DRUJ on lateral radiographs. A computed tomography scan can provide additional insight. Axial views of the DRUJ can be compared with the contralateral side. Subluxation or frank dislocation may often be identified, in addition to bony fragments suggestive of palmar or dorsal radioulnar ligament avulsions.

Once the radius fracture has been reduced and stabilized, the DRUJ may be examined under anesthesia and compared with the contralateral side. The dorsal lunate facet may be fractured, from which the dorsal limb of the radioulnar ligament originates. The most common cause for DRUJ instability is via a fracture through the base of the ulnar styloid, and requires the determination of instability after radius fracture internal fixation through manual testing. When managing this fracture, greater than 1 cm of dorsal to palmar translation mandates instability presumption. Distal radioulnar joint instability is then addressed through open reduction and internal fixation of the ulna styloid fracture. A literature review suggests not addressing the ulnar styloid fracture if the DRUJ is stable after fixation of the radius, and using either fixation of the ulnar styloid or reduction and supination splinting if the DRUJ is unstable.[20]

A prospective cohort study aimed to identify an association between DRUJ instability and potential predictors such as age, gender, dominant hand involvement, mechanism of injury, fracture pattern, ulnar styloid fracture, and fracture displacement. A total of 163 adult patients with unstable distal radius fractures were treated with volar locking plates and then evaluated by manual intraoperative examination and repair of the TFCC when needed. The authors found 11 complete radioulnar ligament tears at the fovea of the ulnar head. The only noteworthy independent risk factor was an increase of DRUJ gap distance by 1 mm on PA radiograph, which increases by 5-fold the risk of radioulnar ligament tear in a patient of average wrist width.[21]

BONE GRAFTING

Whereas grafting with autologous bone or bone substitutes has been described for corrective osteotomies of malunited distal radius fractures, some studies recommend its use in unstable distal radius fractures as well. Various tricalcium phosphate preparations and rapidly hardening bone cements have been described for this purpose. This may not be needed unless the fracture has been approached dorsally, which disrupts the stability provided by the retinacular framework of the extensor compartments. Substantial physiologic or soft tissue compromises are additional reasons for its use.

A recent literature review concluded that grafting may improve radiographic alignment or short-term outcome, but no overall influence on final result was seen.[22] These results resemble those of a Cochrane Review that considered 10 trials including 874 patients, all of which presented insufficient evidence to draw conclusions regarding functional outcome and safety.

Given the added cost of allografting and the increased morbidity of autografting radius fractures, its use should be limited to corrective osteotomy cases and distal radius fractures that are treated between 3 and 6 weeks after injury, unless uncommon extenuating circumstances prevail creating a much compromised healing environment.

MEDIAN NERVE DECOMPRESSION

Carpal tunnel syndrome (CTS) after distal radius fracture is common and may occur as a result of the concussive insult at the time of trauma or extrinsic nerve compression, the latter of which may occur in both an acute and delayed manner.

Causes for nerve compression are numerous and include hematoma, tenosynovitis, forces induced by fracture manipulation during closed reduction efforts, maintenance of a flexed wrist posture after reduction, surgical trauma, and excessive fracture callus formation. A case-control series reported acute CTS to occur frequently in young patients sustaining high-energy trauma, but found fracture translation to be the only significant risk factor for its development. A 1% translation was reported to cause an increment of 0.26 in the odds of developing acute CTS.[23]

The development of delayed median nerve dysfunction was shown to occur in 24 of 282 patients (8.5%) treated with volar plating efforts. Locking plates had a higher incidence than nonlocking plates (10.2% vs 3%), which was postulated to be the result of their more distal placement.[24]

Given that elevated pressure on the median nerve may lead to permanent dysfunction if not surgically relieved, close monitoring of neurologic function, both in the acute and later stages of care, is imperative.

MANAGEMENT IN THE ELDERLY

To date, there is no consensus regarding the appropriate treatment for unstable distal radius fractures in elderly patients, because only minor differences exist between functional outcomes and activities of daily living after surgical and nonsurgical treatment 1 year after injury.[25] Although activities will eventually decrease with advancing age, today's elderly patients are increasingly remaining more active. In addition, the potential separation between actual, physiologic, and perceived age needs to be considered when managing distal radius fractures in this age group.

In low-functioning patients living a sedentary lifestyle, nonoperative management with avoidance of finger stiffness is appropriate given the realization that outcomes are good. Nonoperative treatment, even in the presence of deformity, makes this cost-effective management worthwhile. If nonoperative treatment is chosen, cast disease—namely, atrophy and joint stiffness—must be avoided. Fingers in the elderly may be arthritic and are particularly susceptible to detrimental stiffness if the joints are not ranged shortly after injury.[7]

Malunion acceptance may not benefit elderly patients who are more active and place greater functional demands on the upper extremity. Increased efforts to restore articular alignment and pre-injury radius anatomy should be considered. Despite a lack of large-scale, randomized, controlled trials to clearly position volar plating as superior, its use in the elderly is on the rise.[7]

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JOURNAL CME QUESTIONS

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What x-ray view best visualizes the dorsal ulnar cortex of the distal radius?

a. 45° pronated oblique view
b. 45° supinated oblique view
c. Hyperpronated lateral view
d. Hypersupinated lateral view
e. Anteroposterior view

What risk factor(s) contribute to the cumulative risk for loss of reduction following a distal radius fracture?

a. Age > 50
b. Greater than 10° dorsal angulation
c. 3 mm of radial shortening
d. Dorsal comminution
e. All of the above

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