The Distal Radioulnar Joint

Peter C. Tsai, M.D., and Nader Paksima, D.O., M.P.H.

Abstract

The distal radioulnar joint (DRUJ) acts in concert with the proximal radioulnar joint to control forearm rotation. The DRUJ is stabilized by the triangular fibrocartilage complex (TFCC). This complex of fibrocartilage and ligaments support the joint through its arc of rotation, as well as provide a smooth surface for the ulnar side of the carpus. TFCC and DRUJ injuries are part of the common pattern of injuries we see with distal radius fractures. While much attention has been paid to the treatment of the distal radius fractures, many of the poor outcomes are due to untreated or unrecognized injuries to the DRUJ and its components.

The distal radioulnar joint (DRUJ) has been extensively studied; however, much debate remains concerning its stabilizing elements. Osseous or soft tissue injuries about the DRUJ are relatively common. Moreover, malunions of the distal radius or ulna, or both, may manifest as pain and rotational difficulties. This review examines the anatomy, classification, physical and radiologic examinations, and the treatment of DRUJ injuries, with a focus on distal radius fractures.

Anatomy and Stability

The DRUJ is conferred stability through intrinsic and extrinsic mechanisms. Intrinsic stabilizers include the triangular fibrocartilage (TFC), the volar and dorsal radioulnar ligaments, the capsule, and the ulnar collateral ligament. Extrinsic stability is achieved through static and dynamic forces. The extensor carpi ulnaris (ECU) subsheath and the interosseous membrane (IOM) are assisted by the pronator quadratus, which actively compresses the ulnar head into the sigmoid notch, and by the flexors and extensors of the forearm, which dynamically compress the DRUJ.

The bony and ligamentous restraints of the DRUJ enable controlled pronation and supination.[1] Though slightly asymmetric to the ulnar head, the sigmoid notch has been shown to contribute approximately 20% of the stability of the DRUJ.[2,3] The larger radius of curvature of the sigmoid notch results in a shallow concavity in comparison to the convex ulnar head. As a result, the ulna can translate both volarly and dorsally, allowing full pronation and supination while still accommodating the crossing over of the radius on the ulna (in pronation, the ulna translates 2.8 mm dorsally from neutral and in supination translates an average of 5.4 mm volarly). The IOM tethers the radius and ulna at the proximal radioulnar joint and along the length of the forearm.[4] Consequently, the DRUJ has an arc of motion of approximately 150°, while the hand has a range of motion of 180° on the forearm axis. The forearm axis itself lies between the radial head and the distal ulna.

Motion at the DRUJ occurs through the ulna, seated within the sigmoid notch, and the gliding undersurface of the fibrocartilaginous disk of the triangular fibrocartilage complex (TFCC) (Fig. 1). The volar and dorsal radio-ulnar ligaments are continuations of the deep fascia of the deepest volar and dorsal muscular layers [flexor digitorum profundus (FDP)-flexor pollicis longus (FPL) and extensor digitorum comunis (EDC)-extensor digiti quinti (EDQ), respectively] (Fig. 2).[3] The distal edges of both the dorsal and volar fascia merge with the articular disk. This disk is then attached by thick tissue to the base of the ulnar styloid and by thinner tis-

Peter C. Tsai, M.D., was a Chief Resident in the Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, New York, and is currently in private practice with the Hawaii Permanente Medical Group, Honolulu, Hawaii. Nader Paksima, D.O., M.P.H., is Clinical Assistant Professor, New York University School of Medicine, Division of Hand and Wrist Surgery, Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, NYU Langone Medical Center, New York, New York.

Correspondence: Nader Paksima, D.O., M.P.H., Suite 8U, 530 First Avenue, New York, New York, 10016; npaksima@gmail.com.

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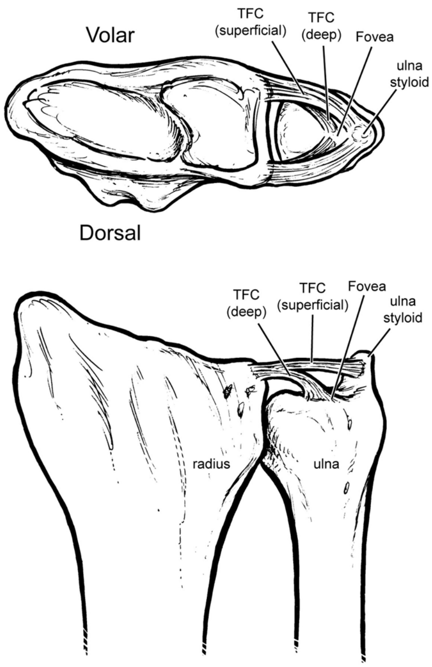

Figure 1 Anatomy of the DRUJ.

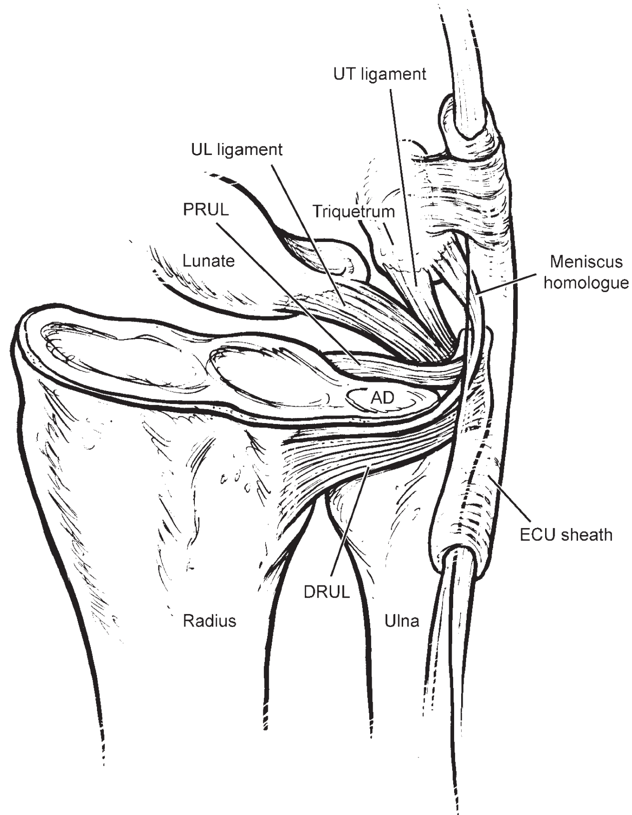

Figure 2 Deep ligaments of the DRUJ.

sue to the edge of the radius just proximal to the radiocarpal articular surface. The distal surface of the TFCC is a bearing surface for the lunate and forms a sling between the distal radial articular surface and the ulnar collateral ligament.[5]

The soft tissues play an important role in stability of the joint during rotation. Many studies have sequentially sectioned DRUJ soft tissue restraints.[6] Three landmark articles addressed mechanisms of DRUJ stability. First, in 1985, af Ekenstam and Hagert explored the joint using cadaveric dissection.[7] They excised the central articular disc to examine the TFCC at the level of the insertion of the ligamentum subcruentum on the fovea of the ulna. As a result, their conclusions were based primarily on the role of the deep fibers of the TFCC. Then, in 1991, Schuindet and colleagues studied the joint using a stereophotogrammetric method that measured tension across the TFCC by the movement of phosphorescent markers.[8] These markers rested on the surface of the TFCC, and their measurements, therefore, represent tension across only the superficial fibers of the TFCC. The two papers yielded conflicting results and sparked a controversy that lasted 9 years. Finally, in 1994, Hagert[9] reconciled the conclusions of these two research groups by explaining the role of each in yet a third article, and included his assertion that the 1985 article held true regarding the deep fibers of the TFC complex, while the 1991 article correctly described the role of the TFCC's superficial fibers. When the findings in all three papers are considered in concert with one another, the role of the TFCC in supination and in pronation is level-dependent and is not a matter of dispute. The deep fibers of the ligamentum subcruentum are, as af Ekestam and Hagert described, intrinsic stabilizers of the DRUJ. The palmar fibers prevent pathologic palmar translation of the radius and carpal bones during pronation, while the dorsal fibers buttress the joint during supination. Conversely, as detailed by Hagert, the superficial dorsal fibers of the TFCC provide dorsal stability in pronation and palmar stability in supination.

The dorsal and palmar radioulnar ligaments are not the only TFCC components that confer stability to the DRUJ. The IOM plays several important roles, including force transfer from the radius to the ulna, providing an origin for several flexor and extensor muscles of the forearm; maintenance of longitudinal forearm stability; and support of the stability for the DRUJ. Watanabe and associates[10] examined the contribution of the IOM to DRUJ stability and found that dorsal dislocations of the radius relative to the ulna most likely indicated distal IOM rupture. In addition, they found that the distal IOM constrained the movement of the radius in all positions of forearm rotation; thereby, preventing its dislocation from the DRUJ. Their study indicated that the middle and proximal portions of the IOM were less important than the distal portion in conferring stability to the DRUJ.

The congruency of the DRUJ is maintained by a connection between the distal radius and the distal ulna. This attachment is created by the TFCC, including the sheath of the (ECU) and its attachment at the base of the ulnar styloid, and as well by the two ulnocarpal ligaments. Shen and coworkers[11] examined the role of the deep and the superficial distal radioulnar ligaments and the role of longitudinal stabilization of the DRUJ. They found that with sectioning of the deep DRUJ ligaments there is significantly more proximal migration of the radius with respect to the ulna, leading to increased ulnar positive variance. The volar and dorsal radioulnar ligaments not only provide stability with rotation, but also longitudinal restraint.

Dynamic stabilizers of the DRUJ include the extensor carpal ulnaris (ECU) and the pronator quadratus. In fact, these muscles are invested in fascia that is confluent with the dorsal and palmar radioulnar ligaments and, therefore, are intimately associated with the stability of the joint. The deep head of the pronator is the prime stabilizer of the DRUJ, whereas the superficial head is a more powerful pronator. Through viscoelastic forces, the deep head of the pronator actively compresses the ulnar head into the sigmoid notch in pronation and acts to do the same, but in lesser magnitude, during supination.[5]

DRUJ innervation is derived mostly from the anterior interosseous nerve on the ulnar side and by some lesser contributions from the posterior interosseous nerve. Ulnar innervation also occurs through branches entering from the dorsal side of the joint. Arterial supply is by a volar interosseous artery that may represent an end artery. This anatomical configuration may be responsible for nonunions seen following fractures of the ulnar styloid. A dorsal interosseous artery supplies the dorsal aspect of the DRUJ.[5]

Examination of the DRUJ

DRUJ injury must be suspected when, on examination, there is a lack of pronation or supination (with or without elbow injury). Dorsal dislocations of the ulna present with a dorso-ulnar prominence with a block to supination; in volar dislocations, a volar-ulnar prominence is associated with a palpable radial sigmoid notch and a block to pronation.[12] Instability can be evaluated by shucking the DRUJ in positions of neutral, supination and pronation, and should be compared to the contralateral DRUJ. Other tests can specifically assess injury to stabilizing aspects of the DRUJ, including ECU subluxation and TFCC tears. ECU subluxation or instability can be evaluated by testing for abnormal ECU motion during pronation and supination of the hand in ulnar deviation. TFCC tears can be evaluated using the highly sensitive "press test," which axially loads the wrist in ulnar deviation as the patient pushes him or herself up from a seated position.[13]

Radiography

Initial radiographic evaluation of the DRUJ includes a true lateral radiograph of the wrist, with the forearm in neutral rotation. A variation of 10° in either pronation or supination will result in an inaccurate lateral view that cannot be used to assess the DRUJ.[14] In addition to a true lateral, postero-anterior views of the wrist are helpful in assessing changes in overlap between the radius and ulna. Increased overlap indicates volar ulnar dislocation. In contrast, increased distance between the sigmoid notch and the distal ulna indicates dorsal ulnar dislocation. Ulnar styloid fractures at the base may suggest injury to the origin of the TFCC.

CT and magnetic resonance imagine (MRI) scans may also be used to evaluate the DRUJ. CT (computed tomography) is often used to evaluate DRUJ congruency. Several different methods have been described, including the Mino method,[14] the congruency method,[15] and the radioulnar ratio method.[16] The Mino method is based on two lines drawn on the volar and dorsal aspects of the distal radius, delineating the boundaries of where the ulnar head should lay. If more than 25% of the head is outside of the area formed by these two lines, then subluxation of the head has occurred.[14] The congruency method is a subjective measurement of the congruency from the distal ulna to the sigmoid notch.[15] The most recent method, described by Lo and colleagues evaluates congruity by the radio-ulnar ratio.[16] Although MRI can be used to examine the TFCC, no clinical study has used MRI to identify TFCC defects at the time of initial DRUJ injury.[17]

Isolated Injury to the DRUJ

Subluxations and dislocations without concomitant fracture of the forearm, distal radius, or ulnar styloid are uncommon but have been described.[4.] By convention, DRUJ dislocation is defined on the basis of the final location of the ulna. Dorsal dislocations are more common: the mechanism is hyperpronation. The mechanism for dorsal subluxation and dislocation is extreme pronation and extension, with a tightened ECU and ulnar carpal ligaments, which pull the ulnar head out through the dorsal capsule. TFCC avulsion and attenuation of the palmar radioulnar ligament will allow this dislocation.[12] While plain radiographs can reliably identify dislocation, a CT scan or fluoroscopy with examination of the uninjured contralateral side can identify subluxation.[18]

Acute dislocations can be categorized as simple or complex. Simple dislocations can be readily reduced or even undergo spontaneous reduction. Complex dislocations can be characterized by irreducibility or by an inability to maintain reduction.[19] Typical obstructions to reduction are the ECU and extensor communis, the TFC, and the extensor digiti minimi (EDM), either in concert or alone. Other etiologies for irreducibility include unrecognized proximal dislocations, mal-reduced distal radius fractures, or forearm fractures of both bones

Injuries Associated with Fractures

The most common fracture associated with DRUJ instability or dysfunction is the distal radius fracture.[20-25] Malunited distal radial fractures may cause derangement of the DRUJ by creating instability, incongruity, or ulnocarpal impaction. DRUJ incongruity may result from intra- and extra-articular fractures. The incidence of symptomatic TFCC rupture is not known; however, May and associates have shown that 11% to 19% of patients with distal radius fractures suffered from problems of the DRUJ.[26] It is known that distal radius fractures with associated DRUJ instability are associated with poorer outcomes than those fractures without DRUJ instability.[24,25,27] Ulnar styloid fractures accompany 51% to 65% of distal radius fractures. The effect of ulnar styloid fracture on the incidence of distal radius fracture-associated TFCC disruption varies by report. Geissler[28] performed an arthroscopic examination of 60 consecutive distal radius fractures with and without associated ulnar styloid fractures. He found a 16% incidence of TFCC disruption in cases involving a fractured ulnar styloid versus a 10% incidence of TFCC disruption in the cases where the ulnar styloid was intact.

Multiple studies have examined the impact of distal radial morphology on DRUJ mechanics. Kihara and coworkers[29] evaluated the effect of dorsal angulation on the DRUJ with and without sectioning of the TFCC and IOM. They found that incongruency of the DRUJ occurred most dramatically with a 10° dorsal angulation (effectively ~20° from anatomic volar tilt). This amount of angulation also caused IOM tightness with limitations in pronation and supination.[29] Residual subluxation of the DRUJ after distal radius fracture has also been shown to significantly reduce forearm rotation. Ishikawa and colleagues[30] examined the effects of distal radial malunion and deficits in forearm rotation and found that residual dorsal tilt resulted in limited pronation. Adams[31] reported that malunions with dorsal angulation, shortening, and translation had a negative effect on DRUJ function, whereas loss of radial inclination did not significantly alter DRUJ mechanics. Af Ekenstam[32] reported on the differing radii of curvature of the sigmoid notch and ulnar head. There is combined rotation and sliding of the DRUJ.

Radial shortening is associated with symptomatic ulnocarpal impaction between the ulnar head and the proximal carpal row. Traumatic TFCC injuries alone can cause 0.5 to 3.0 mm of proximal radial migration. Radial shortening secondary to traumatic or TFCC degenerative changes creates increased contact pressures along the ulnar-sided sling of the TFCC. This manifests as impaction and erosion against the lunate and lunotriquetral ligament.

Treatment

Decisions concerning treatment depend upon the etiology of the DRUJ disruption. DRUJ dislocations must first be assessed with true AP and lateral views of the wrist. Simple or complex dislocations not involving fractures can be treated by reduction and immobilization in a cast or with temporary pin immobilization. If cast immobilization is chosen, the forearm should be immobilized in supination for dorsal dislocations and in pronation for palmar dislocations. A sugar-tong splint or Munster splint (a forearm-based splint that has extensions which allow flexion extension of the elbow but limit forearm rotation) can effectively limit forearm rotation. Kirschner-wires may be used if the reduction cannot be held by the appropriate forearm rotation.

Simple ulnar dislocations require closed reduction maneuvers that typically involve either pronation or supination, depending on the direction of the dislocation, in conjunction with direct pressure over the prominent distal ulna. Complex (locked) dislocations require open reduction and removal of the offending elements, surgical evaluation and (if necessary) repair of the TFCC. The TFC is approached through the fifth and sixth extensor compartments and is then reattached to the distal ulna via nonabsorbable suture or anchors, or both. Arthroscopic repairs of the TFC act only to oppose the superficial fibers of the TFCC to the capsule of the DRUJ. The deep fibers are not addressed in terms of reinsertion to their foveal origins. Nonetheless, comparable results have been reported following arthroscopic and open repairs.[33-35]

Treatment of the DRUJ after distal radial fractures depends upon the etiology of DRUJ dysfunction and the functional demands of the patient. Extra-articular malunion can be addressed by extra-articular osteotomy and restoration of radial anatomy with respect to the sigmoid notch and the distal ulna. Malone and associates. evaluated the use of osteotomy of the distal radius and volar plating and found that not only did flexion and extension increase but pronation and supination increased, from 20% of the contralateral side to nearly 100% of the unaffected limb.[36] Similar findings were echoed by Thiavos and McKee.[37] Jupiter and Ring showed that treatment of malunions with early or late corrective osteotomy resulted in comparable results, gaining significant pronation and supination in either treatment group.[21]

Intra-articular malunions can be treated with intra-articular corrective osteotomy, distal ulna resection, the Sauvé-Kapandji procedure or prosthetic replacement.[38-40] Ring and coworkers[41] reported on intra-articular osteotomy for treatment of intra-articular malunion of the distal radius and found that the results were similar to the results attained after osteotomy for extra-articular distal radial malunions. The sigmoid notch has also been reported as a site of malunion correction. Two reports exist in the literature presenting cases of instability attributable to the sigmoid notch; subsequent osteotomy and grafting of the malunion resulted in stability of the DRUJ.[42,43]

Ruch and colleagues[44] evaluated arthroscopic TFCC soft tissue repairs in patients with distal radius fractures. They found that arthroscopically-assisted TFCC repair at the time of external fixation of the distal radius fractures resulted in good to excellent clinical results in 12 of 13 patients. The study population did not have any further complaint of ulnar-sided wrist pain. Unfortunately, this study did not include a control group.

Chronic dislocations with intact articular surfaces can be treated either with reconstruction or with salvage. Multiple anatomic reconstructions of the DRUJ have been evaluated in the medical literature. All of them have been associated with favorable results. Petersen and Adams[45] performed a biomechanical study evaluating the efficacy of the extra-articular DRUJ reconstructions. They identified shortcomings of direct and indirect radioulnar tether reconstruction. The anatomic reconstruction reported by Adams and Berger[46] used a tendon graft to fashion an intra-articular reconstruction of the DRUJ ligaments. Stability was reportedly achieved in 12 of 14 patients. The reconstruction failed in only two patients: one with incompetent wrist ligaments and one with a sigmoid notch deficiency. The investigators proposed this reconstruction for those with intact wrist ligaments and articular surface preservation.

Chronic dislocations with articular degeneration require one of several salvage procedures, including the Darrach, Sauve-Kapandji, hemiresection, or replacement.[38-40] Initially described in 1912, the traditional Darrach procedure entailed a subperiosteal distal ulnar resection with retention of the distal ulnar styloid.[47] The subperiosteal resection was later altered to extraperiosteal removal of the distal ulna to prevent regeneration of the distal ulna. The procedure is useful when rotation is limited and when DRUJ dysfunction is due to a shortened radius, recurrent dislocation, late instability and pain. Complications include "dynamic radio-ulnar convergence," and distal radioulnar convergence, as described, in 1996, by Mckee and Richards.[48] They postulated that the convergence was due to muscular forces. Their study also found that approximately 8% of patients with this convergence were symptomatic and that symptoms were positively correlated with the extent of distal ulnar resection. Nonetheless, patients were satisfied with the procedure. More recent studies in younger, more active patient populations have reported a lower incidence of patient satisfaction with the Darrach procedure. The Darrach is now reserved for an older, less active patient population.[38,39]

The Sauve-Kapandji procedure was described in 1936.[40] In this operation, the distal ulna is fused to the distal radius so that rotation occurs via a pseudoarthrosis created proximal to the arthrodesis. The preservation of the distal ulna allows the ulnocarpal sling to remain intact so that contact forces across the wrist are preserved. Frank instability or dislocation of the DRUJ is a relative contraindication for the Sauve-Kapandji approach. Taleisnik reviewed 23 patients of whom nine reported distal ulnar stump pain and two required reoperation.[49] When Nakamura and associates performed the procedure on 12 patients with chronic dislocations of the DRUJ, he found temporary ulnar stump pain in four of the 12 and persistent ulnar stump pain in an additional four of the 12.[50] Positive reports on the outcomes of the Sauve-Kapandji procedure state that patients retain 70% to 80% of grip strength and almost full pronation and supination.[51,52]

An alternative to fusion or resection is a hemiresection, of which several types have been investigated. The hemiresection procedure retains the distal ulnar styloid and removes the offending distal ulnar piece. Watson and Gabuzda[53] presented the distal ulnar hemiresection, which had been used since 1967. Bowers presented an interpositional hemiresection, a version of this procedure developed in the mid-1970s. Watson then went on to further refine the procedure into the "matched" hemiresection, which emphasized the congruency of the resected distal ulna to the retained sigmoid notch.[53,54] Watson and Gabuzda reported good to excellent results were noted in 24 of 32 patients and that the outcome was related to the severity of the patient's initial problem. Pronation and supination were largely preserved, while providing for pain relief and return to function.

Few studies have compared these different procedures. Minami and coworkers[39] reported that the Darrach yielded inferior pain relief, and the Sauve-Kapandji and hemiresection afforded patients better pronation and supination; more patients were able to return to work following the Sauve-Kapandji procedure. In a comparison of the procedures for posttraumatic situations, George and colleagues[38] found the Darrach and Sauve-Kapandji to be equally ineffective in patients less than 50 years of age.

Prosthetics

Prosthetic replacements of the ulnar head continue to evolve. Stanley reviewed the results of 20 Swanson silastic ulnar head implants used in posttraumatic situations. The study revealed that 70% of patients had satisfactory results. However, 40% had tilting of the prosthesis and 15% had frank fracture of the implant. The Herbert prosthesis has been available since 1995 and can be used in situations where salvage in posttraumatic situations is necessary, or even to salvage an unsuccessful Darrach or Sauve-Kapandji procedure. This implant requires a competent TFCC as well as a congruent sigmoid notch. Complications following implantation of the ulnar head include recurrent instability, which may be multifactorial and attributable to technical errors, such as over-reaming or failure to recognize subchondral defects. Results of ulnar head replacement have been favorable, with maintenance of clinical and radiological results at 10-year follow-up.

Conclusions

The DRUJ is a complex articulation dependent upon both soft tissue and bony stability. The disruption of this complex can be purely ligamentous or can involve bony trauma. The DRUJ has been shown to be a source of pain following wrist trauma. Increasing attention has been given to the diagnosis and treatment of injuries in this region to maximize clinical, radiographic, and functional outcomes.

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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