



Complications in the Management of Distal Radius Fractures: How Do We Avoid them?

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Published online: 2 March 2019

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Abstract

Purpose of this review Distal radius fractures are one of the most common fractures in the upper extremity. The purpose of this review is to outline common complications that may arise when caring for distal radius fractures and to describe the treatment strategies when faced with such complications.

Recent findings Tendon complications are not uncommon after distal radius fractures. Recent literature highlights new plating technology for dorsal plating techniques. Moreover, new literature has outlined parameters for flexor tendon complications when using volar locking plates in an effort to avoid flexor tendon irritation and rupture.

Summary In summary, it is important to understand the various complications that can arise when treating distal radius fractures in an effort to avoid suboptimal outcomes.

Keywords Distal radius · Fracture · Complication · Tendon irritation · Malunion · Volar locking plate

Introduction

When caring for common injuries in the upper extremity, the orthopedic surgeon must not only be aware of the most up-to-date treatment strategies but also understand the various complications that can occur during the treatment course. Many distal radius fractures can be treated without surgery. Even when monitoring patients in the non-operative setting, many complications can arise including tendon irritation, or rupture, malunion, nonunion, and deformity. Close attention to detail, frequent follow up, and conversion to operative treatment when necessary are important when treating distal radius fractures with conservative measures.

Operative treatment for distal radius fractures is a good option for displaced and unstable fractures. Although most patients do well with current fixation techniques, numerous complications that may ensue. Tendon irritation and rupture

can be seen with dorsal and volar plating. Infection, nonunion, pain syndromes, posttraumatic arthritis, and nerve injury may also occur. It is important to be aware of these various complications and have a treatment plan to mitigate the problem.

Tendon-related complications

Tendon irritation and rupture are known complications after operative and non-operative treatment of distal radius fractures (DRFs). The extensor tendons, specifically the extensor pollicis longus (EPL), is in close proximity to the bony architecture of the dorsal distal radius and therefore is at risk for injury. At the wrist, flexor tendons can also be at risk after surgical fixation.

Non-displaced fractures

EPL tendon ruptures are not infrequent after minimally or non-displaced DRFs treated with immobilization [1]. The mechanism for this injury is unknown but likely related to the direct apposition of the tendon over the distal radius as it passes through the third dorsal wrist compartment. Patients should be made aware of this potential complication in the outset. The treatment is either intercalary tendon grafting or

This article is part of the Topical Collection on *Distal Radius and Wrist Fractures*

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an extensor indicis proprius (EIP) tendon transfer. Both options have been shown to be successful treatment alternatives [2].

Kirschner wire fixation

The risk of extensor tendon injury during the placement of percutaneous pins is relatively low. A recent meta-analysis of 875 patients from seven randomized studies found a 0.7% incidence of tendon rupture from Kirschner wire (K-wire) fixation [3]. Another study documented only one extensor tendon rupture out of 64 cases [4]. While these tendon rupture rates are low, there are some recommendations to further avoid this pitfall. As pointed out by Chia and colleagues, injury to the first dorsal extensor compartment can be avoided by either entering the radial styloid through a small open incision [5]. These authors also recommended avoiding K-wire placement 5 mm ulnar to Lister tubercle to prevent injury to the tendons within the fourth extensor compartment.

Dorsal plating

Historically, open reduction using dorsal plates have been fraught with hardware complications affecting primarily the extensor tendons with reported incidences up to 48% [6]. A careful analysis of the literature reveals that the seemingly high rate of complications is likely due to the types of plating systems used rather than the dorsal approach itself [7]. Low-profile, contemporary dorsal plate designs are better contoured to the bone, hence reducing the incidence of extensor tendon-associated complications. In series of 73 patients, Carter and colleagues noted no extensor tendon ruptures, but 10% of the patients required hardware removal for radial-sided tendon impingement [8]. In another series of 60 patients treated with a low profile plate, the authors had no extensor tendon-related complications [9]. Matzon et al., in a series of 110 patients treated with low profile dorsal plates found that 9 (8%) required hardware removal for tenosynovitis, and no patients had tendon ruptures [10]. Finally, when comparing the incidence of tendon complications from dorsal plating to that of volar-locked plating, Yu and colleagues found no difference with respect to tendon complications [11].

Dorsal bridge (spanning) plating systems are a relatively new option to treat complex DRFs. In this setting, Hanel et al. found only one EPL tendon rupture and two tendon adhesions in a series of 134 cases [12].

Volar-locked plating

As the use of volar-locked plating (VLP) systems has become commonplace, extensor and flexor tendon-associated complications have been increasingly recognized, both in the form of tenosynovitis and ruptures. When the flexor tendons are

affected, the flexor pollicis longus (FPL) is most commonly involved given its anatomic proximity to the volar surface of the distal radius. One series examined 141 patients treated with VLP of which nine required hardware removal due to flexor tenosynovitis [13]. The incidence of volar plate hardware removal was 10% in a pooled series of 374 patients treated by five different surgeons, mostly due to tendon-related complications [14••]. Flexor tendon ruptures can occur over a year after the index procedure, with three cases of flexor tendon ruptures reported in a series of 73 patients at an average of 20 months after the fracture repair [15].

One factor associated in VLP flexor tendon complications is placement of the volar plate too distally, which can lead to mechanical impingement of the flexor tendons. The distal radius watershed line is a horizontal ridge on the volar distal radius just proximal to the articular surface that is not covered by the pronator quadratus (PQ) muscle [16]. This anatomic landmark should be used as the distal most margin of VLP placement to avoid hardware impingement on the flexor tendons [17, 18]. A classification system assessing the placement of volar plates was devised by Soong and his team using radiographic criteria [19]. The grading scheme is based on a line drawn tangential to the volar rim of the distal radius parallel to the longitudinal axis of the radial shaft. (Fig. 1) Grades 0, 1, and 2 were assigned to the level of prominence of the distal radius volar plate at the watershed line. The higher the grade, the higher the incidence of flexor tendon related complications [14••, 19, 20••].

There are several treatment options in cases of FPL rupture that can restore thumb interphalangeal joint flexion. Ring or long finger flexor digitorum superficialis (FDS) tendon transfer to the FPL tendon has been shown to reliably achieve adequate thumb flexion [21, 22]. An intercalary tendon graft has also been described with good outcomes using the palmaris longus (PL) tendon [23]. If, however, there is some concern of distal FPL stump scarring or in the presence of underlying degenerative joint disease, an interphalangeal joint arthrodesis can be considered.

Extensor tendon injuries have been reported with the use of VLP, mostly due to hardware prominence on the dorsal surface of the radius. Standard imaging can be inaccurate in determining dorsal prominence of volarly placed screws. The overall incidence of these injuries are estimated to be 3% to 5%, mostly involving the EPL tendon [13, 19]. A large retrospective study examined 576 patients with DRFs treated with VLP fixation. The authors noted 12 extensor tendon ruptures (2% complication rate), and tendon irritation in another 1.7% of the cohort [24•]. Although many mechanisms of injury have been hypothesized, prominent screws are noted to be a common cause [25].

The most important factor in preventing extensor tendon-associated complications in VLP is the intraoperative identification of dorsal screw protrusion. There have been several

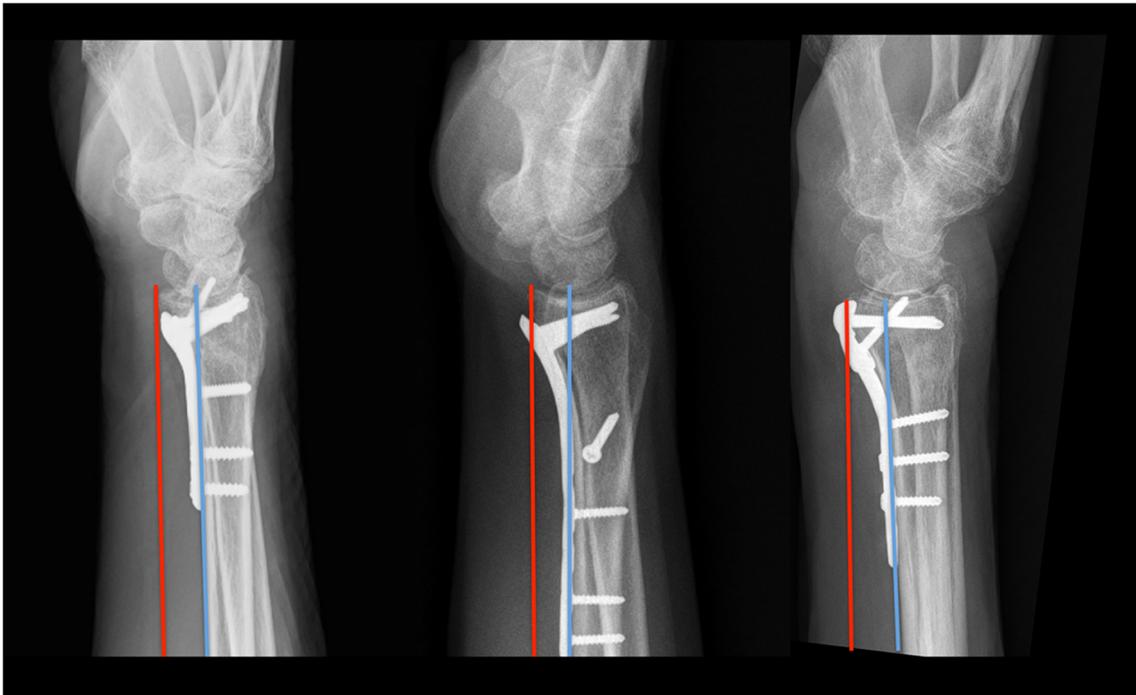


Fig. 1 Three lateral projections of the distal radius demonstrating various Soong classification grades. **a** Grade 0 (volar plate is dorsal to the critical line). **b** Grade 1 (volar to critical line, proximal to volar rim). **c** Grade 2 (Volar to critical line, at volar rim)

methods to reduce the incidence of dorsally prominent hardware with VLP. The use of dorsal tangential views combined with oblique views can reliably detect screws protrusions 2 mm or more in second, third, and fourth extensor compartments [26]. Using multiple views intraoperatively can aid to better assess dorsally prominent screws such as the skyline view, horizon, and Hoya views [27••, 28–31]. However, no radiographic view can routinely assure proper screw length. A cadaveric study has demonstrated that distal screws spanning only 75% of the bicortical length provide similar primary stability to 100% screw length [32]. While additional attention to intraoperative fluoroscopic views during placement of hardware can minimize the risk of hardware prominence, avoiding bicortical fixation and using shorter screw lengths during VLP appears to be a reliable solution.

Nerve complications

Nerve injury after DRF is not uncommon. Incidence ranges from 2 to 8% [33, 34]. The median is injured most frequently [35], but radial and ulnar nerve injuries can occur as well. Nerve injuries may be the result of direct injury from the fracture, hematoma/swelling, over-distraction (particularly with external fixation or spanning plate fixation), or may occur during surgical fixation. Reduction with the wrist in a position of flexion increases the pressure substantially within the carpal tunnel [36] and is to be avoided.

Median nerve injury

Median nerve symptoms that occur in the acute setting after injury may be either contusion of the nerve or acute carpal tunnel syndrome (aCTS). Differentiating between the two is critical, as aCTS is a surgical emergency whereas median nerve contusions are expected to resolve with time. Symptoms of aCTS include progressively worsening pain and numbness which develop over time, whereas with a median nerve contusion, symptoms begin at the time of injury and remain static. Initial management of a patient with acute median nerve symptoms includes a reduction of the fracture (with the wrist in a neutral position), splitting the cast if needed, and close observation. If symptoms persist or progress despite the above, urgent carpal tunnel release is performed. Dyer et al. [37] reported that patients with ipsilateral upper extremity trauma, women less than 48 years of age, and patients with greater than 35% fracture translation were at increased risk for aCTS.

Performing prophylactic carpal tunnel release in patients without median nerve symptoms remains controversial, with some authors reporting increased rate of complications [38, 39] and others reporting favorable outcomes [40]. It is the authors' preference to perform carpal tunnel release through a single incision, hybrid FCR approach concurrent with DRF fixation in patients with median nerve symptoms, or prophylactically in those patients with risk factors as noted above, with high energy injuries, or in whom the potential for significant post-operative swelling is a concern.

Delayed median nerve dysfunction is also not uncommon after DRF and has been estimated to occur in 2–8.5% of patients [41]. Patients who develop delayed onset median nerve symptoms are generally treated in a manner similar to idiopathic carpal tunnel syndrome, with surgical release performed in patients whose symptoms are refractory to conservative care.

Damage to the palmar cutaneous branch of the median nerve (PCBMN) can occur during the surgical approach for volar plate fixation. Although the nerve is typically described as running ulnar to the flexor carpi radialis (FCR), Jones et al. [42••] noted anomalous PCBMN branches crossing or running within the FCR sheath in 5.5% of patients undergoing volar plate fixation. Surgeons should be aware of this potential and be vigilant to identify and protect these branches during the approach.

Radial nerve injury

Symptoms referable to the superficial branch of the radial nerve (SBRN) can occur after DRFs and is also most commonly associated with iatrogenic injury. This can result from direct trauma to the SBRN during percutaneous K-wire insertion, or during half pin insertion for external fixation [41]. Small incisions with gentle retraction of the soft tissues, direct visualization of the starting point on bone, and oscillating (K-wires) during insertion can help minimize this complication. A 14-gauge angiocatheter can also be used as a soft tissue sleeve during K-wire insertion to minimize the risk of wrapping up the soft tissues.

Fracture Malunion

Malunion of DRFs can be extra-articular, intra-articular, or both. It occurs when a fracture heals with improper alignment or articular incongruity [43]. Extra-articular malunions may be in any of the three planes. Commonly in the sagittal plane, the malunion results in loss of the palmar tilt. In the coronal plane, the malunion presents as loss of radial inclination and radial shortening. Rotational deformities or displacement in the axial plane can occur and is best appreciated with a CT scan [44].

A clear definition of malunion has not been established, thus making it difficult to compare outcome studies. Malunion has been defined by different authors as radial inclination of less than 10–15°, dorsal tilt equal or greater than 10°, radial height (length) less than 10 mm, ulnar variance of greater or equal to 2–3 mm, and articular step-off greater than 2 mm [45]. Loss of palmar tilt can lead to incongruence at the distal radial ulnar joint and tightening of the interosseous membrane resulting in loss of forearm rotation [46]. This type of malunion can go on to two types of carpal instability. The wrist will exhibit dorsal radial subluxation with maintenance

of mid carpal alignment or adaptive mid carpal instability. The latter is usually more symptomatic and may be due to ligamentous laxity. The loss of palmar tilt also limits flexion and supination whereas increased palmar tilt decreases extension and pronation [47]. Eventually, the disruption in wrist mechanics can lead to osteoarthritis in the radiocarpal, midcarpal, and distal radioulnar joint (DRUJ).

There are no absolute indications for surgery when a patient has a distal radius malunion. The degree of impairment and functional demands for the injured extremity must be considered. Jupiter et al. [48] found the results of early and late reconstruction of malunited fractures of the distal end of the radius are comparable. However, grip strength averaged 42 kg after the early reconstructions, compared with 25 kg after late reconstructions. They felt for those patients who have radiographic characteristics predictive of functional limitation, and early reconstruction is technically easier and the overall period of disability is less. Figure 2 demonstrates a dorsally angulated malunion treated with volar osteotomy and plate fixation. (Fig. 2).

Malunions with an intra-articular component require advanced imaging such as computerized tomographic (CT) scan. Good results can be achieved if surgery is performed while the fracture is still healing and can be used to guide realignment. Based on a report of 23 patients, Ring and colleagues [49] found the results of treatment of intra-articular and extra-articular osteotomies to be comparable. This osteotomy can lead to improved wrist function and may prevent the development of osteoarthritis. This can be accomplished through a dorsal or volar approach. A dorsal capsulotomy is best suited for dorsal subluxation and articular malunions in the sagittal plane. The volar approach should be utilized when the articular malunion leads to volar radiocarpal subluxation. In this setting, release of the stabilizing volar capsular structures should be avoided.

Fracture nonunion

Nonunion of the DRF is rare [50, 51]. Open fractures, those with severe comminution, de-vascularized bone fragments, soft tissue interposition, and medical conditions including diabetes and smoking are predisposing factors [52–55]. Most nonunions are synovial [52, 53, 56–58].

There are several reports in the literature detailing nonunion incidence [52, 53, 56–58]. Bacorn and Kurtzke report a DRF nonunion rate of 0.2% in a study of 2000 New York workman's compensation patients [50]. Segalman presented a series of 12 distal radius nonunions in 11 patients during a 24-year period [53]. Prommersberg et al. reported operative repair of 23 distal radius nonunions by comparing 10 with distal fragments less than 5 mm of subchondral bone supporting the articular distal radius to the nonunion site with a group

Fig. 2 Pre operative AP (a) and lateral (b) of a dorsally displaced malunion which was surgically corrected with a volar osteotomy and healed in a more anatomic position as seen on post op AP (c) and lateral (d) radiographs



of 13 patients with larger fragments [58]. Liverneux analyzed the literature between 1987 and 2015 finding approximately 20 articles reporting cases or clinical series of pseud arthrosis after DRFs, i.e., less than one article per year, with a total of 86 published cases in less than 30 years [59].

Generally speaking, DRFs that do not show radiographic signs of bridging trabeculae across the fracture site at 6 months can be categorized as a nonunion, whereas those with no signs of healing at 3–4 months post-injury can be considered a delayed union [56]. CT scan is useful in not only confirming the nonunion but can also assist in preoperative planning [60].

Surgical options for DRF nonunion include bone grafting and stabilization with internal fixation as a single-stage procedure, primary distraction lengthening with secondary stabilization and bone grafting, or salvage procedures such as

complete or partial arthrodesis [61]. Standard wrist arthrodesis techniques using specific wrist fusion plates have proved adequate for DRF nonunion [52, 53]. Fernandez and colleagues have used two plates in orthogonal planes for greater fixation points in the small distal fragments [56]. Ring et al. described operative repair to included open removal of the fibrous or synovial tissue, opening of the sclerotic fracture ends and intramedullary canal to facilitate ingress of vascular supply, providing cells, nutrients, and growth factors to support healing. Surgeons repairing a DRF nonunion must be prepared to release or lengthen the brachioradialis, flexor carpi radialis, use a distractor, external fixator, spanning bridge plate, bone graft, fixed angle internal fixation plates, radius lengthening, radius shortening, ulna shortening, or distal ulna resection [61, 62].

Loss of reduction

Most fractures of the distal radius can be treated without surgery. This is most often achieved by splinting, bracing, or casting based on surgeon preference and predicated on the nature of the fracture with or without a closed reduction. However, close follow-up with serial radiographs is necessary to ensure maintenance of the reduction. Predictive criteria for the instability and ensuing loss of fracture reduction have been proposed by LaFontaine [63]. These include (1) dorsal tilt > 20°, (2) dorsal comminution, (3) intra-articular fracture, (4) concomitant ulnar fracture, and (5) age > 60 years. The presence of three or more of these factors are predictive of fracture displacement prior to healing. Would predict collapse and displacement of the fracture.¹ These criteria have since been validated. Nesbitt et al. [64] reported a 54% rate of failure rate with respect to maintenance of reduction (followed over 4 weeks), with advanced age being the statistically significant predictor for displacement. In a large subsequent series, MacKenney et al. confirmed age to be an important factor as well, in addition to the position of the fracture at presentation (radial length), and the presence of dorsal comminution [65].

Infection

As the paradigm has shifted in the management of DRFs from pin fixation and external fixation to internal fixation with VLP and to some extent dorsal bridge plate technology, the infection rate has also decreased. In a large meta-analysis looking at 1520 operative DRFs, the infection rate was 11% for those treated with external fixation and 0.8% for those treated with internal fixation [66]. When percutaneous fixation is used, chlorhexidine sponges and standard pin site care with hydrogen peroxide were both ineffective at preventing pin site infections [67].

Open DRFs also pose risk for infection. Much of the available literature on open fractures involves long bone open fracture data, which may or may not apply to DRFs. The most appropriate management algorithm for open DRFs is unknown, but many have asserted that Gustilo Anderson grade one injuries can be treated similar to closed fractures. The higher the grade of open fracture, the greater likelihood for infection and other complication [68•].

Complex regional pain syndrome

Complex regional pain syndrome (CRPS) can occur with both surgical and non-surgical treatment of DRFs. CRPS is characterized clinically by pain and objective findings of sympathetic nervous system dysfunction such as swelling, stiffness, vasomotor changes such as hyperhidrosis and allodynia. CRPS

is classified as type 1 (occurring after a noxious stimulus such as surgery or trauma) or type 2 (associated with a definable nerve injury, including compression neuropathies).

Prevention of CRPS type 1 is paramount. Avoiding overdistraction, prolonged immobilization, and undue tightness of cast immobilization can help minimize this occurrence. Zollinger et al. [69] reported a decreased rate of CRPS 1 in patients who were given 500 mg per day vitamin C for 50 days after fracture. Shah et al. [70] also reported on the efficacy of vitamin C for preventing CRPS. Although further definitive evidence is lacking (and other recent studies found no benefit to Vitamin C), use of vitamin C has been recommended by the AAOS in the clinical practice guidelines for the treatment of DRFs.

Women, elderly, and those with psychological predisposition have been suggested to be at greater risk of development of CRPS 1 [71]. Early diagnosis and prompt treatment is imperative in addressing CRPS 1. Radiographs may be useful in showing osteopenia, but this can take several weeks to develop. Bone scan has demonstrated a high specificity but low sensitivity in diagnosing CRPS [71]. As such, CRPS remains largely a clinical diagnosis. Treatment of CRPS type 1 requires a multidisciplinary approach including pain management, hand therapy, oral medications, stellate ganglion blocks, and psychiatry if needed. Treatment of CRPS type 2 relies upon identifying the source of pathology. In patients with compressive neuropathy, release of the appropriate nerve is warranted.

Posttraumatic arthritis

Posttraumatic arthritis (PA) can occur after fractures of the distal radius, with increased incidence with intra-articular fractures, and those that heal in a malunited position. The classification for PA according to Knirk and Jupiter for DRFs includes grade 0 representing no signs of PA, grade 1 slight narrowing of the joint surface, grade 2 demonstrating marked narrowing with osteophyte formation, and grade 3 representing bone-on-bone PA with osteophytes and cysts [72].

Radiographic findings of PA after sustaining a DRF is common with reports ranging from 30% to 97%. In spite of this incidence, most patients enjoy excellent functional outcomes with only minor loss of motion. In 1986, Knirk and Jupiter reported the prevalence of radiologic PA following DRFs to be as high as 65% after 6.7 years of follow-up [72]. A review of 106 adults who sustained a DRF from 1960 to 1968 had radiographic assessment at a mean follow-up of 38 years demonstrating PA after intra-articular fracture in 68% of patients [73]. A systematic search of the literature published prior to January of 2015 identified 733 patients with DRFs in non-osteoporotic patients with a prevalence of PA of 50%. This

systematic review revealed that PA after a DRF worsens over time with 31% after a follow-up of 0–36 months versus 64% after 36 months [74]. Catalano and Goldfarb reported a 7-year and 15-year respective follow-up of the same patient cohort with intra-articular DRFs treated by open reduction and internal fixation and demonstrated radiocarpal arthrosis of 76% (16 of 21) at 7 years and 81% (13 of 16) at 15 years [75, 76]. Older age at the time of injury was associated with earlier development of PA [73]. Egol et al. compared DRFs in the elderly. Forty-six patients (mean age 76) treated non-operatively and 44 (mean age 73) treated operatively reported no difference in functional status at 1 year. The prevalence of PA grade one to three after 12 months was 80% (37/46) in the non-operative group and 34% (15/44) in the operative group [77].

Fractures that healed with residual radiocarpal incongruity had a higher rate of radiographic arthrosis (91%) versus fractures that healed with a congruous joint (11%) [72]. DRFs that healed with a residual gap, step-off, or overall intra-articular incongruence of greater than or equal to 2 mm are associated with a significant risk for arthrosis [72–75, 78–80]. Eighty-one intra-articular DRFs treated with open reduction and internal fixation followed for a mean period of 9 years demonstrated a prevalence of PA in 97.5% (79/81) while range of motion in the sagittal plane was significantly decreased for arthritis stage 2 (108.4°) compared to stage 1 (118.2°). Lutz et al. showed that an increase of the anteroposterior distance of an average of 2 mm in comparison to the uninjured side is correlated with a higher incidence of PA while no statistically significant difference in DASH, pain level, and grip strength correlated with arthritis stage [81].

Conclusion

Tendon irritation and rupture, nerve injury, malunion, non-union, pain syndromes, loss of reduction, and posttraumatic arthritis must all be considered when treating distal radius fractures. Appropriate intervention can lead to good outcomes in spite of problems that may be encountered.

Compliance with ethical standards

Conflict of interest Daniel Seigerman, Kevin Lutsky, Daniel Fletcher, Brian Katt, Moody Kwok, Donald Mazur, Samir Sodha, and Pedro Beredjiklian each declare no potential conflicts of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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