Fracture of the distal radius is one of the most common injuries in orthopaedics, accounting for up to 15% of all extremity fractures.1 Given its prevalence, it is important to understand the potential treatment options and the associated complications. From the time of Hippocrates to the early 18th Century, distal radius fractures were mistaken for dislocations of the wrist. The earliest accurate description of distal radius fractures was made by Pouteau, as reported by Peltier.2 Pouteau described this injury as a fracture of the distal end of the radius, with posterior tipping. However, his observation was not accepted, so his work received little attention outside of France. Abraham Colles, who is credited for his work in this field, was a professor at the Royal College in Ireland, and, being unaware of Pouteau’s work, published classic articles describing the injury and the reduction maneuver.3 The physician who performed the postmortem exam on Abraham Colles attached Colles’ name to this fracture, and thus it is known today as Colles fracture. In his description, he stated that if the fracture is not reduced, it will result in a “doomed” patient, adding “the limb will at some remote period again enjoy perfect freedom in all its motions, and be completely exempt from pain; the deformity, however, will remain undiminished throughout life.”3

Complications of distal radius fracture fixation may arise from the injury or method of treatment, as well as both. The overall complication rate of distal radius fractures ranges from 6% to 80% and has been associated with poor functional outcomes.2 There is variability and lack of a standardized system in reporting distal radius complications. Often focus is placed on physician-reported complications, whereas patient-reported outcomes would allow a better understanding of how minor complications that may not be clinically apparent to the physician have a significant and detrimental impact on the patient’s function. McKay and colleagues4 assessed a consecutive cohort of 250 patients with distal radius fracture and developed a complication checklist of incidence and type of complications (Table 1). Interestingly, they found discordance between the physician-reported complication rate (27%) and patient-reported complication rate (21%), with physicians describing complications as diagnoses and patients reporting them as symptoms. The current article reviews the potential complications of distal radius fracture fixation and their treatment. These complications include compartment syndrome, complex and regional pain syndrome, Dupuytren’s disease, nerve injury, tendon and ligament injuries, nonunion, and malunion.

Compartment Syndrome

Compartment syndrome associated with distal radius fractures is rare, with an incidence of 1%,4 and can occur up to 54 hours after the initial injury.5 It occurs more frequently in younger patients who are more likely to sustain higher energy injuries. McQueen and coworkers6 reviewed 6395 cases of distal radius fracture to determine the risk of developing compartment syndrome. They found an overall incidence of 0.25%, with a mean age of 26 years. They also reported that the incidence in patients younger than 35 was 1.4% and in those over 35 years of age it was 0.04%.5

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Complex Regional Pain Syndrome (CRPS)

Complex regional pain syndrome (also called causalgia and reflex sympathetic dystrophy (RSD) syndrome) has been associated with poor outcomes. It may present early in the treatment course as unexplained pain, changes in skin color and temperature, persistent swelling, and decreased active range of motion (ROM). Reported incidence following distal radius fracture is 8% to 35%. It is more common in the elderly and in patients with psychological or psychiatric conditions. Over-distractions with an external fixator or a tight cast may be associated with development of CRPS. Warwick and associates assessed patients with distal radius fracture 10 years post-injury and found that, in patients who felt they had an unsatisfactory outcome, the prevalence of CRPS was 62% versus 6% in those satisfied with their outcome.

In a double-blind prospective multicenter trial, 427 wrist fractures were allocated to receive placebo or varying doses of vitamin C for 50 days after injury and the effect of age, gender, fracture type, and cast-related complaints on occurrence of CRPS was analyzed. They found a prevalence of 2.4% in the vitamin C group and 10.1% in the placebo group. Early cast-related complaints were strongly predictive of the development of CRPS (p = 0.001). Based on their data, investigators recommended 500 mg of daily vitamin C for 50 days following a wrist fracture. Early recognition of CRPS and a multidisciplinary approach, including psychiatric intervention (alleviate heightened pain response), occupational therapy (restore function and motion), and pain management is paramount in obtaining a good functional outcome in these patients.

**Dupuytren’s Disease**

The development of Dupuytren’s disease following a distal radius fracture was first noted by Goyrand, in 1935, and since then has been reported sporadically in the literature. The causal relationship between the two has not been elucidated, and its reported incidence in literature is highly variable, ranging from 0.2% to 11%. It usually occurs within 6 months following a distal radius fracture. The most common findings are nodules and skin pits, with the disease being mild in nature with minimal contractions. In most patients, the disease tends to occur in the palm along the fourth ray, and its progression ceases after its appearance. Treatment is based on the severity of contractures, which are usually mild.

**Nerve Injury**

Nerve injuries are commonly reported after operative and nonoperative management of distal radius fractures. These could be the result of the fracture severity or its treatment. Incidence has been reported in the literature from 0% to 17%, with the median nerve being the most common followed by the radial and the ulnar nerves.

The median nerve is most commonly affected because of its close proximity to the fracture and its confinement within the carpal canal. As reported in Kozin and Wood, anatomical studies have shown that the median nerve lies within 2 to 3 mm from distal fracture fragments. Symptoms can occur from direct compression, edema of the tenosynovium, swollen pronator quadratus muscle, hematoma in the carpal canal or, rarely, from bony fractured edges. Multiple reduction attempts in the emergency room can also place the nerve at risk. Median nerve injury can present acutely at the time of initial fracture presentation, in the immediate postoperative period, or even late, as in a case of a malunion of a fracture, resulting in median nerve compression. In an acute setting, splinting or casting the wrist in severe flexion should be avoided. Splinting in more than 15° of flexion has been shown to increase the risk of carpal

<table>
<thead>
<tr>
<th>Table 1 Distal Radius Fracture Complications and Incidence*</th>
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<tr>
<td>Loss of motion (0-31%)</td>
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<tr>
<td>Delayed/nonunion (0.7-4%)</td>
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<tr>
<td>Nerve related (0-17%)</td>
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<td>Pain syndromes (0-8%)</td>
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<td>Hardware related (1.4-26%)</td>
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<td>Radioulnar (0-1.3%)</td>
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<td>Arthrodesis (7-65%)</td>
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<td>Nonunion (0.7-4%)</td>
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<td>Ostemyelitis (4-9%)</td>
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<td>Malunion (5%)</td>
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<td>Tendon (0-5%)</td>
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<td>Keloid (3%)</td>
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<td>Ligament injury (98%)</td>
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<td>Dupuytren’s (2-9%)</td>
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<td>Unrecognized (2%)</td>
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tunnel syndrome, digital stiffness, and CRPS. Gelberman and colleagues measured carpal canal pressures in asymptomatic adults with varying degrees of wrist flexion. They found that mean carpal canal pressure was 18 mm Hg with the wrist in neutral, 27 mm Hg with the wrist in 20° of flexion, and 47° with the wrist in 40° of flexion.

Mild carpal tunnel symptoms occur in approximately 22% of patients and most resolve with observation. In such patients, hand elevation and finger motion should be emphasized, and a non-circumferential bandage should be placed. Acute carpal tunnel syndrome requiring urgent carpal tunnel release ranges from 5.5% to 9% and is more likely to occur following severely comminuted fractures, representing a high energy injury. Acute carpal tunnel release should be considered in patients presenting with severe or progressive median nerve symptoms and in patients in whom considerable postoperative swelling is anticipated. Studies looking at immediate versus delayed decompression of the median nerve have shown that early decompression has a better outcome, and delaying treatment can result in an incomplete recovery or a prolonged time for functional recovery. Odumala and coworkers assessed the role of prophylactic carpal tunnel release (CTR) in distal radius fractures without median nerve symptoms versus patients undergoing volar plating and found no difference in postoperative median nerve symptoms between the treatment groups. Their data suggested that the CTR group was twice as likely to develop morbidity related to the median nerve. In another study, slit catheters were placed for continuous monitoring of carpal canal pressures after volar plating; the investigators found all pressures remained below 40 mm Hg and concluded that prophylactic carpal tunnel release is not recommended.

Late median neuropathy is defined as developing after the fracture has healed, and its occurrence has been reported in literature from 0.5% to 22%. It is associated with fracture malunion, residual palmar displacement, callus formation that impinges on the nerve itself, or prolonged immobilization in the Coton-Loder position (flexion and pronation deviation). Treatment is directed towards correcting the cause and may include a realignment osteotomy, or decompression.

Injury to the superficial radial nerve has been reported in literature in up to 11% of cases. Its anatomic location puts it at risk, because it lies tethered underneath the deep fascia between the brachioradialis and extensor carpi radialis longus. Injury to the superficial radial nerve can occur during K-wire insertion, external fixator pin placement, or a poorly placed cast. Several investigators have recommended mini-open K-wire insertion and use a tissue protector to avoid this complication.

Injury to the ulnar nerve is rare. Its reported incidence is approximately 1% to 6%. Acute compression occurs in Guyon’s canal and may result in sensory, motor, or a combination of deficits based on the site of compression. It results from a markedly comminuted and dorsally angulated fracture. Late ulnar neuropathy in Guyon’s canal is similar to median nerve neuropathy and is usually due to malunion.

Tendon Complications

Tendon-related complications in distal radius fractures can occur early or late and range from early tendonitis caused by irritation to frank rupture that is due to impingement. Dorsal plating of the distal radius fell out of favor due to extensor tendon complications. Several techniques used to minimize extensor tendon irritation include subperiosteal dissection of the second and fourth extensor compartments and creation of a retinacular interposition flap, with varying degrees of success being reported.

One of the purported advantages of locked volar plating is the elimination of extensor tendon problems. However, as volar plating has gained popularity, the complications of nearly every tendon that crosses the wrist joint has been reported. Extensor tendon rupture following volar locked plates has been reported in this context in the literature. It can occur from entrapment in the fracture fragment, during drilling of the distal locking screws, and as a result of contact with prominent screw tips that pierce the dorsal cortex.

Benson and associates performed a cadaveric and a clinical study to assess problematic screw holes in three commercially available volar-locked plates (4-hole std, 5-hole wide: Hand Innovations, Miami, Florida, and Accumé, Hillsboro, Oregon). In the cadaveric study, the three different volar plates were placed and then the third dorsal compartment was dissected to determine screw penetration. In their clinical study, mini-dorsal incisions were made in 10 nonconsecutive patients after volar plating, which were used to identify potential holes that correlate with the third dorsal compartment. The investigators suggested the following as the problematic drill holes: the ulnar second hole in the proximal row of the standard Hand Innovations’ 4-hole plate, the center screw in the Hand Innovations’ wide plate, and the center two proximal screws in the Accumé plate. They recommended leaving the identified screw holes empty, placing shorter screws, or unicortical drilling. Additionally, using small dorsal incisions in patients with dorsal comminution would allow direct visualization of the extensor pollicis longus, elimination of any sharp fracture fragments that are cutting into the tendons, and the filling of fracture gaps.

Flexor tendon ruptures have been reported in up to 12% of cases. They can result from fracture displacement, malunion, or bony prominences. Unlike extensor tendons, flexor tendons are not intimately attached to the bone. There is a natural concavity to the volar surface of the distal radius with a volar lip and pronator fossa, which bowstrings the flexor tendons away. Therefore, a volar plate is housed under the pronator quadratus muscle. With volar plating, flexor pollicis longus (FPL) ruptures have been shown to occur with plates that are placed too distal or off the bone, resulting in the distal edge of the plate abrading the traversing
tendon. Also, a cross-threaded locked screw may be seated improperly and has the potential to abrade the tendon with its sharp edge. Orbay and colleagues discussed the importance of the transverse ridge or the “watershed” area of the radius at the distal margin of the pronator. Plates positioned distal to the transverse ridge have the potential to impinge on the traversing flexor tendons. Therefore, plate placement and screw lengths must be carefully scrutinized with intraoperative fluoroscopy. Several investigators have recommended plate removal after union if the plate was placed too distally.

**Intercarpal Ligament Injury**

Ligament injuries of the wrist associated with distal radius fractures are often unrecognized. The prevalence and natural history is unknown, largely due to the lack of a reliable diagnostic modality. The diagnosis of intercarpal ligamentous injury in the absence of a gross deformity is difficult with plain radiographs, ultrasound, arthrograms, and even magnetic resonance imaging (MRI). Some investigators propose that the most accurate method of diagnosis is arthroscopic visualization. Understanding the fracture pattern and energy imparted can be used to assess the potential for injury to the ligament. The reported prevalence of ligament injuries about the carpus is up to 98% in distal radius fractures. An injury to the triangular fibrocartilage complex (TFCC) and the scapholunate ligament has been reported in various studies to be as high as 78% and 54%, respectively. Richards and coworkers performed arthroscopy on 118 distal radius fractures that had associated ligament injuries and compared the ligament lesions found intra-articularly to extra-articular distal radius fractures. They discovered that TFCC tears were more common in extra-articular fractures, whereas scapholunate ligament injuries were seen more often in intra-articular fractures. Unrecognized ligamentous injury has been associated with a poor functional outcome and may lead to long-term carpal instability or deformity.

Tang and associates reported on 20 of 424 consecutive patients with fractures of the distal radius who presented with evidence of scapholunate dissociation on radiographs and traction-view fluoroscopy. Scapholunate gaps were recorded at the time of injury and sequential follow-up visits. All patients were treated in a cast. At 3.5 year-follow-up, 18 out of 20 had fair to poor results, and 8 of 20 had persistent symptoms requiring further surgery. Surgery included arthroscopic confirmation of scapholunate intersosseus ligament disruption (and stabilization of the carpus). The investigators suggested early operative treatment of unstable concomitant ligamentous injury that was identifiable on plain radiographs. Radiographic clues that may help predict intercarpal ligament injury have also been studied. An increase in ulnar variance of more than 2 mm, compared to the opposite side, is associated with a four-fold increase in the risk of scapholunate ligament injury. The investigators of this study argue that previous studies that have not shown a correlation between ulnar variance and scapholunate ligament injury have used an absolute value rather than a relative value. Other radiographic clues of potential intercarpal ligamentous injury are fracture lines that exist between the lunate and scaphoid fossa and an oblique fracture line through the radial styloid or an avulsion of the volar aspect of triquetrum.

Intercarpal ligamentous injuries should always be considered in distal radius fractures with specific fracture patterns and high energy injuries. We suggest that after plate fixation of the distal radius fracture, intraoperative fluoroscopy and stress radiographs can help identify any significant carpal instability. Ligament integrity should also be evaluated in patients with persistent pain after a healed distal radius fracture. Early recognition and treatment can avoid a prolonged recovery and a poor functional outcome.

**Nonunion**

Nonunion following a distal radius fracture is rare (under 1%) but has become more common in the recent years. Nonunion has been associated with both nonoperative and operative management of distal radius fractures; however, nonunion is seen more commonly as a complication of operative fixation. Its low incidence is attributed to the excellent healing potential of cancellous metaphyseal bone, impaction of the fracture fragments, and less soft tissue disruption in a low-energy fall. Factors predisposing to distal radius nonunion are open comminuted fractures, infections, pathologic lesions, soft tissue interposition, inadequate fixation, excessive distraction with an external fixator, and a concomitant fracture of the distal ulna. Although nonunion is a rare entity in these fractures, it is becoming more common, as surgeons become more comfortable with operative fixation techniques, and attempts to restore length may leave bony gaps with potential for nonunion. Regardless of the cause, a distal radius nonunion can result in a painful, unstable, and stiff wrist for which operative treatment is imperative.

Patients with nonunion fracture of the distal radius present with pain, weakness, and symptoms of instability. Radiographs may show a persistent fracture line, scalloping, or bone loss of the distal segment, as well as loosened or broken hardware. Diagnosis can be confirmed with radiographs of the wrist in flexion and extension, confirming motion at the fracture site. Because of the rarity of this complication, there is no general consensus on the treatment algorithm. Preserving wrist motion is favorable, as even small improvements in wrist motion can improve upper limb function. Nonoperative treatment may be acceptable in a medically comorbid patient with limited demands. Operative treatment options are governed by the size of the distal fragment and the ability to reliably obtain stable fixation in the small, metaphyseal distal fragment. Some investigators have suggested that less than 6 mm of bone between the lunate and scaphoid facet of the distal radius and fracture site is inadequate to support stable
internal fixation. Surgical options for treatment include ORIF with an autogenous graft and wrist arthrodesis. Internal fixation with two-orthogonal plates is useful in obtaining a greater number of fixation points in the tenuous distal fragment. Also, fixed-angle screws rather than standard screws can be an advantage in cases with disuse osteopenia. Wrist arthrodesis is optimal in patients in whom pain relief is the goal, those with limited functional demands, and in patients with previously failed attempts at union. Unlar-sided wrist procedures may be necessary in some cases.

Malunion

Malunion is defined as malalignment resulting in dysfunction. Distal radius malunion is the most common complication following a distal radius fracture. The incidence of distal radius malunion has been reported to be up to 17% and is more common in those treated nonoperatively than those treated surgically. A malunited distal radius in a low-demand elderly patient may be of minimal functional consequence. Therefore, impairment of function rather than radiographic malunion determines if an intervention is necessary. Malunion should be categorized as either extra-articular or intra-articular, because treatment may differ. The most common deformity following an extra-articular distal radius fracture is shortening, rotation of the distal fragment, loss of volar tilt, and loss of ulnar inclination. A malunited distal radius affects wrist and forearm function.

Biomechanical and clinical studies have evaluated distal radius deformity and wrist mechanics. Radial shortening changes the radiolunate contact area and shifts the load on the lunate facet. It also has been shown that 10 mm of shortening reduced forearm pronation by 47% and supination by 29%. A shortened radius increases the strain on the TFCC, which may result in distal radioulnar joint (DRUJ) instability. Lastly, a shortened radius effectively lengthens the ulna and increases the load borne by the ulna, resulting in ulnocarpal impaction. A decrease in radial inclination shifts the load from the scaphoid to lunate fossa. A dorsally angulated fracture effectively shifts the load on the dorsal aspect of the wrist joint at all radiocarpal articulations. It causes incongruity at the DRUJ, resulting in loss of forearm rotation. Lastly, dorsal angulation may cause compensatory carpal instability. Two patterns of carpal instability have been described. In type I carpal instability, dorsal radiocarpal subluxation occurs and the carpus maintains its alignment. It is likely to occur in young individuals with ligamentous laxity and results in a good range of motion despite the deformity. This type of malalignment would improve or even correct with a distal radius realignment osteotomy. Type II carpal instability is a midcarpal dorsal intercalated segment instability, which is a “fixed” deformity. It does not improve with a distal radius osteotomy and may require other surgical procedures.

A thorough preoperative history, especially of previous surgeries, locations, and severity of pain, as well as an assessment of functional loss and a detailed physical examination will help in assessing the impact of the malunion. Preoperative planning with adequate radiographs and computed tomography (CT) scans is essential to understand the deformity in all planes. The goal of the surgery is to restore normal load distribution across the wrist, establish normal carpal kinematics, and realign the DRUJ. If there is significant posttraumatic arthritis or persistent instability at the DRUJ after a corrective osteotomy of the radius, a distal ulna resection may be necessary. In some cases, the DRUJ may be stabilized with soft tissue techniques or implant arthroplasty. There are no fixed radiographic parameters for which a distal radius osteotomy is indicated. Fournier and colleagues have suggested symptoms are likely to develop with radial deviation between 20° to 30°, dorsal tilt between 10° to 20°, and a shortening of 1 to 2 mm. Contraindications to a distal radius osteotomy are advanced degenerative changes, fixed carpal malalignment, limited functional disability, and extensive osteoporosis.

The timing of osteotomy is also debated. Early intervention allows correction of the deformity through immature callus before soft tissue contracture develops, minimizes potential DRUJ dysfunction or arthritis, and lessens the period of disability for the patient. Advocates of late intervention argue that functional disability should be declared before undergoing a potentially unnecessary surgical procedure. The concept of intentional delay is often prudent, in which a comminuted fracture is allowed to heal in order to create bone stock, with plans for future osteotomy. Jupiter and coworkers compared early versus late timing for osteotomy and found no clinical difference. However, they felt that early intervention is technically easier and decreases the duration of disability.

Surgical techniques for distal radius malunion depend on the type of deformity, DRUJ dysfunction, and surgeon preference. There are numerous osteotomies mentioned in the literature, and all share similar concepts. A closing wedge osteotomy allows a stable construct with bone-on-bone contact, obviating the need for bone graft and offering minimal potential for nonunion. However, this technique shortens the distal radius and, therefore, a distal ulna procedure is often required to maintain the DRUJ. An opening wedge osteotomy is more popular, because it restores radial length and creates a “free” distal fragment. The fragment could be placed anywhere in space to correct the deformity. However, doing so creates a more unstable situation, with a higher risk of nonunion and requires a bone graft. After the distal radius osteotomy, an intraoperative assessment of the DRUJ should be made and assessed for stability, arthrodesis, incongruity, and ligament competence in order to choose the appropriate ulnar-sided procedure.

Summary

Distal radius fractures are injuries commonly treated by orthopaedic surgeons; therefore, a thorough understanding
of the potential complications is important. Early recognition allows for early intervention when complications arise and ultimately provides the patient with the best chance for an optimal outcome. Although patients can do well with proper management, prevention of complications is paramount.

Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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