Arthritis of the Distal Radioulnar Joint: From Darrach to Total Joint Arthroplasty

Abstract
The distal radioulnar joint (DRUJ) is a complex structure that contributes to full, painless forearm rotation and weight bearing. Stability requires adequate bony architecture and robust soft-tissue support. Arthritis of the DRUJ between the sigmoid notch of the distal radius and the ulnar head can be caused by traumatic, inflammatory, congenital, and degenerative processes. Initial management of symptomatic DRUJ arthritis is nonsurgical. Surgery is reserved for patients with refractory pain. Although outcomes typically are positive following excision of the distal ulna, serious potential postoperative complications include instability and potentially painful impingement of the residual distal ulnar stump. Procedures used to manage the unstable residual ulna include soft-tissue stabilization techniques and DRUJ implant arthroplasty.

Anatomy
The bony architecture of the DRUJ consists of the articulation between the sigmoid notch of the distal radius and the ulnar head. This relationship is notable for its significant asymmetry. Anatomic studies have demonstrated that the sigmoid notch has a 4- to 7-mm greater radius of curvature than the ulnar head; thus, motion through the DRUJ consists of both rotational and gliding components (Figure 1). Only 20% of DRUJ constraint is provided by the articulation of the ulnar head in the sigmoid notch; most DRUJ stability comes from soft-tissue support, including the triangular fibrocartilage complex (TFCC). The TFCC is a complex structure consisting of the dorsal and volar radioulnar ligaments, dorsal and volar ulnocarpal ligaments, articular disk, meniscus homolog, and extensor...
carpi ulnaris (ECU) tendon sheath. The TFCC originates on the medial border of the distal radius adjacent to the sigmoid notch and inserts onto the base of the ulnar styloid, both volarly and dorsally.\(^3\) (Figure 2). Anatomic studies have confirmed important contributions to DRUJ stability from the dorsal and volar radioulnar ligaments, pronator quadratus muscle, and interosseous membrane.\(^4,5\) Recent work has shown that the triangular fibrocartilage and the radioulnar ligaments can maintain normal DRUJ kinematics in the absence of other soft-tissue stabilizers.\(^6\) Conversely, DRUJ kinematics were also preserved in an anatomic model—despite loss of triangular fibrocartilage and radioulnar ligament—when other soft-tissue stabilizers, such as the interosseous membrane, were preserved. This surprising finding suggests that DRUJ stability may be more diffusely distributed than previously thought.\(^6\) Although certain biomechanical aspects of DRUJ stability remain controversial, multiple investigators have shown that contact pressures and differential tightening of the distal radioulnar ligaments during forearm rotation contribute substantially to stability.\(^7\)

The DRUJ is important in weight bearing and maintaining radioulnar distance during forearm rotation. The concept of ulnar variance, which is the relative length relationship of the distal ends of the radius and ulna, is helpful in understanding force transmission through the DRUJ. Some investigators have proposed that the ulnar-neutral wrist transmits 20% of force to the distal ulna through the ulnocarpal joint.\(^8\) Recent work has shown that this number may be as high as 33%.\(^9\) However, even more important are the changes in load transmission and DRUJ dynamics that occur with changes in ulnar length.

Nyggaard et al\(^9\) showed that increasing the length of the ulna relative to the radius (from ulnar-neutral to ulnar-positive) by 1 mm may increase ulnocarpal loading by more than half, whereas ulnar shortening (from ulnar-neutral to ulnar-negative) routes more force through the radiocarpal joint.\(^9\) Ulnar shortening may increase peak pressure in the DRUJ while simultaneously stabilizing it by increasing TFCC tension.\(^10,11\) Longitudinal gliding occurs at the DRUJ throughout forearm ro-
tation, resulting in dynamic ulnar variance of relative positivity in pronation and relative negativity in supination. The ulnar head also functions to maintain radioulnar distance during forearm rotation. With excision of the ulnar head or discontinuity of the distal ulna, such as occurs following resection arthroplasty, that relationship is lost and radioulnar convergence can occur. The multiple functions and complex biomechanics of the DRUJ contribute to the challenges inherent in its reconstruction.

**DRUJ Pathology**

DRUJ pathology takes numerous forms. We focus here on arthritis at the articulation of the sigmoid notch and the distal ulna. Other pathologic states affecting the joint include instability, ulnocarpal impaction, and TFCC injury. Pathology of the DRUJ at the sigmoid notch can arise from traumatic, inflammatory, congenital, and degenerative etiologies.

The sequelae of distal radius fracture are common causes of posttraumatic DRUJ dysfunction, although it can occur following a variety of fractures. Distal radius fractures that propagate into the sigmoid notch can result in joint asymmetry and predispose to arthrosis. Radial deformity, including fracture malunion, can lead to DRUJ dysfunction secondary to altered biomechanics. The amount of tolerable deformity is controversial, but residual dorsal angulation of >20° to 30° has been associated with pathologic wrist biomechanics. Children can experience malunion and fracture propagation into the sigmoid notch, but growth arrest following physical fracture has been reported to occur in approximately 4% of fractures involving the distal radius and up to 50% of those in the distal ulna. The resulting deformity and altered DRUJ biomechanics can predispose to dysfunction and degeneration.

Inflammatory conditions also affect the DRUJ. Rheumatoid arthritis is the most common inflammatory disorder of the joint, and pathology at this site may be its first clinical manifestation. Congenital sources of pathology are less common but are nonetheless significant and require prompt diagnosis to prevent ongoing insult. Madelung deformity, which is an idiopathic arrest of the ulnoulnar portion of the distal radial epiphysis, is a common congenital cause of DRUJ dysfunction. Deformity occurs around the tether as longitudinal growth continues through remaining functional epiphyses, resulting in angular deformity and altered DRUJ biomechanics. Neoplasia, such as osteochondroma, can also impair wrist dynamics, even if not located immediately within the DRUJ.

Instability and ulnar impaction syndrome should be considered in the context of any arthritic DRUJ. These diagnoses often coexist, and all modes of pathology must be appreciated to guide comprehensive management. DRUJ instability refers to failure of the bony and soft-tissue components to maintain proper alignment and support during full range of motion (ROM) and weight bearing. May et al found that 11% of distal radius fractures were accompanied by DRUJ instability and reported that risk factors include fracture at the base of the ulnar styloid and significant ulnar styloid fracture displacement. Ulnar impaction syndrome refers to chronic compressive overloading through the ulnocarpal joint, often from ulnar-positive variance, leading to degenerative bony changes and TFCC tears.

**Physical Examination**

Physical examination of the DRUJ begins with inspection. Salient observations include skin changes such as erythema or edema, prior surgical scars, deformity, and asymmetry compared with the contralateral limb. Particular attention should be paid to the appearance of the distal ulnae because asymmetric prominence may exist in the setting of distal radius malunion. Palpation follows inspection, with emphasis on the distal ulnar diaphysis and styloid. Palpation of the ulnar styloid in pronation has been proposed, but we have found a tender styloid to be symptomatic regardless of wrist position. ROM testing and provocative maneuvers follow.

Pronation and supination are espe-
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Imaging

Imaging begins with standard AP and lateral radiographs of the wrist. Bilateral imaging is often helpful. For example, bilateral positive ulnar variance is normal in some persons, but unilateral positive ulnar variance is more concerning for pathology. Forearm rotation must be consistent between radiographs and within 10° of neutral, as greater rotation can hamper evaluation of the DRUJ. Plain radiographs should be assessed for ulnar variance, signs of fracture malunion and malalignment, and degenerative changes in the carpus. Particular attention should be paid to the articulation between the sigmoid notch and ulnar head. Differences in overlap may indicate subluxation. Significant asymmetry and degenerative changes can be noted on plain radiographs.

CT is helpful in assessing for bony incongruity within the sigmoid notch and should be considered when there is concern for fracture extension into the DRUJ. Dynamic CT can be considered for patients with clinical signs of instability. MRI, specifically a 3T dedicated wrist coil, is optimal for assessing the relevant soft tissues. Although several systems have been proposed for radiographic evaluation of subluxation, no system exists for DRUJ arthritis.

Nonsurgical Management

Nonsurgical measures should be considered before proceeding to surgical intervention. An initial trial of activity modification, gentle physical therapy, nonsteroidal anti-inflammatory drugs, and immobilization should be offered. A trial of nonsurgical treatment is especially important for patients who present with chronic, ill-defined symptoms and normal imaging. We are unaware of any high-level study that examines the outcomes of nonsurgical modalities for DRUJ arthritis.

Surgical Management

Resection Arthroplasty

Resection arthroplasty remains one of the main surgical techniques to manage symptomatic DRUJ arthrosis. DRUJ kinematics are consistently altered following distal ulna resection, and patients should be counseled that although surgery can improve their symptoms, it may be unrealistic to expect entirely normal postoperative function. The type of resection arthroplasty should be tailored to the demands and degree of pathology of each individual patient.

Darrach Procedure

First described in the 19th century and later popularized by Darrach, distal ulnar resection was originally indicated for the management of chronic DRUJ instability. The indications have been broadened and refined over the years. The Darrach procedure remains the preferred option for relatively low-demand patients with DRUJ arthrosis and a nonreconstructible joint.

The Darrach procedure involves limited distal ulna resection with meticulous preservation of supporting soft-tissue structures, with the goal of balancing symptomatic relief via the resection while maximizing postoperative stability. The distal ulna is excised subperiosteally just proximal to the sigmoid notch (Figure 4). The TFCC, periosteum, and ECU tendon sheath are preserved when possible. Some authors recommend maintaining the ulnar styloid in situ to optimize postoperative TFCC function. The extensor retinaculum can be used to reinforce the dorsal soft-tissue layer and provide a sling to maintain the ECU on the dorsal wrist. Bone resection should be minimal, with just enough to clear the sigmoid notch, thereby preserving the interosseous membrane to optimize residual stump stability.

Hemiresection Procedures

Hemiresection techniques provide localized resection of only the articular region of the distal ulna while preserving soft-tissue stabilizers, especially the TFCC insertion onto the ulnar styloid. Hemiresection is appropriate only in the setting of an intact TFCC.

In the classic technique, the articular portion of the ulnar head and its immediate subchondral bone is ex-
cised, with the remainder left in situ and the attachments of the TFCC preserved to optimize stability.24,25 A common variation is the hemiresection interposition technique (HIT). With this method, the resection component is unchanged, and the interposition involves the insertion of soft tissue into the resection cavity in an attempt to prevent convergence of the radius and ulna.26 Another modification is matched distal ulna resection, in which the distal ulna is resected in a convex fashion to optimize congruency within the sigmoid notch during forearm rotation (Figure 5). The ulnar styloid is usually removed with this technique, but the continuity of the TFCC is otherwise maintained.24,25

**Sauvé-Kapandji Procedure**

The Sauvé-Kapandji procedure combines DRUJ fusion with distal ulna resection just proximal to the sigmoid notch and creation of a proximal ulnar pseudarthrosis (Figure 6). Maintaining the ulnar head preserves the ulnar column and carpal articulation, thereby preventing ulnar translation of the carpus and providing a better postoperative appearance compared with the Darrach procedure.27 The Sauvé-Kapandji procedure is thought to be more appropriate for young, active patients with a nonreconstructible DRUJ. However, there is limited high-level evidence comparing outcomes or critically assessing the appropriate procedure (ie, Sauvé-Kapandji, Darrach) for each patient population.28

Soft-tissue preservation and minimal bone resection are key to success. Through a dorsal or ulnar approach, 10 to 15 mm of ulnar neck is resected. Cancellous bone at the articular surface of the distal radius and ulna is exposed for fusion. Fixation is achieved with two Kirschner wires or 3.5-mm cancellous screws in compression, with purchase in three cortices. The ulnar head is secured into the sigmoid notch in neutral position and variance, and the pronator quadratus fascia is interposed in the osteotomy site to prevent reossification.27 A strip of flexor carpi ulnaris (FCU) can be tenodesed through a drill hole in the ulnar stump for additional stability.29 Insufficient bone stock and tenuous fixation are risk factors for nonunion and fixation failure. Fujita et al30 described a modified technique to improve stability and union that uses a 30-mm distal ulnar segment that is rotated...
90° and inserted into a 10-mm hole created in the sigmoid notch of the radius.

**Outcomes of Resection Arthroplasty**

Distal ulnar resection typically provides improved pain, grip strength, and motion in 80% to 90% of patients. Although some patients can return to heavy labor, caution is advised when performing distal ulna resection on higher-demand persons. Long-term follow-up data on young patients and high-demand patients are limited. Although outcomes are often favorable, complications include pain, residual ulnar stump instability, reossification at the Sauvé-Kapandji resection site, ulnar translation of the carpus, and painful abutment of the ulnar stump on the radius. Encroachment of the distal ulna on the radius is known as radioulnar convergence, and impingement is the symptomatic clinical entity (Figure 7).

There is evidence that residual ulnar instability is prevalent. Biomechanically, DRUJ kinematics are consistently abnormal after distal ulnar resection, and radiographic signs of radioulnar impingement have been noted in up to 74% of cases. In a recent series of 105 patients treated with the Sauvé-Kapandji procedure, 97% experienced pain relief and 74% had radiographic evidence of radioulnar convergence. In a different study, 50% of patients reported subjective instability after undergoing the Sauvé-Kapandji procedure. Although symptomatic improvement is typically achieved following HIT, DRUJ kinematics remain abnormal. Favorable long-term results after HIT have been noted in patients with rheumatoid arthritis. Watson and Gabuzda noted good to excellent results in 24 of 32 patients who underwent matched resection, with outcome proportional to preoperative morbidity. Minami et al reported long-term retrospective follow-up for 61 patients with DRUJ arthritis who were treated with the Darrach procedure, Sauvé-Kapandji procedure, or HIT. Postoperative pain improved in all groups, more so in the Sauvé-Kapandji and HIT subsets than in the Darrach group, although the difference did not reach statistical significance. Distal ulnar instability was frequent after all procedures: 60%, 50%, and 20% of patients reported clinical instability following the Darrach procedure, Sauvé-Kapandji procedure, and HIT, respectively.

The persistently symptomatic, unstable residual ulnar stump (ie, failed ulnar resection) is problematic, with persistently poor outcomes despite multiple attempted stabilization pro-
An important unanswered question is which patients go on to develop instability following resection arthroplasty. Minimal data exist, but it makes empirical sense that excessive resection of soft-tissue stabilizers or inferior preoperative soft-tissue support could be risk factors. Thus, we advocate meticulous soft-tissue handling during any distal ulna resection.

**Soft-tissue Stabilization of the Unstable Ulnar Stump**

Numerous soft-tissue stabilization procedures have been developed to control the unstable residual ulnar stump. ECU and FCU tenodesis has shown success. In this procedure, a proximally based ECU slip and a distally based FCU slip are used as a weave to control the unstable distal ulna. In a study by Breen and Jupiter, all eight patients treated with this technique obtained stable ulnae postoperatively. Tenodesis techniques using tendon allografts have also been described. A more recently described technique involves reinforcing Achilles tendon allograft in the interosseous space of the DRUJ with two slips of brachioradialis tendon passed through the distal radius and then wrapped volarly and dorsally around the recalcitrant ulna stump (Figure 8). Initial outcomes are favorable, but long-term outcome data are lacking.

**Implant Arthroplasty**

DRUJ implant arthroplasties have recently been developed to offer additional salvage options. Devices range from partial ulnar head replacements to self-constrained systems that replace the entirety of the DRUJ.

**Partial Ulnar Head Hemiarthroplasty**

Partial ulnar head hemiarthroplasty is the least intrusive implant arthroplasty option. Several partial ulnar head replacements are available. These implants can take various forms (eg, pyrocarbon spacers) and are intended for cases of isolated DRUJ arthritis without instability. This type of implant can be considered after failed HIT but is contraindicated following a Darrach procedure because the entirety of the ulnar head has already been excised. The focal pathologic site is resected, and the partial ulnar head replacement is inserted without disrupting the soft-tissue attachments, thus minimally altering joint biomechanics (Figure 9). Early results in three patients treated with partial ulna head replacement showed average pronation of 65° and average supination of 70°, as well as uniform 4-kg (8.8-lb) lifting ability throughout forearm rotation. Pain was improved, and no significant complications were noted.

**Total Ulnar Head Arthroplasty**

Total ulnar head arthroplasty involves complete replacement of the distal ulnar head with a stemmed implant (Figure 10). Initial designs were plagued by material failure, but newer implants with more modern components (eg, ceramic head affixed to a titanium intramedullary stem) have yielded favorable results without evidence of material complications. Unlike partial ulnar head hemiarthroplasty, which is intended for the setting of arthritis in an otherwise stable joint, total ulnar head replacement is indicated for painful instability after failed distal ulnar resection, isolated instability, and, oc-
Biomechanics are more altered with total ulnar head arthroplasty than with hemiarthroplasty because the soft-tissue components of the DRUJ cannot be anatomically preserved. Some devices attempt to maximize joint stability via attachment of the TFCC or capsule through holes in the implant. Notably, total ulnar head arthroplasty requires some contribution from native tissues for stability because the implant has no intrinsic mechanism to stabilize the DRUJ.

At a mean follow-up of 54.3 months, Yen Shipley et al reported a 1.68-point improvement in visual analog pain score and good modified Mayo wrist scores, regardless whether the procedure was performed in a primary or revision setting. Three of 22 wrists required revision, 2 because of persistent symptomatic instability and 1 because of implant breakage following a fall. Mayo scores were good in two and excellent in one of the patients who required revision. Two other wrists demonstrated asymptomatic instability.

**Total DRUJ Arthroplasty**

Total DRUJ implant arthroplasty is indicated in the setting of incompetent native soft tissues and offers a salvage option for the multiply operated failed distal ulnar resection (Figure 11). Several total DRUJ replacements exist, but to our knowledge, only two are available in the United States. Although there are individual differences, total DRUJ replacements are differentiated from all other designs because the entirety of the DRUJ, including its stabilizing mechanisms, is replaced by the implant, obviating the need for native soft-tissue support. This is an intriguing idea, especially given the common clinical finding of incompetent and nonreconstructible native soft tissues in the salvage setting. Some early total DRUJ implants were problematic because of implant loosening, specifically along the intramedullary ulna stem; however, this problem has not been noted consistently with more recent designs and in more recent studies. Recent work has documented preserved postoperative grip and pinch strength as well as ROM, in addition to reduced pain and improved Disabilities of the Arm, Shoulder, and Hand and subjective questionnaire scores in patients undergoing total DRUJ replacement.

Scheker reported on 49 patients who underwent total DRUJ arthroplasty. At a minimum 2-year follow-up, average postoperative grip strength was 63.4% of the contralateral side, lifting ability increased from 1.2 to 5.3 kg (2.6 to 11.6 lb), and the visual analog pain score fell from 3.8 to 1.3. At final follow-up, mean pronation was 79° and mean supination was 72°. Six complications were noted: two superficial infections, two episodes of ECU tenosynovitis, one case of ectopic bone formation at the distal ulna, and one instance of transient bone resorption.

Most total DRUJ arthroplasties have been performed secondary to failed resection arthroplasty. However, some surgeons have used it to manage congenital conditions, specifically in the setting of Madelung deformity.

**Other Salvage Options**

Several alternatives exist for managing complex and refractory DRUJ
pathology. Wolfe et al51 performed wide excision of the distal ulna (ie, 25% to 50%) to manage failed resection arthroplasty. Outcomes were positive in 83% of patients, including preserved strength, which is surprising given the load-bearing role of the DRUJ.

Perhaps the ultimate alternative for forearm instability is radio-ulnar synostosis (RUS), or creation of a one-bone forearm (OBF). First described by Hey Groves52 in 1921, RUS is done in an attempt to transform a painful, unstable forearm into a painless, stable one by eliminating a painful, unstable forearm into one-bone forearm (OBF). First described by Hey Groves52 in 1921, RUS is done in an attempt to transform a painful, unstable forearm into a painless, stable one by eliminating a painful, unstable forearm into one-bone forearm (OBF). First described by Hey Groves52 in 1921, RUS is done in an attempt to transform a painful, unstable forearm into a painless, stable one by eliminating a painful, unstable forearm into one-bone forearm (OBF). First described by Hey Groves52 in 1921, RUS is done in an attempt to transform a painful, unstable forearm into a painless, stable one by eliminating a painful, unstable forearm into one-bone forearm (OBF).

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