External fixation techniques of distal radius fractures: does it work in plates era?

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Summary

Fractures of the distal radius are common injuries. Low- or high-energy mechanisms may be involved. Unstable distal radius fractures present a challenge to the treating orthopaedic surgeon. External fixation is a valuable instrument for fracture reduction and stabilization. Limited open incisions, early range of motion and management of complex wounds are a few of the benefits of external fixation. Fixators may be spanning or non-bridging, and may be used alone or in combination with other stabilization methods to obtain and/or maintain distal radius fracture reduction. Augmentation with percutaneous wires is beneficial for optimal fracture stabilization. Moderate distraction at the carpus does not create post-operative stiffness. The distal radioulnar joint must be assessed, and complications of external fixation must be anticipated. In this manuscript we review the principles, indications, and techniques of external fixation, as it applies to the treatment of distal radius fractures. **Riv Chir Mano 2012; 1: 3-18**

Key words

Digital radius fractures, external fixation, orthopaedic surgeons

Tecniche di fissazione esterna nelle fratture del radio distale: attuali anche nell'era delle placche?

Riassunto

Le fratture del radio distale sono lesioni comuni. Possono essere coinvolti meccanismi a bassa o ad alta energia. Le fratture instabili del radio distale rappresentano una sfida per il chirurgo ortopedico. La fissazione esterna è uno strumento prezioso per la riduzione e la stabilizzazione della frattura. Limitate incisioni aperte, un'iniziale range di movimento e gestione delle ferite complesse sono solo alcuni dei vantaggi della fissazione esterna. I fissatori possono essere radio-radiale o radio-carpico, e possono essere usati da soli o in combinazione con altri metodi di stabilizzazione per ottenere e/o mantenere la riduzione della frattura distale del radio. L'aumento della stabilità con fili percutanei è vantaggiosa per la stabilizzazione ottimale della frattura. Una distrazione moderata del carpo non crea rigidità post-operatoria. Deve essere valutata l'articolazione radio-ulnare distale e devono essere anticipate le complicazioni della fissazione esterna. In questo lavoro vengono rivisti i principi, le indicazioni e le tecniche di fissazione esterna e la loro applicazione al trattamento delle fratture del radio distale.

Parole chiave

Fratture radio distali, fissatore esterno, chirurgia ortopedica

Introduction

Distal radius fractures are extremely common injuries and tend to occur in a bimodal age distribution with a peak in younger patients and a second peak in older individuals. The mechanism of injury is unique to each group, with high-energy injuries being more common in the younger group and

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low-energy injuries being more common in the older group. They are also seen most frequently seen in children and again later in life in elderly, osteopenic women (1). Such injuries account for approximately one-sixth of fractures treated in US emergency departments (27).

Most distal radius fractures are low-energy fractures, the result of a fall, and may be treated non-operatively with some form of closed immobilization. High-energy distal radius fractures are more common in younger adults. In each of these subsets of patients the need for operative stabilization may arise. The high-energy fractures frequently have articular comminution and displacement that require open means to reduce. A percentage of some of the comminuted, osteoporotic low-energy fractures may be unstable injuries that require operative stabilization. The need for operative fixation of distal radius fractures in the elderly is becoming more common as the life expectancy in society increases and the elderly population stays more active and physiologically healthier.

The use of external fixators in the treatment of distal radius fractures is a common modality. External fixation can be used for various injuries about the wrist and in combination with other fixation methods (9). Currently the trend is towards open reduction and internal fixation and away from external fixation. We believe the external fixator is a still a valuable tool for fracture treatment and through this review will demonstrate its effectiveness. This manuscript will focus on the different techniques of external fixation by reviewing the peer reviewed literature and describing personal techniques. We have focused our literature search to peer review studies in the orthopaedic literature that have added clinically useful information to the current state of external fixation.

Pathophysiology and etiology

Distal radius fractures constitute up to 15% of all extremity fractures (28). The mechanism of injury is usually a fall on an outstretched hand. The most simple fracture mechanism is a bending fracture, typical in an elderly woman. This usually leaves the articular surface intact but creates a fracture in the metaphysis. There may be a degree of metaphyseal comminution based on the amount of energy absorbed by the extremity. High-energy fractures can occur from various mechanisms, including falls from a significant height and motor vehicle accidents (5). These fractures can combine metaphyseal and articular comminution. The distal radius has two articular surfaces, the radio-carpal joint with the scaphoid and lunate facets, and the sigmoid notch that articulates with the distal ulna. Both of these articular surfaces must be realigned properly for optimal function.

Diagnosis

A distal radius fracture usually presents with pain and swelling at the wrist over the fractured bone. There is often an angular deformity at the wrist, and it may assume the classic "dinner-fork" deformity with apex-volar angulation. Tenderness in the anatomic snuffbox should also be examined for, as fractures and dislocations of the carpus may coexist with a distal radius fracture. Anteroposterior (AP) and lateral plain radiographs are usually sufficient to characterize the distal radius fracture. If there is severe shortening of the radius or ulna, then an elbow radiograph should be obtained to evaluate for forearm instability or elbow fractures. Computed tomography (CT) scans of the radius are occasionally helpful to learn more about the articular involvement of the radius. This information may help in planning operative approaches to better gain access to the most displaced and unstable fragments. Reduction of the distal radioulnar joint should also be evaluated to ensure forearm stability. A triangular fibrocartilage injury may manifest itself as distal radioulnar joint subluxation by showing dorsal displacement of the ulna (10). In a true lateral radiograph the pisiform sits between the volar limits of the scaphoid and volar cortex of the capitate. With this true lateral radiograph the distal ulna sits in the dorsal half of the radius, with the dorsal cortices co-linear.

MANAGEMENT OPTIONS

Treatment options for the care of distal radius fractures span a wide spectrum of operative to non-operative methods. For a nondisplaced extraarticular fracture, a short arm cast may be sufficient. As displacement increases, the need for closed reduction increases. The exact values for inadequate reduction are debated, and vary for age, handedness and occupation of the patient. Radiographic values can be used as guidelines for inadequate reduction of the fracture (Tab. 1) (8, 16).

If closed reduction is successful in realigning the fracture, then immobilization usually is extended above the elbow. This can be a long arm cast or sugar-tong type splint. Long arm immobilization limits rotation of the forearm and minimizes the pull of the brachioradialis. If closed reduction does not restore or maintain these alignment values, then operative intervention is warranted. Contraindications for surgical repair include patients that cannot tolerate general or regional anesthesia and poor bone stock that can not accept screws or pins for fixation. Some fractures may be deemed unstable at presentation. An unstable distal radius fracture can be defined by several criteria (Tab. 2) (13, 17). The parameters usually represent mechanical instability, and often these fractures benefit from operative treatment. Closed treatment of these fractures have shown instability with a tendency to redisplace (13, 17).

Other indications for operative treatment include: patients with lower extremity injuries who need weightbearing through the upper extremity; associated fractures of the ipsilateral upper extremity that demand stable fixation of the radius to rehabilitate the arm; and open injuries to allow proper treatment of the bony and soft-tissue injury.

Table 1. *Criteria for inadequate reduction after closed reduction (8, 16).*

Radiographic parameter	Value
Articular step off	>2 mm
Dorsal tilt	>10 degrees
Radial shortening	> 5 mm
Ulnar inclination	< 15 degrees

Table 2. *Criteria for instability of distal radius fractures at presentation (13, 17).*

Radiographic parameter	Value/Type
Comminution	>50% from dorsal to volar
Angulation	>20 degrees dorsal tilt
Shortening	>10 mm
Fracture Pattern	Shearing, carpal fracture dislocation (Barton's)
Combined pattern	Radiocarpal fracture dislocation
Displacement	>100% loss of opposition

Operative management options may involve a wide range of surgical techniques. These include percutaneous pinning, external fixation, external fixation augmented with K wires, intramedullary fixation, and formal open reduction and internal fixation (ORIF) with plates and screws. Various combinations of the preceding methods can be used and give the surgeon great flexibility in his surgical tactic.

Regardless of the treatment option, Restoration of the distal radius anatomy is crucial. Guidelines for acceptable reduction are (1) radial shortening <5 mm, (2) radial inclination >15°, (3) sagittal tilt on lateral projection between 15° dorsal tilt and 20° volar tilt, (4) intra-articular step-off <2 mm of the radiocarpal joint, and (5) articular incongruity <2 mm of the sigmoid notch of the distal radius (28).

SURGICAL TECHNIQUES

The goals of treatment of distal radius fractures include: (1) restoration of length, (2) reduction of articular step off, (3) restoration of palmar tilt, (4) restoration of ulnar inclination, (5) and maintenance of a stable distal radioulnar joint. External fixation of distal radius fractures is a widely used tool for initial or definitive management. The clinical situations where external fixator use is effective in the wrist include several different fracture types

Table 3. *External fixation uses in wrist injuries.*

Purpose of fixator	Reduction forces
Definitive reduction of fracture	Length, moderate volar flexion, ulnar inclination
Unload carpus for ORIF of distal radius	Length, axial distraction
Reduction tool for augmented fixation	Overdistraction, hyperflexion and ulnar deviation; return to neutral alignment after percutaneous pins placed
Stabilize carpal dislocations and ligamentous injuries, sub-acute perilunate injuries	Length and neutral alignment
Fracture stabilization during management of complex open wounds	Length and neutral alignment

(Tab. 3). The advantages of external fixators include their ease of application, access to soft-tissue, and their versatility which easily allows combination with other fixation techniques.

Fixator frames function by maintaining length and neutralization of compressive, torsional, and bending forces across the fracture site (3). Ligamentotaxis is used for indirect reduction of fracture fragments. Distraction, ulnar deviation, and slight flexion can aid in reducing fragments that have capsular attachments. This can reduce large peripheral fragments but is ineffective in reducing impacted central (die-punch) articular pieces. Flexion alone cannot restore volar tilt as the dorsal capsular ligaments are more expansile than the volar ligaments and cannot rotate the fracture fragments effectively (2). With moderate distraction external fixators are an excellent method of unloading the carpus to allow tenuous articular fragments, osteopenic metaphyseal bone and inserted bone graft to heal (4). In recent years the use of external fixator has decreased in frequency and seems to be falling out of favor. However, the fixator is a technique that is well proven in the orthopaedic literature and it should not become a forgotten tool (7, 14, 21).

External fixation in the wrist

The utility of external fixation includes the ability to stabilize the fracture at a distance from the site of injury, allow unimpeded access to the injury site for wound care or additional procedures, adjustable length and alignment after application, and mobilization of the involved extremity. The rigidity of the fixator-bone construct increases with crossbar proximity to the bone, pin-fracture proximity, increased pin diameter, and increasing pin spread. In addition, stacking of crossbars and placement of pins in more than one plane also increases construct stiffness (3). These principles should be considered when using external fixation as a temporizing measure or definitive fracture management. If the fixator is to be used only as temporary spanning frame or combined with ORIF, then the radial shaft pins should be distant enough from the fracture site to allow plate placement away from the pin tracts.

Bridging external fixation

Radiocarpal spanning external fixation is a widely used method of distal radius fracture stabilization. Ligamentotaxis is used to indirectly reduce fracture fragments. Good and excellent results of distal radius fractures treated with unaugmented external fixation have been reported (7, 26). The amount of distraction applied and its effect on stiffness is a topic of much debate. In a recent study we evaluated the effects of distraction across the wrist on the clinical outcome of 24 patients with distal radius fractures treated with bridging external fixator plus percutanous K-wires. We were able to show that moderately increased distraction of the carpus at the initial fracture reduction is correlated with improved clinical outcome and does not have an adverse affect on subsequent wrist range of motion. Our data showed, based on functional rating by the Gartland and Werley evaluation system, 11 excellent, 10 good, 3 fair, and no poor outcomes, for an 88% rate of good or excellent results (29).

A standard technique for applying a bridging external fixator is described below.

Proximal threaded half pins, 3.0 to 4.0 mm, are placed approximately one hand's breadth proximal to the radial styloid tip, at the bare area of the radial shaft. This bare area lies just proximal to the muscles of the first and third compartments (the outrigger muscles). A single 3 to 4 cm incision should be used for both proximal pins, with care taken to identify and protect the tendons of the mobile wad and the superficial branch of the radial nerve. Blind, stab incisions place these structures at risk and are to be avoided. The extensor carpi radialis longus and brevis interval is used. This is slightly more dorsal than the brachioradialis extensor carpi radialis longus interval and thus lies further away from the superficial branch of the radial nerve. Also, this interval provides a tendon buffer on either side of the pins and has less nerve irritation because the nerve typically exits between the brachioradialis and extensor carpi radialis longus. These tendons are not usually irritated postoperatively because the wrist extensors are immobilized by the frame while the brachioradialis still has some excursion. Distal pins are placed in the proximal metaphyseal flare and shaft of the second metacarpal. These pins should have a smaller thread diameter (2.5 mm) to help avoid fracturing the metacarpal. Open pin placement will help avoid injury to the first dorsal interosseous muscle and dorsal branch of the radial artery. In addition, pins should not be transfixed into the third metacarpal to avoid damage to the second interosseous muscle and the motor branch of the ulnar nerve. Both sets of pins should be bicortical and placed 45-degrees in the radial-dorsal plane. Placing the frame in this plane allows full retropulsion of the thumb and aids in achieving unobstructed lateral radiographs (Fig. 1).

The most efficient technique is to next close all the incisions at the pin sites. This is easier at the time of pin insertion than at the close of the procedure where spanning bars and other exposed hardware make closure tedious. After pins and bars are placed, but before tightening of clamps, the fracture must be reduced. It is tempting to apply traction and excessive volar flexion to reduce the deformity of the usually dorsally displaced fracture. Volar flexion greater than 40° may be needed to obtain radiographic reduction. However, this degree of positioning results in elevated carpal tunnel pressures and may induce carpal tunnel syndrome (24). Instead traction, palmar translation and only mild (<10°) flexion of the carpus should be applied. In addition, ulnar deviation should not exceed 20° because this may place excessive strain on the triangular fibrocartilage complex (9). If one cannot achieve fracture reduction within these parameters, then additional reduction or fixation techniques are needed. A small subset of distal radius fractures can be treated with a spanning, non-augmented frame. With this configuration, the fixator pins need to be close to the fracture site to effectively control reduction. At the close of the procedure, the position of the wrist and degree of distraction must be critically assessed. Flexion should not be more than 10° because this prevents power grip of the hand and can induce median nerve compression. Full passive flexion of the fingers into the palm should be easily achieved. If this is impossible or the fingers have significant rebound, then the distraction is excessive and needs to be reduced. This prevention of flexion is caused by tension of the extensor digitorum communis tendons and will seriously jeopardize final finger ROM. Examination of the final fluoroscopy image should show even distraction across all the carpal joints. There should not be asymmetrical widening of the midcarpal joint compared with the radiocarpal joint. This can also be manifested as distraction of the scaphoid in relation to the lunate, signifying a scapholunate tear. Again, distraction should be moderated if this is seen. In the AP and lateral views the carpus should be concentrically reduced, with the lunate and scaphoid in there respective fossa.

Figure 1. *(A) The proximal fixator pins are placed through one open incision. The pins are placed between the tendons of the radial wrist extensors. The superficial radial nerve can be seen volar to this interval. (B) Half pins with a 2.5mm thread diameter are placed in the second metacarpal. The proximal pin is placed at the metaphyseal flare and the distal pin is placed in the shaft. (C) Placement of proximal and distal half-pins in a 45 degree dorsal-radial plane.*

Augmented external fixation

Distal radius fractures often require additional fixation methods after placement of the external fixator. The addition of K wires to an external fixation construct has been proven in the lab to have increased rigidity (6, 25). In addition, the use of k-wires will likely help avoid loss of fracture reduction over time. This may be required if fracture reduction can not be obtained by ligamentotaxis with the fixator alone, or if an excessive, non-physiologic position of the wrist is needed for fracture reduction. In this latter case the fixator can be used as a provisional reduction tool. Often the fracture requires hyperflexion, ulnar deviation, and significant palmar translation. After this is achieved the reduction can be held with crossed Kirschner wires (0.062" or 0.054"), one or two placed in the radial styloid and an additional pin placed in the ulnar corner of the radius. The radial side pins pass from straight radial to ulnar or slightly volar to dorsal, while the ulnar corner pin is placed obliquely from dorsal to volar. Biomechanical investigations have shown that crossed pins of a 0.062" size provide optimal construct stability (20). Once the pins are placed, the external fixator is adjusted back to a more neutral and physiologic alignment. Supplemental Kirschner wires may also be used as a reduction joy-stick to move articular fragments into anatomic position before final pin positioning. This technique can improve alignment of articular fragments in comminuted fractures (Fig. 2).

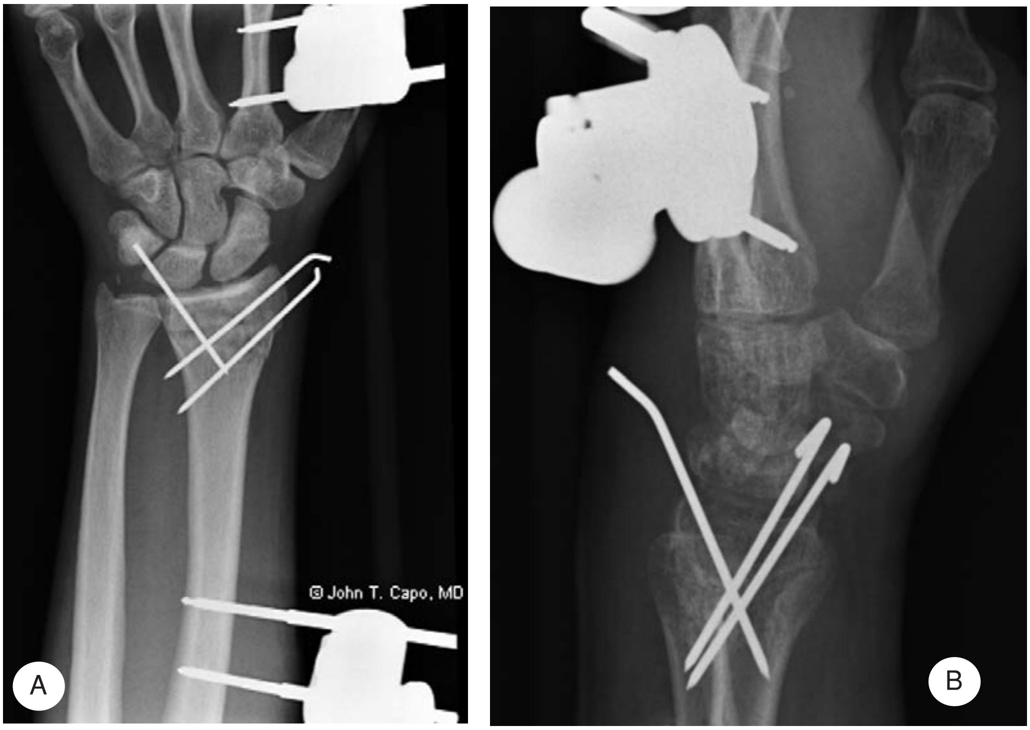

Figure 2. *(A) AP view of distal radius fracture treated with augmented external fixation. The carpus is reduced on the distal radius and there is no over-distraction at the radiocarpal or midcarpal joints. (B) Lateral view of the wrist in the external fixator showing neutral alignment of the carpus and good restoration of the volar tilt of distal radius.*

Augmented fixation can also be beneficial during the postoperative course. With the presence of dual fixation, either the fixator or K wires can be removed earlier if they become problematic. This can be especially helpful in the presence of a pin tract infection or to initiate early range of motion therapy. The fixator may need to be removed early if there is pin irritation or infection and some of the smooth pins can be left in place as early motion is begun. Augmented external fixation avoids open exposures to the distal radius and becomes an attractive option for unstable distal radius fractures. The ability of augmented external fixation to obtain good results has been well documented in the literature (12, 23, 26).

Zanotti et al. (26) prospectively studied the subjective, functional and radiographic outcomes of 20 patients with unstable distal radius fractures treated with external fixation alone or in combination with percutaneous pins. All patients were treated with the Wrist Jack (Hand Biomechanics Lab, Sacramento, CA) adjustable external fixator and followed up for a minimum of 2 years. Pins and frame were removed, on average, approximately 7 weeks postoperatively. Final intraoperative radiographs showed an average radial length, radial inclination and palmer tilt to be 11.1 mm, 20.3°, and 6.5°, respectively. At final followup, final measurements for length, inclination, and tilt were 12.3 mm, 18.7°, and 3.7°, respectively. Outcomes were rated as excellent in one patient, good in 15 patients, fair in four patients, and poor in none. When analyzed by mechanism, patients who sustained a high-energy injury were more likely to require supplemental fixation (percutaneous pins) and in general had a poorer outcome. Those with fair results were shortened an average radial length of 3.5 mm, a radial inclination of 12.3° and a palmer tilt of 4.5°. Restoration of length appeared to correlate with rated outcome. The authors concluded that external fixation with supplemental K wires is a viable treatment option for high-energy distal radius fractures. However, modest results should be expected for those patients with high-energy complex injuries, regardless of treatment method.

Non-bridging external fixation

Nonbridging external fixation is a recently described technique for unstable distal radius fractures (11, 18, 19, 22). In theory, this method allows for more direct control of the distal fracture fragments, more stable fixation, and earlier, improved ROM of the wrist. The distal fragment is purchased with two threaded half-pins and can be manipulated directly into flexion and ulnar deviation. The intervals used distally are typically between the first and second compartments and in the third compartment after retracting the extensor pollicis longus tendon. The pins are placed slightly convergent from dorsal to volar. A crucial element of the technique is to gain purchase in the volar cortex to increase the moment arm for reduction of the fragment. The proximal pins are placed in a similar interval as a spanning frame but can be placed slightly more dorsal to attach the frame. A standard fixator set can be used to connect the frame in a delta configuration or a custom distal Y or T type clamp can be used to simplify the frame. Extra-articular distal radius fractures are ideal situations for treatment with a nonbridging frame that can be made into a very low-profile design.

Tapio et al. (22) treated 52 patients with a nonbridging fixtor. Distal pins were inserted in the distal radius via a transverse incision over the third dorsal compartment. The fixator remained in place for an average of 48 days; average followup was 16 months. The authors reported good radiographic reduction and maintenance of reduction. Functional results were good, with ROM and grip strength restored to approximately 90% the contralateral limb. Somewhat surprisingly, however, subjective results were less favorable, with 27 good, 11 fair, and seven poor results. This was perhaps secondary to a relatively high (19%) infection rate and relatively short follow-up.

Combined techniques

An external fixator can be used as one component in the fixation hardware of a distal radius fracture. This is ideal for severe high-energy fractures that have metaphyseal and articular comminution. The external fixator is used to buttress the metaphyseal fragmentation while small plates or percutaneously placed wires are used to align and fix the articular fragments. Ideally, the fixator is placed first in the standard 45° dorsal-radial position and traction is applied. This position allows access for a dorsal, volar, or radial approach to the radius. Excessive traction and angulation can be applied to help align fragments for fixation by supplementary means. When the fragments are secured and bone graft applied when necessary, then the fixator can be backed off to a physiologic position. The traction serves to provide mild distraction, which unloads the carpus from the distal radius. This fixator can be removed early (3-5 weeks), because of the stability provided by the other hardware, and wrist ROM may be initiated. High-energy distal radius fracture can be effectively treated with a combination of external fixation, volar plating, and percutaneous pinning (Figg. 3, 4).

Stabilization of DRUJ

The importance of addressing the distal radioulnar joint cannot be overstated. Indeed, distal radioulnar joint injury occurs in approximately 10% of patients with distal radius fractures and is a major cause of discomfort after successful healing of these fractures (10). At the completion of distal radius fixation, the distal radioulnar joint should be assessed for stability. This is done with elbow placed on the hand table and flexed at 90°. The radius is stabilized and the ulna is stressed volarly and dorsally. This maneuver is done in neutral rotation and again in full pronation and supination. If there is abnormal translation or a significant click or sense of subluxation, the distal radioulnar joint should be stabilized. If the ulna is unstable in a dorsal direction then the forearm is placed in supination, if the ulna subluxates volarly then pronation usually stabilizes the ulnar head. If addressed acutely, the distal radioulnar joint can be reduced and immobilized by above elbow splinting

Figure 3. *A) AP and (B) lateral views of an open, severely comminuted and displaced distal radius fracture. C) AP and (D) lateral x-rays showing initial stabilization of an external fixator. The distal most, proximal pin is near the fracture site which may interfere with future plate placement.*

Figure 4. *A) Intra-operative AP and (B) lateral x-rays demonstrating restoration of the joint surface with a small volar plate and additional percutaneous wires placed in the styloid. C, D) radiographs at 6 month follow-up showing healing of the fracture, reduction of the carpus and articular congruity at the distal radius.*

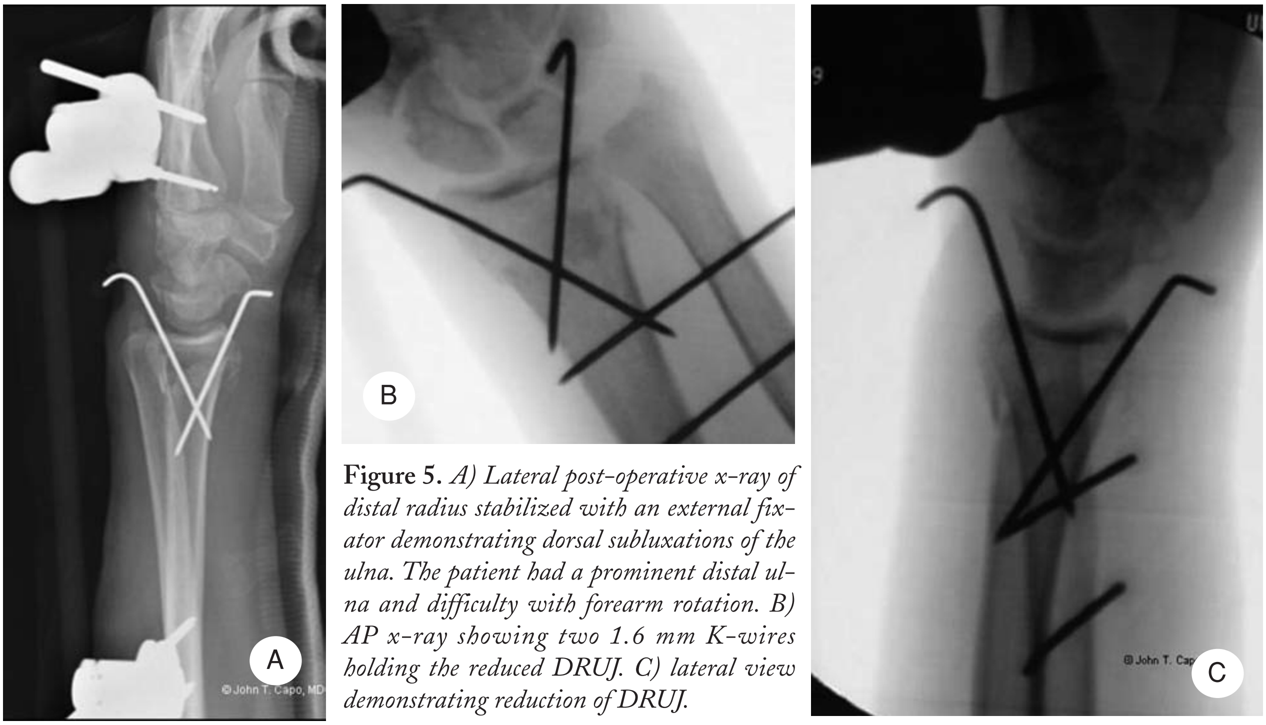

Figure 5. *A) Lateral post-operative x-ray of distal radius stabilized with an external fixator demonstrating dorsal subluxations of the ulna. The patient had a prominent distal ulna and difficulty with forearm rotation. B) AP x-ray showing two 1.6 mm K-wires holding the reduced DRUJ. C) lateral view demonstrating reduction of DRUJ.*

or casting. Alternatively the DRUJ can be immobilized with percutaneous ulno-radial pins (Fig. 5), or by inclusion of the ulna in the external fixator construct (Fig. 6). Fixation of forearm rotation should be maintained for 6 to 10 weeks, and then progressive motion is started under guidance of a therapist.

If associated distal radioulnar instability is not treated at initial injury, progressive subluxation of the ulna and joint incongruity with limitation of active rotation will soon develop. This problem when addressed chronically is much more complex and usually requires open reduction and ligament reconstruction.

Aftercare

Pin tract irritation and infection may occur. The importance of daily pin care must be reinforced to patients. Care-givers responsible for elderly or infirm patients must also understand the importance of compliance with pin care. After the first postoperative dressing change, pin site care is begun. Cleaning is usually twice daily and can utilize either one-half strength hydrogen peroxide, alcohol, soap and water or saline. After the pin insertion sites are dry some practioners allow their patients to shower with the external fixator.

Equally important are daily exercises of the involved extremity. Formal therapy is used in approximately 2/3 of our patients. The decision for therapy is made in the first few weeks after fixation. External fixation across the wrist allows for early and free digital and elbow ROM. Forearm rotation can also be initiated if there is no distal radioulnar joint instability. Non-bridging external fixators allow additional motion at the radiocarpal joint. The goal is to have complete digital and elbow ROM at the time of fixator removal.

Complications

Complications associated with external fixation of distal radius fractures are common, ranging from

Figure 6. *A) AP and (B) lateral view of a comminuted distal radius fracture. C) Post-operative x-ray showing stabilization of fracture with volar plating, dorsal pin fixation and an external fixator. D) the external fixator construct is extended to the ulnar shaft with an outrigger bar to stabilize the DRUJ.*

20 to 85% in published series (7, 21). The majority of noted complications include minor pin tract infections and transient neuropraxias. However, more involved infections requiring débridement are not uncommon, as are nerve irritation, tendon rupture, loss of reduction and complex regional pain syndrome. Wrist and finger stiffness are also complications that may be associated with external fixators.

Harley et al. (12) performed a prospective randomized trial comparing augmented external fixation versus percutaneous pinning and casting for unstable distal radius fractures. Forty-one patients were followed up for 6 months. They noted no difference in clinical outcome between the two groups, though they did note percutaneous pins and casting were more likely to result in articular gaps and defects. There was a trend towards more frequent pin tract infections, reflex sympathetic dystrophy, and nerve injuries in the external fixator group. One may conclude from this study that external fixation, though minimally invasive, is not a benign procedure, and alternative treatment options might be reasonable in the low demand or elderly patient. Pins and casting has potentially fewer complications, but may result in an inferior long-term result in high demand patients. The two groups had no difference in postoperative ROM.

Kaempffe and Walker (19) have suggested a causal relationship between fixator induced carpal distraction and postoperative ROM deficits. This often quoted study, however, did not show a statistically significant adverse effect of the amount distraction on functional outcome. Only duration of external fixation was statistically correlated with decreased wrist ROM. If properly used and excessive distraction is avoided, the fixator itself does not seem to lead to stiffness. When viewing the fluoroscopic view during the external fixator placement, the radiocarpal and midcarpal joints should have similar and only mild distraction. It appears that stiffness in fractures treated by external fixation is more a function of the injury rather than the distraction induced by the fixator.

Superficial pin tract infections after external fixation are a well-known postoperative development. Most can be treated with meticulous pin care and oral antibiotics. However, occasionally pin tract infections require débridement or fixator pin removal. In such cases, the presence of augmentation such as K wires can be very valuable for maintaining the reduction. The rate of pin tract infections, superficial and deep, is about 20% (21). Some have advocated delaying surgery 7 to 10 days before pin placement to allow swelling to subside and potentially decrease the rate of pin tract infections, with relatively lower rates of infection (26). The use of a wrist splint to support the fixator may relieve some of the tension on the pins and help minimize pin-tract drainage and infection.

Complex regional pain syndrome or neuritis also can occur after external fixation of distal radius fractures. Rates of 10 to 22% have recently been reported (4, 12, 18). It is unclear if this is due to the nature of the injury or a complication of the treatment. Also, the incidence of nerve irritation may be significant but the occurrence of true complex regional pain syndrome is relatively rare. The importance of open pin placement cannot be overstated. Others have implied that it is the degree of the soft tissue injury itself that is most directly related to complications and therefore patient outcome (19).

Discussion

Distal radius fractures are common fractures that are seen in all age groups. These fractures represent a large percentage of nearly all orthopedists' clinical practice. The choice of the appropriate treatment for distal radius fractures depends on the personality of the fracture and the patient, and also the experience of the surgeon. Many fractures can be treated nonoperatively with alignment that is not ideal, but that may provide function that is adequate for a low demand patient.

As patients' functional demands and activity level increase, the necessity for anatomic reduction is more critical. External fixation is a tool that can help in achieving this required reduction. The use of an external fixator is often adequate by itself or can be combined with other fixation methods. One of the advantages of standard external fixators is the flexibility it provides with choice of pin placement location. Pins may be placed out of the zone of injury, may be extended to the ulna to stabilize the DRUJ or extended to different areas of the hand to fixate associated injuries. Through this review several conclusion can be made concerning the use of external fixation in the wrist.

Several clinical and biomechanical studies support the use of augmented fixation.

The inability of ligamentotaxis via external fixation alone to restore distal radial volar tilt was described by Bartosh et al. (2) in the early 1990s and also indicates the need for supplementary fixation. The biomechanics of augmented external fixation has also been studied in the lab. Wolfe et al. (25) performed a cadaveric study comparing osteotomized distal radii stabilized with external fixator alone or with various supplemental K wire configurations. Both fracture transfixion wires as well as outrigger wires placed into the distal fragment and secured to the external fixator were superior to external fixation alone in reducing fracture motion. A single wire was enough to gain appreciable stability, and additional wires did not improve stability further.

Early ROM is one of the goals after successful fracture reduction and stabilization. However, an overly aggressive approach to therapy may potentially lead to fracture motion and loss of reduction. The increased stability provided by augmented external fixation and the ability to remove the fixator early and free the wrist joint assist in increasing eventual motion. Dunning et al. (6) studied unstable cadaveric distal radius fracture stability by using a computer-controlled wrist-loading device used to generate simulated finger and forearm motions. Specimens were stabilized using spanning external fixation with or without radial styloid pins or with a dorsal distal radius plate. They showed that supplemental K wires reduce fracture fragment motion when compared with external fixation alone. The stability gained by this construct approached that reached with dorsal plating technique.

An alternate method of augmented external fixation was recently described by Werber et al. (23) They performed a randomized, prospective study comparing external fixation of distal radius fractures using the standard four pin technique with a five pin external fixator that included an additional pin placed in the radial styloid and attached to the fixator. Kirschner wires were used to help joy-stick fracture fragments but all supplementary wires were removed at the end of the index procedure. Fifty patients were followed up clinically and radiographically for 6 months. The authors found that the five-pin fixator was better at restoring and maintaining radial inclination, length, and volar tilt. There was no difference in articular step-off between the groups. In addition, and most importantly, the five-pin group had a better clinical outcome. These patients had better ROM, better grip strength, and better overall clinical scores when compared with the four-pin group.

With this compelling evidence it seems prudent to always combine a fixator with supplementary percutaneous pins. The fracture is more directly held, and a more anatomic reduction can be achieved. The fixator can also be used as a reduction tool as the pins are placed. With the pins holding the fracture in a reduced position the fixator can be backed off to a more physiologic position. This promotes early finger and elbow range of motion. With augmented fixation the spanning fixator can be removed at a relatively earlier time to begin radio-carpal motion.

The use of low profile and nonspanning fixators decreases the complications and increases the tolerance of frame wear. The literature has demonstrated the improved effectiveness of non-spanning frames over spanning, non-augmented frames.

McQueen (18, 19) supports the use of nonbridging external fixation. She has reported improved initial and maintained reduction, and better functional outcomes using this method. In a prospective, randomized study (18) of 60 patients with unstable extra-articular distal radius fractures, the author was able to obtain an average of 5° volar tilt using a nonbridging technique versus 3.6° dorsal angulation in the spanning group. Importantly, in the nonbridging group, the reduction was maintained at 1 year postoperatively, compared with the spanning external fixator group, where the reduction deteriorated to an average of 12.2° apex volar. Radial length and alignment were also obtained better and maintained in the nonbridging group. In addition, the nonbridging group was reported to have better grip strength and ROM at final follow-up. However, the nonbridging group had two patients with extensor pollicis longus ruptures, possibly because of irritation by the distal pins. This complication must be considered and emphasizes the need for open pin placement, particularly with distal radius pins. The spanning external fixator group had two episodes of reflex sympathetic dystrophy, whereas the nonbridging group had none.

In a similar fashion to augmented fixation, non-spanning frames have a more direct hold on the distal fracture fragment. The application of non-spanning frames is technically demanding and often the fragment can not adequately accept standard half pins. Augmented fixation is technically easier and appears to have similar results.

The recent trend for fixation of distal radius fractures has been towards more open reduction and internal fixation with rigid plating systems. Locked plates have been advocated for dorsal, volar or radial and ulnar column placement. These plating techniques have shown good results in the short term. However, there is a definite incidence of hardware irritation, tendonitis and tendon rupture with all plating techniques in the distal radius. To adequately compare the performance of external fixation versus these modern plating systems a prospective randomized study comparing the two with similar fracture patterns should be undertaken.

The external fixator is a technique that has been well known to orthopaedic surgeons for many years and should not become a forgotten skill. With attention to the details of anatomy and fracture reduction as described in this article, it can be a safe, effective, and useful tool.

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