Distal Radius Fractures

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Summary: Distal radius fractures are a common injury, particularly in the elderly population. Severity of these fractures is directly related to the bone mineral density of the patient, and clinical results are dependent on this parameter as well. In terms of treatment, several options exist. Nonoperative management consists of closed treatment with casting. Operative treatment options include intrafocal pinning, nonbridging and bridging external fixation, arthroscopic-assisted external fixation, and various methods of open reduction internal fixation. When operative intervention is indicated, considerations include the characteristics of the fracture and the experience of the surgeon with the treatment modalities.

Key Words: distal radius fracture, review

EPIDEMIOLOGY

Overall distal radius fractures account for approximately 200,000 fractures per year in the United States.[1] Although a large percentage of these occur in elderly individuals, there has been a large increase in the prevalence of patients with distal radial fractures in all age groups.[2]

The prevalence of distal radius fractures in women older than 35 years of age has been cited as up to four times more common than in their male counterparts.[2] The incidence in women significantly increased beyond the perimenopausal period.[2]

A recent study looking at 108 postmenopausal women followed over 15 years has shown that the intramedullary diameter increases and the strength index decreases in the distal radius proportionally to decreases in estradiol levels. It can be expected that once a decrease of one standard deviation of strength index is achieved, there will be a 3.8 increase in the risk ratio of sustaining a distal radius fracture.[3]

In a prospective analysis of over 4000 consecutive acute fractures of the distal radius presenting to the Edinburgh Orthopaedic Trauma Unit, there was an expected bimodal age distribution with a spike among young males and elderly

females. In this series, 87% of the elderly were independent for all the activities of daily living before fracture. Even with an age of 80 years, over 50% were still living completely independent lives (Edinburgh patient database).[4]

Over 50% of the fractures in the Edinburgh series were AO type A3.2 (extra-articular with metaphyseal comminution) or C2.1 (simple articular with metaphyseal comminution).

BIOMECHANICS

Biomechanical testing has shown that overall bone mineral density is inversely proportional to the severity of the distal radius fracture sustained with a fixed load.[5] Lower cortical volumetric density, decreased cortical area, and lower mean cortical thickness have all been implicated in determining severity of displacement in distal radius fractures.[6] Also, in women older than 40 years of age, it has been show that in terms of wrist mobility, grip strength, and pain relief at 1-year follow up, clinical results correlated better with bone mineral density than with radiologic parameters.[7]

It has been shown that a number of factors, including age, radial length, and initial dorsal angulation, have an influence on metaphyseal instability, thus changing the mechanics and alignment of the radiocarpal articulation.[8,9] Park et al has shown that changes in carpal alignment results from dorsal malunion of the distal radial metaphysis, which can result in adaptive dorsal carpal instability (DISI deformity).[10] Also, radial shortening has been suggested to cause a decrease in the functional length of the tendons crossing the wrist. This has been postulated to decrease grip strength with malunited distal radius fractures.[11]

TREATMENT

Nonoperative Management

Closed Treatment With Casting

Closed treatment of distal radius fractures historically was the mainstay of treatment in the elderly. It relies on the principle of ligamentotaxis to reduce fracture fragments. No control can be expected for depressed articular fragments that lack ligament attachment. As little as 1 mm of scaphoid fossa depression or 3 mm of lunate fossa depression can increase contact pressures in adjacent areas of the radiocarpal and intercarpal complex that could potentially lead to advanced degenerative changes.[12,13]

A prospective, randomized series of 100 patients presented at the 2003 Orthopaedic Trauma Association meeting (Salt Lake City, UT) evaluated two methods of splint immobilization, short arm splinting verses sugar-tong splinting. For patients with nondisplaced fractures or stable

fractures, there was no difference in maintenance of reduction or ultimate need for surgical intervention based on the splint type used. The authors had defined stability as less than 4-mm overall shortening, less than 5-mm decrease in radial height, less than 10° change in volar tilt from the contralateral extremity, and less than 50% dorsal comminution. In patients with unstable fractures, sugar-tong immobilization did significantly better at maintaining reduction with significantly fewer patients requiring surgical intervention.[14]

In a recent meta-analysis of three studies with a total of 404 patients, no significant difference in anatomic outcome or complications was established based on the technique of closed reduction and immobilization treatment. This included the type of anesthesia used for reduction (none, hematoma block, intravenous sedation), type of traction (manual traction with or without finger-traps), rotational position of immobilization, or material used for immobilization.[15] A recent clinical analysis of 13 patients treated for 6 weeks with cast immobilization evaluated grip strength, range of motion, wrist circumference, and forearm circumference. Forty-eight hours after cast removal, there was a significant difference in forearm rotation, flexion, extension, radial and ulnar deviation, grip strength, forearm circumference, and wrist circumference compared with the contralateral side. Patients had persistent dysesthesias of the involved hand at a minimal 6-month follow up.[16]

The ability of closed reduction and cast immobilization to maintain reduction of comminuted distal radius fractures in the elderly has been questioned. A recent study demonstrated that 53 of 60 fractures (average patient age, 82 years) that underwent closed reduction and cast immobilization lost fracture reduction. There was no correlation between fracture classification or the amount of displacement with the final result. Of the 53 fractures that lost reduction, 75% of them did so within 1 week of initial reduction.[17] In an attempt to evaluate stability of distal radius fractures based on injury films, two scoring systems (MacKenney formula and Adolphson formula) were evaluated in a recent study. After prospectively reviewing 105 patients, it was found that both scoring systems underestimated the degree of fracture instability.[18] In an attempt to determine signs of early (1 week) and late (6 weeks) instability of conservatively treated extra-articular distal radius fractures in the elderly, an observational study of 71 patients showed that radial shortening and volar tilt greater than 20° were the best predictors of early instability, whereas radial inclination less than 10°, radial shortening, age older than 65 years, and dorsal tilt greater than 20° were predictive of late instability.[19]

A prospective, randomized study analyzing 90 patients with displaced intra-articular distal radius fractures with an average of 4-year follow up looked at functional outcomes based on mode of treatment (plaster immobilization, external fixation, plate and screw fixation). Good or excellent results were achieved in 43%, 80%, and 63%, respectively.[20]

Operative Management
Intrafocal (Kapanji) Pinning

This method of fixation involves percutaneous wires introduced dorsally into the fracture site of extra-articular distal radius fractures. These wires are subsequently directed retrograde and advanced until they gain purchase through the volar cortex of the proximal fragment. The distal fragment's position is maintained by abutment of its dorsal cortex against the intrafocal pin (Fig. 1A–D). In a prospective follow up of 18 patients with dorsally angulated distal radius fractures, intrafocal pinning was found to significantly provide better maintenance of volar tilt and ulnar variance at 11 weeks postintervention when compared with closed reduction and cast treatment alone.[21] At a mean of 11.3 months postinjury, it has been shown that although radial length was maintained, recurrence of dorsal angulation occurred in 22 of 26 patients. This did not appear to make a significant impact on functional outcomes.[22] With the use of intrafocal pinning, maintenance of radial length has been shown to be most important in providing superior functional outcomes when compared with maintenance of radial tilt or palmar tilt.[23]

Dorsal intrafocal pinning can be combined with external fixation. Recently, 61 patients with a mean of 34-month follow up were compared based on treatment with intrafocal pinning either alone or in combination with external fixation. Patients were evaluated based on one or two cortices of comminution and on age. Younger patients with dorsal cortical comminution had significantly better outcomes with respect to range of motion, grip strength, and pain relief when intrafocal pinning alone was used. Older patients with similar fractures significantly benefited from the addition of formal spanning external fixation (partially threaded pins proximal and distal to the radial carpal joint connected by external bars and clamps). When patients had at least two cortices of comminution, both young and old did significantly better when intrafocal pinning was combined with external fixation.[23]

Nonbridging External Fixation

This technique uses pins in the distal radial fragment and pins proximal to the fracture without bridging the radiocarpal joint. Fracture fragments are reduced by direct manipulation and distraction through the fracture site. The distal pins are inserted from the dorsum of the distal fragment through an open incision, protecting the extensor tendons. The starting point is midway between the fracture and the radiocarpal joint with one pin on either side of Lister's tubercle and the extensor pollicis longus. The pins are inserted parallel to each other and to the radiocarpal joint on the lateral view. All pins must engage the volar cortex (Fig. 2A–B).[24] The pins are then used as a "joystick" to reduce the distal fragment.

One of the reasons for the increasing use of nonbridging external fixation is the unreliability of bridging external fixation in obtaining and maintaining the reduced position. Bridging external fixation requires reduction through ligamentotaxis to improve length and alignment by tightening the volar capsular ligaments. However, intra-articular displacement and palmar tilt may not be adequately addressed. In addition, the dorsomedial fragment often remains malreduced because the dorsal wrist ligaments are Z-shaped components that are thinner and fewer than the palmar wrist ligaments.[25] This had been confirmed in a number of studies with residual dorsal angulation between 5° and 10°[26–32] (Fig. 2C).

FIGURE 1. (A–B) Anteroposterior and lateral radiographs of injury. (C–D) Anteroposterior and lateral radiographs of Kapanji technique used in fixation of a 23-A2.2 distal radius fracture.

Function has been shown to be superior when the volar tilt and carpal alignment have been restored.[32] In a randomized comparison with bridging external fixation, nonbridging external fixation was shown to maintain a mean volar tilt of 5° at 1-year follow up.[32] In a similar group of patients treated with bridging external fixation, there was a mean dorsal angle of 3.6° at the end of the period of fixation, which had deteriorated to a mean of 12° at 1 year. Similar statistically significant differences were seen in radial length. No explanation was given as to why loss of alignment was seen in the bridging external fixation group at 1 year. Maintenance of range of motion, grip strength, and carpal alignment were significantly higher in the nonbridging group.[32]

For those without experience using the technique of nonbridging external fixation of the distal radius, there are a number of perceived barriers to its successful use. These include concerns that the technique is difficult and only applicable in expert hands. There are also concerns voiced that the technique is only applicable to a limited number of fractures and that complications, especially pin pullout in osteoporotic bone and extensor tendon ruptures, would preclude its safe use. These concerns have been addressed in a review of 488 cases of unstable fractures of the distal radius treated in Edinburgh with external fixation over a period of 5 years. Of the 488 cases, nonbridging external fixation was used in 268 patients of which the majority was AO type A3.2 or C2.1 fractures. Seventy-seven percent of cases were performed by orthopaedic residents. There was no pin pullout from the distal fragment and the extensor pollicis tendon rupture rate was 1% in both the bridging and nonbridging cases (Edinburgh patient database).[4]

Bridging External Fixation

With this method of stabilization, pins are placed dorsally in a metacarpal and proximal to the fracture site in the radius to span the radiocarpal joint. In severely comminuted fractures of patients with osteoporosis, this technique is often used to bridge the injured area in hopes of attaining better purchase (Fig. 3A–D). In a randomized trial of 40 patients with osteoporosis (greater than –2.5 T score) treated with either cast immobilization or external fixation, 20% of those treated with cast immobilization exhibited redisplacement, whereas 0% in the external fixation group had redisplacement.[33]

Concerns with rigidity of fixation and fragment immobilization have been analyzed. Compared with fragment
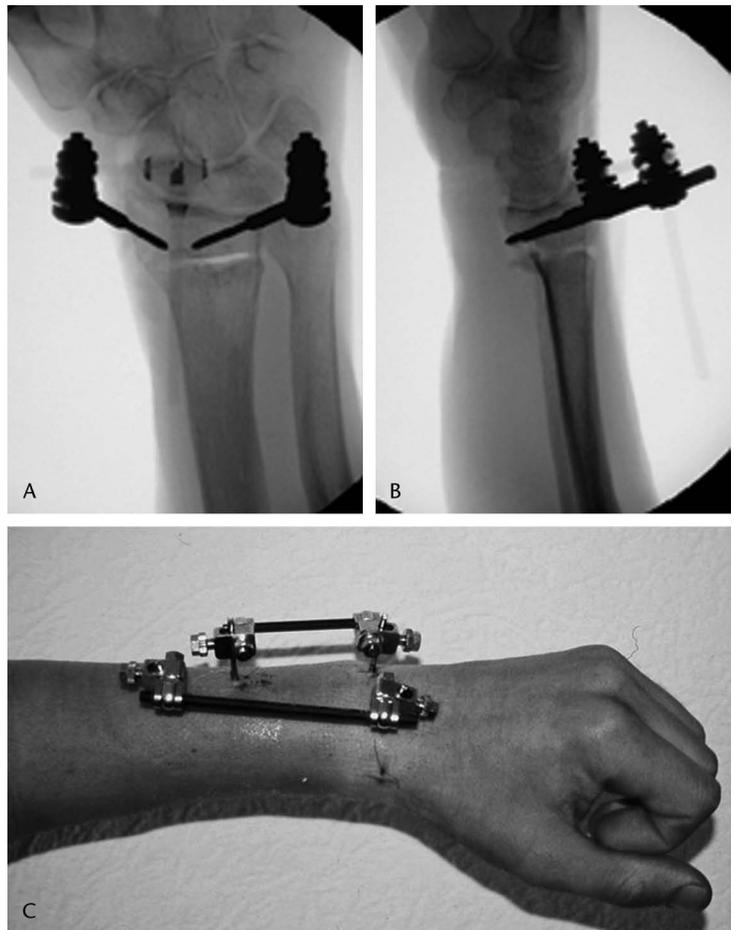
FIGURE 2. (A–C) Clinical photograph and anteroposterior and lateral radiographs of nonbridging wrist external fixation used in fixation of a 23-A3.2 distal radius fracture.

specific fixation, bridging external fixation is significantly less rigid.[34] Of note, there is large variability in the stiffness of fixation provided by commonly marketed bridging external fixators.[35] In an effort to improve stability of fracture fragments treated with external fixation, Kirschner wire supplementation has been used. Recent biomechanical studies have shown regardless of the type of external fixation, Kirschner wire supplementation significantly increased rigidity of the construct approaching that achieved with a dorsal plate.[36]

FIGURE 3. (A–B) Anteroposterior and lateral radiographs of injury. (C–D) Anteroposterior and lateral radiographs of bridging wrist external fixation used in fixation of a 23-A3.1 distal radius fracture.

External fixation can also be combined with internal fixation in especially unstable situations with intra-articular comminution that may be uncontrolled by ligamentotaxis. In a series of 30 patients treated with external fixation ± supplemental pinning or in combination with internal fixation, those with combined internal and external fixation were able to have the external fixator removed sooner and ultimately had less pain at final follow up.[37]

Use of external fixation in osteoporotic bone can be challenging as a result of pin loosening, pin tract infection, and loss of reduction. A recent prospective, randomized trial of 20 women with osteoporosis treated with external fixation evaluated the affect of supplemental hydroxyapatite coating of pins compared with standard tapered pins. Pin insertion torques were recorded intraoperatively and extraction torques were recorded 6 weeks later at removal. In the group treated with standard pins, extraction torques were less than half of insertion torques and two patients developed a superficial pin tract infection. The group treated with hydroxyapatite-coated pins, extraction torques significantly increased compared with insertion torques, and no pin tract infections were seen.[38]

In an effort to further provide maintenance of reduction, the use of a five-pin external fixator, with the fifth pin stabilizing the distal radial articular segment, has been suggested. In a recent study, 50 patients with unstable distal radius fractures were randomized to either a four- or five-pin external fixator. At 6-month follow up, those with five-pin fixators had significantly less pin tract infections and loss of alignment or length. Also, those patients had significantly better range of motion and grip strength.[39]

Potential complications with external fixation of distal radius fractures include malunion, contracture of fingers, injury to the superficial branch of the radial nerve, pin tract infection, and aseptic loosening of pins prior to healing.[40–44]

Arthroscopic-Assisted External Fixation

Fixation of intra-articular distal radius fractures can be challenging, especially with standard, fluoroscopically assisted internal or external fixation techniques. Although there can be a substantial learning curve, arthroscopically assisted external fixation allows the surgeon to directly visualize the articular surface for anatomic reduction and fixation of the joint and minimize operative dissection.[45,46] In 18 patients treated with arthroscopically assisted reduction and fixation, over 90% of them returned to their previous employment by 6 months. At an average follow up of 24.7 months, minor loss of reduction was noted radiographically in only two patients, who had not received bone grafting at the time of the index procedure.[45]

In 15 intra-articular distal radius fractures, this technique was shown to detect articular gapping not appreciated with plain radiographs or fluoroscopy. In this series, plain radiography and fluoroscopy had similar success as arthroscopy in detecting articular stepoff.[47] Also, this technique has been found to help with identifying and treating concomitant injuries (ie, scapholunate ligament tears, 18%; lunotriquetral ligament tears, 12%; or triangular fibrocartilage complex tears, 54%) in a series of 33 patients. All patients had excellent or good results at a minimal 24-month follow up.[48]

A recent study looked at 33 patients whose fractures were reduced and stabilized with standard techniques and then re-evaluated intraoperatively with arthroscopy. With increased severity of fractures, there was an increased need for rereduction and application of fixation once visualized arthroscopically. Seventy-four percent of Type IV fractures were modified once arthroscopy was incorporated.[49]

Open Reduction and Internal Fixation

Open reduction with internal plate fixation is often used for treating unstable distal radius fractures.[50–53] Traditional plating techniques often used a dorsal approach for plate placement. Although this fixation allows early motion and satisfactory outcomes, there can be plate failure, poor cosmesis, and extensor tendon complications such as tendonitis, attrition, and rupture.[52,54–58] These may require the need for removal of hardware or other procedures.[52,54–58]

Axelrod and McMurty reported removal of dorsal plates secondary to extensor tendon problems in five of 20 (25%) patients.[54] To eliminate the extensor tendon problems associated with dorsal plating, the low-profile π-plate (Synthes, Ltd., Paoli, PA) was developed.[57] Ring, however, found extensor tendon problems in five of 22 (23%) patients treated with the π-plate, thus showing that extensor problems still occurred with low-profile dorsal plates.[58]

In fractures with metaphyseal comminution in osteoporotic bone, early motion with nonlocked dorsal plating can potentially result in loss of fixation. Gesensway et al did show that screws loosened distally after cyclical loading when using dorsal plates. This could account for fracture settling and decreased fixation stability. Screws in the proximal fragment did not loosen.[59]

The recent introduction of locked plating (Fig. 4A–D) and fragment-specific plating has helped expand the surgeon's ability to incorporate the benefits of rigid fixation and potentially limit some complications. When comparing locked volar plating with standard dorsal or volar plating in single-cycle axial loading, the locked volar plate was the only one able to restore stability comparable to that of the intact radius when subjected to physiological loading.[60,61] A recent study showed that locked plating was significantly better at maintaining reduction of extra-articular fractures after cyclical loading when compared with standard dorsal plating.[62]

In two recent clinical reports,[63,64] a volarly placed fixed-angle plate demonstrated rapid fracture healing, a low incidence of bone grafting, and a low tendon complication rate. The authors speculated that the lack of dorsal dissection and the interposition of the pronator quadratus between the implant and flexor tendons have attributed to their decreased incidence of complications. They also suggested that the fixed-angle nature of the device achieved adequate stability for unstable fractures of the distal radius. This can allow early range of motion, leading to improved strength and ultimate range of motion after sustaining a distal radius fracture.[65]

In a recently presented, clinical series of 43 patients treated with a locked volar plate, there was an average 118° arc of wrist flexion–extension and 156° arc of wrist pronation–supination at 9-month follow up. Patients also attained 83% grip strength compared with the contralateral side.[66] Another

FIGURE 4. (A–B) Anteroposterior and lateral radiographs of injury. (C–D) Anteroposterior and lateral radiographs of volar locking plate.

recent clinical report of 50 fractures treated with a locked volar plate demonstrated 92% good to excellent results at 2 years with 46% of the previously fractured radii being radiographically identical to the uninjured side.[67]

If the geometry in a severely comminuted fracture will not allow adequate fixation with a single implant, combined dorsal and volar fixation may be necessary. A recent study evaluating 25 patients with 23-C3.2 distal radius fractures who underwent dorsal and volar fixation yielded 54°/51° of extension/flexion and 79°/74° of pronation/supination with a 78% maintenance of grip strength. Radiographically, the patients averaged 2° dorsal angulation, 21° of ulnar inclination, and 0.7 mm of articular incongruity. The authors did acknowledge the relatively high need for a second operation, most commonly removal of hardware.[68]

Fragment-Specific Fixation

Fragment-specific fixation (ie, Trimed Inc, Valencia, CA) uses a series of "mini"-plates and clips to individually supply rigid, low-profile fixation to fracture fragments. In a recent comparison to standard external fixation, fragment-specific fixation provided significantly greater stiffness in four of six motion axes under cyclical loading with physiological loads when stabilizing a four-part distal radius fracture model.[34] This could potentially allow for early motion with

stable fixation. With an average of 29-month follow up, a recent clinical trial of 27 fractures showed 25 of 27 fractures treated with fragment-specific fixation healed in acceptable alignment. Patients attained an average of 115° arc of dorsi- and palmar flexion.[69]

Recently, the use of fragment-specific fixation has become more popular. Proponents state that dorsal and volar plates allow implant placement to match the individual fracture pattern. The surgeon has the choice of extra-articular placement for simpler fixation or juxta-articular placement for more complex fractures. Many companies now supply minifragment plates, which allow more individualized fixation based on fracture pattern (Fig. 5A–F).

Intramedullary Fixation of the Distal Radius Fracture

Recent reports of intramedullary fixation of unstable distal radius fractures have shown this novel treatment method to be effective.[70,71] The Micronail (Wright Medical Technology, Inc., Arlington, TN) is an implant designed for minimally invasive fracture repair of the distal radius. The nail is inserted through a radial styloid portal and contains three 2.4-mm fixed-angle locking screws distally that are subchondral and diverge dorsally and volarly. Two 2.7-mm self-tapping, bicortical screws are placed proximally through an attached
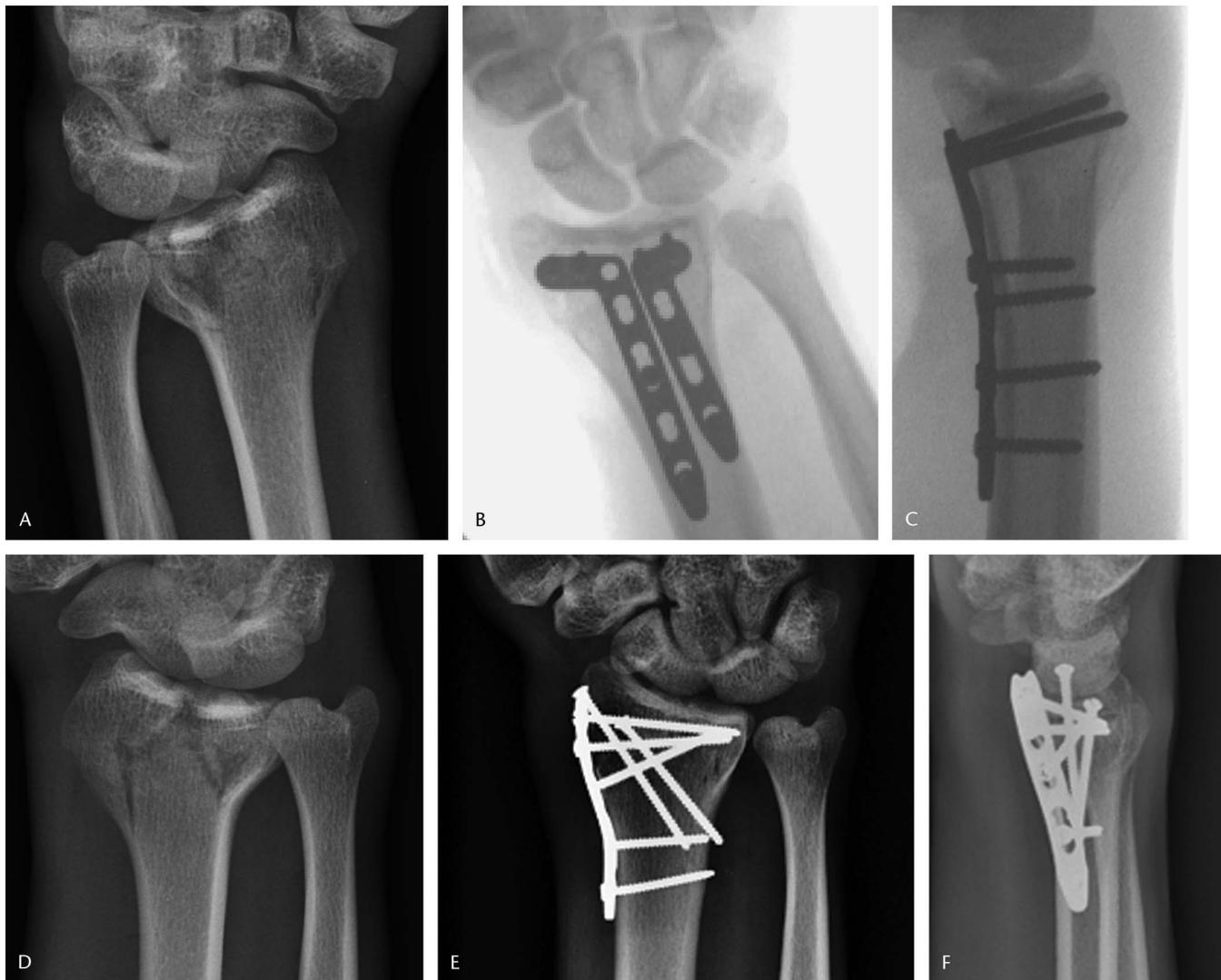
FIGURE 5. (A) Anteroposterior radiograph of injury. This patient had bilateral distal radius fractures. The opposite extremity is demonstrated in E–H. (B–C) Anteroposterior and lateral radiographs of fragment-specific fixation for a distal radius fracture. (D) Anteroposterior radiograph of injury. (E–F) Anteroposterior and lateral radiographs of fragment-specific fixation with fixation of the radial styloid.

outrigger guide. The nail sits completely intramedullary and only the recessed heads of the proximal interlocking screws sit outside the bone. This implant is indicated for extra-articular or simple intra-articular distal radius fractures (Fig. 6A–B).

A recent investigation reported on the results of 23 consecutive patients treated for isolated unstable distal radius fractures using an intramedullary implant.[71] There were 10 A2 fractures, three A3 fractures, four B3 fractures, on C1, and five C2 fractures in the group. Functional outcome at 6 months postsurgery demonstrated average flexion of 58°, extension of 73°, supination of 78°, pronation of 87°, and a DASH (Disabilities of Arm, Shoulder and Hand) score of 8. Radiographs showed an average volar tilt of 4°, radial inclination of 22°, and ulnar variance of 0.2 mm positive. There were no cases of infection, complex regional pain syndrome, hardware failure, or soft tissue irritation (Fig. 6C–D).

Concomitant Ulna Styloid Fracture

The effect of concomitant ulna styloid fractures with distal radius fractures has been questioned. Some authors have found a correlation with ulna styloid fractures to the incidence of distal radioulnar joint (DRUJ) instability, concomitant triangular fibrocartilage complex tears, decreased range of motion, or decreased grip strength in the affected wrist.[72–81] A recent review of 166 distal radius fractures yielded a 58% incidence of concomitant ulna styloid fracture. Of the 166 patients, 11% of them developed DRUJ instability, all of which had a concomitant ulna styloid fracture. Fractures of the ulna styloid that were at the base and had greater than 2 mm of displacement were found to significantly affect DRUJ

FIGURE 6. (A–B) Anteroposterior and lateral injury films demonstrating an unstable distal radius fractures with metaphyseal comminution and intra-articular extension. (C–D) Anteroposterior and lateral radiographs showing proper subchondral placement of the distal locking screws. The fracture has healed with adequate alignment and good articular alignment.

stability.[81] When surgically addressing distal radius fractures, fixation of the ulna styloid with Kirschner wires or screws may be necessary.

Osteobiologic Supplementation

Distal radius fractures with metaphyseal voids are often supplemented with bone graft (autologous or allograft). With the introduction of calcium phosphate cement, adjunctive structural reinforcement to maintain reduction can be provided without associated morbidity or risk of disease transmission. In a cadaveric model, calcium phosphate bone cement has been shown to be as stiff as Kirschner wire fixation in single-cycle loading and more resistant to shortening during cyclical loading.[82] Biomechanically, the addition of calcium phosphate bone cement to Kirschner wire fixation significantly increased the stiffness of the construct.[83]

A recent prospective series evaluated 52 females with osteoporosis treated with percutaneous pinning and cast immobilization with or without injectable calcium phosphate at an average 24-month follow up. The patients who had supplemental calcium phosphate bone cement were immobilized for 3 weeks, whereas immobilization was maintained for
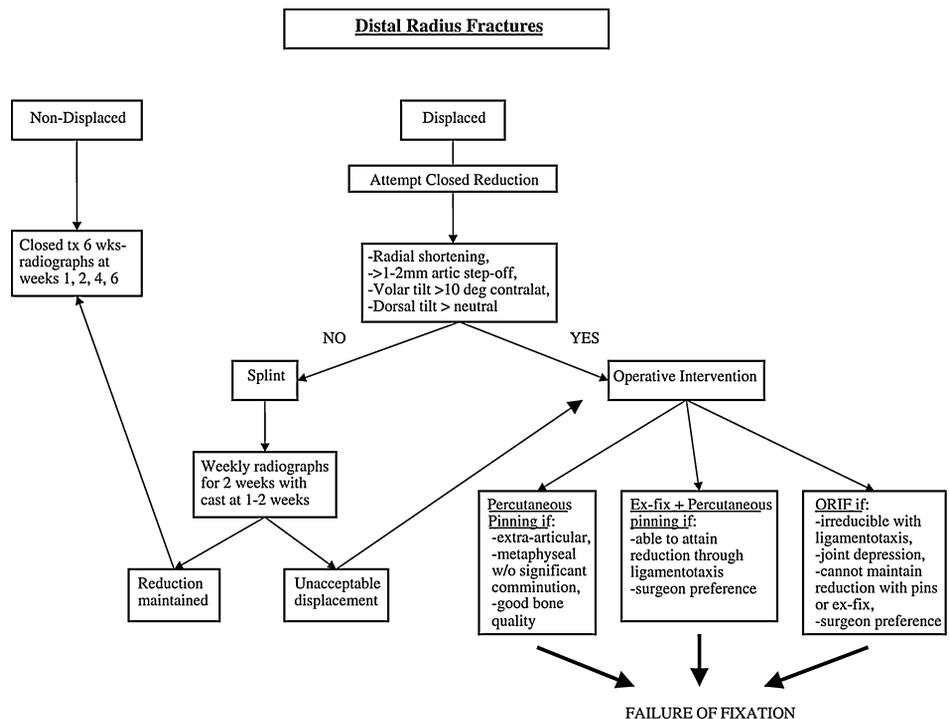

FIGURE 7. Treatment algorithm for distal radius fractures.

6 weeks in the other group. Those treated with supplemental calcium phosphate bone cement had significantly better range of motion, grip strength, and maintenance of reduction.[84] In 110 patients older than 50 years old, supplemental calcium phosphate bone cement without hardware was compared with cast immobilization alone. Those treated with combined therapy had 81.5% good to excellent results at 1 year compared with 55.5% in the group treated solely with cast immobilization.[85] A review of 323 patients that were prospectively, randomized into two groups: cast immobilization ± Kirschner wires + injectable calcium phosphate versus cast immobilization ± Kirschner wires or external fixation ± Kirschner wires, showed that the group receiving injectable calcium phosphate had better grip strength, wrist range of motion, digital motion, SF-36 scores, and less swelling for the first 3 months postoperatively.[86]

SUMMARY

Currently, many options are available for the treatment of distal radius fractures. A general treatment algorithm is suggested in Figure 7. If operative treatment is indicated, the DRUJ must be evaluated after acquiring stable fixation to determine if concomitant ulna styloid fixation is needed.

The decision to treat nonoperatively or operatively is based on a number of unique factors per patient as previously described. With operative interventions, fracture pattern and surgeon experience are additional considerations in determining the treatment modality.

ACKNOWLEDGMENT

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