

Distal Radius Instability and Stiffness: Common Complications of Distal Radius Fractures

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KEYWORDS

- Distal radius fractures • Distal radio-ulna joint
- Instability • Stiffness

There is a plethora of peer reviewed journal articles, manuscripts, and book chapters in the hand surgical and general orthopedic literature on methods of treating distal radius fractures. The overwhelming majority of these writings focus on providing guidance to treating surgeons for making the most appropriate choices needed to realign displaced distal radius fracture fragments and to re-establish painless function of the upper limb after trauma-induced fractures of the distal radius. Most investigators focus on the importance of articular congruity and alignment, emphasizing the critical nature of the articular support surface for the carpus. It is presumed that only with meticulous realignment of joint surface anatomy is long-term, healthy carpal mechanics possible. Until the 2 most recent decades, however, little emphasis has been placed on the great morbidity and compromise to upper limb function that is associated with distal radioulnar joint (DRUJ) pathology occurring with fractures of the distal radius.¹⁻³ Emphasis, however, in the literature regarding distal radius fracture management over the past hundred years has been on restoration of anatomic radiocarpal alignment. The premise of this article is emphasizing to treating surgeons that the attention they give to restoration of

anatomy of the DRUJ should be considered at least as important as the attention given to the radiocarpal relationship.

For more than 100 years, practicing clinicians have understood that forearm rotation (not radiocarpal flexion/extension or radioulnar deviation) is the critical movement of the upper limb that enables the hand to be put or placed advantageously in space, into positions that most maximize the ability of the hand to perform work (Fig. 1). DRUJ health is critical to the effectiveness of hand function. In extreme cases of distal radius fracture where resultant painful traumatic arthritis of the radiocarpal joint threatens effective hand function, arthrodesis of the wrist can eliminate pain, provide stability, and restore effective use of the hand. Contrary to this, painful traumatic arthritis of the DRUJ resulting from severe fracture extension through the sigmoid fossa severely compromises forearm rotation by stiffness and pain, leading to incapacitating dysfunction of the entire upper limb. The ability to effectively put or place the hand in space has been lost. Without healthy, painless, and stable forearm rotation, limb function is lost; substitution of combined shoulder/elbow kinematics is inadequate to compensate for the stiff forearm. Function of the

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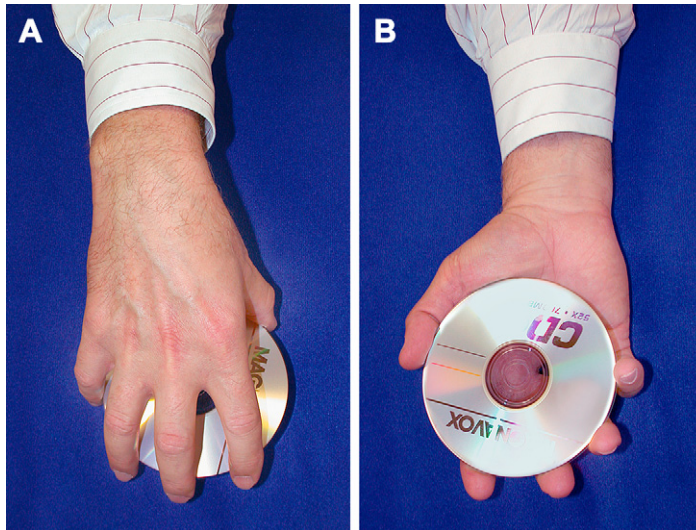


Fig. 1. Rotation of the forearm is critical for putting or placing the hand in space for maximum function (A,B).

limb would be severely inhibited by DRUJ arthrod-esis.⁴⁻⁶

In spite of this common awareness, too little attention has been focused on the DRUJ in treating fractures of the distal radius. As discussed in this article, the energy of injury can result in fracture comminution that extends into the sigmoid fossa (resulting in significant displacement and disruption of DRUJ mechanics), axial compression, and shortening of the distal radius relative to the ulna, resulting in ulnar-plus variance,⁷ or into the guidance mechanism for forearm rotation between distal radius and ulna by damage to the triangular fibrocartilage (TFC). This article also points out how stiffness of forearm rotation can result from a well-treated distal radius fracture and how this function-compromising complication can be effectively treated to restore healthy upper limb function.

BASIC ANATOMY

The seat of the distal ulna is a fulcrum around which all distal forearm movement and mechanics take place (freedom of rotation of the radial head at the proximal radioulnar joint [PRUJ] of the elbow is critical to normal forearm mechanics; because this article is focused on pathology of the distal radius, only the DRUJ is considered). In the bipedal human condition, the radius/carpus/hand unit rests squarely on this fulcrum, with gravity and an extrinsic extensor and flexor muscle load pulling the sigmoid fossa (the DRUJ contact area of the radius) securely against the seat of the ulna in neutral forearm rotation.¹⁻³

In neutral rotation, the radius/carpus/hand unit sits squarely on the fulcrum provided by the ulnar seat. In equilibrium, the load borne by the hand (F) multiplied by the distance of this load from the DRUJ fulcrum (L) must equal the force required to stabilize the radial head at the PRUJ (F') multiplied by the length of the entire forearm (L') (**Fig. 2**). Therefore, in equilibrium, $F \times L = F' \times L'$. The total load borne by the DRUJ fulcrum (the seat of the ulna) is referred to as the joint reaction force (JRF) (**Fig. 3**). This JRF is equal to the sum of the moments ($F \times L$) on both the distal and proximal sides of the DRUJ fulcrum. Therefore, the DRUJ JRF = $F \times L + F' \times L'$ (**Fig. 4**). The JRF at

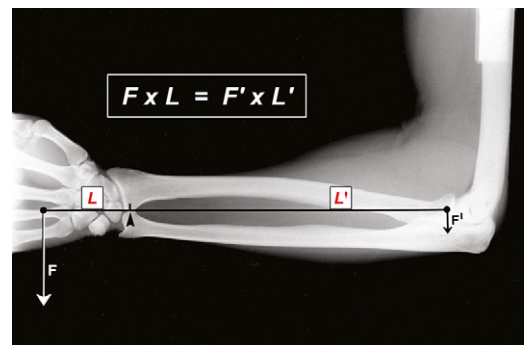


Fig. 2. In equilibrium, the moments on the distal and proximal sides of the ulnar seat fulcrum must be equal. The load in the hand (F) times the distance of the load from the fulcrum (L) must be equal to the length of the forearm from the fulcrum (L') times the resistance to displacement provided by the annular ligament at the radial head (F').

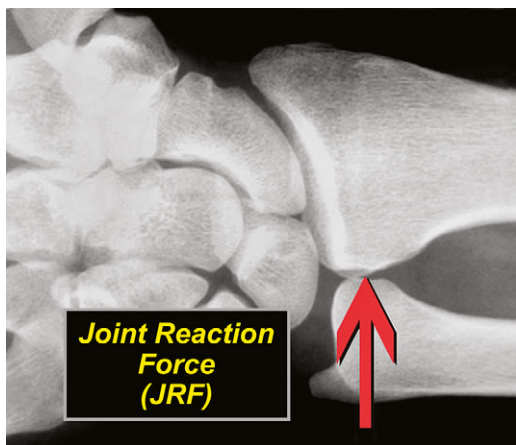


Fig. 3. The seat of the ulna is the fulcrum for all DRUJ mechanics. Because most upper limb activities in the bipedal human occur with the radiocarpal unit “on top” of the ulnar seat, the JRF at the DRUJ can be enormous. The JRF is proportional to the load in the hand, the force of all muscles acting to pull the radius and ulna together for stability, and the force of gravity acting on the hand/forearm unit.

the DRUJ can be enormous, easily 6 to 8 times body weight.

The ulna does not participate in actual rotation of the forearm. It is fixed to the humerus at the ginglymus ulnotrochlear joint. The ulna flexes and extends at the elbow but does not rotate. All forearm rotation involves a pivoting motion of the radius/carpus/hand unit from a position parallel to the ulna in full forearm supination to a crossover position of the radius relative to the ulna in full pronation (**Fig. 5**). Because the ulna is fixed with respect to forearm rotation, the radius shortens relative to the fixed ulna length as it crosses over the ulna into pronation.

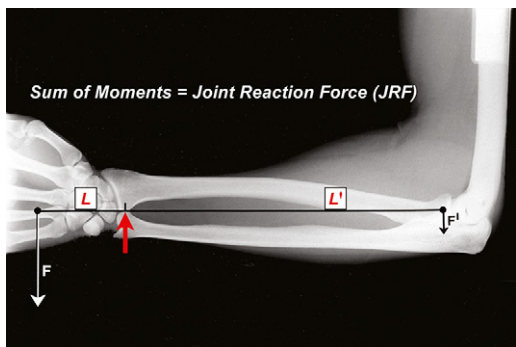


Fig. 4. The sum of the moments on the distal and proximal sides of the fulcrum equals the JRF at the DRUJ.

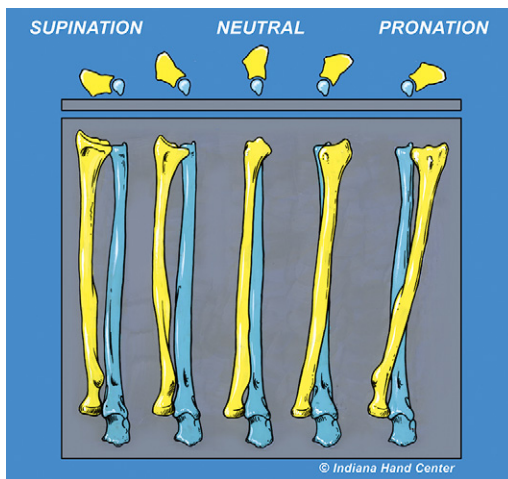


Fig. 5. As the radius rotates from full supination to full pronation around a nonrotating, fixed ulna, the radiocarpal unit shortens relative to the ulna, resulting in ulnar-plus variance in the pronated position. (Courtesy of The Indiana Hand to Shoulder Center.)

As the radial head at the PRUJ rotates around the fixed, longitudinal axis of rotation, the sigmoid fossa of the distal radius rotates and translates relative to the fixed seat of the ulna. In full supination, the principal axis of load bearing (the principal axis is an engineering term used to define an imaginary point at the center of an infinite number of cluster points between 2 loaded surfaces in contact with each other) between sigmoid fossa and ulnar seat is volar and proximal.

In full forearm pronation, with radius crossed over the ulna (and relatively shortened), the principal axis of load bearing is at the dorsal and distal margin of the sigmoid fossa. Thus, through a full arc of forearm rotation, the center of contact points on the articular surfaces of the sigmoid fossa and ulnar seat forms a tracking line along the fossa, from proximal-volar in supination to distal-dorsal in pronation (**Fig. 6**).

Long-term health of the diarthrodial DRUJ is based on cartilage integrity and anatomic structures that guide the radius around the ulna from full supination to full pronation. Surface cartilage thrives under conditions of physiologic compression.

In cases of intra-articular injury to the DRUJ created by distal radius fracture, resultant step-off deformity generates surface shear forces at the DRUJ causing chondrolysis, which predisposes the joint to traumatic arthritis. The best efforts at anatomic alignment of displaced intra-articular DRUJ fracture fragments are to reduce this propensity toward painful traumatic arthritis that

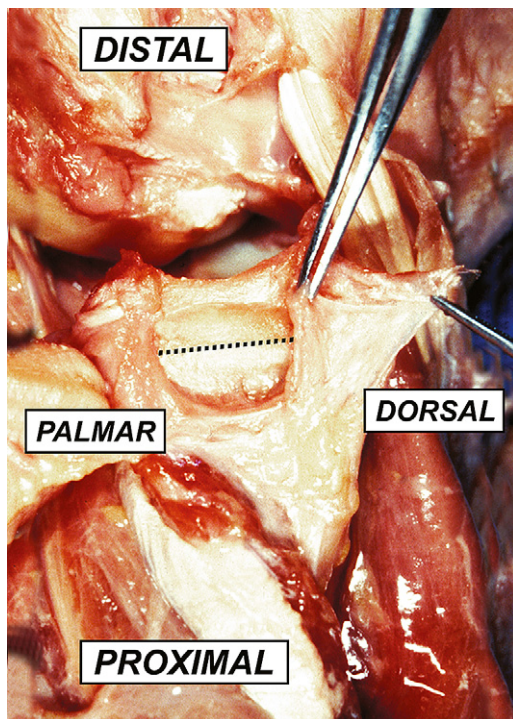


Fig. 6. The principal axis of load-bearing tracks across the sigmoid fossa from proximal/volar in supination to distal/dorsal in pronation.

predictably results from step-off deformity and loss of DRUJ cartilage, secondary to shear forces.

DRUJ stability through a full arc of pronosupination is provided by extrinsic structures arising proximal to the distal end of the ulna and intrinsic structures at the distal end of the ulna itself. Extrinsic stabilizers contribute DRUJ guidance to a minor degree. They consist of (1) the extensor carpi ulnaris tendon (ECU), (2) the sixth dorsal compartment subsheath for the ECU,^{8,9} (3) the superficial and deep heads of the pronator quadratus muscle,¹⁰ and (4) the interosseous ligament.¹¹

Much more significant for providing DRUJ stability through its physiologic arc of pronosupination is its intrinsic stabilizer, the TFC.^{1-3,12-21} This small, architecturally complicated piece of connective tissue is critical for normal DRUJ mechanics. Among other components (**Fig. 7**), the TFC consists of deep and superficial peripheral portions, coursing along its dorsal and volar margins. These peripheral fibrous portions of the TFC are well vascularized.^{14,15} They attach the medial border of the distal ulna to the medial border of the distal radius and are also referred to as the dorsal and palmar limbi of the TFC. They are responsible for providing primary guidance to the radius/carpus/hand unit as it rotates

and translates around the fixed ulna (see **Figs. 5** and **6**).

Injuries to the peripheral TFC in association with distal radius fractures have the potential to disrupt the critical rotation/translation DRUJ guidance system, leading to painful ulnar-sided wrist instability and, if left untreated, shearing of the cartilage surfaces of the DRUJ and eventual traumatic arthritis. This predictable degeneration of joint surfaces can occur even with displaced, extra-articular distal radius fractures that do not involve fracture extension into the DRUJ articular surface. Articular congruity and DRUJ surface alignment are critical for long-term healthy function after trauma.

The most important component of the TFC for providing rotation/translation guidance for the radius/carpus/hand unit is the deep component, called the ligamentum subcrurium. This thick, strong, fibrous connective tissue arises at the well-vascularized fovea of the distal ulna and attaches to the medial volar and dorsal margins of the distal radius, just distal to the sigmoid fossa. Because of its wide angle of attachment from origin to insertion, the ligamentum subcrurium (dorsal and volar components) is more effective in providing guidance for rotation than the superficial components of the peripheral TFC, which originate from the more medial ulnar styloid, and blend together with the fibers of the ligamentum subcrurium on the medial, distal radius (**Fig. 8**). The well-vascularized superficial and deep components of the TFC envelope the poorly vascularized articular disc of the TFC, the central structure responsible for axial load transfer from the ulnar side of the carpus to the pole of the distal ulna (see **Fig. 7**).

CONSEQUENCES OF SUPRAPHYSIOLOGIC LOADS ON THE TFC IN ASSOCIATION WITH FRACTURES OF THE DISTAL RADIUS

The association of ulnar styloid fractures with distal radius fractures has been observed even before the advent of radiographs more than 100 years ago. Although the mechanism of injury to the radius has been easy to reproduce (conceptually and in the laboratory), the mechanism of injury to the distal end of the ulna has been more of a mystery until the past 25 years. In 1990, Pogue and colleagues²² published a landmark article from their laboratory data, shedding considerable light onto the black box of disorders at the distal end of the ulna. These researchers attempted to simulate extra-articular fractures of the distal radius by removing a variety of metaphyseal cadaver bone sections and observing whether or

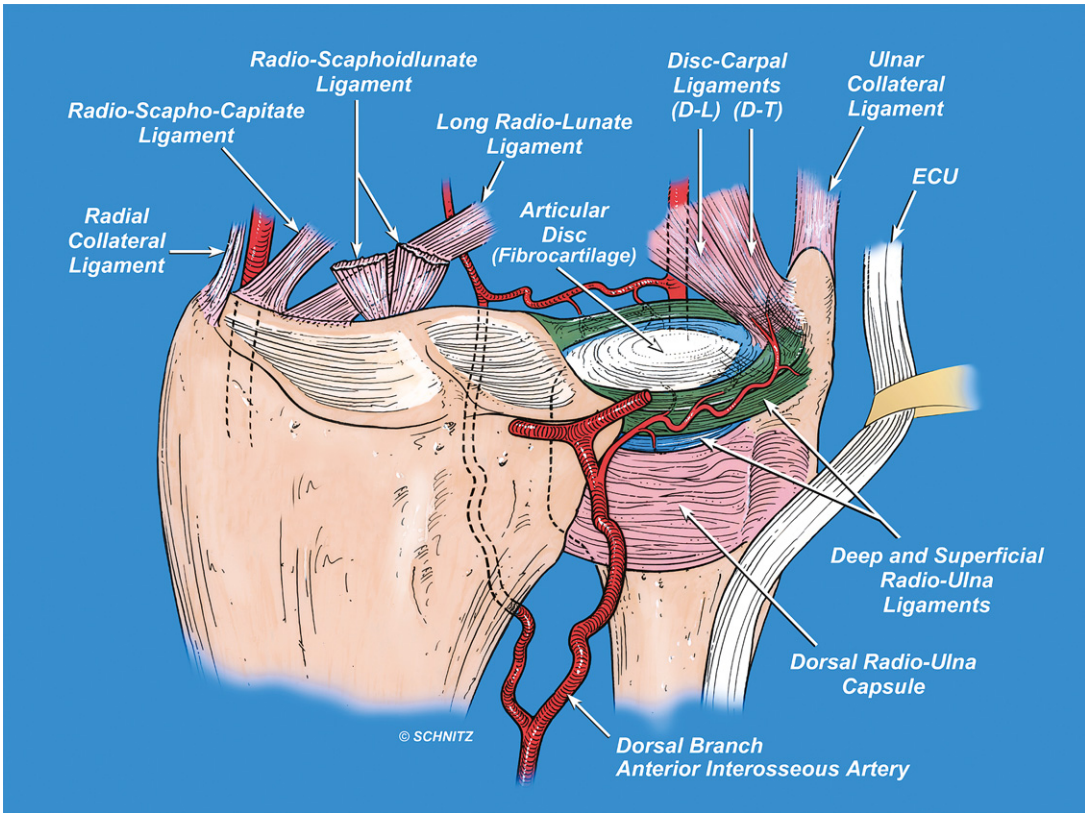


Fig. 7. The primary intrinsic stabilizer of the DRUJ is the TFC. The TFC complex consists of superficial (green) and deep (blue) radioulnar fibers, the 2 disc-carpal ligaments (disc-lunate and disc-triquetral), and the central articular disc (white). The articular disc is responsible for load transfer from the medial carpus to the pole of the distal ulna, particularly in ulnar deviation. The vascularized, peripheral radioulnar ligaments (green and blue) are nourished by dorsal and palmar branches of the posterior interosseous artery, and are responsible for guiding the radiocarpal unit around the seat of the ulna. (Courtesy of The Indiana Hand to Shoulder Center.)

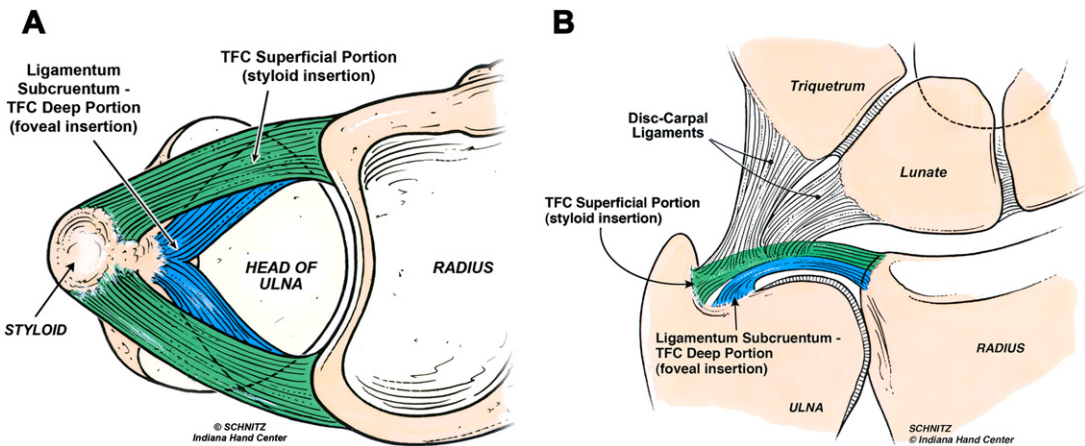


Fig. 8. The TFC supporting the DRUJ has two distinct origins from the ulna (A). The deep portion (blue) is referred to as the ligamentum subcruentum and originates from the fovea, just medial to the articular surface of the ulnar pole. The superficial portion (green) originates from the base of the ulna styloid. These 2 independent insertions allow different components of the TFC to tighten in different positions of forearm rotation (B). The angles of origin to insertion of these 2 components of the TFC are quite different, making the deep, blue fibers (ligamentum subcruentum) considerably more effective as a DRUJ stabilizer through the full arc of forearm pronosupination. (Courtesy of The Indiana Hand to Shoulder Center.)

not the remaining fragments of radius could be apposed without osteotomizing the ulnar styloid through its base (the components of the TFC remained intact). The investigators demonstrated that they could shorten the distal radius 2 mm and 4 mm and still bring the remaining bone segments together securely without releasing the tethering effect of an intact TFC by cutting through the base of the ulnar styloid. Similarly, they were able to change the inclination of the radiocarpal articular surface to 10° and the tilt of the distal radius to 0° , both without cutting through the base of the ulnar styloid. Shortening the radius more than 4 mm, changing the radius inclination to 0° , and creating a dorsal radius tilt of 15° or 30° , however, were all unachievable without first cutting through the ulnar styloid base, thus relieving the tethering effect of the intact TFC. Pogue and colleagues²² theorized, "Severely displaced distal radius fractures not displaying an ulnar styloid fracture might have a TFCC disruption."

The implications of this work are considerable: in vivo, as the distal radius fails from the usual

mechanism of fall on the outstretched hand; supraphysiologic forces surpass the load-bearing capacity of the bone. The bone fractures (shortening, collapsing dorsally, tilting radially, or a combination) as sudden and extreme force is propagated through the bone and farther on into the TFC through the limbi of its peripheral fibers. If displacement of fracture fragments is great enough, then the connective tissue of the TFC itself will fail (resulting in a peripheral tear) or the kinetic energy dissipated by the failing, collapsing distal radius will continue along its path of least resistance (the intact TFC) into the ulnar styloid (Fig. 9). If the energy bolus is sufficient to cause displacement of the radius fracture fragments, it can cause an avulsion fracture of the ulnar styloid through its base. Basilar styloid fractures in association with displaced fractures of the distal radius are common; they occur because of the anatomy of the origin of the superficial component of the TFC from the proximal portion of the styloid.¹⁻³

With a thorough understanding of the anatomy of the TFC, it can be appreciated that if an avulsion fracture of the ulnar styloid occurs (via extreme

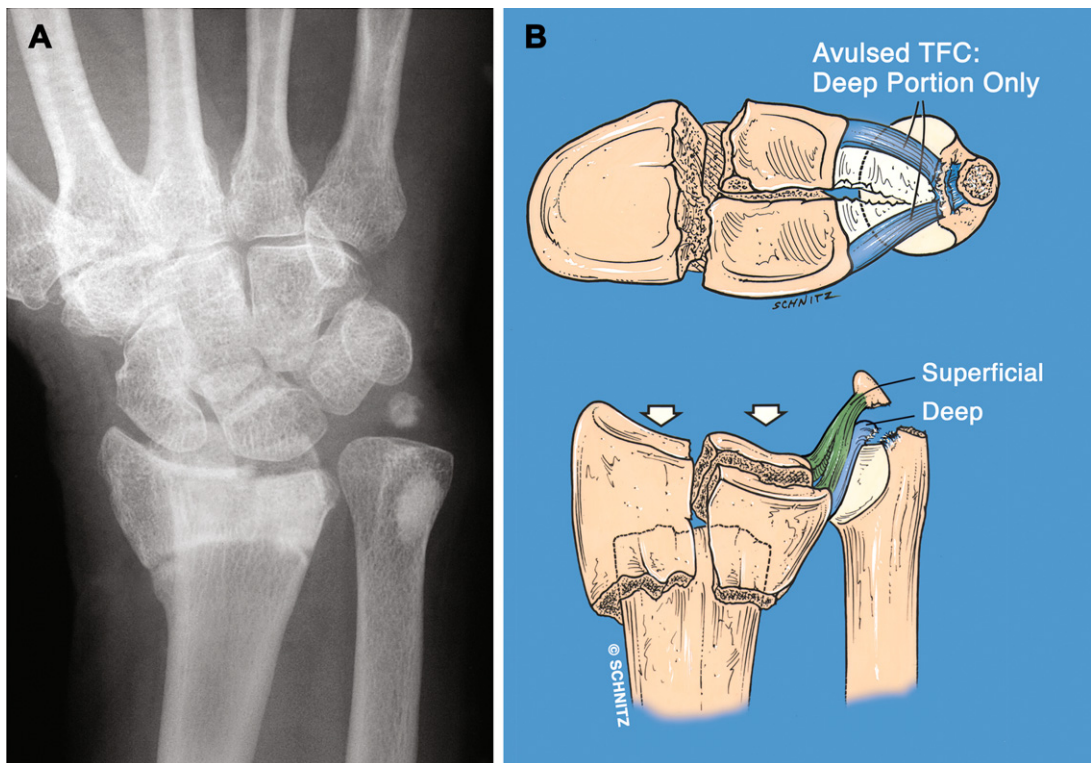


Fig. 9. Anteroposterior radiograph (A) and artist rendering (B) of the effect of a distal radius fracture on the TFC. Displacement or shortening of the distal radius transmits forces through the tethering TFC, tearing the superficial and deep fibers from their respective origins (styloid and fovea, respectively) or avulsing the ulnar styloid from its base, with tearing of the deep ligamentum subcrucium from its foveal origin. Shortening and fragment collapse of the distal radius must be significant enough to affect the TFC. (Courtesy of The Indiana Hand to Shoulder Center.)

tension on the superficial TFC from a collapsing distal radius fracture) and if the ulnar styloid is displaced, then—by definition—the deep fibers of the TFC (ligamentum subcrurium, originating at the fovea of the distal ulna) must also be torn from their origin. The degree of separation of the ligamentum subcrurium from its foveal origin must be equal to the degree of displacement of the ulnar styloid from its base (see **Fig. 9**). Because the superficial and deep components of the TFC run together intimately and insert together on the medial radius, separation of the fractured ulnar styloid from its base (with an intact superficial TFC component) must equal separation of the failed ligamentum subcrurium from its foveal origin.

Although the article by Pogue and colleagues²² is important in providing insight into potential failure of TFC components in association with fractures of the distal radius, their work was only a laboratory simulation of radius trauma. It could not address inherent elasticity or stretchability of the tissue of the TFC itself. Is it fair or accurate to suggest that every displaced basilar styloid fracture must be associated with a complete separation of the ligamentum subcrurium from its foveal origin, resulting in DRUJ instability? In the clinical arena, the inherent elasticity of the peripheral components of the TFC must be taken into consideration when discussing why certain catastrophic failures of the distal radius are associated with neither styloid fracture nor TFC injury. But the work of Pogue and colleagues provides fuel for thought. In every case in which an avulsion basilar ulnar styloid fracture is observed, thought should be given to carefully examining the DRUJ relationship by a stress test of the joint under anesthesia (**Figs. 10** and **11**). The potential for DRUJ instability always exists if a displaced distal radius fracture is associated with a basilar ulnar styloid fracture.



Fig. 10. Stress test of the dorsal, deep fibers of the ligamentum subcrurium for pain, mechanical instability, or both (findings must be compared with the opposite, uninjured side).



Fig. 11. Stress test of the volar, deep fibers of the ligament subcrurium for pain, mechanical instability, or both (findings must be compared with the opposite, uninjured side).

Whether or not surgical attention should be paid to the TFC or the displaced ulnar styloid fracture should be based on clinical findings obtained by examination under anesthesia. The following are guidelines I have used for many years to establish criteria for surgical management of the ulnar side of the wrist in cases of radius open reduction and internal fixation (ORIF) when the degree of initial radius fracture displacement suggests there should be legitimate concerns about DRUJ stability.

ALGORITHM FOR SURGICAL MANAGEMENT OF THE ULNAR SIDE OF THE WRIST IN ASSOCIATION WITH DISPLACED FRACTURES OF THE DISTAL RADIUS

Step 1: If a clinician thinks that indications are present for ORIF of a distal radius fracture for radiocarpal and DRUJ alignment, surgical stability of the radius must first be attained using whatever technique the surgeon thinks is in the best interest of the patient. **Fig. 12** shows severe fragment displacement requiring ligamentodesis plus percutaneous Kirschner (K)-wire fixation for alignment after application of a hand-forearm external fixator. In another example, **Fig. 13** shows rigid internal fixation achieved with a volar buttress locking plate and screws. DRUJ stability relies, then, predominately on the volar ligamentum subcrurium in pronation.

Step 2: With rigid stability of the distal radius fracture fragments achieved, a surgeon can stress test the stability of the DRUJ by fully supinating the forearm and trying to displace the distal ulna volarly. Full forearm supination renders the superficial volar fibers of the TFC ineffective, whereas stability relies almost entirely on the deep, dorsal fibers of the ligamentum subcrurium (**Fig. 14**). This provocative maneuver places supraphysiologic load on the dorsal fibers of the ligamentum



Fig. 12. Stability of a severely comminuted intra-articular distal radius fracture achieved by rigid external fixation and multiple percutaneous K-wire fixation. With radius stability achieved, the stability of the DRUJ can be tested by provocative maneuvers.

subcruentum, the most critical DRUJ stabilizer of the TFC in full supination. Landmark work published by Hagert in 1994²⁰ illustrates the importance of the deep fibers of the TFC when stressing the forearm in supination. Once a surgeon demonstrates any degree of DRUJ instability in supination, then the forearm can be pronated. As the sigmoid fossa of the radius translates volarly in pronation, the head of the ulna (seat and pole) moves under and outside the guidance control of the superficial dorsal TFC fibers (**Fig. 15**). Stress testing the volar fibers of the ligamentum subcruentum demonstrates how important this part of the TFC is in preventing supraphysiologic volar translation of the radius/carpus/hand (see **Fig. 14**).

Consider rupture of the entire peripheral origin of the TFC, except for the thinnest, yet intact portion of the volar ligamentum subcruentum. As the forearm is rotated into pronation, and the radius/carpus/hand unit passively translated volarly on the ulnar seat, the DRUJ will still be stable. As the examining surgeon rotates and translates the forearm into supination, however, injury to the dorsal ligamentum subcruentum will allow the sigmoid fossa to translate dorsally off the seat of the ulna, resulting in gross DRUJ instability in supination. Similarly, if there has been rupture of the entire TFC in association with the displaced distal radius fracture, but a thin portion of the dorsal ligamentum subcruentum remains intact, then, although passive supination of the forearm reveals the DRUJ to be stable, there would be gross instability in pronation (ie, supraphysiologic volar translation of the sigmoid fossa relative to the ulnar seat).

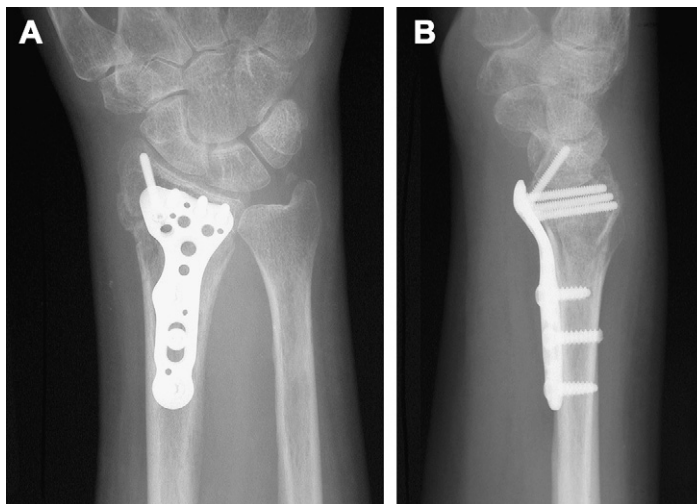


Fig. 13. (A–B) AP and lateral x-rays showing rigid internal or external fixation of a displaced distal radius fracture (in this case, by Acu-Loc plate and screws) affords the surgeon an opportunity to stress test the integrity of the components of the TFC.

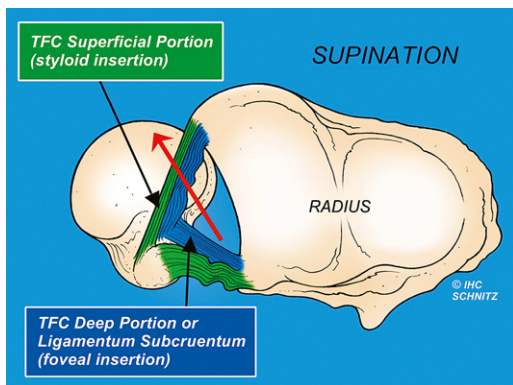


Fig. 14. An illustration of tightening of the dorsal, deep fibers of the ligamentum subcruentum as the radius rotates and translates dorsally off the seat of the ulna in supination. The head of the ulna translates along the sigmoid fossa, and herniates out from under cover of tightening superficial palmar TFC fibers, rendering these fibers ineffective in controlling DRUJ mechanics. (Courtesy of The Indiana Hand to Shoulder Center.)

If the TFC has been completely avulsed from the ulnar fovea and from the intact ulnar styloid (complete failure of deep and superficial fibers), then the DRUJ will be globally unstable when stress tested in pronation and supination. These also are the findings with complete foveal avulsion of the ligamentum subcruentum and a displaced fracture through the base of the ulnar styloid (see Fig. 9).

Step 3: The surgeon should next put on an extra pair of sterile gloves and perform the same stress maneuvers on the undamaged, contralateral

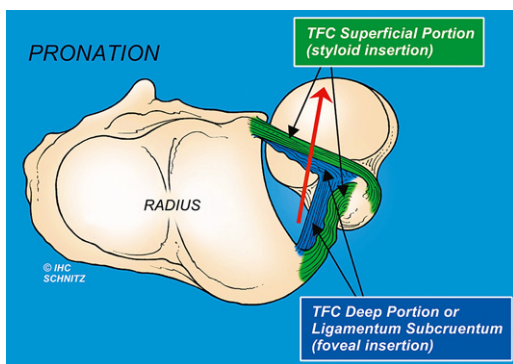


Fig. 15. An illustration of tightening of the volar, deep fibers of the ligamentum subcruentum as the radius rotates and translates palmarly off the seat of the ulna in pronation. The head of the ulna translates along the sigmoid fossa and herniates out from under cover of tightening superficial dorsal TFC fibers, rendering these fibers relatively ineffective in controlling DRUJ mechanics. (Courtesy of The Indiana Hand to Shoulder Center.)

forearm, sensing any differences in stability between the normal and injured sides.

When continuing to acquire information about the integrity of the TFC with a distal radius fracture that has required ORIF, surgeons should be cognizant of the important laboratory work by af Ekenstam and colleagues in 1984 and 1985^{13,18} regarding DRUJ instability with simulated distal radius fracture malunion and intact TFC components. Extra-articular malunions of the distal radius resulting from poorly reduced or inadequately fixed distal radius fractures are notorious for demonstrating concomitant DRUJ instability, even with the TFC uninjured. Not only is the radio-carpal articular surface malaligned, predisposing to many pathologic conditions, including carpal instability,²³ and not only is the tracking line for the principal axis of load bearing at the DRUJ improperly oriented for healthy mechanics (predisposing the DRUJ to cartilage breakdown from surface shear over time) but also the capacity of the dorsal limbi of the peripheral TFC to stabilize pronosupination of the radius/carpus/hand around the ulnar seat is rendered ineffective by the dorsal collapse of the distal radius malunion. The cadaver work of af Ekenstam and Hagert²⁴ simulates structural changes in TFC alignment with radius malunions of 30° dorsal tilt. The investigators demonstrate how—with an intact TFC—the DRUJ can appear grossly unstable as the sigmoid fossa translates and rolls dorsally off the ulnar seat. The fossa itself is no longer mechanically able to contain the ulnar seat, and the orientation of the dorsal fibers of the TFC in cases of malunion allows the seat of the ulna to seem to subluxate against the volar capsule of the DRUJ. The appearance is suggestive of an ineffective check-rein effect of the volar ligamentum subcruentum, but, in cases of dorsal malunion, collapse of the dorsal radius without TFC injury of any kind can allow the seat of the ulna to supraphysiologically translate volar relative to the sigmoid fossa.²⁴

Step 4: Demonstrable DRUJ instability associated with the distal radius fracture and coexistence of a basilar displaced ulnar styloid fracture indicate not only that energy introduced into the system by the injury has pulled off the styloid via the superficial peripheral fibers of the TFC but also, by definition, the ligamentum subcruentum has been avulsed from the fovea, leading to gross instability. By anatomically reducing the ulnar styloid by ORIF (Fig. 16), not only is the tension of the superficial TFC restored to normal but also the critical, injured ligamentum subcruentum is restored as closely as anatomically possible to the fovea, allowing for primary healing to take place at its origin.

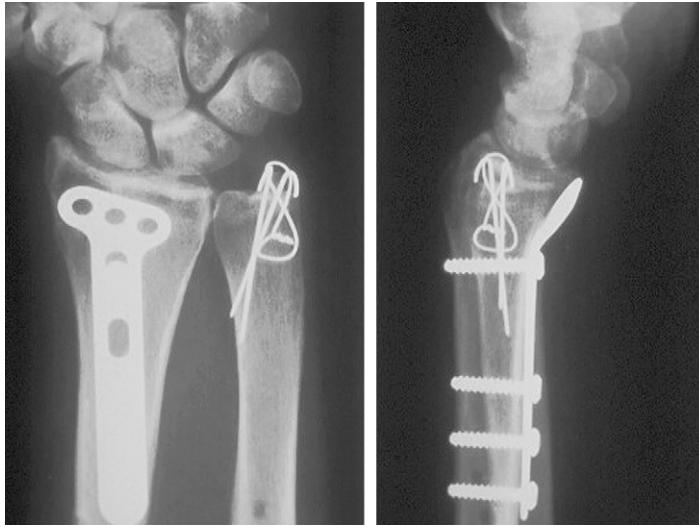


Fig. 16. Anteroposterior and lateral postoperative radiographs of a 36-year-old man who fell on his outstretched hand, resulting in a closed, comminuted extra-articular distal radius fracture, with avulsion of the ulnar styloid by an intact superficial component of the TFC. Once anatomic reduction of the radius was secured by rigid plating, an ORIF of the ulnar styloid was anatomically achieved by tension band wiring. This technique brings the ligamentum subcruciatum back to its site of foveal origin for healing.

The literature on the subject remains contradictory and controversial; but personal experience suggest a strong indication for restoration of bony anatomy, if the basilar ulna styloid fracture fragment is displaced more than 2 mm.

Step 5: If there is demonstrable instability (relative to the contralateral side) but no fracture of the ulnar styloid, then there has to have been a substantial tear through the periphery of the TFC itself. In these cases, the TFC must be repaired or reattached to the ulnar fovea to avoid chronic DRUJ instability once the distal radius has healed and the patient rehabilitated. If an external fixator has been used to stabilize the radius fracture, then triangulation of the fixator to the ulna obviates cast immobilization (**Fig. 17**). With more common use of volar locking plates and other plate fixation devices over the past decade, I have replaced frame triangulation with the simple external fixation provided by percutaneous pins and long-arm cast, which minimize the risks of subtle and inadvertent pronosupination during the 6-week TFC healing period. **Fig. 18** shows a simple K-wire and wire-loop technique of ORIF of the ulnar styloid. **Fig. 19** shows placement of two 0.062-in percutaneous K-wires with a bone anchor used to restore the anatomy of an avulsed ligamentum subcruciatum. **Fig. 20** shows the sequence of steps used in implanting a bone anchor and sutures into the ulnar fovea, securing the TFC to its original place of origin. In 2009, Souer and colleagues²⁵ published their level III research study of the effect of an unrepaired

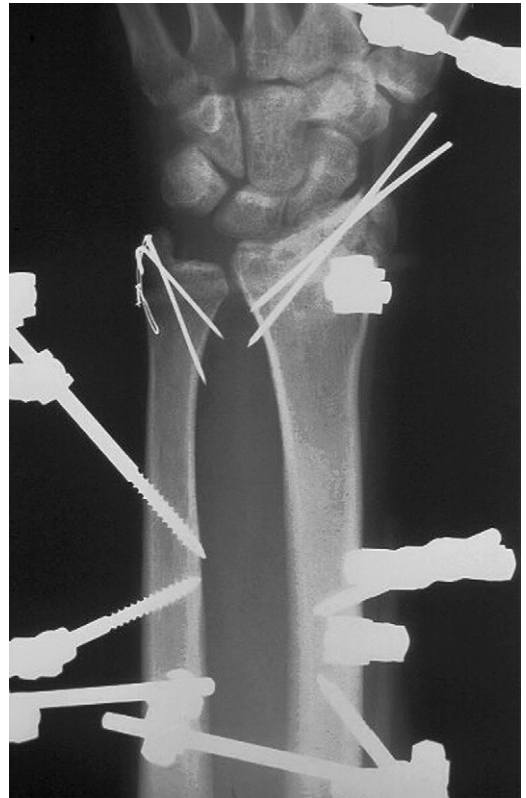


Fig. 17. Hand-forearm rigid external fixation (radius to second metacarpal) can be triangulated to the ulna to rigidly hold the forearm bones in neutral rotation while the injured ligamentum subcruciatum heals.



Fig. 18. Tension band wiring of an avulsed ulnar styloid fracture is technically not demanding and allows predictable styloid and ligamentum subcrucium healing, avoiding DRUJ instability.

fracture of the ulna styloid base on patient outcomes after plate-and-screw fixation of a distal radial fracture. Two cohorts of seventy-six matched patients were used for their study. The authors concluded no significant differences

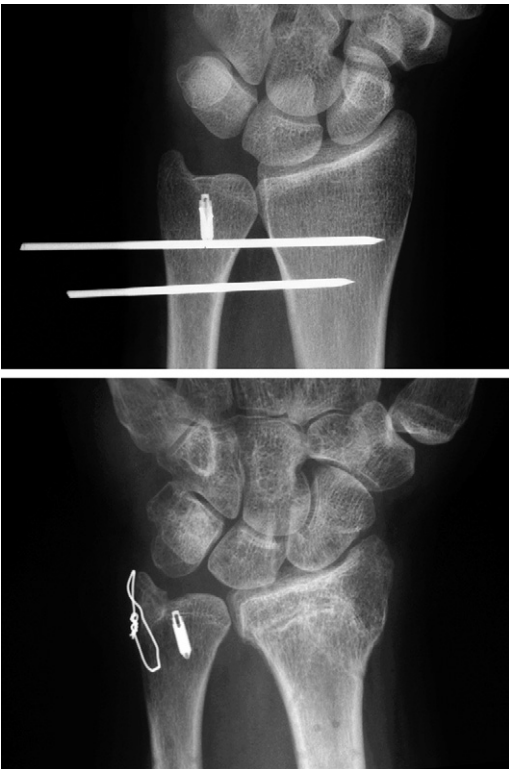


Fig. 19. Two examples of bone anchors placed deep into the fovea. Attached sutures grasp the ligamentum subcrucium, pulling it deep into its foveal origin for healing.

were found between patients with unrepaired fractures of the styloid base and those with no ulnar styloid fracture. Styloid fracture displacements were greater than 2 mm.

In 2009, Sameer and colleagues²⁶ reported on a 5-year cohort of patients subjected to the Michigan Hand Outcomes Questionnaire (MHOQ). Each patient had undergone ORIF of a displaced distal radius fracture. Each had a concomitant ulnar styloid fracture. The interest of the investigators was whether or not ORIF of the concomitant ulnar styloid fracture affected the subjective outcome of treatment. The background of their work was a century of clinical studies that have been inconclusive about the relationship of chronic DRUJ instability and displacement of a fractured ulnar styloid. They concluded that patients with DRUJ instability post ORIF of a displaced distal radius fracture did not benefit subjectively from ORIF of the displaced distal ulnar styloid fracture. Outcomes seemed to be similar whether or not the styloid was fixed.²⁶

Jupiter and colleagues, also in 2009,²⁷ corroborated the work of Chung and colleagues, by suggesting, in a retrospective review of their two cohorts of 76 matched patients, that the displaced ulnar styloid, in association with a displaced distal radius fracture, does not have to be fixed to achieve a good outcome.

There are important questions to be asked about the conclusions of these works. First, regarding the article by Chung and colleagues, is the MHOQ an appropriate measuring tool for assessment of the chronic DRUJ instability dilemma? Second, has any of the patients studied in either report experienced a displaced basilar styloid fracture? And third, how is postradius fixation DRUJ instability measured intraoperatively? Is it precise? Is it consistent?

Commentary by Jupiter²⁸ on the 2009 work by Chung and colleagues²⁵ suggests the importance of fibers of the distal oblique bundle of the interosseous membrane (IOM) in preventing DRUJ instability. Jupiter defines instability only in gross terms: the piano key sign or the palpable clunk of the medial radius rolling off the seat of the ulna at the end arc of pronation or supination. I consider this definition of DRUJ instability is an oversimplification. DRUJ instability is a spectrum of pathologic laxity at the distal end of the ulna, ranging from microinstability demonstrated only by provocative maneuvers that cause pain to gross mechanical instability alluded to by Jupiter in his commentary. Whether or not the distal oblique fibers of the IOM are intact, it is an anatomic fact that displacement of a basilar ulnar styloid fracture cannot occur without rupture or significant

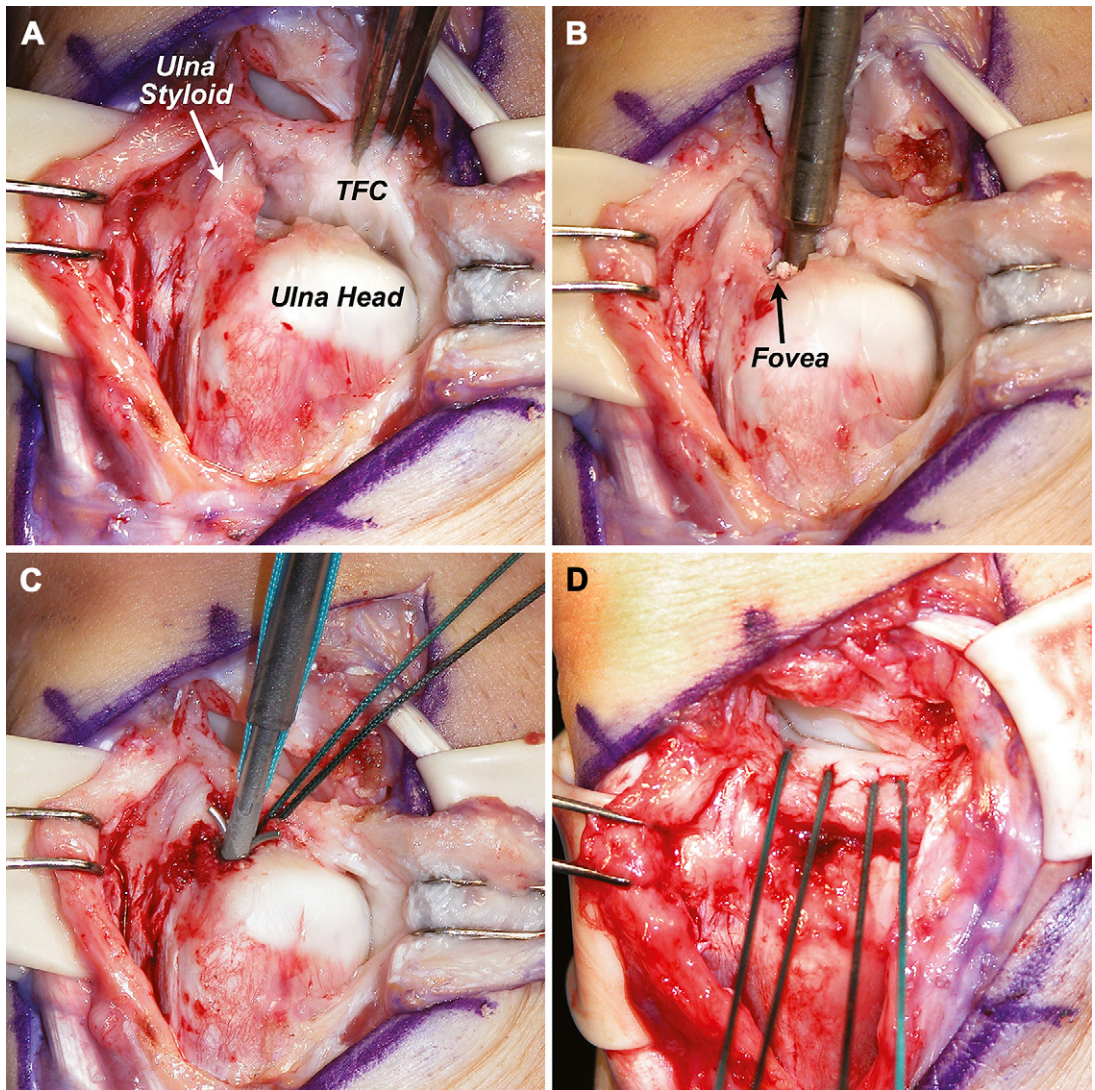


Fig. 20. (A) the exposed components of the distal end of the ulna; (B–C) once placed deeply into the fovea, the standard 2-0 suture material manufactured with the anchor can be reinforced by the surgeon by adding additional suture material to the anchor, giving a potential 4-strand attachment of the avulsed, deep radioulnar fibers of the ligamentum subcrurium to bone; (D) the final position of sutures prior to the ligamentum subcrurium being tied securely to the ulna fovea. Currently, many companies manufacture two 4-strand bone-anchors of appropriate size.

attention of this origin of the ligamentum subcrurium (deep TFC fibers, primarily responsible for DRUJ stability) from their foveal attachment, independent of the TFC origin from the ulnar styloid itself.

Although I agree with the authors'^{25,26} assessment of middle- and distal-third styloid fractures, extensive clinical experience and intimate knowledge of the anatomy of TFC suggest strong indications for ORIF of the displaced basilar styloid fracture. Failure to do so can lead to chronic, painful DRUJ instability. For these reasons, I continue

to teach my fellows and recommend to my patients ORIF of basilar styloid fractures when in association with displaced distal radius fractures requiring ORIF. DRUJ instability should always be suspected preoperatively and demonstrated with a stress test intraoperatively.

In 1991, I published experience of reattaching the damaged periphery of the TFC to the ulnar styloid in chronic cases of painful instability after delayed treatment for trauma.²⁸ Since then, there have been 2 important developments: (1) appreciation of the anatomy of the TFC has evolved to



Fig. 21. Long-term follow-up anteroposterior radiograph. The patient recovered full, painless pronation/supination under load.

a better understanding of the dominance of the deep, foveal origin of the TFC (ligamentum subcruentum) in providing the primary guidance system at the DRUJ for pronosupination² and (2) the development of bone anchors to assure excellent fixation of the avulsed ligamentum subcruentum to the fovea (see [Fig. 20](#); [Fig. 21](#)), rather than to a more peripheral position with sutures through the ulnar styloid, as I described 20 years ago. The beauty of the current use of bone anchors to reattach the avulsed TFC to the fovea (performed in conjunction with ORIF of fracture of the distal radius) is that reconstitution of stable, painless forearm pronosupination can be assured by direct and secure fixation of the TFC to an anatomic point now considered the critical origin of the TFC guidance system for the radius/carpus/hand unit.

CONSEQUENCES OF FAILING TO APPRECIATE TFC ANATOMY WHEN TREATING DISPLACED DISTAL RADIUS FRACTURES

An example of the consequences of failure to respect all components of these severe distal radius fractures, with potential for disturbance of normal DRUJ mechanics, is illustrated as follows. A 19-year-old female college student fell off her bicycle onto her outstretched dominant hand, incurring a grossly displaced, extra-articular distal radius fracture ([Fig. 22](#)). The extent of shortening and dorsal angulation is clear. Also readily seen is significant displacement of the ulnar styloid, avulsed through its base by an intact superficial radioulnar component of the TFC. The patient was treated elsewhere by closed reduction and cast immobilization until healed clinically and radiographically ([Fig. 23](#)). She presented for a second opinion at my office 9 months after her initial treatment ([Fig. 24](#)), complaining of disabling pain at the distal end of the ulna, particularly at the end arcs of loaded pronation and supination. Physical examination revealed (1) subtle hypermobility at the sigmoid fossa on a stress test of the ligamentum subcruentum, using the provocative maneuvers (described previously) shown in [Figs. 10](#) and [11](#) (relative to the opposite side). The patient had full pronation and supination and 65° wrist extension/75° wrist flexion. There was no tenderness on direct palpation of the ulnar styloid fracture nonunion. The piano key sign was negative.

Radiographs of this young woman show a 6-mm, radially displaced malunion of the distal radius, with a 6-mm displacement of her ulnar styloid, avulsed through its bony base by the superficial dorsal and palmar radioulnar components of the TFC (see [Fig. 24](#)). The ulnar styloid has been displaced from its base exactly the

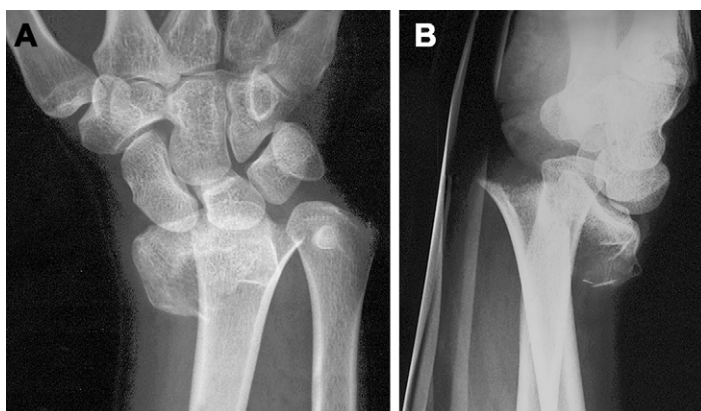


Fig. 22. Anteroposterior (A) and lateral (B) radiographs of a 19-year-old woman who fell off a bicycle onto her outstretched dominant hand. The magnitude of radius shortening, dorsal angulation, and complete loss of inclination is readily seen.



Fig. 23. The patient was treated elsewhere by closed reduction and cast immobilization for 6 weeks. Anteroposterior radiographs out of plaster reveal lateral displacement of the distal radius fragment, with similar lateral displacement of the ulnar styloid through its base, avulsed by the intact superficial radioulnar ligaments of the TFC.

same millimeter distance as the lateral displacement of the distal radius malunion. The original injury displacement of the distal radius fracture pulled the ulnar styloid from its base the same distance by force transmission through the intact superficial dorsal and palmar components of the TFC. As the bony styloid was avulsed from its base, the deep foveal attachments of the ligamentum subcruentum failed as well, destabilizing the DRUJ by loss of its critical anchor point. Failure by the first treating surgeon to anatomically reduce



Fig. 24. Nine months after the initial injury, the radius is healed. The displaced ulnar styloid fracture nonunion is ankylosed and nontender, but the DRUJ is painful and unstable through a full arc of pronation/supination. Provocative maneuvers that stress the deep dorsal and deep palmar fibers of the ligamentum subcruentum were positive for pain and instability.

the distal radius not only resulted in a radius malunion and ulnar styloid nonunion (see **Fig. 23**) but also left the avulsed fibers of origin of the ligamentum subcruentum directly on top of the hyaline cartilage of the distal ulnar pole. There was no potential whatsoever for the ligamentum subcruentum to heal to the fovea because of the magnitude of the initial fracture displacement. In this patient, failure of the ligamentum subcruentum to heal properly to its anatomic origin at the ulnar fovea resulted in chronic, painful DRUJ instability under load. The patient's 6-mm radius malunion not only shifted the ulnar styloid from its anatomic base but also left the ligamentum subcruentum displaced to a position from which it could not be reanchored to the fovea without corrective osteotomy of the radius.

A dome osteotomy of the radius was performed (**Fig. 25**), allowing a 6-mm medial shift of the distal radius along with the superficial radioulnar ligaments and articular disc, all still attached to the ulnar styloid. The restored anatomy of the radius then allowed the ulnar styloid fibrous union to be taken down, reduced, and anchored anatomically to its base using a tension band wiring technique. With the ulnar styloid anatomically reduced, the ligamentum subcruentum could be restored to its anatomic origin at the ulnar fovea with a bone anchor and sutures (see **Fig. 25**).

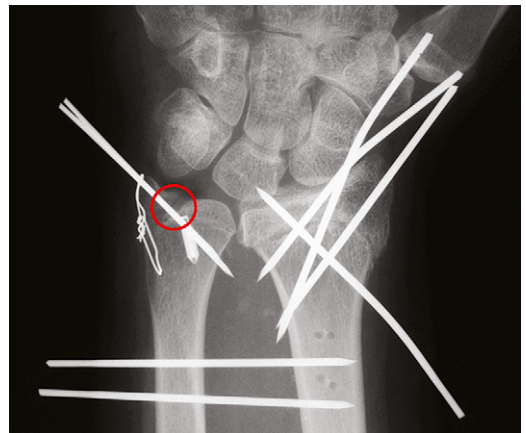


Fig. 25. Dome osteotomy of the radius malunion allowed a 6-mm medial shift of the distal radius fragment in this patient. The ulnar styloid could then be anatomically reduced at its base and held with tension band wires. With the bony anatomy restored, the critical, deep radioulnar ligaments of the ligamentum subcruentum were now juxtaposed to the fovea (circle) and could be securely reattached with a bone anchor. To eliminate any forearm rotation for 6 weeks, two 0.062-in K-wires were introduced percutaneously through the distal shaft of the ulna into the radius.

The critical concept in treating this case effectively was to shift the entire distal forearm unit medially, enabling anatomic restoration of the ligamentum subcrucium to the fovea and restoration of normal DRUJ mechanics. **Fig. 20** illustrates the intraoperative technique of preparing the fovea for reattachment of the ligamentum subcrucium, installing the bone anchor, and passing sutures through the TFC before pulling the deep fibers securely into the fovea. As seen in the postoperative radiograph (see **Fig. 25**), 2 additional percutaneous 0.062-in K-wires were passed through the distal ulna into the radius before tying the bone anchor sutures as tightly as possible in neutral forearm rotation. The K-wires maintain rigid stability of the DRUJ during early postoperative healing. All percutaneous K-wires seen in **Fig. 25** were removed 6 weeks after surgery. After rehabilitation, the patient regained full, painless pronosupination, with normal load-bearing capacity at the DRUJ. Her final radiograph is seen in **Fig. 21**.

OTHER DRUJ-DESTABILIZING INJURIES TO THE TFC IN ASSOCIATION WITH FRACTURE OF THE DISTAL RADIUS

The usual failure pattern of the TFC (as the radius fractures and collapses away from the intact ulna) is by peripheral tearing and separation of connective tissue fibers from their origin at the ulnar styloid or fovea or by an avulsion fracture of the ulnar styloid itself through its base (by the superficial TFC components).¹⁻³ As discussed previously, separation of the styloid from its base usually implies concomitant separation of the ligamentum subcrucium origin at the fovea. Palmer²¹ classified as type IB those peripheral TFC injuries that occur in the well-vascularized periphery; and, as the literature shows,²⁹ type IB TFC injuries are amenable to direct repair and healing. Repairs of peripheral tears of the TFC are now performed routinely, using an open or arthroscopic technique, based on the location and magnitude of the avulsion injury.

Palmer type IB tears of the TFC occur in the fibrous dorsal or volar portions connecting the medial distal ulna to the medial distal radius. Collagen fibers of this connective tissue have a transverse orientation from ulna origin to radius insertion. Microcirculation penetrates approximately 20% of the TFC dorsally and 20% volarly.^{14,15} Nutrition of these portions of the TFC is entirely by its microcirculatory anatomy.

Palmer type IA lesions of the TFC involve the central articular disc, made up of fibrocartilagenous tissue nourished by ulnocarpal synovial washing. Type IC lesions are rare and involve the disc-lunate

or disc-triquetral volar components of the TFC. Palmer type ID injuries to the TFC involve separation of the TFC attachment to the medial border of the distal radius.

In my experience, acute type IA central injuries to the articular disc (the hypovascular, central portion of the TFC [see **Fig. 7**]) are rarely associated with displaced, distal radius fractures. Likewise, type IC failures of the volar disc-carpal ligaments (disc-lunate and disc-triquetral [see **Fig. 7**]) are also rare. More frequent (but still uncommon) are the type ID separations of the TFC insertion from the medial radius, in association with displaced distal radius fractures. Even with severe comminution and displacement of the medial column of the radius with intra-articular extension into the sigmoid fossa, a portion of the TFC attachment may be lost, but the bulk of the structure remains intact. In those unusual cases where there has been DRUJ instability rendered by TFC tearing from the medial border of the fractured radius, bone-anchor reattachment can be performed using open (or arthroscopic) techniques at the time of ORIF of the displaced distal radius fracture.

RESULTANT FOREARM STIFFNESS AFTER EFFECTIVE ORIF AND HEALING OF A DISPLACED DISTAL RADIUS FRACTURE

Forearm rotational stiffness is one of the most function-comprising consequences of wrist trauma. Although often painless, forearm stiffness leaves patients unable to put or place their hand in space effectively, because of the reduction in the arc of pronation or supination.^{1,30,31}

If DRUJ instability has been identified at the time of ORIF of a distal radius fracture, and a direct repair of an injured TFC has been performed, then postoperative immobilization of the forearm and elbow is required until healing of the repaired TFC has been assured. Treatment consists of 2 percutaneous 0.062-in K-wires and a long-arm cast for 6 weeks. When the cast and pins are removed, initial efforts at rotation are frustrating to patients because of the stiffness caused by reactive fibrosis during the period of immobilization. This is to be expected. Serious efforts under the direction of a certified hand therapist to reconstitute rotation and translation of the radius/carpus/hand around the distal ulnar seat are initiated. Active, active-assisted, and passive range-of-motion exercises begin immediately, with interval long-arm splinting. At 8 postoperative weeks, dynamic orthoses (joint active splints) can be useful in providing continuous gentle load in pronation and supination. As patients attempt to regain supination, the medial 4 fingers of

the opposite hand are placed on the dorsal ulna, and the thumb is placed on the distal radius metaphysis. As patients actively try to supinate, 4 medial fingers lift the ulna forward while the thumb pushes the radius backward. This exercise results in forearm rotation and translation at the DRUJ. Similarly, as patients try to pronate, the medial 4 fingers of the opposite hand push (lift) the distal ulnar shaft upward (dorsally) while the thumb pushes the distal radius away (volarly), generating rotation and translation at the DRUJ. The repaired deep, foveal fibers of the ligamentum subcruentum of the TFC provide a checkrein to supraphysiologic motion of the sigmoid fossa relative to the ulnar seat. Dynamic rotational orthoses cannot create physiologic translation of the fossa on the ulnar seat.

Eventually, after at least a few months of conscientious rehabilitation, patients should have regained full pronosupination. In spite of extensive rehabilitation, some patients may struggle and fail to achieve this goal. It is important for the surgeons to accept that forearm rotational stiffness is a potential complication in the management of fractures of the distal radius. This awareness should be communicated to patients during the early aftercare period. Rotational stiffness can result after closed or open treatment of distal radius fractures, with or without concomitant treatment of TFC or ulnar styloid pathology.

In any circumstance, restoration of a healthy forearm range of motion can be inhibited by contracture of the distal radioulnar joint capsule. A dorsal capsular contracture limits pronation; a volar contracture limits supination. Both may occur together. Like all other diarthrodial joints, the DRUJ articulating surfaces are covered by hyaline cartilage, which is nourished by the synovial tissue lining the joint. The entire joint is surrounded by elastic connective tissue forming a capsule and, as in any other diarthrodial joint, can be subjected to fibrosis and contracture during prolonged immobilization after trauma.

In 1993, laboratory and clinical work on the subject of posttraumatic DRUJ contracture was published.³⁰ The anatomy of the DRUJ capsule in fresh, frozen cadavers was critically studied, shedding insight into why posttrauma supination was so much more difficult to achieve than posttrauma pronation. With closed or open treatment of distal radius fractures, the magnitude of hemorrhage and swelling, combined with prolonged immobilization, is a clinical setup for loss of native DRUJ capsule elasticity, with resultant contracture that checkreins supination or pronation. Redundant folds of native volar DRUJ capsule make this portion of the capsule more susceptible to stiffness after reactive fibrosis has occurred. In

most cases, commitment to rehabilitation by patient and therapist overcomes this inherent predisposition to volar or dorsal stiffness, but, in many cases, pronosupination efforts plateau too early, leaving the forearm relatively stiff, significantly compromising upper limb function.

On the basis of laboratory and clinical research produced by author and his colleague, Dr Thomas Graham²⁹, a surgical approach to the contracted DRUJ volar capsule in cases of limited supination and to the contracted dorsal DRUJ capsule limiting pronation was designed. Since the publication of this initial work, DRUJ capsulectomy has been used extensively at The Indiana Hand to Shoulder Center and has been accepted as a logical and reasonable approach to improving forearm rotation in patients who (1) have healed their distal radius reconstruction, (2) have had alignment restored at the DRUJ articular surfaces, and (3) have a TFC that is uninjured or has been reconstructed. It is critical for surgeons to recognize that if it has been technically impossible to restore perfect alignment of the sigmoid fossa and ulnar seat components of the DRUJ, then DRUJ capsulectomy should never be performed.^{1,30,31} If there is step-off incongruity of the DRUJ articular surfaces or a poorly oriented sigmoid fossa tracking line for the principal axis of load bearing, then performing a DRUJ capsulectomy only exposes the joint to increased surface shear forces and predisposes the joint to painful, progressive degenerative cartilage breakdown and inflammation. The capsulectomy (whether or not dorsal or palmar) will fail. Postreduction (open or closed) malalignment of DRUJ articular anatomy is a significant contraindication to DRUJ capsulectomy, volar or dorsal.

If forearm rehabilitation plateaus with persistent stiffness, then surgical intervention should be considered. Because of the differences in anatomy between the dorsal and volar DRUJ capsules,³⁰ limited forearm supination is more commonly observed after distal radius fracture, treated closed or open. Functional limitation of supination can be treated surgically by radical silhouette capsulectomy of the entire volar radioulnar DRUJ capsule, proximal to the most proximal fibers of the ligamentum subcruentum (**Fig. 26**). Once performed, intra-operative manipulation of the forearm by rotation and translation should restore full supination. Similarly, limitation of forearm pronation can be surgically addressed by radical dorsal DRUJ silhouette capsulectomy proximal to the dorsal fibers of the TFC (**Fig. 27**). Manipulation of the forearm by rotation and translation into pronation restores a full arc of forearm motion. Any bony angulatory, rotational, or length malalignment at the DRUJ must be corrected

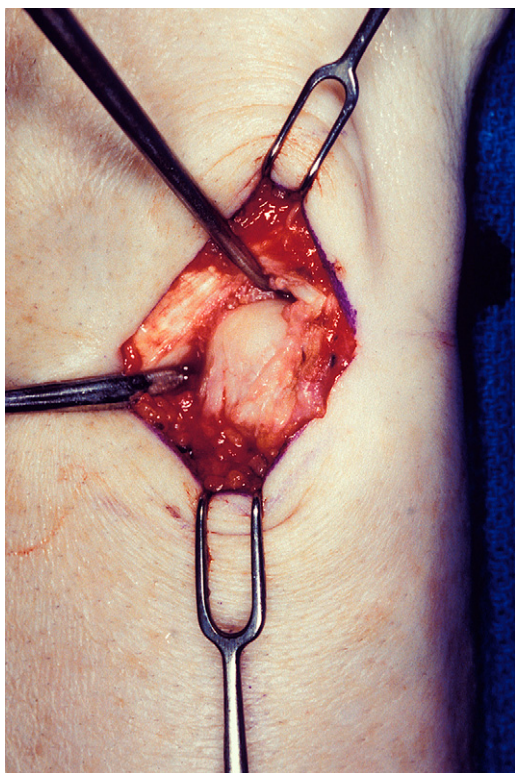


Fig. 26. Silhouette capsulectomy of the palmar DRUJ capsule must be performed proximal to the palmar ligamentum subcruentum of the TFC. The entire capsule should be removed and in any intra-articular adhesions lysed. Once this is accomplished, rotation and translation of the DRUJ should result in 90° of passive forearm supination.

before consideration can be given to DRUJ capsulectomy.

TRAUMATIC ARTHRITIS OF THE DRUJ IN ASSOCIATION WITH FRACTURE OF THE DISTAL RADIUS

Fracture extension into the DRUJ results in what is unfortunately a common complication of distal radius fractures: traumatic DRUJ arthritis. Even without comminuted fracture displacement, simple damage to the articular surface of the sigmoid fossa can result in progressive chondrolysis and exposed subchondral bone.³² Failure to anatomically align displaced DRUJ fracture fragments can accelerate the degenerative process.

Fig. 28 shows the wrist radiographs of a 45-year-old man who incurred a high-energy industrial accident. Comminution was extensive; dorsal collapse and shortening was impressive. In spite of prolonged intraoperative efforts (with distraction) to reconstitute some semblance of

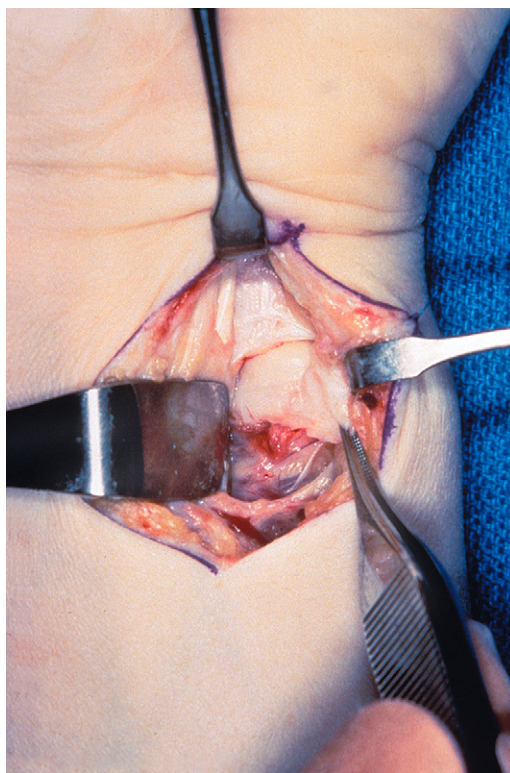


Fig. 27. Silhouette capsulectomy of the dorsal DRUJ capsule, followed by lysis of all intra-articular adhesions, should result in 90° of passive forearm pronation.

architectural alignment of joint surfaces, the result was persistent dorsal tilt at the radiocarpal joint and destruction of the DRUJ (**Fig. 29**). Predictably, the patient went on to have severe pain and stiffness with forearm rotation, requiring elimination of the DRUJ by Darrach resection of the distal ulna, stabilized by adjunctive tendon transfers (**Fig. 30**).³³

Most surgeons today recognize the 30% reported failure rate after simple Darrach resection in the high-demand hand,³⁴ most commonly associated with winging or impingement of the unstable proximal stump of ulna.³⁵⁻³⁹ Since Darrach described his procedure,⁴⁰⁻⁴² a variety of solutions have been proposed for the post-Darrach problem of proximal ulnar stump instability.^{1,32}

The matched ulna resection (Watson and colleagues)^{38,39} and the hemiresection interposition technique (Bowers),^{36,37} popular in the 1980s, recognized the propensity for the 2 forearm bones to impinge and wing after ulnar seat-pole resection for painful DRUJ arthritis. The investigators addressed the issue by ulnar contouring with or without rolled-up tendon interposition.

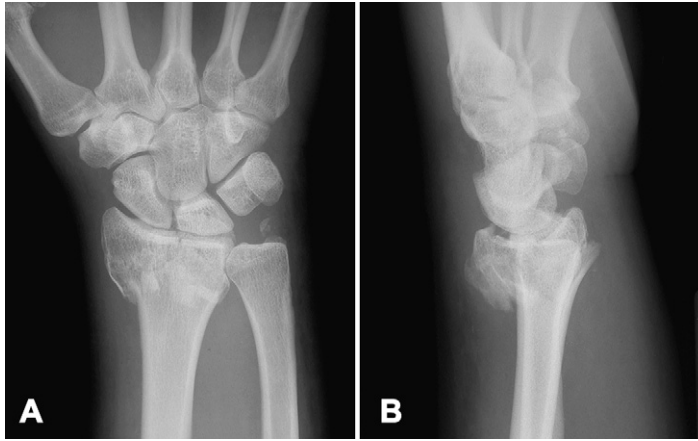


Fig. 28. (A) Anteroposterior and (B) lateral radiographs of a devastingly comminuted distal radius fracture in a 45-year-old man injured on an industrial accident. The sigmoid fossa of the radius was destroyed. The articular surface of the radiocarpal joint was severely damaged.

Synostosis of the head of the ulna to a damaged, painful sigmoid fossa, with creation of a pseudarthrosis just proximal to the fusion mass (Suavé and Kapandji),^{43,44} eliminates joint pain, but subjects patients to similar problems of proximal stump instability seen with simple Darrach resection. Even Taleisnik's thoughtful use of the pronator quadratus⁴⁵ to help stabilize the proximal ulnar stump of a Sauvé-Kapandji procedure leaves patients with persistent weakness and a propensity for the ulnar stump to wing or impinge against the medial border of the radius.

During the past few decades, various attempts have been made by clinical researchers to design prostheses to replace the distal end of the ulna and provide a fulcrum for forearm rotation. These have had limited effectiveness in the higher-demand hand because of the persistent pain

caused by prosthetic loading of the denuded and eburnated bone of the exposed, damaged sigmoid fossa. Scheker and coworkers⁴⁶ have made recent strides in designing a constrained prosthesis that considers both components of the DRUJ: the ulnar seat and the radius sigmoid fossa. Although the surgical technique is demanding, the logic behind the design of this prosthesis is extraordinary. Scheker and coworkers report good long-term results in their patient population.

Treatment of traumatic arthritis of the DRUJ after distal radius fracture remains a conundrum for reconstructive hand surgeons. Until a prosthesis is designed that (1) is truly user friendly, (2) is able to withstand high-demand loads, (3) makes anatomic and biomechanical sense, (4) is affordable, and (5) can be implanted technically without compromising the engineering requirements of the

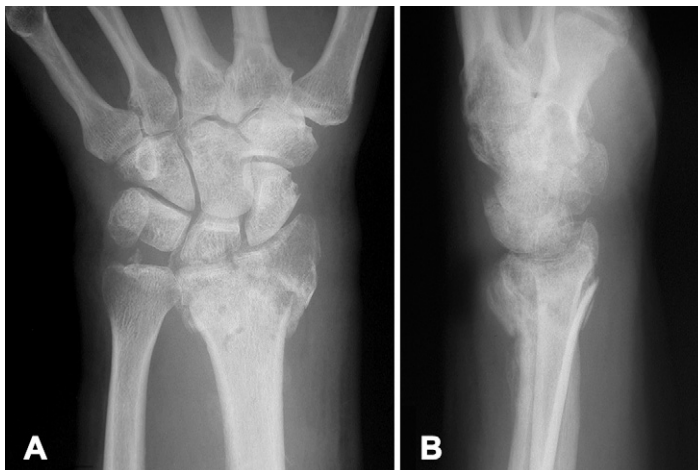


Fig. 29. (A) Anteroposterior and (B) lateral radiographs showing the healed distal radius of the patient in [Fig. 21](#) revealing DRUJ arthrosis and radiocarpal arthrosis. Note the severe 45° dorsal tilt of the distal radius and collapse of the lunate facet of the distal radius.



Fig. 30. Darrach resection of the distal ulna, with stump stabilization by pronator quadrates and ECU tendon transfers supplemented by convergent 0.062-in K-wires for 6 weeks, restored painless forearm rotation to the patient suffering with the DRUJ bony relationship shown in Fig. 29A. (Data from Kleinman WB, Greenberg JA. Salvage of the failed Darrach procedure. *J Hand Surg Am* 1995;20:951–8.)

normal DRUJ, any surgical treatment of painful DRUJ arthritis will remain challenging and frustrating to surgeons and patients alike.

This article provides insight into chronic DRUJ instability and stiffness often associated with fractures of the distal radius. Anatomic alignment and rigid fixation of distal radius fracture fragments by surgeons is only partial treatment of the injury. Surgeons must also understand and be able to focus their attention on (1) the omnipresent potential for extension of the injury into the components of the TFC, with resultant chronic DRUJ instability, and (2) contracture of the DRUJ capsule leading to stiffness of forearm rotation and thus significant compromise to global function of the upper limb.

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