Review Article

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

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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.

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The distal radioulnar joint (DRUJ) is a complex structure that contributes to full, painless forearm motion and weight bearing. It is a common generator of ulnar-sided wrist pain. There is a relatively shallow groove for bony articulation. Thus, stability is maintained by a complex network of ligamentous and musculotendinous supports.

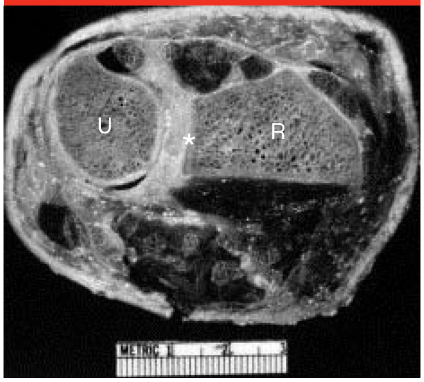
Types of DRUJ pathology include instability, incongruity, and arthrosis. Symptomatic arthrosis of the DRUJ has the potential to cause disability of both the wrist and the forearm; historically, it has been managed with distal ulna resection following failed nonsurgical management. Although outcomes are typically favorable, unstable residual distal ulnar stump is a challenging complication of DRUJ resection arthroplasty. Soft-tissue stabilization procedures and DRUJ implant arthroplasties have been developed to manage residual ulnar instability.

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[1] (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).[2]

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

Figure 1



Axial cross-section of the distal radioulnar joint in a cadaver specimen. The sigmoid notch (asterisk) is much flatter and has a larger radius of curvature than the ulnar head (U). This geometry provides limited osseous stability to the joint. R = radius. (Adapted with permission from Cooney WP III, Berger RA: Distal radioulnar joint implant arthroplasty. *Journal of the American Society for Surgery of the Hand* 2005;5[4]:217-231.)

Figure 2

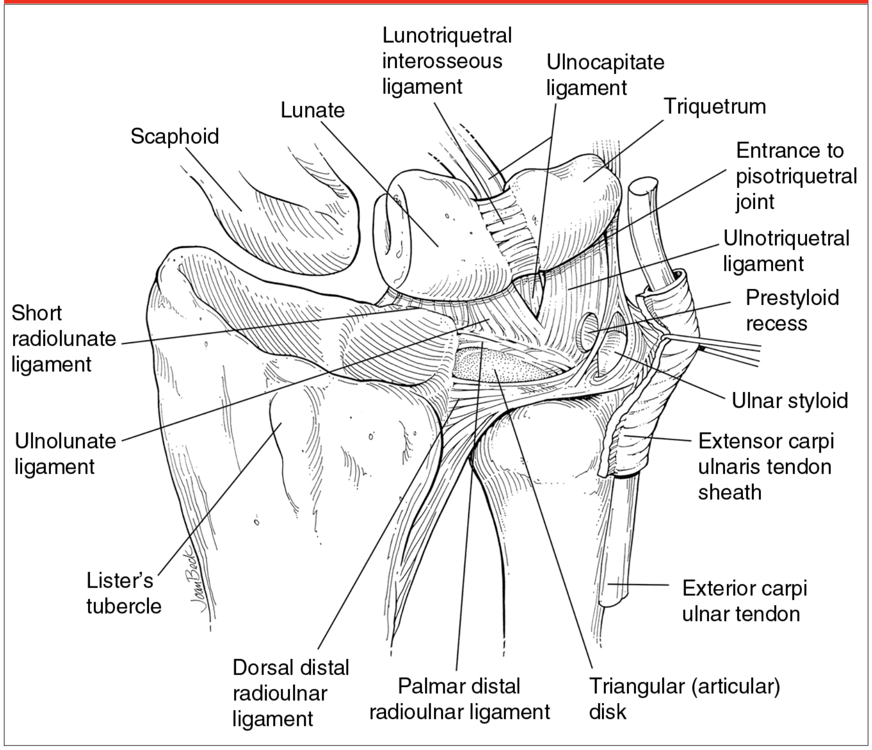


Illustration of ulnar wrist anatomy. The triangular fibrocartilage complex consists of the dorsal and volar radioulnar ligaments, dorsal and volar ulnocarpal ligaments, articular disk, meniscus homolog, and extensor carpi ulnaris (ECU) tendon sheath. The meniscus homolog is not shown. (Reproduced from Shin AY, Deitch MA, Sachar K, Boyer MI: Ulnar-sided wrist pain: Diagnosis and treatment. *Instr Course Lect* 2005;54:115-128. By permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

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 that 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.

Nygaard 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-

Figure 3

Lateral radiograph demonstrating malunion of a distal radius fracture with residual volar displacement and distal radioulnar joint subluxation. (Reproduced with permission from Shea K, Fernandez DL, Jupiter JB, Martin C Jr: Corrective osteotomy for malunited, volarly displaced fractures of the distal end of the radius. *J Bone Joint Surg Am* 1997;79[12]:1816-1826.)

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[12] (Figure 3). Children can experience malunion and fracture propagation into the sigmoid notch, but growth arrest following physeal 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.[13] 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.[14] 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 ulnovolar 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.[15]

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[16] 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.[3]

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,[17] but we have found a tender styloid to be symptomatic regardless of wrist position. ROM testing and provocative maneuvers follow.

Pronation and supination are especially informative and must be compared with that of the contralateral wrist. Crepitus and decreased or painful rotation, especially in the context of instability, should raise suspicion for DRUJ pathology. Instability can be assessed by grasping the distal ulna and exerting dorsal and volar stresses, assessing for pain or movement of the ulna relative to the radius. This maneuver, known as the "shucking" test, should be repeated in supination, neutral positioning, and pronation. Both wrists should be compared because findings can vary based on an individual's baseline ligamentous laxity. Radioulnar impingement typically presents with crepitus and pain during forearm rotation, which can be elicited by pronating and supinating the wrist while compressing the ulna against the radius. Specific tests can be done to evaluate specific components of the DRUJ. Repetitive pronation and supination in ulnar deviation can reveal ECU subluxation. The press test, in which the patient uses her or his arms to rise from a chair, axially loads the wrist in ulnar deviation and is painful in persons with a TFCC tear.[17-19]

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.[20] 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,[21] 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,[22] 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.[23] Bone resection should be minimal, with just enough to clear the sigmoid notch, thereby preserving the interosseous membrane to optimize residual stump stability.[23]

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-

Figure 4

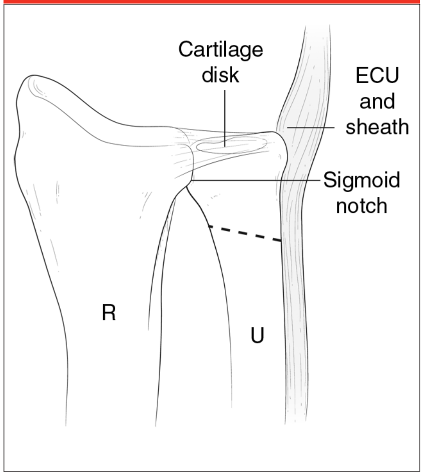


Illustration of components of the Darrach procedure. The distal ulna is resected just proximal to the radioulnar joint. The osteotomy is slanted 30° to 40° obliquely (dashed line). Although it is important to clear the sigmoid notch, minimal bone resection is favored to preserve ulnar stump stability. ECU = extensor carpi ulnaris tendon, R = radius, U = ulna. (Adapted with permission from Nolan WB III, Eaton RG: A Darrach procedure for distal ulnar pathology derangements. *Clin Orthop Relat Res* 1992;[275]: 85-89.)

Figure 5

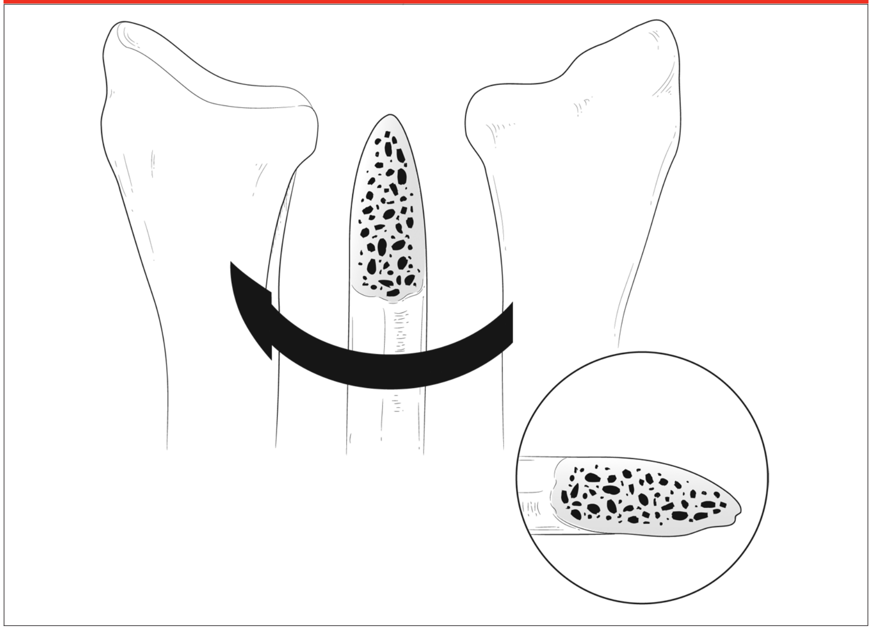


Illustration of matched distal ulna resection, which involves tapering the resection in a smooth, curved fashion to optimize congruence with the distal radius during forearm rotation (inset). The overall resection can be 5 cm in length and typically requires resection of the ulnar styloid. (Adapted with permission from Watson HK, Gabuzda GM: Matched distal ulna resection for posttraumatic disorders of the distal radioulnar joint. *J Hand Surg Am* 1992;17[4]:724-730.)

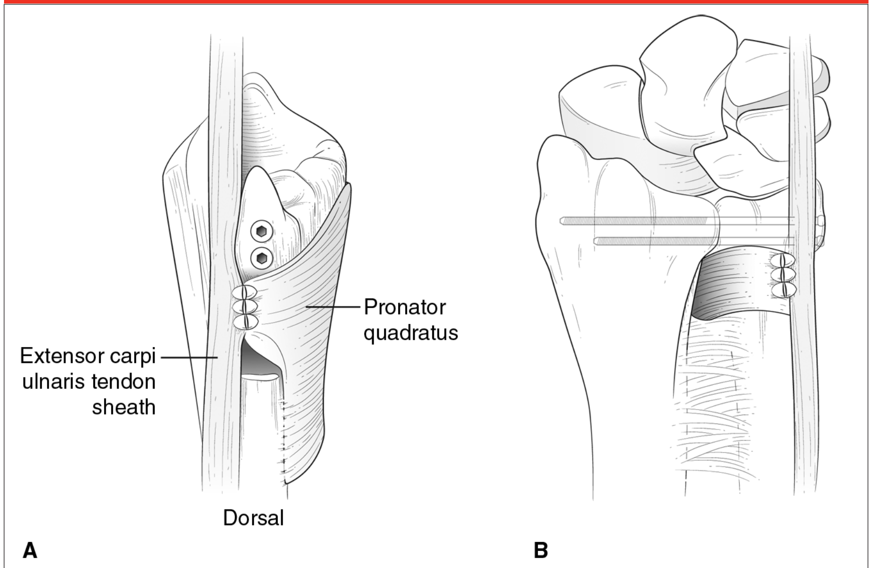
cised, with the remainder left in situ and the attachments of the TFCC preserved to optimize stability.[24,25] A common variation is the hemiresection interposition technique (HIT). With this method, the resection component is unchanged, and the interposition involves the insertion of soft tissue into 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 al[30] described a modified technique to improve stability and union that uses a 30-mm distal ulnar segment that is rotated

Figure 6



Illustrations of the Sauvé-Kapandji procedure. **A,** Lateral view demonstrating fusion of the distal ulna to the radius at the sigmoid notch using screws. Approximately 1 cm is resected proximally and interposed with the pronator quadratus muscle. The flexor carpi ulnaris or extensor carpi ulnaris tendon can be used to further stabilize the ulnar stump. **B,** Dorsal view demonstrating the final appearance following the procedure. (Adapted with permission from Slater RR, Szabo RM: The Sauvé-Kapandji procedure. *Tech Hand Up Extrem Surg* 1998;2:148-157.)

Figure 7

AP plain radiograph demonstrating radioulnar impingement following distal ulna resection and extensor carpi ulnaris–flexor carpi ulnaris tenodesis. (Reproduced with permission from Scheker LR: Implant arthroplasty for the distal radioulnar joint. *J Hand Surg Am* 2008;33[9]:1639-1644.)

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.[23,27,31,32] Although some patients can return to heavy labor, caution is advised when performing distal ulna resection on higher-demand persons.[31] 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[24,31] (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.[21] 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.[33] In a different study, 50% of patients reported subjective instability after undergoing the Sauvé-Kapandji procedure.[34] Although symptomatic improvement is typically achieved following HIT, DRUJ kinematics remain abnormal.[30,35] Favorable long-term results after HIT have been noted in patients with rheumatoid arthritis.[36] Watson and Gabuzda[24] noted good to excellent results in 24 of 32 patients who underwent matched resection, with outcome proportional to preoperative morbidity. Minami et al[37] 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 procedures.[38] 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.[39,40] 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.[39] In a study by Breen and Jupiter,[39] all eight patients treated with this technique obtained stable ulnae postoperatively. Tenodesis techniques using tendon allografts have also been described.[40] 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.[40,41]

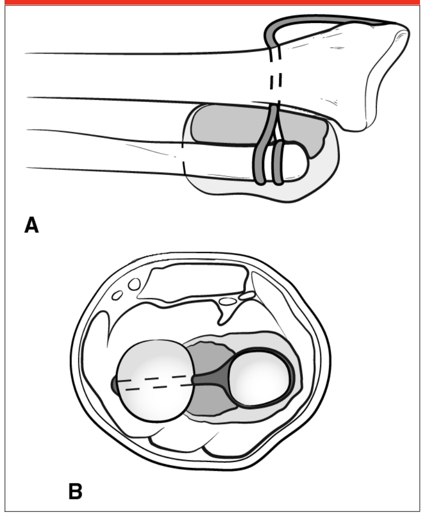
Implant Arthroplasty

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

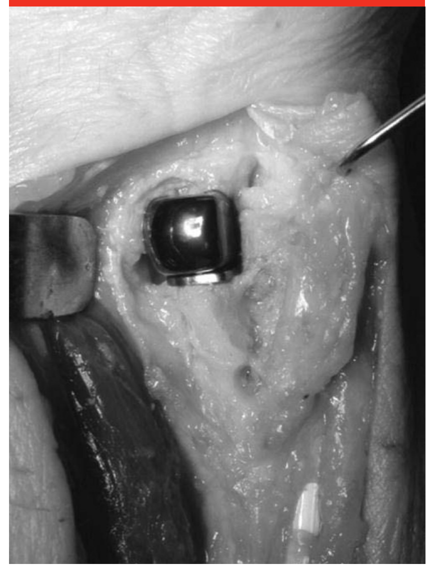
Partial ulnar head hemiarthroplasty is the least intrusive implant arthroplasty option. Several partial ulnar head replacements are available. These implants can take various forms (eg, pyrocarbon spacers) and are intended for cases of isolated DRUJ arthritis without instability. This type of implant 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[42] (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.[42]

Figure 8



AP (**A**) and axial (**B**) illustrations of soft-tissue stabilization of an unstable distal ulnar stump. Achilles tendon allograft in the interosseous space is further stabilized using two slips of a divided brachioradialis tendon passed through the distal radius and wrapped volarly and dorsally around the distal ulna. (Adapted with permission from Allende C: Allograft tendon interposition and brachioradialis tendon stability augmentation in revision surgery for failed Darrach distal ulna resections. *Tech Hand Up Extrem Surg* 2010;14[4]:237-240.)

Figure 9



Dorsal photograph demonstrating partial ulnar head replacement using the Eclypse implant (Tornier, Cedex, France). (Reproduced with permission from Garcia-Elias M: Eclypse: Partial ulnar head replacement for the isolated distal radio-ulnar joint arthrosis. *Tech Hand Up Extrem Surg* 2007; 11[1]:121-128.)

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.[43] 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-

Figure 10

AP radiograph demonstrating total ulnar head replacement using the Herbert Ulnar Head Prosthesis (KLS Martin Group, Tuttlingen, Germany). (Reproduced with permission from Herbert TJ, van Schoonhoven J: Ulnar head replacement. *Tech Hand Up Extrem Surg* 2007;11[1]:98-108.)

Figure 11

AP radiograph demonstrating total distal radioulnar joint (DRUJ) replacement using the Aptis DRUJ prosthesis (Aptis Medical, Glenview, KY).

casionally, acute trauma.[43-45] 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[44] 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.[46-48] 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.[47-49] 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.[46-49]

Scheker[48] 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.[50]

Other Salvage Options

Several alternatives exist for managing complex and refractory DRUJ pathology. Wolfe et al[51] 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 radioulnar synostosis (RUS), or creation of a one-bone forearm (OBF). First described by Hey Groves[52] in 1921, RUS is done in an attempt to transform a painful, unstable forearm into a painless, stable one by eliminating forearm rotation. In a small series, patients who underwent posttraumatic OBF creation had decreased pain and preserved strength.[53] However, results were more varied for RUS performed for nontraumatic conditions; multiple prior procedures were identified as one risk factor for a poor outcome after creation of an OBF.[54]

Authors' Preferred Treatment Algorithm

At our institution, management begins with a thorough history and physical examination. Particular attention is paid to provocative physical examination maneuvers, including the shuck and press tests to assess for instability and arthrosis of the DRUJ.

Meticulous care is required to preserve soft-tissue stabilizers during any procedure involving the DRUJ. Currently, we reserve the Darrach procedure for elderly, low-demand patients because outcomes for younger, active patients appear to us to be less favorable. Initial surgical management typically consists of either a Sauvé-Kapandji procedure or HIT for young patients, based on whether the TFCC is ruptured or intact, respectively. For management of distal ulnar stump instability, we prefer ECU-FCU tenodesis with concomitant repair of amenable soft tissues or capsulorrhaphy. We prefer total DRUJ arthroplasty for recalcitrant instability and for patients who present with multiple prior procedures and incompetent soft tissues. We have had favorable postoperative outcomes with this technique.

Summary

Our understanding of the DRUJ has advanced significantly in recent years. The DRUJ is critical in both forearm rotation and weight bearing, and its stability relies on soft-tissue support. The biomechanics of this structure are complex, and reconstruction is challenging. DRUJ pathology is a common cause of ulnar-sided wrist pain and is often noted following distal radius fracture. Resection arthroplasty remains a mainstay for managing symptomatic DRUJ arthrosis, although instability of the residual ulnar stump is a problematic complication. Multiple procedures exist to manage failed resection arthroplasty, including novel DRUJ implant arthroplasties. Initial results with these devices have been favorable, but further research is needed to assess long-term outcomes.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 12, 28, and 37 are level III studies. References 13, 16, 22-27, 30-36, 38-40, 42-51, 53, and 54 are level IV studies.

References printed in **bold type** indicate those published within the past 5 years.

1. af Ekenstam F: Anatomy of the distal radioulnar joint. *Clin Orthop Relat Res* 1992;(275):14-18.
2. Stuart PR, Berger RA, Linscheid RL, An KN: The dorsopalmar stability of the distal radioulnar joint. *J Hand Surg Am* 2000;25(4):689-699.
3. Palmer AK, Werner FW: The triangular fibrocartilage complex of the wrist: Anatomy and function. *J Hand Surg Am* 1981;6(2):153-162.
4. Cole DW, Elsaidi GA, Kuzma KR, Kuzma GR, Smith BP, Ruch DS: Distal radioulnar joint instability in distal radius fractures: The role of sigmoid notch and triangular fibrocartilage complex revisited. *Injury* 2006;37(3): 252-258.
5. Watanabe H, Berger RA, Berglund LJ, Zobitz ME, An KN: Contribution of the interosseous membrane to distal radioulnar joint constraint. *J Hand Surg Am* 2005;30(6):1164-1171.
6. Gofton WT, Gordon KD, Dunning CE, Johnson JA, King GJ: Soft-tissue stabilizers of the distal radioulnar joint: An in vitro kinematic study. *J Hand Surg Am* 2004;29(3):423-431.
7. Schuind F, An KN, Berglund L, et al: The distal radioulnar ligaments: A biomechanical study. *J Hand Surg Am* 1991;16(6):1106-1114.
8. Palmer AK, Werner FW: Biomechanics of the distal radioulnar joint. *Clin Orthop Relat Res* 1984;(187):26-35.
9. **Nygaard M, Nielsen NS, Bojsen-Møller F: A biomechanical evaluation of the relative load change in the joints of the wrist with ulnar shortening: A 'handbag' model. *J Hand Surg Eur Vol* 2009;34(6): 724-729.**
10. **Nishiwaki M, Nakamura T, Nagura T, Toyama Y, Ikegami H: Ulnar-shortening effect on distal radioulnar joint pressure: A biomechanical study. *J Hand Surg Am* 2008;33(2):198-205.**
11. Nishiwaki M, Nakamura T, Nakao Y, Nagura T, Toyama Y: Ulnar shortening effect on distal radioulnar joint stability: A biomechanical study. *J Hand Surg Am* 2005;30(4):719-726.
12. Jupiter JB, Ring D: A comparison of early and late reconstruction of malunited fractures of the distal end of the radius. *J Bone Joint Surg Am* 1996; 78(5):739-748.
13. Cannata G, De Maio F, Mancini F, Ippolito E: Physeal fractures of the distal radius and ulna: Long-term prognosis. *J Orthop Trauma* 2003;17(3):172-180.
14. **Murray PM: Current concepts in the treatment of rheumatoid arthritis of the distal radioulnar joint. *Hand Clin* 2011; 27(1):49-55.**
15. **Pritsch T, Moran SL: The management of congenital and acquired problems of**

the distal radioulnar joint in children. *Hand Clin* 2010;26(4):579-591.

16. May MM, Lawton JN, Blazar PE: Ulnar styloid fractures associated with distal radius fractures: Incidence and implications for distal radioulnar joint instability. *J Hand Surg Am* 2002;27(6): 965-971.
17. Szabo RM: Distal radioulnar joint instability. *J Bone Joint Surg Am* 2006; 88(4):884-894.
18. Lester B, Halbrecht J, Levy IM, Gaudinez R: "Press test" for office diagnosis of triangular fibrocartilage complex tears of the wrist. *Ann Plast Surg* 1995;35(1):41-45.
19. **Tsai PC, Paksima N: The distal radioulnar joint. *Bull NYU Hosp Jt Dis* 2009;67(1):90-96.**
20. **Amrami KK, Moran SL, Berger RA, Ehman EC, Felmlee JP: Imaging the distal radioulnar joint. *Hand Clin* 2010; 26(4):467-475.**
21. Gordon KD, Dunning CE, Johnson JA, King GJ: Kinematics of ulnar head arthroplasty. *J Hand Surg Br* 2003;28(6): 551-558.
22. Darrach W: Habitual forward dislocation of the neck of the ulna. *Ann Surg* 1913;57:928-930.
23. Tulipan DJ, Eaton RG, Eberhart RE: The Darrach procedure defended: Technique redefined and long-term follow-up. *J Hand Surg Am* 1991;16(3):438-444.
24. Watson HK, Gabuzda GM: Matched distal ulna resection for posttraumatic disorders of the distal radioulnar joint. *J Hand Surg Am* 1992;17(4):724-730.
25. Watson HK, Ryu JY, Burgess RC: Matched distal ulnar resection. *J Hand Surg Am* 1986;11(6):812-817.
26. Bowers WH: Distal radioulnar joint arthroplasty: The hemiresection-interposition technique. *J Hand Surg Am* 1985;10(2):169-178.
27. **Slater RR Jr: The Sauvé-Kapandji procedure. *J Hand Surg Am* 2008;33(9): 1632-1638.**
28. **Nikkhah D, Rodrigues J, Dejager L: Do patients really do better after the Sauve-Kapandji procedure when compared to the Darrach procedure? A systematic review. *J Hand Surg Eur Vol* 2011;36(7): 615.**
29. Fernandez DL: Radial osteotomy and Bowers arthroplasty for malunited fractures of the distal end of the radius. *J Bone Joint Surg Am* 1988;70(10):1538-1551.
30. Fujita S, Masada K, Takeuchi E, Yasuda M, Komatsubara Y, Hashimoto H: Modified Sauvé-Kapandji procedure for disorders of the distal radioulnar joint in patients with rheumatoid arthritis. *J Bone Joint Surg Am* 2005;87(1):134-139.
31. Hartz CR, Beckenbaugh RD: Long-term results of resection of the distal ulna for post-traumatic conditions. *J Trauma* 1979;19(4):219-226.
32. **De Witte PB, Wijffels M, Jupiter JB, Ring D: The Darrach procedure for post-traumatic reconstruction. *Acta Orthop Belg* 2009;75(3):316-322.**
33. Zimmermann R, Gschwentner M, Arora R, Harpf C, Gabl M, Pechlaner S: Treatment of distal radioulnar joint disorders with a modified Sauvé-Kapandji procedure: Long-term outcome with special attention to the DASH questionnaire. *Arch Orthop Trauma Surg* 2003;123(6):293-298.
34. Inagaki H, Nakamura R, Horii E, Nakao E, Tatebe M: Symptoms and radiographic findings in the proximal and distal ulnar stumps after the Sauvé-Kapandji procedure for treatment of chronic derangement of the distal radioulnar joint. *J Hand Surg Am* 2006; 31(5):780-784.
35. Glowacki KA: Hemiresection arthroplasty of the distal radioulnar joint. *Hand Clin* 2005;21(4):591-601.
36. **Ahmed SK, Cheung JP, Fung BK, Ip WY: Long term results of matched hemiresection interposition arthroplasty for DRUJ arthritis in rheumatoid patients. *Hand Surg* 2011;16(2):119-125.**
37. Minami A, Iwasaki N, Ishikawa J, Suenaga N, Yasuda K, Kato H: Treatments of osteoarthritis of the distal radioulnar joint: Long-term results of three procedures. *Hand Surg* 2005;10(2-3):243-248.
38. Bieber EJ, Linscheid RL, Dobyns JH, Beckenbaugh RD: Failed distal ulna resections. *J Hand Surg Am* 1988;13(2): 193-200.
39. Breen TF, Jupiter JB: Extensor carpi ulnaris and flexor carpi ulnaris tenodesis of the unstable distal ulna. *J Hand Surg Am* 1989;14(4):612-617.
40. Sotoreanos DG, Göbel F, Vardakas DG, Sarris I: An allograft salvage technique for failure of the Darrach procedure: A report of four cases. *J Hand Surg Br* 2002;27(4):317-321.
41. **Allende C: Allograft tendon interposition and brachioradialis tendon stability augmentation in revision surgery for failed Darrach distal ulna resections. *Tech Hand Up Extrem Surg* 2010;14(4): 237-240.**
42. Garcia-Elias M: Eclypse: Partial ulnar head replacement for the isolated distal radio-ulnar joint arthrosis. *Tech Hand Up Extrem Surg* 2007;11(1):121-128.
43. Herbert TJ, van Schoonhoven J: Ulnar head replacement. *Tech Hand Up Extrem Surg* 2007;11(1):98-108.
44. **Yen Shipley N, Dion GR, Bowers WH: Ulnar head implant arthroplasty: An intermediate term review of 1 surgeon's experience. *Tech Hand Up Extrem Surg* 2009;13(3):160-164.**
45. **Berger RA: Indications for ulnar head replacement. *Am J Orthop (Belle Mead NJ)* 2008;37(8 suppl 1):17-20.**
46. **Laurentin-Pérez LA, Goodwin AN, Babb BA, Scheker LR: A study of functional outcomes following implantation of a total distal radioulnar joint prosthesis. *J Hand Surg Eur Vol* 2008;33(1):18-28.**
47. **Schuurman AH, Teunis T: A new total distal radioulnar joint prosthesis: Functional outcome. *J Hand Surg Am* 2010;35(10):1614-1619.**
48. **Scheker LR: Implant arthroplasty for the distal radioulnar joint. *J Hand Surg Am* 2008;33(9):1639-1644.**
49. **Zimmerman RM, Jupiter JB: Outcomes of a self-constrained distal radioulnar joint arthroplasty: A case series of six patients. *Hand (N Y)* 2011;6(4):460-465.**
50. **Coffey MJ, Scheker LR, Thirkannad SM: Total distal radioulnar joint arthroplasty in adults with symptomatic Madelung's deformity. *Hand (N Y)* 2009;4(4):427-431.**
51. Wolfe SW, Mih AD, Hotchkiss RN, Culp RW, Keifhaber TR, Nagle DJ: Wide excision of the distal ulna: A multicenter case study. *J Hand Surg Am* 1998;23(2): 222-228.
52. Hey Groves EW: *On Modern Methods of Treating Fractures*, ed 2. Bristol, England, John Wright and Sons, Ltd, 1921.
53. Allende C, Allende BT: Posttraumatic one-bone forearm reconstruction: A report of seven cases. *J Bone Joint Surg Am* 2004;86(2):364-369.
54. Peterson CA II, Maki S, Wood MB: Clinical results of the one-bone forearm. *J Hand Surg Am* 1995;20(4):609-618.