Acute Dislocations of the Distal Radioulnar Joint and Distal Ulna Fractures

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KEYWORDS

- Distal radioulnar joint • Dislocation
- Ulna fractures • Wrist trauma

ANATOMY AND BIOMECHANICS OF THE DISTAL RADIOULNAR JOINT

The ulna is the fixed unit of the forearm joint, with the hand, carpus, and radius rotating around it.[1] Rotational forearm motion occurs at the distal radioulnar joint (DRUJ) and proximal radioulnar joint (PRUJ) at the elbow. DRUJ motion is primarily rotational, but there are components of axial and translational motion that occur during loading and rotation. Axial motion is due to the crossing relationship of the radius to the ulna in pronation. This axial motion can produce changes in the ulnar variance that may be as great as 2 mm with full forearm rotation.[2–5] Dorsal and palmar translational motion of the radius about the fixed ulnar head also occurs with supination and pronation, respectively.[6–8]

Joint stability at the DRUJ is provided through a combination of bony architecture and soft tissue constraints, which include the ligaments found in the triangular fibrocartilage complex (TFCC), the pronator quadratus, and the interosseous membrane (IOM). The bony architecture of the DRUJ accounts for only 20% of the joint's stability[9]; thus most of the stability is provided by the soft tissue attachments. In addition, individual variation in the bony configuration of the DRUJ may also affect its stability. A study by Tolat and colleagues[10] defined the shape of the sigmoid notch in the transverse plane in 4 different configurations: flat face (42% incidence), ski slope (14%), C-type (30%), and S-type (14%). Although the study did not include biomechanical evaluation of the different joint configurations, the investigators proposed that this may have important implications in the bony contribution to joint stability.[10]

The primary stabilizer of the DRUJ is the TFCC, originally described by Palmer and Werner.[11] The TFCC is composed of several structures, including the triangular fibrocartilage (TFC), the ulnocarpal meniscus (meniscus homolog), the ulnar collateral ligament, the dorsal radioulnar ligament, the palmar radioulnar ligament, and the subsheath of the extensor carpi ulnaris (ECU).[11] These structures are not readily distinguishable on anatomic dissection and together are referred to as the TFCC. The central portion of the TFC makes up the articular disk. This disk forms the ulnocarpal articulation and effectively cushions the ulnar head. In contrast to the peripheral TFCC, the articular disk is relatively avascular and therefore is presumed to be incapable of significant healing capabilities.[12]

The dorsal and palmar radioulnar ligaments are thought to be responsible for most of the stability at the DRUJ.[9,13] Significant research has been performed to determine which component of the

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radioulnar ligament complex (palmar or dorsal) is more critical for joint stability.[14–16] Hagert,[13] in 1994, helped answer this question and recognized that palmar and dorsal components of the radioulnar ligaments were necessary for DRUJ stability. Hagert described the existence of superficial and deep portions of the the dorsal and palmar radioulnar ligaments. The superficial fibers attach to the base of the ulnar styloid and thus are susceptible to injury in cases of peripheral TFCC tears. The deep fibers, sometimes referred to as the ligamentum subcruentum, attach to the fovea and are thus susceptible to injury in cases of basilar ulnar styloid fractures. In pronation, the dorsal superficial fibers tighten together with the palmar deep fibers. Conversely, in supination, the palmar superficial fibers together with the dorsal deep fibers are taut and effectively constrain DRUJ motion.[13] Other studies have confirmed the reciprocal relationship between the superficial and deep portions of the radioulnar ligament, further emphasizing that the deep palmar and dorsal ligaments attach to the fovea and prevent dorsal and palmar subluxation with forearm rotation, respectively. The superficial palmar and dorsal ligaments attach to the ulnar styloid and act as rotational restraints to supination and pronation, respectively.[17,18] Work by Stuart and colleagues[9] and other investigators have shown that dorsal displacement of the distal ulna relative to the radius is most likely because of failure of the palmar radioulnar ligament, whereas palmar displacement of the ulna relative to the radius is because of failure of the dorsal radioulnar ligament.[19–21]

An additional secondary constraint to palmar displacement and dislocation includes the IOM.[16,22–24] The IOM contains several ligamentous components along its length. The central band is a stout ligament that runs obliquely from proximal on the radius to distal on the ulna, fanning out towards its insertion on the ulna.[25] The central band is thought to play an important role in the longitudinal stabilization of the forearm.[25,26] The distal oblique bundle is a thick band of tissue in the distal one-sixth of the membrane. It originates proximally on the ulnar shaft, in the same location as the proximal pronator quadratus muscle, and attaches distally to the capsule of the DRUJ. The bundle may contribute some fibers to the volar and dorsal radioulnar ligaments.[23] Although this structure is consistently present, its thickness may vary from patient to patient.[22,23]

Acute Isolated DRUJ Dislocation

As previously mentioned, the ulna is the fixed structure of the forearm, and anatomically it is the radius that dislocates away from its original anatomic position. However, the clinical and radiographic appearance of DRUJ dislocation is one of ulnar dislocation relative to the radius, which has resulted in the historic description of such injuries in terms of the ulna's relationship to the radius. In this article, the authors use this technically incorrect but widely accepted description. They refer to a dorsal dislocation as occurring when the ulna resides dorsal to the radius and volar dislocation as occurring when the ulna resides volar to the radius.

Isolated acute dislocation of the DRUJ (with or without ulnar styloid fracture) is less common than dislocation associated with a fracture of the radius or distal ulna.[27] The first report of an isolated dislocation of the DRUJ without fracture was by Desault in 1777.[28,29] Since then, there have been numerous case reports and small series describing such injuries.[6,19,30–35] The direction of dislocation can be either volar or dorsal, although dorsal dislocation is probably more common.

Dorsal dislocations are believed to result from a hyperpronation force, and volar dislocations from a hypersupination force.[19–21] Although an acute dislocation must result in an injury to the TFCC, the amount and degree of injury required for dislocation of the DRUJ is not entirely clear and DRUJ dislocation may not require complete disruption of the TFCC.[19,32,36,37] One premise for this observation is that, in many cases, the DRUJ is notably stable after reduction of the dislocation.[6,32] Hagert[13,38] has described injury of the volar radioulnar ligament and dorsal joint capsule with dorsal dislocation. The reverse mechanism also occurs with rupture of the dorsal radioulnar ligament and volar joint capsule in a volar dislocation.[36]

In a dorsal dislocation, there is typically a history of hyperpronation force, usually as a result of a fall on the outstretched hand. In this situation, the hand is typically fixed by gravity to the ground, and the body, together with the ulna, rotates around the hand, wrist, and radius unit. The patient presents with the hand fixed in pronation, with the inability to supinate and a dorsal prominence of the ulnar head.

In cases of volar dislocation, there is a history of hypersupination and the patient is unable to pronate. The ulnar head is usually not visibly prominent on the volar wrist because of the overlying soft tissues. However, there can be a hollow dorsally where the ulnar head is usually visible in the uninjured wrist. The wrist can appear narrow because of the now compressive pull of the pronator quadratus muscle, resulting in a diminished transverse dimension.[29,36] In either direction of dislocation, the examination findings can be obscured by ecchymosis and swelling.

Plain 2-view radiographs that include the wrist, forearm, and elbow are critical for the evaluation of suspected DRUJ dislocation. The anteroposterior (AP) view in a dorsal dislocation typically shows a widened DRUJ with divergence of the radius and ulna when compared with the contralateral normal DRUJ, whereas a volar dislocation demonstrates an overlap of the radius and ulna at the DRUJ because of the convergent pull of the pronator quadratus. In an anatomically reduced DRUJ in neutral rotation, the ulnar styloid is located at the most medial (ulnar) aspect of the ulnar head. A standard posteroanterior view of the wrist is taken with the shoulder abducted 90° and the elbow at 90° flexion and neutral forearm rotation. This view is often not possible in the setting of acute DRUJ dislocation because of mechanical blockage caused by the dislocation, pain, or splint immobilization, and unfortunately, oblique films are obtained more often than true orthogonal radiographs. Therefore, one must be careful in the interpretation of these radiographs. As little as a 10° obliquely malaligned view of a dislocation may appear to be reduced and thus falsely interpreted as negative.[39] One valuable criterion in determining a true lateral radiograph is the scaphopisocapitate alignment.[40] In this analysis, the volar cortex of the pisiform overlies the central third of the interval between the volar cortices of the distal pole of the scaphoid and the capitate head, confirming a true lateral view.[40] An axial computed tomographic (CT) scan may be helpful in the acute setting to determine joint reduction and congruity.[39,41] Various measures have been described to evaluate for translation at the DRUJ, with the subluxation ratio method being the most reliable in terms of intra- and interobserver reliability.[42]

Treatment of acute DRUJ dislocations

Treatment of the acute dislocation without fracture begins with closed reduction. This treatment is typically accomplished under local anesthesia with or without sedation. In dorsal dislocations of the ulna, reduction is accomplished with gentle traction, dorsal pressure (translational force) over the ulnar head, and supination. The joint must be assessed for instability and typically is most stable in supination. In volar dislocations, reduction can be more difficult because of the pull of the pronator quadratus muscle. To achieve reduction, one may have to distract the ulna from the radius (or vice versa) in conjunction with the volar pressure (translational force) over the ulnar head and pronation. Regional or general anesthesia may be necessary to achieve closed reduction. Because of the vascularity and healing potential of the peripheral TFCC,[12] closed treatment is frequently successful in the restoration of a stable construct.

So-called complex dislocations occur when there is interposed soft tissue that blocks closed reduction. These dislocations typically occur in conjunction with a Galeazzi fracture and are discussed later; however, nonreducible simple dislocations without soft tissue interposition can also occur. In such a case, the ulna may be irreducible because of a bony mechanical blockage at the volar lip of the sigmoid notch of the radius (**Fig. 1**).[43] If it is necessary to perform open reduction, then direct repair of the TFCC to the foveal insertion is preferred. The procedure is performed using suture anchors or heavy suture through bone tunnels. Although this is the authors' preference, they know of no studies demonstrating improved outcomes over reduction and immobilization in this situation. A study by Ruch and colleagues[44] looked at patients with distal radius fractures and DRUJ instability with a large, displaced ulnar styloid fragment. The 2 treatment groups consisted of (1) open treatment with tension band fixation and (2) DRUJ immobilization with an ulnar outrigger in 60° supination. The investigators found a tendency toward improved supination

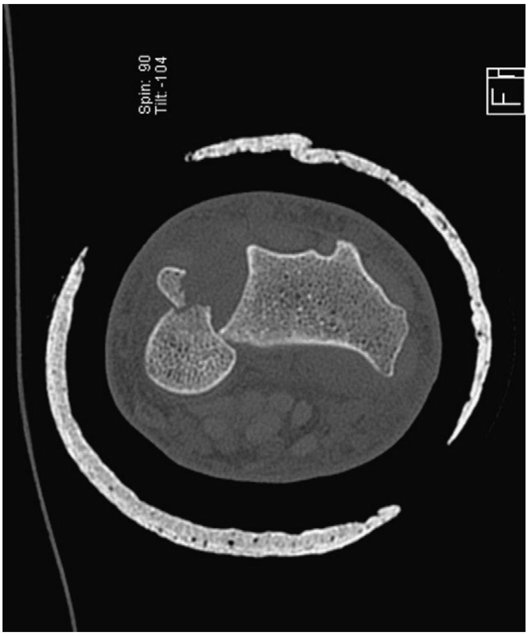

Fig. 1. Axial CT scan of a simple volar dislocation with ulnar styloid fracture. The dislocation required open reduction because of the mechanical blockage of the volar lip of the sigmoid notch.

and fewer DRUJ-related complications in the group of patients treated with the external fixator.[44] After TFCC repair, the forearm can be immobilized in a long-arm or Munster-type cast with or without transcutaneous radioulnar pinning. The authors' preference is to place two 0.062-in Kirschner (K) wires just proximal to the DRUJ obtaining purchase of 4 cortices and leaving the wires slightly prominent on the radial and ulnar superficial cortices, which allows for easy wire removal should one or both pins break between the radius and ulna. The authors prefer immobilization in neutral rotation to facilitate recovery of pronation and supination after the period of immobilization. Alternatively, the forearm is immobilized in the position of maximal stability, supination for dorsal dislocations and pronation for volar dislocations. After 6 weeks, a removable splint is provided and a gradual, progressive, active range of motion program is begun.

Galeazzi Fracture

A Galeazzi fracture represents a diaphyseal fracture of the radius with an associated DRUJ dislocation. This fracture pattern is named after Riccardo Galeazzi, who in 1934 published a series of 18 patients with this fracture pattern.[45] The Galeazzi fracture occurs at least 4 to 5 cm proximal to the radiocarpal joint.[46] The mechanism is typically high-energy trauma, such as a motor vehicle accident or a fall from a height.[47,48] The pathomechanics of the injury is thought to be wrist hyperextension with pronation.[49] Clinically and radiographically there is typically an angular deformity of the radius with radial shortening and dorsal prominence of the ulnar head (**Fig. 2**).[47]

The Galeazzi fracture is ''the fracture of necessity,'' implying that operative fixation is required for adequate return of function.[50] Historically, nonoperative management has been associated with poor results.[49,51,52] Casting alone is associated with a poor outcome because of the strong deforming forces acting on the distal fragment, which include the pronator quadratus, brachioradialis, and thumb extensors and abductors.

Not all diaphyseal radius fractures result in an injury to the DRUJ, but it has been suggested that a quarter of all radial shaft fractures have some associated injury to the DRUJ.[53] The distance that the fracture lies from the articular surface can help the surgeon predict the likelihood of DRUJ injury. Fractures occurring within 7.5 cm from the midarticular surface of the radius have been found to have a higher incidence of concomitant DRUJ injury.[48] An associated fracture at the base of the ulnar styloid, widening of the DRUJ on AP radiographs, dislocation of the ulna on lateral view, and greater than 5 mm of radial shortening are all suggestive of a DRUJ injury.[47,54] Plain radiographs may not always represent the true extent of soft tissue injury. Mikic[49] reported, in his study of 125 Galeazzi fractures, that while 80% of patients presented with a complete dislocation of the DRUJ, 20% presented with only radiographic evidence of subluxation, complicating the diagnosis. Clinical assessment of DRUJ should be performed intraoperatively after skeletal fixation of the radius shaft fracture. Arthroscopy has not been described as an adjunct for evaluation and treatment with Galeazzi fractures; however, as in the case of distal radius fractures, arthroscopy may prove useful for evaluation and treatment of TFCC injuries after operative repair.

A distinction has been made between simple and complex dislocations. Simple dislocations are those without interposing soft tissue in the dislocated DRUJ. Complex dislocations are those with interposing soft tissue that blocks closed reduction.[6,35,55–57] Complex dislocations are typically high-energy injuries and, to the authors' knowledge, have not been reported except in association with a fracture, especially a Galeazzi-type fracture. The most common interposing structure is the ECU tendon,[6,55–59] although other interposed structures have been described, including the extensor digiti minimi and extensor digitorum communis tendons.[56] The diagnosis of a complex dislocation is suggested by the failure of closed reduction of the DRUJ after open reduction and internal fixation (ORIF) of the radius fracture. In this situation, the interposing soft tissue blocks the closed reduction and a mushy sensation can be appreciated when reduction is attempted.[6] In this case, one must be careful not to force reduction because a radiographic reduction may be apparent even with the soft tissue interposed. In a complex dislocation, an open reduction is indicated with extraction and reduction of the soft tissue and open repair of the TFCC.[6]

Surgical approach

Galeazzi fractures are approached through a modified Henry incision within the forearm. Volar placement of the plate is performed using standard techniques. Dynamic compression plates are the authors' preferred treatment choice and have been shown to produce excellent results.[54] Screw purchase should include 6 cortices above and below the fracture site with a 3.5-mm plate (see **Fig. 2**C, D). Once the radius is reduced and fixed, the DRUJ is assessed for stability. Often a concomitant basilar ulnar styloid fracture is

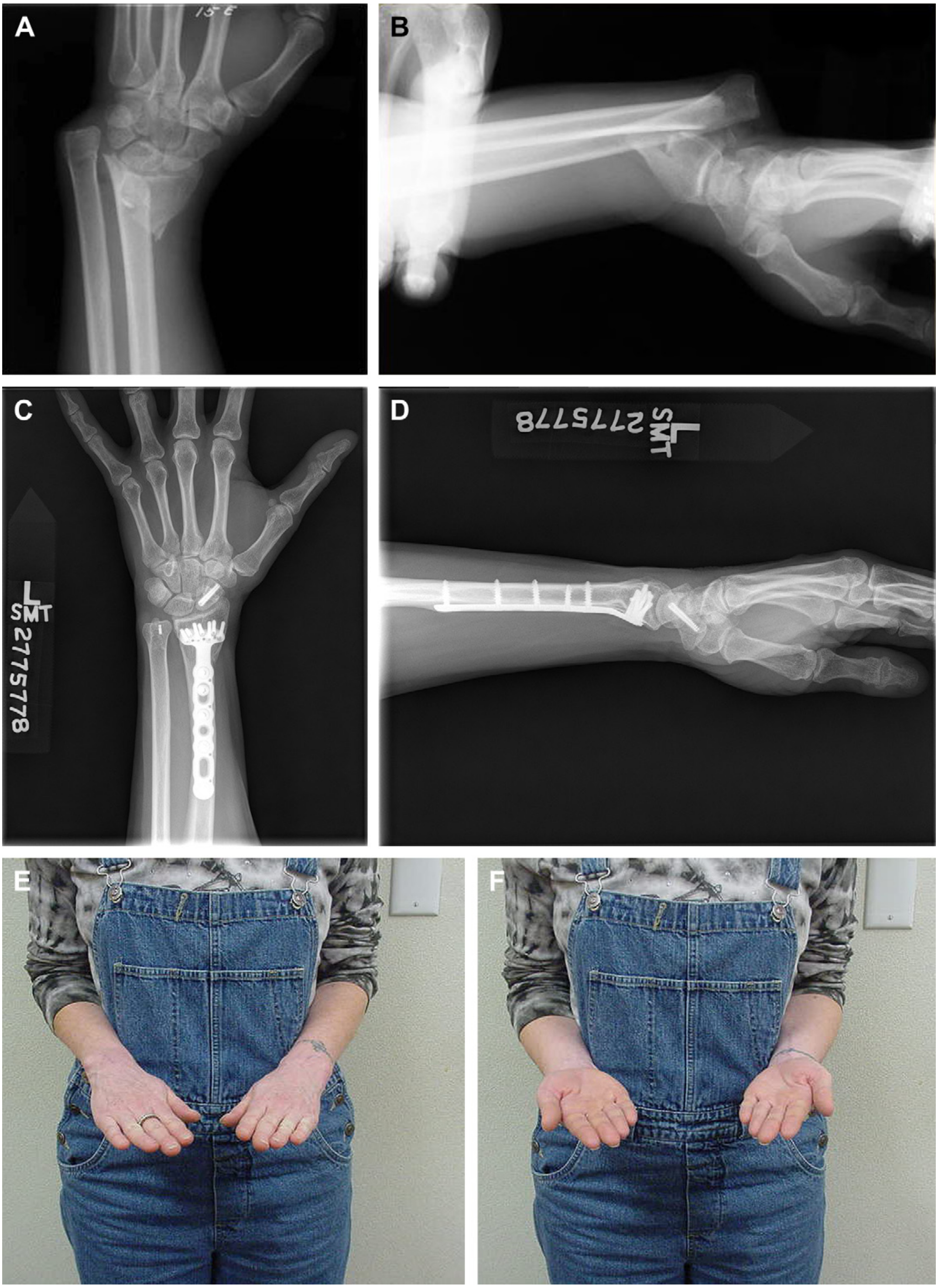

Fig. 2. Anteroposterior (*A*) and lateral (*B*) radiographs of a Galeazzi fracture with an associated scaphoid fracture. The radius fracture was treated with a long volar plate, and the TFCC was repaired with a suture anchor at the foveal insertion; radiograph 4 years after surgery shows good healing (*C*, *D*). Nine months after the surgery the patient regained painless forearm rotation (*E*, *F*).

present, which may be fixed with the tension banding technique. Persistent DRUJ instability after radial shaft fixation and ulnar styloid fixation may be addressed with arthroscopy to fully evaluate the TFCC. Significant instability may require open ligamentous repair and/or radioulnar pinning to obtain stability as previously discussed. The forearm is immobilized in a neutral position in a Munster-type cast for 4 to 6 weeks after surgery. When there is significant ulnar instability, immobilization in the more supinated position has been recommended.[60,61]

Essex-Lopresti Injury

In 1946, Curr and Coe[62] published a case report of a patient with a fracture dislocation of the radial head in combination with a dorsal dislocation of the DRUJ. In 1951, Essex-Lopresti[63] described 2 cases of a dislocation injury of the DRUJ in combination with a comminuted radial head fracture, the injury that now bears his name. The injury pattern is a manifestation of an axial compression force that results in longitudinal radioulnar disruption and involves the DRUJ, IOM, and PRUJ or radial head. The radial head is the primary constraint to proximal migration of the radius. The secondary constraints include the IOM and TFCC. In Essex-Lopresti injuries, there is loss of primary and secondary constraints. As such, the radius is freed of its constraints to the ulna and migrates proximally. These injuries can also occur in conjunction with distal radius fractures or radial shaft fractures.[64–66] The diagnosis can be difficult because the tendency is to focus on the obvious injury at the elbow.[67] The long-term problem lies in the longitudinal axial instability, which can present early or delayed as occurs after radial head excision or gradual failure of the IOM after the loss of radial head restraint. The manifestation is proximal migration of the radius, with radiocapitellar impingement proximally and ulnar impaction distally.[68,69]

The primary contributor to longitudinal forearm stability is the radial head, with the TFCC and IOM functioning as secondary stabilizers. A complete discussion of radial head fractures is beyond the scope of this article. However, the elbow must be assessed for stability and to rule out concomitant coronoid fracture and medial collateral ligament injury. One must also be vigilant in examination for axial injuries to the forearm, which would include the IOM and DRUJ. The patient typically has a history of a high-energy axial force to the hand or forearm. Examination frequently demonstrates a dorsally prominent ulna, limited wrist extension, and limited forearm rotation. Examination should include an assessment of longitudinal forearm stability.[70,71] Smith and colleagues[71] described the radius pull test in a cadaver study, whereby the radius is distracted proximally with a load of 9.1 kg. The investigators found that there was at least 3 mm of proximal radius migration when the radial head and IOM were disrupted and greater than 6 mm of proximal migration when the radial head, IOM, and TFCC were disrupted.

Radiographic evaluation includes 2 views of the elbow, forearm, and wrist. Grip views can be helpful in the assessment of dynamic radial shortening and should be compared with the contralateral normal wrist.[72] Similarly, bilateral AP wrist radiographs are obtained to evaluate differences in ulnar variance.[73] Magnetic resonance imaging and ultrasonography are important adjuncts to evaluate the soft tissue injury of the IOM.[74,75]

The primary goal of treatment is reestablishing the radiocapitellar articulation by repair or replacement of the radial head. Edwards and Jupiter[64] described a classification system that determines the surgical management of the radial head fracture. Type I fractures are those that have large fragments amenable to ORIF. Type II fractures are comminuted and ORIF is not an option. These injuries require radial head excision and prosthetic replacement. Type III injuries are chronic injuries with irreducible proximal radial head migration. The investigators recommend radial head replacement in conjunction with an ulnar shortening osteotomy procedure. Outcomes correlate to the timeliness of diagnosis and treatment within the first week.[65] Trousdale and colleagues,[65] in a summary of reported cases including their own, reported that 9 of 10 patients treated within 1 week had a satisfactory result as opposed to only 4 of 14 patients achieving a satisfactory result when treated more than 1 week after injury. Excision of the radial head is contraindicated in Essex-Lopresti injuries because there is nothing to stop proximal migration of the radius in this situation. Therefore, radial head replacement is indicated.[63,76,77] If nothing else, in this situation, the radial head replacement may function as an internal splint while the IOM, TFCC, and surrounding soft tissues are allowed to heal.

Once the radiocapitellar articulation is reestablished, the DRUJ is assessed for stability. If the DRUJ is unstable, then direct assessment of the TFCC can be performed arthroscopically. If significant instability is present or complete foveal disruption of the TFCC is noted on arthroscopy, the authors prefer direct repair of the foveal insertion with suture anchors or heavy suture through bone tunnels with or without radioulnar pinning.

The forearm is maintained in a Munster-type splint or cast until 6 weeks, when a gradual and progressive range of motion program is initiated.

Distal Radius Fractures and the DRUJ

Recent prospective studies have shown that concomitant injury to the TFCC at the time of distal radius fracture may be as high as 60% to 84%.[78,79] Despite this observation, there is still no accepted algorithm for the evaluation and treatment of these injuries.[1] The association between DRUJ injuries and distal radius fractures has been noted as early as 1814, when Abraham Colles stated, “If the surgeon proceeds to investigate the nature of this injury, he will find that the end of the ulna admits of being readily moved backward and forward.”[80] Studies that used arthrography to examine TFCC injuries associated with distal radius fractures have noted an incidence of 45% to 65%.[81,82]

More recent studies using arthroscopy have revealed similar findings. Geissler and colleagues[78] examined 60 consecutive patients who had failed closed reduction and had greater than 2 mm of articular stepoff within the radius. In this study, 26 of the 60 patients were found to have an injury to the TFCC (43%); of these injuries 13 were peripheral ulnar-sided tears (Palmer 1B), 7 were radial-sided tears (Palmer 1D), and 6 were central perforations (Palmer 1A).

Lindau and colleagues[83] reported on a prospective series of 51 young patients with displaced distal radius fractures. Diagnostic nontherapeutic arthroscopy was performed on all patients. The investigators found that 43 patients (84%) had an injury of the TFCC. Worse outcomes were associated with DRUJ instability. At a median follow-up of 12 months, 19 patients (37%) had DRUJ instability, including 10 of the 11 patients diagnosed with complete avulsion at the time of arthroscopy and 7 of the 32 patients with partial peripheral or central tears.[83] Based on these studies, one can conclude that TFCC injury is commonly associated with distal radius fractures and if untreated may increase long-term morbidity.

Diagnosis of DRUJ instability after distal radius fracture

Diagnosis of DRUJ instability based on physical examination is difficult after distal radius fracture injury in the nonanesthetized patient. Therefore, stability is best assessed intraoperatively after fracture fixation in an anesthetized patient. A certain amount of laxity may be normal, and therefore comparison with the contralateral side may be necessary. Lindau and colleagues[83] reported the sensitivity and specificity of clinical diagnosis of 0.59 and 0.96, respectively. It has been suggested that if greater than 1 cm of dorsal-to-palmar translation is present, instability should be assumed.[84]

Prereduction radiographic findings may help to increase the surgeon’s suspicion of DRUJ injury. Cadaveric studies suggest that if there is no evidence for an ulnar styloid fracture but the preoperative radiographs reveal significant shortening of the radius relative to the ulna (>7 mm), then a disruption of the DRUJ ligaments has likely occurred.[85] Four additional signs that may indicate DRUJ injury include (1) ulnar styloid base fracture, (2) widening of the DRUJ interval on AP radiographs, (3) dislocation of the DRUJ on lateral radiographs, and (4) more than 5 mm of radial shortening.[54] May and colleagues[86] noted a correlation with distal radius comminution and DRUJ instability; however, other studies have not shown a clear correlation between radiographic findings and DRUJ instability.[60,78,79,83,87] In Lindau and colleagues’[83] prospective study of 51 patients, the investigators found no correlation between radiographic findings (at the time of injury or at follow-up) and DRUJ instability.

A CT scan can provide additional information and may be obtained in the acute setting to further study distal radius fractures. Axial views of the DRUJ can be compared with the contralateral side. Subluxation or frank dislocation may often be identified in addition to bony fragments suggestive of palmar or radioulnar joint ligamentous avulsions (**Fig. 3**).[39,88]

If radiographs are nondiagnostic and the physical examination is suggestive of instability after

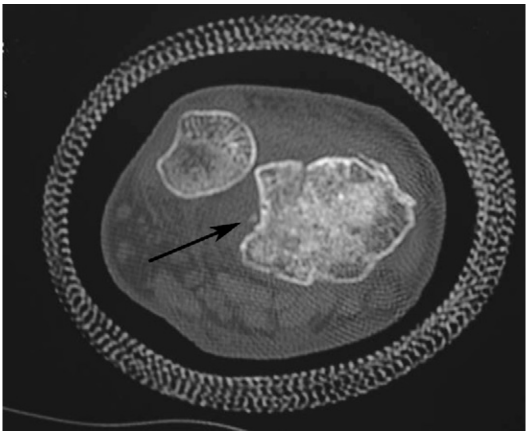

Fig. 3. Axial CT scan of a dorsal dislocation with distal radius fracture involving the sigmoid notch. The small osteochondral fragment (*arrow*) was found at surgery to represent the palmar radioulnar ligament. (*From* Carlsen B, Rizzo M, Moran S. Soft-tissue injuries associated with distal radius fractures. Operat Tech Orthop 2009;19(2):107–18; with permission.)

fracture reduction, the authors prefer arthroscopy of the TFCC to evaluate for injury. This approach allows for the possibility of immediate open repair with suture anchors or heavy suture through bone tunnels with or without radioulnar pinning.

Management of ulnar styloid fractures

Frykman[89] included fractures of the ulnar styloid in his classification system for distal radius fractures. He believed that concomitant fractures of the ulnar styloid were predictive of worse outcomes. Several clinical studies have supported this claim.[90–92] Oskarsson and colleagues[91] found ulnar styloid fractures to be associated with a greater loss of mobility and postoperative grip strength when comparing outcomes in patients with distal radius fractures. In addition, Stoffelen and colleagues,[92] in a prospective study of 272 patients, found that all patients presenting with DRUJ instability after distal radius fracture had suffered an ulnar styloid fracture at the time of the original injury. Knirk and Jupiter[90] found, in their long-term outcome study of patients with distal radius fractures, that ulnar styloid nonunions were associated with poorer outcomes. Conversely, other authors have noted no clear association between ulnar styloid fractures and overall outcomes.[93–98] Furthermore, studies using arthroscopy have suggested that an ulnar styloid fracture is not necessarily predictive of TFCC injury.[83,99]

Although the direct correlation between ulnar styloid injury and DRUJ instability is not clearly established, it does seem from the literature that ulnar styloid nonunion and malunion should be avoided.[90,100] Small avulsion injuries from the tip of the styloid are likely to be the result of direct trauma and are unlikely to involve the fovea insertion of the TFCC; however, large fragments, especially those displaced greater than 2 mm, are more likely to be associated with disruption of the foveal insertion of the TFCC and should be fixed.[27,86,101] Ruch and colleagues[84] advocate evaluation of the ulnar styloid with a true lateral radiograph. If the ulnar styloid lies palmar to the axis of the ulnar shaft, one should suspect that the stability of the DRUJ is compromised. Thus the authors recommend repairing all large ulnar styloid fragments, if possible. The authors have found wire reduction alone or tension banding to be most effective for ulnar styloid reduction. Anatomic reduction of the ulnar styloid is usually simple if the radius has been reduced to normal anatomic alignment, especially in terms of rotation and translation of the distal radial fragments.

Large ulnar styloid fractures may be fixed through a 2- to 3-cm incision made at the ulnar aspect of the wrist, directly over the styloid. This incision may be incorporated into the 6U arthroscopic portal, if this has been used to evaluate the radius during fracture fixation. The dorsal ulnar sensory nerve can be identified running with the basilic vein and is gently retracted before opening the joint capsule. The location of the nerve may be marked on the patient before surgical intervention by understanding that its course represents a perpendicular bisection of a line connecting the ulnar styloid to the pisiform. A 0.054- or 0.062-in K wire is used to create 2 transverse drill holes above and below the fracture line within the bone. A 25- or 24-gauge steel wire may then be passed through the drill holes. The styloid fracture is then pinned using two 0.045-in K wires, and the wire is then tensioned appropriately. If the distal styloid fragment is too small for the wire to pass intraosseously, the wire is held distally beneath the K wires, which are cut short and embedded within the distal fragment. Engagement of the ulnar styloid with the K wire is aided with the use of a 14-gauge needle, which is used as a soft tissue protector during K-wire placement. Alternatively, the wire driver can be used on oscillation to protect the soft tissue. The hollow needle is used to engage the periosteum of the ulnar styloid and aids in directing the K wire. K wires may be cut and imbedded into the ulnar styloid or brought out through the skin for removal in 4 to 6 weeks. Once the styloid is repaired, the stability of the DRUJ is reassessed. If the DRUJ remains unstable, repair of the foveal attachment of the TFCC may be necessary. Often the original radiograph shows a separate bony avulsion fragment adjacent to the styloid fracture, representing the foveal insertion of the TFCC,[102,103] which may be repaired arthroscopically or through an open approach.

Sigmoid notch and dorsal ulnar and volar ulnar corner fractures

Distal radius fractures often present with some injury to the lunate facet, more commonly the dorsal ulnar corner, and may also include the volar ulnar corner (marginal) fragment (which can also present with radiocarpal subluxation). These fractures may present with an unstable DRUJ because they include either the dorsal or the volar origin of the radioulnar ligaments. When these fracture fragments are present, if instability is present after reduction and fixation of the radius fracture, then further attention is directed to ensure the reduction and stability of these fragments. Preoperative CT scanning is extremely helpful in identifying these difficult fracture patterns when they are suspected on plain radiographs.

With current locking volar plating systems used to treat distal radius fractures, many of these larger dorsal ulnar fragments can be reduced and then captured by the pegs or screws through the volar plate. However, smaller or more ulnar, dorsal, and distal fragments may not be able to be stabilized without dorsal exposure, reduction, and fragment-specific fixation. On rare occasions, the sigmoid notch may be unstable with a shearing-type subchondral injury (**Fig. 4**). Reduction of these fractures can often be achieved without a dorsal incision, but closed reduction of the dorsal fragment is helped considerably by near anatomic reduction of the radial length, volar tilt, radial inclination, and radiocarpal articular surface. When trying to capture these smaller fragments, close to the DRUJ, one must be careful to make certain that no pins, screws, or pegs are placed within the DRUJ or the lunate facet. When the reduction or fixation is not obtainable without an incision, the dorsal fractures may be approached through the floor of the fourth extensor compartment. This exposure can also allow for DRUJ arthrotomy, through the floor of the fifth extensor compartment, to assist with reduction of the sigmoid notch if needed. The fragment can then be stabilized with K wires, a small plate, or fragment-specific fixation or with the distal and ulnar screws from the volar plate. Dorsal plates should always be applied with careful attention to minimize any prominence and may need to be removed if any tendon irritation is noticed. If there is any concern that the fracture requires specific protection, then the forearm is immobilized for the first few weeks in a Munster-type splint in neutral forearm rotation. Early gentle 30° pronation or 30° supination forearm rotation at 2 to 3 weeks with a removable Munster splint provides a good balance of protection and motion.

Fig. 4. Axial CT scan of a shear-type injury to the sigmoid notch. The fragment includes the radial attachment of the dorsal radioulnar ligament with a small amount of subchondral bone and dorsal comminution.

Although the flexor carpi radialis approach is the most common for volar plating, the volar marginal fragment may be approached using a window on the ulnar side of the flexor tendons and radial side of the flexi carpi ulnaris (FCU) and ulnar nerve and artery. Again careful reduction and fixation is completed using either figure-of-eight suture, tension band, or fragment-specific fixation as needed.[104] Careful physical and fluoroscopic examination should be conducted to confirm the reduction and stability of the fracture fragments and the DRUJ.

Distal Ulna Fractures

Lafontaine and colleagues[105] have described the potential instability of combined distal radius and ulna fractures, particularly in patients older than 60 years. Although conservative treatment of distal ulna fractures typically is not related to late instability of the DRUJ, complications have been reported within a series of 19 (6%) distal ulna fractures that accompanied 320 distal radius fractures. Complications included 2 comminuted distal ulna fractures that were associated with nonunion, 4 of 5 simple neck fractures that had marked restriction of rotation, and 3 other cases that had fracture callus encroachment of the DRUJ that limited forearm rotation.[106] McKee and colleagues,[107] Ring and colleagues,[108] and Fernandez and colleagues[109] have reported on the potential complications, especially nonunion of the radius, with combined distal radius and distal ulna fractures.

In the authors' experience with newer locked volar plating techniques that stabilize the distal radius, many distal ulna fractures are relatively stable after reduction and stabilization of the distal radius fracture and may be treated with supplemental immobilization in a Munster-type splint or cast in neutral forearm rotation.[110] However, unstable, comminuted, or displaced distal ulnar neck and head fractures that accompany distal radius fractures may benefit from surgical treatment.[110,111] With current techniques available to stabilize distal ulna fractures, an attempt at reduction and fixation, when required, is important to maintain the most normal DRUJ congruence, stability, and motion. Options for operative fixation of these fractures include percutaneous K wires, which provide support, even with osteoporotic bone, but this technique requires postoperative immobilization and has morbidity associated with pin site irritation and infection. ORIF may allow secure fixation and earlier motion, but internal fixation may also be challenging because of small, comminuted, or osteoporotic fracture fragments. Plate position on the ulna requires careful attention so that it does not interfere with the DRUJ. The subcutaneous location of the bone and the location of the superficial branch of the ulnar nerve also emphasize the importance of a relatively low-profile implant to minimize symptoms from prominent hardware. When considering ORIF of the distal ulna (head and neck), smaller plate sizes may be appropriate, but traditional plate sizes should be maintained when stabilizing more diaphyseal or metadiaphyseal ulna fractures.

Good results have been reported after ORIF of distal ulna fractures that were associated with distal radius fractures with either condylar blade plate fixation[111] or 2-mm locking plate fixation (**Fig. 5**).[110] Results were favorable in each series with respect to union, motion, and function. The condylar ulnar plate was removed in 7 of 24 patients, and no locking plates required removal; this difference may have been related more to surgeon preference toward plate removal.[110,111]

Locking plate fixation offers a few potential advantages over condylar blade plate fixation. Locking plates allow for a lag-type locking screw and also for more than 1 locked peg to be inserted into the distal fragment, which may enhance articular reduction and stability. In either case, a low profile plate is advantageous when trying to minimize hardware prominence in this subcutaneous location. Stable fixation of the ulnar head fracture

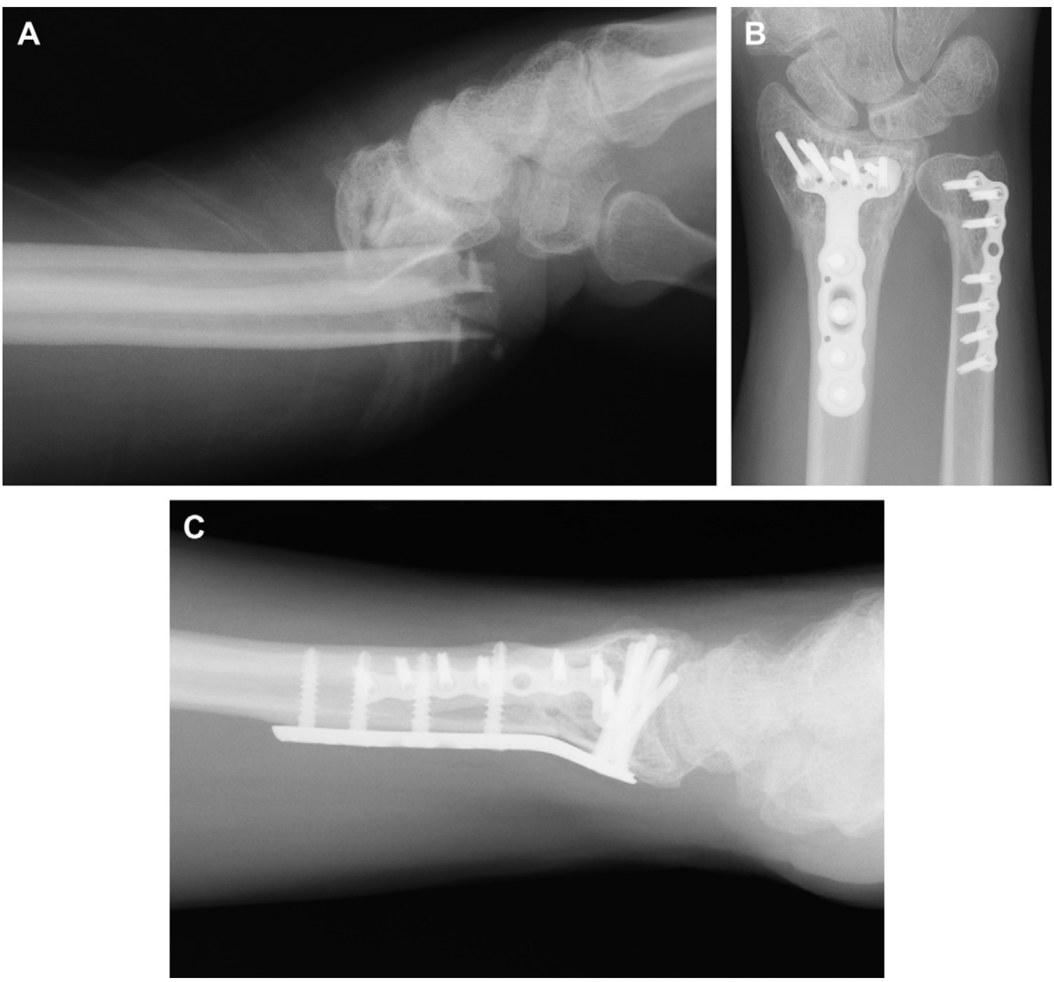

Fig. 5. Comminuted, displaced distal radius fracture and distal ulna fracture (*A*) fixed with a 2.0-mm locking plate of the distal ulna fracture and volar locking plate fixation of the distal radius fracture as shown on AP (*B*) and lateral (*C*) views.

allows for early motion of the DRUJ and ideally may help preserve forearm rotation.

These fractures are typically approached from the ulnar aspect of the wrist, in the ECU-FCU interval, and require careful identification and protection of the dorsal sensory branch of the ulnar nerve. In general, the most helpful step in obtaining a reduced ulna is a well-aligned distal radius and a reduced DRUJ. All efforts should be made to obtain an anatomic reduction and secure fixation of the distal radius, especially with respect to length and correction of the coronal plane translation, in addition to the volar tilt and radial inclination. The distal ulna fracture can then be reduced and temporarily stabilized with any technique, and K wires are often helpful to hold the initial reduction. Definitive fixation can then often be achieved through fragment-specific, fixed-angle, or locked-plate fixation. In addition, if there is an associated ulnar styloid fracture or foveal avulsion, these may be incorporated into the repair. In general, if the comminuted, intraarticular, or displaced distal ulna fracture can be repaired, especially in younger patients, it is likely preferable to either resection or implant arthroplasty.

SUMMARY

Acute dislocations of the DRUJ can occur in isolation or in association with a fracture to the distal radius, radial metadiaphysis (Galeazzi fracture), or radial head (Essex-Lopresti injury). Distal ulna fractures may occur in isolation or in combination with a distal radius fracture. Both injury patterns are associated with relatively high energy. Successful outcomes are predicated on anatomic restoration and stability of the DRUJ.

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