Distal Radius Fractures: Current Concepts

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Despite the frequency of distal radius fractures, studies in the existing literature have not been able to determine the optimal surgical strategies for various fracture patterns. Numerous clinical articles have been written, but most are level IV case series or expert opinion reviews. Good biomechanics studies have been published that suggest advantages of certain fixation methods over others. Transference of these expectations to clinical reality, however, requires well-controlled patient trials. In large part, this has not happened. This article reviews the theoretical pros and cons of different surgical strategies used for adult distal radius fractures, and then looks at randomized controlled trials that have been published in the last 5 years. *(J Hand Surg 2008;33A:1215–1227.*

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

HISTORICAL BACKGROUND

Clinical diagnosis

The mechanism of injury is perhaps the most important element of the history. Specific mechanisms imply greater or lesser degrees of injury, not only to the radius itself but also to associated ligaments, nerves, and other soft tissues. All attempts must be made to quantify both the kinetic energy involved (number of feet fallen off the scaffold, miles per hour of the vehicle at time of accident, etc.) and the direction of force transmission (fall to outstretched hand was forward directed with arm extended = shallow angle of impact vs backward directed with hand placed next to hip = high angle of impact). This information is critical in developing an index of suspicion for associated ligament and nerve injuries and in directing treatment decisions. The surgeon must always ask about pain in the elbow, shoulder, and hand as well as paresthesias in the median nerve distribution.

On physical examination, 1 must search for signs of direct tissue trauma not only at the wrist but also at the elbow, shoulder, and hand. Functional performance and point of tenderness testing should be performed at all levels of the upper extremity. In low-grade distal radius fractures, the patient will often tolerate a direct functional exam of the wrist itself. This may even include stress examination of the intrinsic, scapholunate interosseous ligament (SLIL), the lunotriquetral interosseous ligament (LTIL), and the radioulnar ligament (RUL) that serves as the primary stabilizer of the distal radioulnar joint (DRUJ). The surgeon should measure monofilament sensibility at the digital tips as the best assessment of median nerve function in an environment of direct nerve trauma plus burgeoning swelling within the carpal canal. An increased monofilament score may indicate the need for median nerve decompression at the time of radius fracture fixation to prevent complex regional pain syndrome (CRPS) or permanent median nerve functional loss.[1]

Imaging

Plain radiographs are the mainstay in preoperative assessment of distal radius fractures. The posterior-anterior (PA) view should be shot as a neutral-variance view with the elbow and shoulder at 90° and the forearm in neutral rotation. This standardizes the assessment of ulnar variance, which may play a role in treatment decision making. The lateral should be shot as a 20° inclined view where the beam is directed from distal radial to proximal ulnar, which provides a far better assessment of dorsal tilt and articular congruence than a traditional straight lateral.[2] A 45° pronated

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TABLE 1. Simple Classification of Distal Radius Fractures

	Articular Instability = No	Articular Instability = Yes
Metaphysis Incompetent = No	Prevent recurrent angulation of metaphysis; need not bear axial load	Subchondral interfragmentary compression
Metaphysis Incompetent = Yes	Load-bearing subchondral support bridging metaphysis	Subchondral interfragmentary compression and load-bearing subchondral support bridging metaphysis

For each of the 4 possible combinations, the surgeon must provide the type of fixation listed in the box.

oblique view (originally described for postoperative assessment) is also useful for preoperative assessment in that it profiles the dorsal ulnar cortex that supports the dorsal lunate articular facet and forms the dorsal margin of the sigmoid notch.[2] It is important to recognize that distal radius fractures can be intra-articular fractures not only at the radiocarpal joint but also at the DRUJ. Although not definitive, an inherently unstable fracture is characterized by articular incongruity greater than 2 mm (stepoff is more important than gap), dorsal tilt past neutral, radial inclination less than 15°, ulnar positive variance of greater than 4 mm, ulnar translation of the distal complex greater than 4 mm, and metaphyseal comminution of greater than 50% the PA dimension.

Magnetic resonance imaging of distal radius fractures really plays a role only in cases of diagnostic uncertainty; accuracy levels are not currently sufficient to rule out instability of the SLIL, LTIL, and RUL. Computed tomography scanning has been discussed as a preoperative planning tool and can indeed reveal the position of the fracture fragments. Intraoperatively, the surgeon will be repositioning displaced fragments and accomplishing an intra-articular reduction, but the computed tomography scanner will not be present. After the fragments have been moved, some other method of assessment is needed to judge the accuracy of the reduction, such as arthroscopy, which negates the cost and delay of the computed tomography scan.[3]

Classification

Many classifications for distal radius fractures exist, but none have been proven to surpass the others in clinical utility. Although it is not perfect, from a research standpoint, the AO classification serves its purpose in recognizing 3 broad groups that can be subdivided to either 9 or 27 distinct fracture patterns (A: extra-articular, B: partial fracture of articular surface, C: complete separation of multiple articular fragments from shaft). From a clinical decision-making standpoint, though, radius fractures can be boiled down to an even easier set of 2 fundamental questions (Table 1). Has the articular surface been disrupted to the point of instability between fragments? If so, the surgeon is required to restore the interfragmentary articular relationship. Is the metaphysis incompetent to bear load? If so, the surgeon is required to provide axial stability and subchondral support until the metaphysis has healed.

TREATMENT OPTIONS

Many years ago, distal radius fractures were lumped as a group under the eponym Colles' fractures and considered to "all do well" with a cast. Low-energy, inherently stable distal radius fractures are perfectly well managed with 4 weeks of splint or cast immobilization followed by a transitional, removable splint until clinically healed. An inherently unstable fracture is identified by the mechanism of injury combined with physical examination findings and the radiographic parameters previously described. The remainder of this article will consider inherently unstable fractures that require additional surgical stabilization.

Principles of surgical treatment

The radius fracture itself must achieve a congruent and stable articular surface that is correctly oriented in 3 dimensions and sufficiently supported across an incompetent metaphysis to pursue early range of motion. One method of stabilization has not been proven universally superior to any other in meeting these treatment requirements. Orthopedic device manufacturers have provided a vast array of stabilization options for the surgeon to choose from. When selecting the optimal strategy for an individual patient, factors that must be considered include the biomechanical performance of the general device class, unique biomechanical features specific to that device itself, the soft tissue morbidity associated with application of the device, the anticipated incidence of complications, and the comfort zone of the surgeon's own experience.

Percutaneous pinning/closed reduction internal fixation

Closed reduction and percutaneous pin fixation is appropriate for fractures without articular instability that also lack substantial metaphyseal comminution (Table 1). Pinning alone cannot maintain support in fractures with metaphyseal comminution.[4] The pins are not load-bearing devices. They must assist the reduced fracture fragments in bearing the forces transmitted through the fracture site by the digital flexor and extensor tendons that will be firing as the patient pursues hand range of motion exercises. The most common type of fracture for this method is an extra-articular fracture of the metaphysis created by bending forces without axial impaction. Once the angulation is reduced, the metaphyseal cortices will balance on each other well, as long as the surgeon simply provides maintenance of alignment. Distal to proximal pinning with 1.6-mm (0.062-in) K-wires entering through the radial styloid across to the proximal ulnar cortex of the metadiaphysis accomplishes the additional support needed when coupled with a short arm splint. Some prefer to place the K-wires through the fracture site; this method has been called "intrafocal pinning." The wires can be removed by 4 weeks. Active wrist range of motion sessions with return to an orthoplast splint can then be pursued until the fracture is deemed clinically healed. The patient then progresses through assisted and passive end range motion stretches, strengthening, and eventually task-specific training until achieving unrestricted use anywhere from 6 to 10 weeks from injury. The primary risk with this strategy is impaling the superficial radial nerve, leading to CRPS. Standard precautions for avoiding this complication must be followed. The other primary consideration is pin track infection. In the era of methicillin-resistant Staphylococcus aureus, 1 must be ever vigilant of pin track infections and consider which patients might pose a greater risk than others (eg, patients with diabetes, noncompliant patients).

External fixation

As hand surgeons began to recognize that not all distal radius fractures did well with a cast, some form of stabilization was needed. The next notch up the ladder of sophistication was pins and plaster, which had a certain utility but ultimately proved rather imprecise and has largely been abandoned. Its biomechanical equivalent and replacement was provided by the device manufacturing industry in the form of the external fixator. An external fixator can be applied to any fracture pattern, but it functions poorly for shearing fractures in the coronal plane. External fixation of distal radius fractures used to mean an articular spanning device with 1 pin grouping in the radial diaphysis and 1 in the index metacarpal, relying largely on longitudinal traction (as well as shifts in translation and angulation) to avoid further fracture displacement. Obviously, external fixation without any interfragmentary pins provides at best an indirect reduction without a means to maintain that reduction, and it is rather hard to justify in the modern era. Interfragmentary percutaneous pins directly maintain the fracture reduction. The external fixator is then used to unload the pinned construct during early healing, with removal by 4 weeks. The pins could also be taken out at that time or stay another 2 weeks, depending on details of the individual case. Articular bridging external fixators still play a role in the management of distal radius fractures, particularly in the hands of surgeons who simply aren't comfortable with plates and screws and in the setting of established infection. Excessive longitudinal traction across the carpal ligaments should be avoided because this leads to permanent wrist stiffness. The purpose of the fixator is to maintain overall limb alignment and dampen the effects of outside forces. Pin track infection and superficial radial nerve irritation sometimes leading to CRPS continue to limit the use of external fixators. The scars from the pin placement can prove unsightly, occurring in socially visible locations.

More recently, the industry has seen the availability of fixators designed to span only the fracture site, but not the wrist joint, where the distal pin grouping is placed in the articular fragment of the distal radius. These devices seek to eliminate the complication of excessive wrist joint stiffness due to carpal ligament traction combined with rigid joint immobilization seen with the bridging fixators. They still risk the complications of superficial radial nerve injury and pin track infection. Whereas the bridging fixators could be used in cases of distal fragment comminution, a nonbridging fixator needs a fairly large and stable distal fragment for purchase (seen only in the simpler fracture patterns). Nevertheless, surgeons should be aware that this option is available and represents 1 way to manage distal radius fractures. Twenty-five patients treated with a nonbridging external fixator achieved 55° of wrist extension and 64° of wrist flexion, with 4 cases of collapse and 3 pin track infections.[5]

Individual fragment fixation

Fixation between individual fragments is needed when 1 or more articular fragments are substantially disrupted and unstable relative to the remaining articular surface (Table 1). Limited interfragmentary fixation is possible when the metaphysis is axially stable. In order to pre-

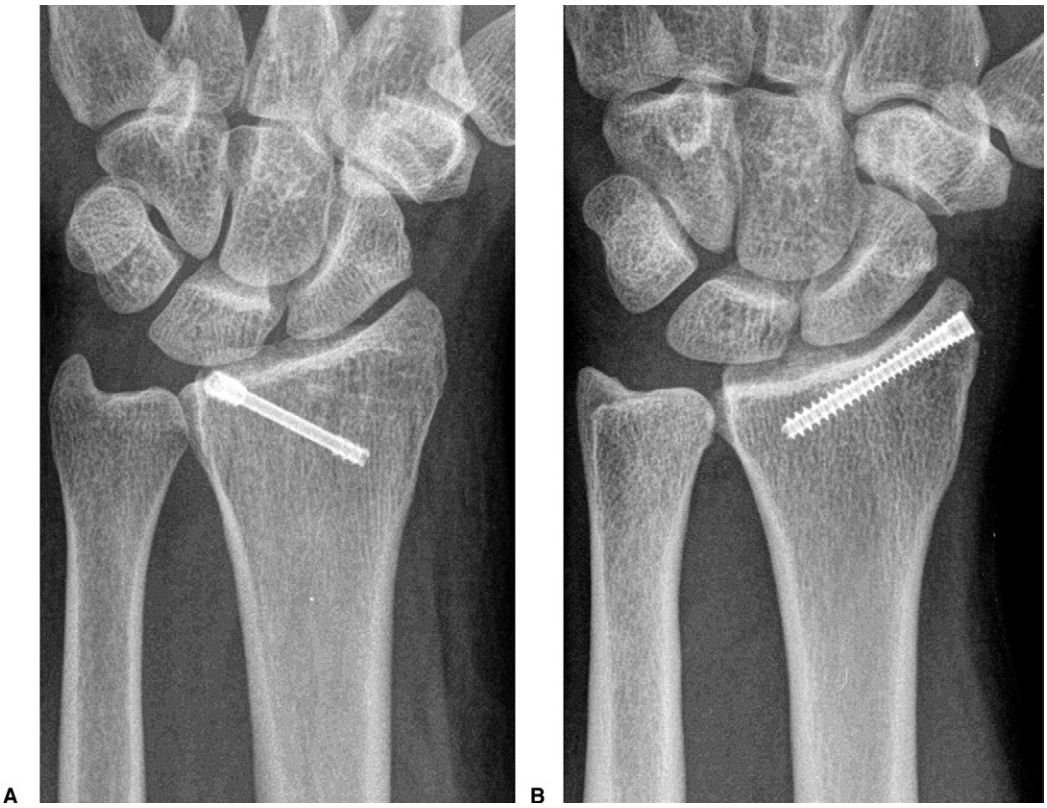

FIGURE 1: A The most common need for interfragmentary compression fixation is isolated fracture of the dorsal lunate facet fragment, which disrupts both the radiocarpal and DRUJ articular surfaces and releases 1 of the RUL anchors. **B** The other common pattern is isolated fracture through the scaphoid fossa in the sagittal plane. Both fixations can be performed by arthroscopic/percutaneous fixation as long as cutaneous nerve branches are properly protected.

vent posttraumatic arthritis, the surgeon must ensure a congruent articular surface by a method that permits early joint motion. Fixation is needed only for the individual fragments that are unstable, allowing less soft tissue disruption in the surgical process. Several device categories apply here. One is the interfragmentary compression screw. Headless differential-pitch compression screws provide excellent fixation for this class of fracture and can generally be applied percutaneously with a small skin opening for the screw to pass (Fig. 1). After the reduction is accomplished, an interfragmentary guide wire is placed. A second wire that prevents the smaller fragment from sliding along the surface of the first wire may also prove useful. The screw is advanced along the guide wire while the surgeon keeps the fragment from losing reduction in the process, always checking to confirm that the final result has not shifted from the provisional reduction. Assessment of the articular reduction can be accomplished by arthroscopy, direct open arthrotomy, or intraoperative fluoroscopy. The first is the most accurate. The last is the least invasive. Arthrotomy is less accurate than arthroscopy and more invasive than fluoroscopy. Another strategy involves custom-designed wire forms that are manufactured to fit specific locations around the radius and render support to the individual fragments. These devices popularized the term "fragment-specific fixation." Fifteen patients treated with this system achieved over 60° motion in all directions and an average Disabilities of the Arm, Shoulder, and Hand (DASH) score of 16.[6] Another series of 85 fractures followed for an average of 32 months found values of 85% wrist flexion, 91% wrist extension, and 92% grip strength compared to the contralateral side, with an average DASH score of 9.[7]

Dorsal plates

Radius fractures with metaphyseal comminution typically collapse in a dorsal direction. Standard orthopedic thinking is to provide structural support at the same cortex as the major collapse. The advantages that can be stated for an open dorsal approach to plating a distal radius fracture are that there are no major nerves in the way, it leads to an open arthrotomy of the joint for evaluation of articular reduction, the extensor pollicis longus tendon can be transposed away from the fracture

site, it provides open access for bone grafting of the metaphysis, and some surgeons may simply be more comfortable working on the fracture from this perspective. For many, those advantages are enough to make this their method of choice for radius fracture fixation. There are, however, a number of real-world problems with dorsal plating compared to its closest competitor, volar fixed-angle plating. Among these are the extensor tendons. The distal radius is formed with concave grooves in its dorsal surface for the first 4 extensor compartments. In order to place a plate in the subchondral position for fracture fixation, at least 3 of these 4 compartments must be disrupted and the plate placed under the tendons. Although there are descriptions of taking a flap of extensor retinaculum and routing it under the tendons and over the plate, problems with extensor tendon irritation and rupture continue to plague this strategy, with no real way to completely overcome that problem despite the descriptions of some products as "low profile." Next is the loss of reduction control over smaller dorsal fragments. The more comminuted the fracture, the more problematic a dorsal approach becomes. Direct dorsal plating requires a subchondral approach. If there are numerous comminuted dorsal fragments, stripping the periosteum in preparation for plating leaves devascularized fragments with no means to control their position because they are too small for direct fixation. This often gives the surgeon the impression that there is an actual metaphyseal "defect" and inspires the act of bone grafting an acute closed fracture. Finally, there is the biomechanics of a dorsal plate. The anatomy of the distal radius is such that the articular surface balances over the volar cortex of the diaphysis. When the foundation for fixation is the dorsal cortex, a greater moment arm is created, and the plate does not bear early motion loading as well as volar fixed-angle plates.[8] Furthermore, the reduced distal radius has a volar tilt of 10°, which can allow distal fragments to strip off the screws and translate volar and proximal in the face of early range of motion.[9]

A retrospective study of 34 patients compared dorsal plates to nonlocking volar plates and found a significantly higher Gartland and Werley score for the volar plates. Dorsal plates were associated with tendon rupture, tenosynovitis, reoperation, and a 25% rate of collapse.[9] In a series of 28 patients treated with 2 different dorsal plates, 9 patients required re-operation for tenosynovitis or rupture of the extensor tendons.[10] With a low-profile design, 30 patients with an average age of 59 years and followed for an average of 18 months achieved values of 88% wrist extension, 81% wrist flexion, and 78% grip strength compared to the contralateral side, with an average DASH score of 15.[11] In another retrospective study of 51 fractures, the designer of a low-profile plate reported no cases of extensor tendon irritation or rupture, a mean DASH score of 11.9, and ranges of motion in all directions greater than 80% of the contralateral side, but the study had mostly low-grade fracture patterns (29 AO type A, 14 type B, and 8 type C).[12]

Volar fixed-angle plates

Although most of the dorsal plates just referenced are not locking, plates applied from the volar side really need to use distal locking for any fracture other than a partial articular volar shearing fracture (volar Barton's fracture, Orthopaedic Trauma Association type B). Whereas a dorsal plate without fixed-angle screws provides a buttressing effect on the side of the major collapse, volar plates depended on the rigid, fixed angle of screws, pegs, or tines relative to the shaft of the plate (screwed to the diaphyseal foundation) to provide subchondral support to the distal articular fragments.[8] Advantages of this strategy range from a socially less visible scar (as opposed to both external fixation and dorsal plating) to rigid enough stability to support immediate functional loading of the hand, wrist, and forearm in both rehabilitation and daily activities (Fig. 2).[2,8,13–15] The approach avoids the superficial radial nerve and lateral antebrachial cutaneous nerve, but it does come close to the palmar cutaneous branch of the median nerve, which must be specifically protected. Full access to even the most ulnar corner of the radius is easily obtained by the volar approach as long as the flexor carpi radialis is retracted radially, as opposed to the classic Henry approach.[15] When properly placed, the plate can be completely covered by repairing the pronator quadratus and eliminating any tendon interference. When improperly placed, the plate causes the flexor pollicis longus to be at risk of irritation and potential rupture across the distal border of the plate or any proud screw heads. One advantage of the volar fixed-angle plating strategy is the use of an intact extensor compartment structural framework to reduce small fragment comminution dorsally (Fig. 2). The corresponding disadvantage is that the extensor pollicis longus is not formally decompressed and is subject to the same delayed attritional rupture as a nonsurgically treated distal radius fracture; the risk of rupture is increased if a screw penetrates its compartment. Other extensor tendons are also subject

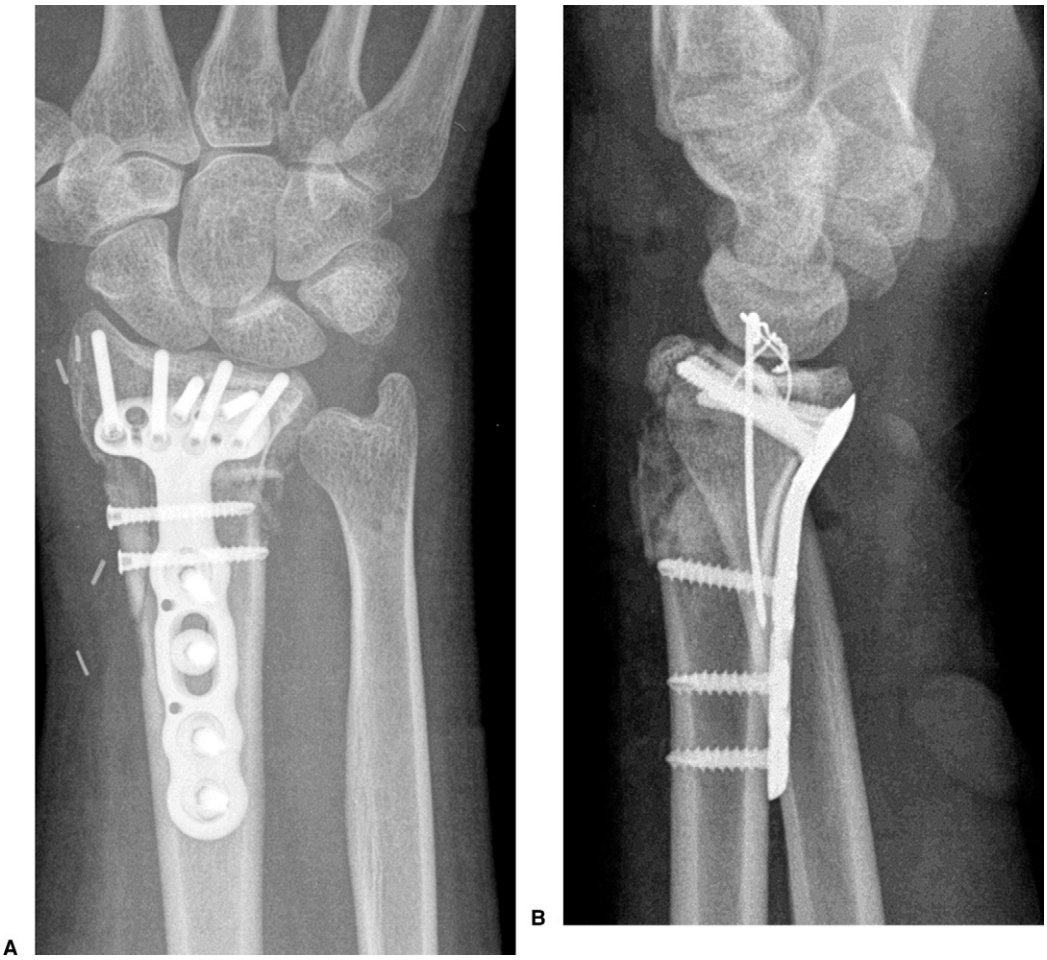

FIGURE 2: A A fixed-angle volar plate must not only provide restoration of length, inclination, and tilt to the fractured articular surface but also translate the distal fragment group back in an ulnar direction to restore DRUJ mechanics. An absolutely critical aspect of plate placement is for the ulnarmost screw to reach out to the far corner of the dorsal lunate facet fragment and lag that anchor of the RUL back into place, simultaneously restoring the articular reduction of the sigmoid notch. **B** When seen laterally, the fixed-angle screws should be placed immediately proximal to the subchondral plate to prevent any further collapse of multiple or individual fragments while lagging in the dorsal fragments. If the procedure is performed correctly, the entire comminuted dorsal cortex of the metaphysis will anatomically reduce indirectly as long as the surgeon has not disturbed the extensor retinacular framework.

to injury by overpenetrated screw tips. Another disadvantage of volar fixed-angle plating is the lack of direct visualization of the articular fragments without an arthroscope. Strategies to overcome this include molding the fragments against the proximal carpal row as a template and relying on fluoroscopy to assess reduction. One of the greatest strengths of the volar fixed-angle plating strategy is the excellent subchondral support provided to the distal fragments, even in the presence of minimal distal bone stock[8] (Fig. 2). This requires that the distal row of screws or pegs be placed immediately subchondral, and it can be difficult to judge whether the screw has penetrated the joint, risking considerable articular destruction with subsequent motion rehabilitation. Although arthroscopy can answer this question, in its absence, the standard PA and lateral views do not fully confirm the true screw position. A 45° pronated oblique, however, will reveal the location of the subchondral screws, confirming lack of joint penetration.[2]

Within this category, there are 2 types of devices. In the first, the subchondral screws or pegs have threaded heads that lock into their corresponding holes in the plate at precisely 1 angle. The angles chosen by the manufacturer are intended to match the normal anatomy of the subchondral contour. In the second, the subchondral screws or pegs have a range of angles that can be set by the surgeon intraoperatively and then

locked into place by various means. The means of locking is primarily what differentiates these devices from each other. One or the other type is not universally better or worse. However, it is absolutely incumbent upon the surgeon to understand how the features of his chosen device interact with the fracture characteristics and affect the sequence of events in the operative plan. The operative plan when using the first type of device depends on first establishing an anatomically correct reduction of the articular surface with provisional fixation by 1.14-mm (0.045 in) K-wires. Next, the subchondral screws or pegs are joined to the articular fragment group. Finally, the plate plus distal fragment group construct is oriented and fixed to the proximal shaft of the radius.[2,15] The more complex the fracture, the more difficult it is to restore volar tilt without the aid of the device using the "lift maneuver." [15] The operative plan when using the second type of device allows the plate to be applied before the fracture is correctly reduced. In theory, individual subchondral pegs or screws can then be strategically placed beneath distal fragments and subsequently manipulated as needed, finishing by locking them into place. In practice, this presents a substantial challenge to even the most seasoned radius fracture expert, and it opens the door for the uninitiated to create an iatrogenic intra-articular malunion. The risk of joint penetration increases because each screw must be individually evaluated. With the first type of device, as long as the articular surface is reduced, the plate is oriented correctly, and the first subchondral screw is correctly placed, then all the other subchondral screws will also automatically be correct.

A prospective study of 87 patients with average age of 49 years and 51% AO type C fractures treated with a volar locking plate were followed to the 12-month postoperative mark. They achieved nearly equal grip and pinch strength, within 85% normal range of motion and near-normal Michigan Hand Outcomes scores.[16] Another group used a different volar locking plate design on 114 patients with average age of 57 years and 52% AO type C fractures followed to a minimum of 12 months. Compared to the contralateral side, values achieved were 82% wrist extension, 72% wrist flexion, and 70% grip strength, with a DASH score of 13.[17] The overall complication rate was 27%, with 2 flexor pollicis longus ruptures, 2 extensor pollicis longus ruptures, extensor tenosynovitis in 4 cases, flexor tenosynovitis in 9 cases, 3 cases of carpal tunnel syndrome, and 5 cases of CRPS. This contrasts a series of 374 patients who had no cases of tenosynovitis, tendon rupture, carpal tunnel syndrome, or CRPS.[1] In older patients, volar plates compared to intrafocal pinning yielded improved early and late range of motion and grip strength.[4]

Intramedullary-based devices

Working from the success of volar fixed-angle plates, another class of device has become available. Fixed-angle subchondral supports lock to an intramedullary stem whose orientation in the canal is set by cross-locking metadiaphyseal screws. Several different devices are available in this category. The advantages that these propose over a volar fixed-angle plate are less surgical dissection to place the device and elimination of tendon irritation over the surface of the device. However, the device still must be inserted into the radius through some degree of surgical approach and is not entirely without morbidity. The key to determining the usefulness of these devices is in the details of where the subchondral support is rendered as it applies to the fracture pattern and the degree of loading that the final construct is capable of bearing in the face of early motion rehabilitation, which appears to be less than that of a volar locking plate.[8]

The role of arthroscopy in radius fractures

Although not every radius fracture needs a wrist arthroscopy, there are a number of strong reasons to consider arthroscopy in many cases. First and foremost, there is no more accurate way to judge an intra-articular reduction than with the arthroscope (Fig. 3). A magnified view of the fracture line demonstrates even the slightest imperfection in the reduction. Arthroscopy is also highly valuable in accomplishing the reduction in the first place, using the shaver, curette, and small pointed probes to manipulate the individual articular fragments. With experience, 1 can recognize that most intra-articular radius fractures fail along natural planes of weakness, yielding the same reproducible fragment patterns time and again (Fig. 4). Many distal radius fractures demonstrate mechanically unstable flaps of torn fibrocartilage tissue from the articular disk (triangular fibrocartilage). There is no way to prove that such flaps of tissue will necessarily be symptomatic if left behind, but they are easily debrided with a radiofrequency probe in a few minutes.[3] This eliminates the question of a second surgery in a patient with ulnar-side wrist pain that might be blamed on a fibrocartilage disk that was never addressed at the time of radius fixation.

The next important role of arthroscopy is in the diagnosis and treatment of intrinsic ligament injuries of the wrist, the SLIL and LTIL (Table 2). These ligaments have a complex function that takes place in

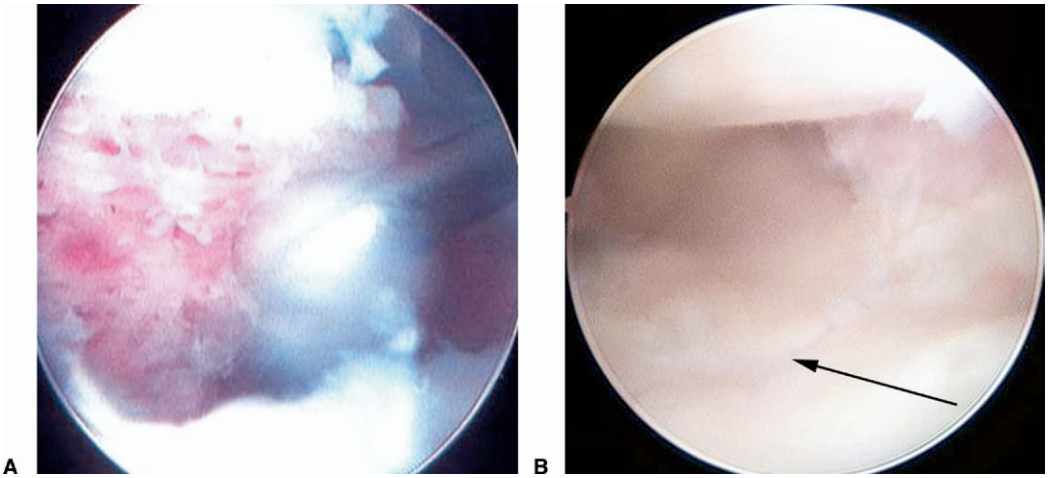

FIGURE 3: A Arthroscopic preparation with curette of intra-articular fracture gap and stepoff. **B** Reduced and pinned fracture interface (arrow) precisely along hyaline cartilage margin.

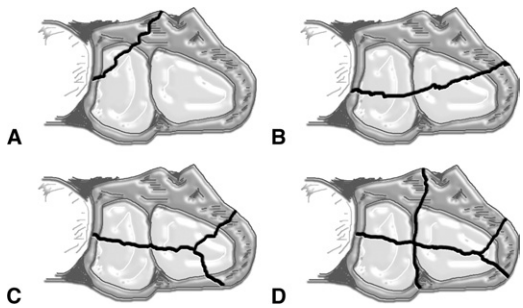

FIGURE 4: The most common intra-articular fracture patterns: **A** small dorsal ulnar fragment confined to lunate fossa; **B** large dorsal ulnar fragment crossing into scaphoid fossa; **C** 3-fragment, Y-shaped coronal split of lunate and part of scaphoid fossa with diamond-shaped radial styloid fragment; **D** 5-fragment pattern with volar and dorsal fragments in both lunate and scaphoid fossae, radial styloid separate.

TABLE 2. The 5 Common Associated Soft Tissue Lesions of a Distal Radius Fracture

Scapholunate interosseous ligament
Lunotriquetral interosseous ligament
Radioulnar ligament
Triangular fibrocartilage disk
Median nerve compression

multiple dimensions controlling diastasis, distraction, translation, and rotation. In order to be clinically useful, a grading system must stress and measure each of these functional parameters[3] (Table 3). The arthroscope allows the surgeon to view the ulnocarpal joint and probe the margins of the triangular fibrocartilage during a stress exam of the RUL, but it is the manual feedback of the stress exam, not what is seen by the arthroscope, that really determines a RUL rupture. When there is a large central disk tear, the foveal insertion of the RUL may be seen and probed through the tear, yielding additional information.

Nonarthroscopic assessment of associated soft tissue injuries

Not every patient will have an arthroscopy, but every radius fracture patient should be assessed for associated ligament injuries. Once the radius fracture has been fixed, the surgeon should manually stress the SLIL with the scaphoid shift test, stress the LTIL with the translational test of surgeon's choice, and examine the RUL in all 3 positions of forearm rotation. There is a normal translational laxity in the DRUJ that varies widely among patients. The radius fracture patient should have the opposite side examined before surgery to establish a frame of reference. Important to the assessment of potential RUL rupture is not just the amplitude of translation but also the quality of the endpoint. When even a naturally lax DRUJ is rotated into full supination or full pronation, the RUL should tighten and translation should be minimal with a firm endpoint. After completing the full RUL examination, an experienced surgeon should be able to reach a conclusion as to whether the RUL is competent. In addition to the manual exam, fluoroscopy can be of some assistance. Carpal mechanics can be observed through the arc of motion during continuous fluoroscopy mode at the expense of a fair degree of radiation. A snapshot taken with longitudinal distraction will demonstrate whether all bones in the proximal row distract evenly or whether the scaphoid

TABLE 3. Comprehensive Midcarpal Stress Test Classification of Intrinsic Ligament Injuries

	Grade I	Grade II	Grade III
Diastasis	Volar diastasis <2.3 mm; no dorsal diastasis	Volar and dorsal diastasis >2.3 mm	Volar and dorsal diastasis >2.3 mm
Distraction	Scaphoid/triquetrum distracts under arthroscopic traction <10% the height of the SLIL/LTIL interface	Scaphoid/triquetrum distracts under arthroscopic traction 10%–25% the height of the SLIL/LTIL interface	Scaphoid/triquetrum distracts under arthroscopic traction >25% the height of the SLIL/LTIL interface
Translation	Scaphoid triquetrum translates with probe <10% the PA dimension of the SLIL/LTIL interface	Scaphoid/triquetrum translates with probe 10%–25% the PA dimension of the SLIL/LTIL interface	Scaphoid/triquetrum translates with probe >25% the PA dimension of the SLIL/LTIL interface
Rotation	Scaphoid/triquetrum rotates with probe <10° relative to lunate distal surface	Scaphoid/triquetrum rotates with probe 10%–25° relative to lunate distal surface	Scaphoid/triquetrum rotates with probe >25° relative to lunate distal surface
Treatment	Partial tear requires splint-protected healing time but not direct pinning	Arthroscopic reduction and pinning of SLIL/LTIL interface; "dart-thrower's" motion at surgeon's discretion	Arthroscopic reduction and pinning of SLIL/LTIL interface; no motion until healed

Type A: radiocarpal view shows smooth synovial membrane encasing torn edge of ligament.
Type B: radiocarpal view shows torn edge of ligament hanging down into joint: limited open direct repair with suture anchor at surgeon's discretion.

shifts distally out of proportion to the lunate (SLIL rupture).

Scapholunate interosseous ligament and lunotriquetral interosseous ligament fixation

When grade II or grade III intrinsic ligament instability has been identified, direct fixation is indicated. Controlling the intercarpal relationships during the 8-week period of ligament healing requires pinning with 1.14-mm (0.045 in) K-wires. The pin configuration must prevent motion within the proximal row, but it should allow midcarpal motion so that the "dart thrower's arc" of motion can still be pursued before the time of pin removal. This requires 2 pins for the SLIL interval, but only 1 is needed at the LTIL. Control is improved by achieving maximum PA separation of the pins (Fig. 5). The surgeon should preset the pins in the scaphoid and/or triquetrum, check them on fluoroscopy, reduce the carpals using direct manipulation of the capitate and scaphoid, and finally advance the pins across the proximal row articulation. Final PA and lateral fluoroscopy images are needed to ensure both correct reduction and pin placement. Cutaneous nerves are at risk—the superficial radial nerve when pinning the SLIL and the dorsal branch of the ulnar nerve when pinning the LTIL. These must be checked to be sure they are not impaled by a pin. Pins should be cut beneath the skin to prevent pin track infection.

Distal radioulnar joint stabilization

An unstable DRUJ due to failure of the RUL can occur in 3 patterns associated with a distal radius fracture.[2,3] When the dorsal lunate facet fragment separates from the rest of the radius, the dorsal limb of the RUL attaches to this fragment, which also constitutes the dorsal margin of the sigmoid notch. Restoration of RUL integrity depends on stabilization of the dorsal ulnar corner of the radius through interfragmentary subchondral fixation. In a simple partial articular fracture, this fragment is stabilized by a headless compression screw (Fig. 1). In a complex fracture pattern, a partially threaded lag screw through the ulnarmost hole in the volar plate will lag in the dorsal ulnar fragment nicely (Fig. 2). The next pattern is a purely soft tissue avulsion of the RUL from its foveal attachment to the ulna. Direct anchor repair of the ligament requires supplementary pinning of the ulna to the radius with two 1.6-mm (0.062-in) K-wires for at least 4 weeks. However, the most common mode of RUL failure is via a fracture through the base of the ulnar styloid such that the foveal attachment of the RUL is to the smaller styloid fragment. Not all ulnar styloid fractures cause an unstable DRUJ, and the determination of instability is made through manual testing as previously described. If unstable, fixation is quite simple with a 1.14-mm (0.045 in) K-wire and 24-gauge wire figure-of-8 tension band (Fig. 6). The fixation provided by such wiring is suffi-

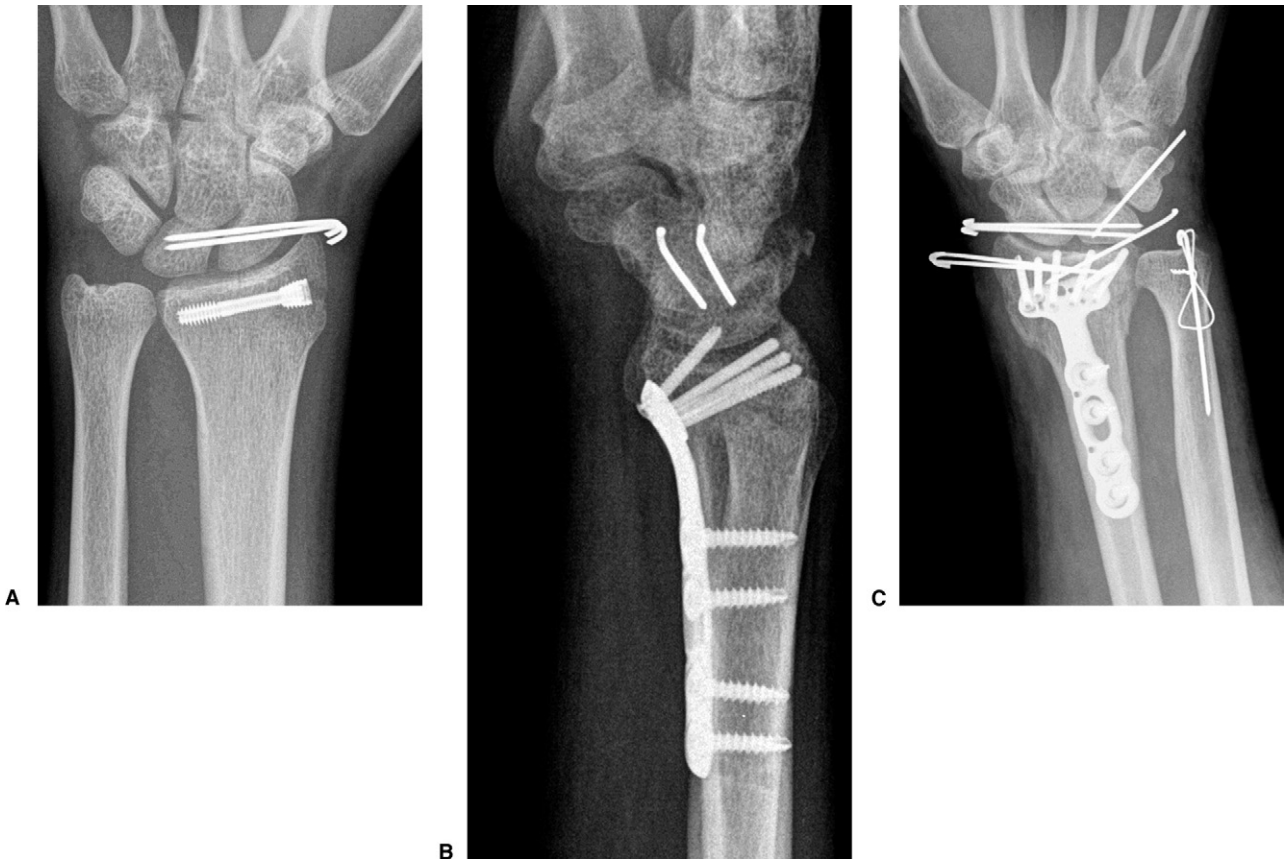

FIGURE 5: A Scapholunate interosseous ligament fixation is performed with two 1.14-mm (0.045 in) K-wires directed from scaphoid to lunate through a 1-cm radial incision used to protect the superficial radial nerve. The reduction of the SLIL interval is performed arthroscopically, which matches well with purely arthroscopic/percutaneous fixation of partial articular fractures. **B** Greater PA separation of the wires ensures better rotational control over the SLIL reduction. **C** Even with complex radius fracture patterns, the methods for intrinsic ligament fixation remain the same.

cient to permit unrestricted early motion. An alternative fixation for a minimally displaced ulnar styloid fracture is a small headless screw. For DRUJ instability created through high-grade comminution of the entire distal ulna, stability is restored by plating.

Bone grafting

Metaphyseal comminution often leads surgeons to bone graft acute distal radius fractures. In a closed acute fracture, there is no actual bone defect unless 1 is created iatrogenically by the surgeon. This occurs most frequently during dorsal approaches when the surgeon disrupts the retinacular framework for the extensor compartments that otherwise preserves and indirectly reduces all the comminuted fragments of the metaphysis. Unless the surgeon makes this mistake, acute distal radius fractures of any severity do not need to be bone grafted. In a series of 374 acute distal radius fractures, only a single case with extreme physiological compromise went on to nonunion, multiple surgeries, and ultimately a free flap.[1] At the other end of the time spectrum, corrective osteotomy of an established malunion requires bone graft to fill the gap that is created surgically.[13] When distal radius fractures present between 3 and 6 weeks after the date of injury, an intermediate scenario exists. In this instance, the need for bone grafting is at the surgeon's discretion; the longer since injury, the greater the need for bone graft. Autogenous cancellous bone graft is not the only choice for the distal radius metaphysis, and various tricalcium phosphate preparations and rapidly hardening bone cements have been described for use in distal radius fractures.

Median nerve decompression

Some radius fracture patients complain of subjective median nerve territory paresthesias and demonstrate objective loss of sensibility when tested with monofilaments before surgery. This is more common in high-energy injuries. These clinical findings can be due to

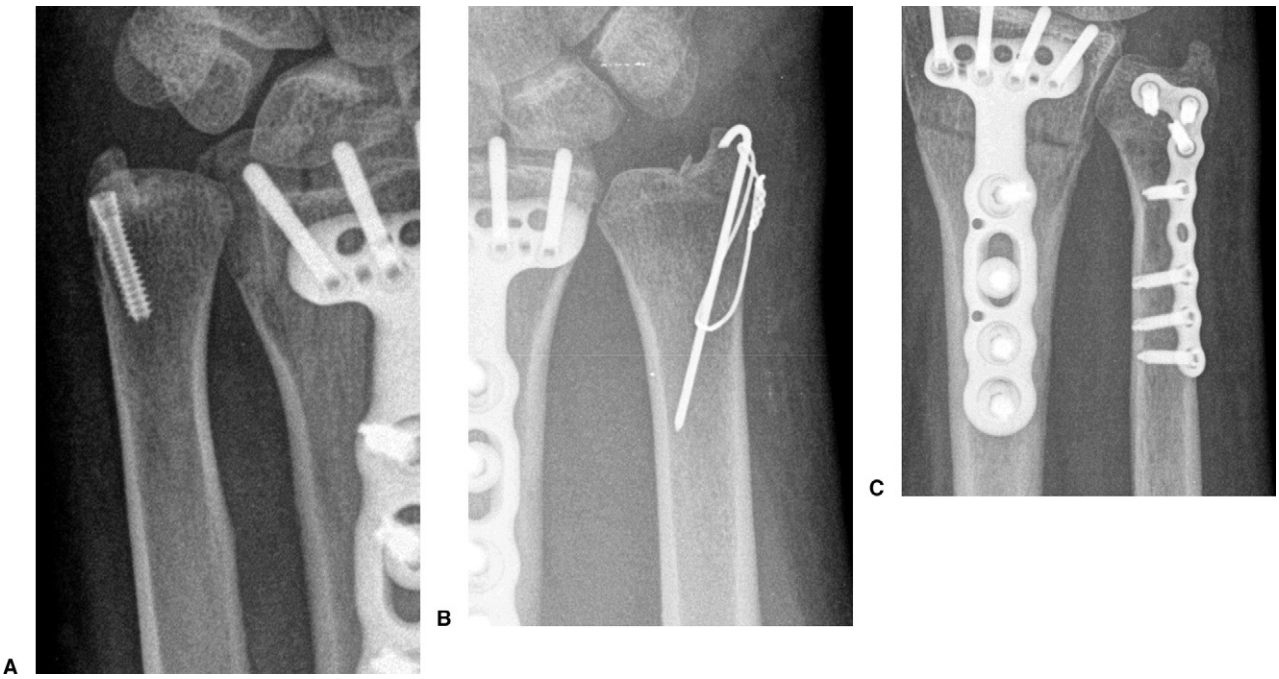

FIGURE 6: A The least invasive method of DRUJ stabilization via ulnar styloid fixation is a percutaneous headless compression screw. **B** The most common method is a tension band wire with a single 1.14-mm (0.045 in) K-wire and 23-gauge wire. **C** For extreme cases of high comminution involving the entire ulnar head and neck, plate fixation may be necessary.

1-time concussive insult to the median nerve, acute nerve compression due to trauma-induced swelling, or a combination of the 2. Unfortunately, there is no way to definitively separate the 3 possibilities. Failure to address an acutely compressed median nerve risks permanent functional loss and CRPS (20% incidence associated with radius fractures).[1] A prospective study of median nerve decompression used only for those radius fracture patients with both subjective and objective loss of sensibility before surgery was able to prevent both postoperative sensibility deficits and CRPS.[1] The surgical approach for median nerve decompression depends on the method of fixation chosen for the fracture. Traditional open carpal tunnel release should be familiar to all surgeons, but it leaves a scar in the palm that will be tender during motion rehabilitation of the wrist, particularly when pushing to gain greater extension.[14] The flexor carpi radialis sheath method for release of the transverse carpal ligament from its far radial attachment is easy to perform, and it is a natural part of the existing surgical approach when volar plating has been selected for the fracture. Finally, endoscopic carpal tunnel release remains an excellent option that is familiar to most hand surgeons. Originally considered dangerous in the setting of acute trauma, it is actually easier to see the undersurface of the transverse carpal ligament in a trauma case than in an elective case that has excessive tenosynovium. Obviously, gross deformity of alignment should be corrected before performing the carpal tunnel release.

Rehabilitation

The details of rehabilitation are highly dependent on individual case variables. Common themes include a clamshell orthoplast removable custom splint, immediate motion of the hand, and desensitization of cutaneous nerves. Immediate motion of the forearm will be appropriate in most cases except those with a soft tissue repair of the RUL. Tension band repairs of the styloid can begin forearm rotation right away. Patients naturally assume a resting posture favoring pronation, and loss of supination is 1 of the chief concerns to be specifically addressed early in rehabilitation. The rehabilitation question that will have the most variation is when to move the wrist. The surgeon must decide what degree of stability has been achieved through the interaction of the fixation method with the inherent characteristics of the fracture. At 1 end of the spectrum, percutaneous pins are not appropriate for immediate motion, whereas nearly all volar fixed-angle plates should pursue unrestricted active motion.[2,8,13–15] Carpal intrinsic ligament ruptures are the primary damper to early wrist motion. Incorporating "dart thrower's arc" motions of the wrist before removing pins from the proximal row is possible and left to individual surgeon discretion. Early callus begins forming by 4 weeks, and

this usually signals an advancement of some type in the therapy program. In fractures without much hardware-derived stability, this means advancing to active motion of the wrist. In those with substantial hardware support, it means cessation of splint wear except in crowd situations and normal lightweight use of the bare hand and wrist such as for office-based activities. After the fracture is deemed clinically healed, passive loading to increase the extremes of motion begins, along with progressive strengthening. Pins for carpal intrinsic ligaments are removed at 8 weeks, with full advancement of rehabilitation to follow. Although patients are typically allowed to do anything they want, including contact sports, by 3 months after surgery, further changes in strength and functional performance will be seen up to a year or longer.

RECENT PROSPECTIVE RANDOMIZED TRIALS

A multicenter trial randomized 144 intra-articular distal radius fractures to either external fixation and percutaneous pins or plate fixation. The method of plate fixation, however, was not controlled by the study and included both dorsal and volar (nonlocking) plates. Results were superior at 24-month follow-up for the plate group, according to the Gartland and Werley scoring system and arthritis grading scale, and were most pronounced in those patients with an AO type C2 fracture.[18]

Six surgeons at a level 1 trauma center randomized 62 patients with AO type C distal radius fractures to either mini-open reduction with percutaneous pins and external fixation or dorsal plating.[19] The authors terminated the study on the basis of a higher complication rate (17 patients vs 8 patients) with the dorsal plating system being used. There were 5 cases of reflex sympathetic dystrophy at the time enrollment was halted (2 in the external fixator group and 3 in the plating group).

A total of 179 patients with intra-articular fractures of the distal radius were randomized to either percutaneous pins with external fixation or to open reduction and internal fixation.[20] The study did not strictly control the methods of open reduction and internal fixation. With 2-year follow-up, there was no statistically significant difference in the radiological restoration of anatomical features or the range of motion between the groups.

One study indicates superiority of plates over external fixation, another stopped the study due to the higher complications seen with a specific model of dorsal plate, and a third could show no difference in the 2 most objective outcome variables. One of the 2 treatments being compared in each of these recently published studies was external fixation, a treatment that is used less and less by hand surgeons these days. None of the studies used the most modern methods of fixation discussed previously in this article. There are not currently any prospective randomized studies regarding the techniques being used most commonly on a daily basis by specialists. For the time being, individual patient treatment strategies should be based on each surgeon's own interpretation of the entire body of literature to date in the context of clinical experience.

The patients who sustain distal radius fractures are as diverse a group as are the patterns of fracture seen on x-rays. Keeping up with this diversity are the available devices in the orthopedic marketplace for radius fracture fixation. There are no absolutely right or wrong ways to approach stabilization of a radius fracture, and surgeons should always work within their own comfort zones. Misapplication of the latest, greatest device will produce a worse result than skillful execution of the procedure with an older-generation device that the surgeon has used many times. Nevertheless, the hope is that our newer devices offer some advantages over those of the past. It is up to the surgeon to learn the biomechanical properties of the device as well as the morbidity of the surgical approach and technique required to apply the device. These factors must be considered anew for each fracture that presents. Ideally, each surgeon will maintain an armamentarium of several strategies that can be applied judiciously as needed. As orthopedics and hand surgery move forward, it is hoped that more level I and level II studies will be performed that can help to shed some light on where we are headed next.

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