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Objective Outcomes Following Semi-Constrained Total Distal Radioulnar Joint Arthroplasty

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ABSTRACT

A dysfunctional distal radioulnar joint (DRUJ) can significantly compromise an individual's forearm rotation, grip, and weight bearing at the hand and wrist. This retrospective study reports surgeon and therapist collected objective wrist function and subjective pain scores of 10 patients who received the Scheker total DRUJ prosthesis. A review of these patients' medical records was performed to collect preoperative measurements of wrist range of motion, grip strength and pain scores (0-10 scale). The degree of pronation, supination, flexion, extension, radial deviation and ulnar deviation were the outcome measures used to evaluate wrist range of motion. Postoperative measurements were collected at a follow up of 5±1.1years in our clinic (minimum follow-up of 2yrs). Mean final wrist flexion and extension were 32.1±22.8° and 44.8±13.9 °, respectively. Mean final supination and pronation were 72.5±14.4° and 69.5±14.6°, respectively. Average grip strength was 54.9±23.7 lbs. The mean pain score was 3.6±3.1.

Although there weren't any statistically significant changes in any of these outcome measures, the Scheker prosthesis improved wrist range of motion (with the exception of wrist flexion) and decreased pain. Grip strength decreased by less than one pound but was still higher than the postoperative grip strength measurements in the literature for this prosthesis. Due to the self-stabilizing nature of this prosthesis and the satisfactory functional outcomes from this study and other studies, the Scheker prosthesis is a viable option for DRUJ pathology that is refractory to non-implant arthroplasties. This is a therapeutic level IV study.

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INTRODUCTION

DRUJ Anatomy and Function

Recognition and proper treatment of distal radioulnar joint (DRUJ) pathology requires an understanding of DRUJ anatomy and function. The DRUJ is comprised of sigmoid notch of the distal radius, the ulnar head, and soft-tissue stabilizers. All components are critical for forearm rotation and weight bearing.

Forearm rotation among individuals ranges from 150-180 degrees with an additional rotation of up to 30 degrees available through the radiocarpal joint. The rotational axis passes near the cross sectional centers of the ulnar head distally and the radial head proximally. That rotational axis is more dorsal during pronation and ventral during supination at the DRUJ. Pronation and supination result from a sliding/translational motion in the anteroposterior plane and rotational motion in the transverse plane. This is due to the fact that the sigmoid notch is shallow with a greater radius of curvature than the ulnar head. The radius of the sigmoid notch is 50-100% greater than the radius of ulnar head.[1, 2]

The difference in radii of curvature of the sigmoid notch and ulnar head accounts for the lack of DRUJ stability derived directly from the articulation of both surfaces. This articulation is only responsible for 20% of DRUJ stability. When the DRUJ is in neutral, articular contact, in terms of surface area, approaches a maximum of 60%. In full pronation or supination, the surface area in contact is less than 10%. Due to this inherent lack of stability from this articulation, soft tissue stabilizers are immensely critical. They are responsible for 80% of DRUJ stability. [1, 3]

Soft-tissue stabilizers can be classified as static or dynamic. The static stabilizers include the radio-ulnar interrosseous membrane (IOM), triangular fibrocartilage (TFC), radioulnar ligaments and ulnocarpal ligaments. The IOM acts as a tether between the radius and ulna and thereby prevents diastasis. It is most taught in supination. It plays an important role in forearm force transmission. The remaining static soft-tissue stabilizers, the TFC, radioulnar and ulnocarpal ligaments, form the triangular fibrocartilage complex (TFCC) which extends from the carpal margin of the sigmoid notch of the radius, reaches the volar base of the fifth metacarpal while cupping the lunate and triquetal bone. The TFC is comprised of a triangular central and peripheral component. The central component supports compressive loads at the DRUJ. The peripheral component arises from the palmar and dorsal portions of the sigmoid notch and attaches to the ulnar head and styloid process.

The radioulnar ligaments are the principal DRUJ stabilizers. The palmar and dorsal radioulnar ligaments are located at the common juncture of the ulnocarpal capsule, articular disk and DRUJ capsule. The palmar and dorsal radioulnar ligaments provide stability at the extremes of pronation and supination. These ligaments are composed of longitudinally oriented lamellar collagen which critical to resistance of tensile loads. They also have a rich vascular supply that is important in the healing process. The ulnocarpal ligaments, the other third of the TFCC, is comprised of the ulnolunate and ulnotriquetal ligaments. These ligaments originate from the base of the styloid and distally move to attach to the lunate and triquetrum volarly. These attachments allows these ligaments to resist dorsal displacement of distal ulna as it relates to the carpus.

The TFCC, as a whole, functions to provide a strong and flexible radio-ulnar connection that allows pronation and supination. It cushions the axial force transmitted across the ulnocarpal joint. It supports the ulnarcarpus through its connections to the radius and ulna. It also extends the articular surface of the distal radius to cover the ulnar head which provides a continuous gliding surface that facilitates carpal movement.

The dynamic stabilizers are the extensor carpi ulnaris muscle (ECU) and the pronator quadratus muscle. The ECU originates from the lateral epicondyle of the humerus and posterior border of the ulna and then crosses the dorsal ulnar head through an osseous groove to attach to the base of the base of the 5th metacarpal. The infratendinous extensor retinaculum holds the ECU in place distally. The ECU resists dorsal ulna dislocation during full pronation and palmar ulna displacement during full supination. The pronator quadratus, which attaches distally to the radius and ulna functions, coapts the ulnar head to the sigmoid notch during pronation. It can also act as a static stabilizer during supination. This is accomplished by passive coaptation of the ulnar head in the sigmoid notch through its viscoelastic constraints. These dynamic stabilizers along with static stabilizers cumulatively strengthen the weak distal radio-ulnar articulation. [1, 2]

DRUJ Dysfunction

DRUJ dysfunction can arise from any disruptive change to the aforementioned anatomical components and biomechanics of the DRUJ. The etiology can be traumatic, degenerative, developmental, inflammatory or neoplastic in nature. It is not uncommon for these etiologies to coexist and interact. Traumatic, degenerative and inflammatory etiologies are the most common. Traumatic etiologies include distal radius fracture, ulnar styloid fracture and TFCC lesions. Post-traumatic DRUJ instability is most common after a distal radius fracture. If the distal radius fracture extends to the sigmoid notch, it can result in joint asymmetry and subsequent arthrosis. In children, a physeal fracture associated with distal radius fracture can lead to growth arrest in 4% of patients. This alters DRUJ biomechanics and leads to degeneration.

The most prognostic risk factors for persistent DRUJ instability after distal radius fracture are severe radial shortening and initial wide DRUJ displacement. Loss of radial length in isolation is less likely to be associated with loss of stability or rotation but radial shortening greater than 5-7mm leads to radioulnar ligament trauma and subsequent DRUJ instability. Otherwise, radial shortening usually results in increased ulnar loading and ulnar impaction. Other radial deformities such as distal radius malunions can also lead to a loss of DRUJ stability. Distal radius and forearm malunions usually present as loss of forearm rotation and ulnar sided wrist pain with ulnar head prominence. 20-30 degrees or more of residual dorsal angulation of the distal radius is associated with palmar DRUJ instability, increased loading of the ulna, radioulnar incongruity as well as TFCC distortion. In order to prevent these sequelae of distal radius fractures, proper fracture reduction and maintenance of radial alignment are immensely important.

Distal radius fractures are commonly associated with ulnar styloid fractures. Approximately 61% of distal radius fractures occur concomitantly with ulnar styloid fractures. Fractures through the tip rarely lead to instability and generally, they don’t require any intervention. Since the tip is devoid of soft tissue attachments, its fractures don’t disrupt the soft tissues that are primarily responsible for stability. The styloid shaft provides insertion sites for ECU tendon sheath, portions of the ulnocarpal ligaments and the limbs of the radioulnar ligaments. Fractures through the styloid base are most worrisome especially when there's displacement because they increase the risk of DRUJ instability by disrupting limbs of the radioulnar ligaments. Fixation of the styloid restores stability assuming there's no damage to the TFCC. Ulnar styloid nonunion, although uncommon, is treated with subperiosteal excision when it is symptomatic. If the TFCC is unstable and the styloid fragment is large, the fragment is excised and TFCC periphery is transosseously sutured to the styloid base. [1]

Traumatic TFCC lesions can compromise DRUJ stability depending on severity and associated injuries. They can arise from a fall on an outstretched pronated hand, a rotational forearm injury or a combination of a distraction injury to the ulnar border of the forearm and an axial load. Palmer's classification of TFCC lesions is the most popular scheme for anatomic description of these tears. However, Palmer's classification is not prognostic and it does not guide treatment.

The decision to treat a TFCC tear as well as how to treat depends on the severity of the tear as well as the presence of DRUJ instability, joint pain from synovitis or mechanical irritation and associated fractures or malunions. A slitlike tear of the disk near its radial insertion that is oriented volar to dorsal without radioulnar ligament involvement rarely causes DRUJ instability but can cause ulnar-sided wrist pain that is aggravated by power grip. It is managed conservatively with rest and anti-inflammatory medications. A complete or partial avulsion of the TFCC from its ulnar attachments can occur with or without an ulnar styloid fracture. Due to the dual ulnar attachments of TFCC, most ulnar styloid fractures do not cause DRUJ instability. A styloid base fracture is more predictive of a TFCC tear and DRUJ instability. Complete avulsion of the radioulnar ligaments and DRUJ instability can occur without a styloid fracture. These tears also lead to ulnar-sided wrist pain. They require immediate above-elbow immobilization in neutral rotation since these tears are more likely to progress to destabilizing TFCC injuries. [1, 6]

The TFCC's ulnocarpal ligaments can be partially or completely torn either at their insertion sites to the lunate, triquetrum or within the ligaments. They can be difficult to diagnose. The most telling sign, if present, is the volar sag of carpus relative to the ulnar head. They can occur in combination with lunotriquetral ligament tears. They're managed conservatively unless there is instability which is unlikely. These tears heal well due to their good vascular supply. Another type of TFCC injury is a partial or complete avulsion of the TFCC from the radius with or without a bony fragment. This injury may also involve one or both of the radioulnar ligaments. These injuries are typically associated with distal radius fractures. Proper fracture reduction remedies this TFCC injury. Open repair is necessary for large radial avulsion fractures that involve the rim of the sigmoid notch. Damage to the sigmoid notch rim compromises DRUJ stability since it provides articular stability as well as attachment sites for stabilizing ligaments. Traumatic TFCC lesions can be benign or seriously compromising depending on severity and the presence of associated DRUJ injuries. [1, 2]

In contrast to traumatic DRUJ pathology, degenerative DRUJ pathology results from chronic processes that involve impaction, inflammation or long standing joint instability. Ulnar impaction syndrome, one of the most common impaction syndromes associated with ulnar-sided pain, is a degeneration process that results from chronic compressive overloading across the ulnar head, ulnar carpus and TFCC. There are substantial loads transmitted through a small surface area in the ulnocarpal joint. Therefore, the ulnocarpal joint is at high risk for degeneration. Tensile forces through the soft tissues as well as shear forces over the articular surface contribute to this degenerative condition. Ulna-positive variance is a risk factor because it leads to an increase in ulnocarpal loading. Ulna-positive variance is commonly idiopathic but can be acquired from an Essex-Lopestri injury, an acute or chronic physeal lesion and radial shortening subsequent to a distal radius fracture. Symptomatically, patients have ulnar wrist pain, localized swelling and limited range of motion. It is important to differentiate ulnar impaction syndrome from DRUJ arthritis, another chronic degenerative condition, since different treatments are indicated. Ulnar impaction syndrome is managed conservatively with wrist splinting, activity modification aimed at reducing repetitive ulnocarpal loading and anti-inflammatory medications.

Recalcitrant ulnar impaction syndrome without DRUJ arthritis is managed surgically to reduce ulnocarpal loading. Wafer procedure is indicated in ulnar impaction syndrome especially with minimally ulnar-positive or ulnar-neutral variance. This surgery involves excision of the ulnar 2 to 4 mm distally. It can be performed open or arthroscopically. This procedure is valuable because it retains the foveal attachments of the TFCC as well as the ulnar styloid. It is not intended to disrupt the articular surfaces of the DRUJ and therefore no more than 3 to 4 mm should be resected. Ulnar-shortening osteotomy is intended for ulnar impaction syndrome secondary to developmental or acquired ulnar-positive variance. It’s advantageous because it preserves the ulnar dome articular cartilage and does not violate the ulnocarpal joint or the DRUJ. The procedure tightens the ulnocarpal ligaments which ameliorates lunotriquetral or DRUJ instability.

Additionally, ulnar-shortening osteotomy is salutary in cases of post-traumatic ulnar-positive variance. It can improve forearm rotation and DRUJ congruity while reducing the risk of arthritis. [1]

The inflammatory etiologies for DRUJ dysfunction include osteoarthritis, post-traumatic arthritis and autoimmune diseases such as rheumatoid arthritis. The arthritic DRUJ presents with pain worsened by forearm rotation, swelling, stiffness, DRUJ point tenderness and decreased grip strength. At its earliest, DRUJ arthritis is seen in the proximal portion of the DRUJ. There is osteophyte formation along the proximal margin of the ulnar head. The sigmoid notch tends to be spared in the early stages. In the advanced stages, the articular surfaces of the DRUJ are so diffusely affected that surgical treatments aim to eliminate the radioulnar articulation. DRUJ osteoarthritis from normal wear and tear is uncommon. Post-traumatic DRUJ arthritis is more common especially after a distal radius malunion. Over 85% of secondary DRUJ arthritis is due to the post-traumatic malunion of the distal radius. Malalignment of the joint surfaces and direct incongruency of the sigmoid notch are the sequelae of a distal radius malunion that disturb joint mechanics and alter load distribution, which leads to DRUJ degeneration. [1, 3]

Rheumatoid arthritis is the most common arthritic condition affecting the DRUJ. Cartilage degradation, synovial expansion with erosion and ligamentous laxity are the pathologic processes involved in the rheumatoid wrist. Synovial infiltration of the prestyloid recess of the distal ulna occurs due to the increased vascular supply in this area. This infiltration leads to styloid erosion and disruption of its ligament attachments. The palmar side of the distal radius, waist of the scaphoid and triquetrum are also eroded. Synovitis also affects many of the extrinsic and intrinsic wrist ligaments such as the palmar radiocarpal, scapholunate and lunotriquetral ligaments. ECU tenosynovitis and DRUJ proliferative synovitis further contribute to DRUJ instability. The infiltrative erosion, ligamentous disruption and cartilage degradation by lysosome culminate in a degenerative arthritic condition. [1, 3, 7]

Traumatic and arthritic DRUJ pathology along with spasticity can result in acquired contractures of the DRUJ. DRUJ trauma, especially distal radius fractures, can lead to contractures of the DRUJ capsule. Post-traumatic contractures of DRUJ capsule are relatively common. However, these contractures need to be differentiated from forearm synostosis, radial head dislocation, and dysplastic congenital conditions which mimic DRUJ contractures. Contractures of DRUJ capsule often result in loss of supination and DRUJ stiffness. The volar capsule has an oblique fold that opens and encapsulates the ulnar head in supination. After trauma and immobilization in pronation, the fold can become adherent, thickened, and shortened. This pathologic process result in restricted supination. Physical therapy should be utilized before considering surgery for at least six months. A splinting program is a critical component of the physical therapy. Volar capsulectomy is performed for loss of supination. DRUJ subluxation and arthritis are contraindications to surgical release. A release in the presence of a subluxated stiff DRUJ may result in a painful joint.

Contracture of the pronator quadratus after injury or prolonged immobilization can result in loss of pronation. Unlike the volar capsule, the dorsal capsule is more homogeneous and thinner. It is significantly less likely to impede pronation after immobilization or trauma. Therefore, it is more likely to respond to therapy when contracted. Dorsal capsulectomy is the surgery of choice for decreased pronation. Severe bidirectional stiffness or fibrous ankylosis requires combined volar-dorsal capsulectomy. [1]

Although rare, neoplastic etiologies can progressively disrupt DRUJ biomechanics and lead to instability. Neoplasms arising in the distal ulna can be either malignant, benign or benign aggressive. For most benign tumors, curettage followed by bone grafting is the most effective treatment since it maintains the functional stability and the structural integrity of the joint. The most common benign aggressive in the distal ulna is giant cell tumour which has a reported incidence of 0.45 to 6% per year. Curettage and bone grafting are also the treatment of choice for benign aggressive tumors. However, circumstances such as a pathological fracture, complete erosion of cortical bone, failed previous surgery or the presence of a soft tissue mass can result in suboptimal results from curettage and bone grafting. This often necessitates excision of the distal ulna. In the case of malignant neoplasms, the distal ulna is resected with a wide margin.[4]

Madelung deformity is one of the most common developmental reasons for DRUJ dysfunction. It results from a growth arrest of the ulnovolar portion of the distal radial epiphysis. Longitudinal growth through functional portion of the epiphysis results in an angular deformity that alters DRUJ biomechanics. There is an ulnovolar tilted distal radial articular surface, a dorsally prominent distal ulna and volar translation of the wrist and hand. Patients are typically adolescent females who present with the deformity, pain and decreased range of motion. The necessity of surgery and the type of surgery depends on the patient's age, remaining distal radius growth, radiographic findings and severity of the deformity and symptoms. [3, 5]

DRUJ Arthroplasty

Degenerative DRUJ disease and/or chronic DRUJ instability that are symptomatic and recalcitrant to medical management necessitates surgical intervention regardless of etiology. [7, 8]Traditionally, partial and complete resections of the distal ulna were used treat a painful and dysfunctional DRUJ. Impingement of the ulnar remnant on the radius was a painful complication of these resections especially in active patients. [2, 10, 11] Ulnar head implants were also developed to replace the resected ulna. They have improved range of motion, grip strength and reduced pain. However, these hemiarthroplasties require an intact radial sigmoid notch as well as a stable DRUJ or a reconstructable triangular fibrocartilage. [12-15] Total DRUJ arthroplasties were invented to address these stability concerns of hemiarthroplasties.

Although resection arthroplasty is one of the oldest surgical treatment modalities, it remains widely used. It entered the medical literature in the 19th century where it was popularized by Darrach. The Darrach surgery balances symptomatic relief through limited distal ulna resection with postoperative stability through meticulous preservation of supporting soft-tissue stabilizers. The distal ulna is resected subperiosteally proximal to the sigmoid notch. The TFCC, ECU tendon sheath, ulnar styloid and its attachements are preserved when possible. The pronator quadratus or soft tissue is interposed between the ulna and radius. A soft tissue stabilization procedure is not performed routinely but can be done to preserve the local tissue cuff. If the Darrach surgery fails due to distal ulnar instability, a soft tissue stabilization procedure can be performed. Flexor carpi ulnaris (FCU) and ECU tenodesis is one of these soft tissue stabilization procedures. A distally based FCU slip and proximally based ECU slip are used a weave to stabilize the ulnar stump. Tendon allografts can also been used. Achilles tendon allograft can be interposed in the interosseous space of the DRUJ along with two slips of the brachioradialis tendons going through the distal radius and then wrapped around the ulnar stump. Despite these two measures, radioulnar convergence and ulnar stump instability are potential issues postoperatively.

The Darrach procedure is preferred for low demand patients with a painful nonreconstructible DRUJ with incongruity or arthritis. This includes elderly patients with post-traumatic arthritis or osteoarthritis, elderly patients with DRUJ incongruity owing to malunion of the radius or ulna and patients with rheumatoid arthritis. 80-90% of these patients have improvement in forearm rotation, grip strength and pain. The undesirable outcomes of radioulnar impingement and ulnar stump instability are more likely with increased amounts of bony resection as well as with high demand patients. A common complaint among active and younger individuals is weakness. Distal ulna resection can increase the risk of ulnar translation of the carpus in the rheumatoid wrist. It also alters DRUJ kinematics which means return to completely normal postoperative function is unlikely. However given the right patient population, distal ulnar resection is viable option with favorable outcomes.

The stability concerns associated with the Darrach procedure provided an impetus for the development of the hemiresection-interposition athroplasty (HIT). This procedure consists of resecting only the articular surface of the distal ulnar while retaining the ulnar attachments of the TFCC to the ulnar styloid. This method of minimizing bony resection and preserving soft-tissue stabilizers addresses the stability concerns with distal ulnar resection. During HIT surgery, soft tissue is inserted into the resection cavity to prevent radio-ulnar convergence. Great care should be taken to avoid elevating and releasing the

ECU sheath as well as detaching the TFCC at its foveal attachments during this procedure. The volar portion of the ulnar head must also be shaped equally. HIT is indicated in early rheumatoid arthritis, osteoarthritis and post-traumatic arthritis. Caution should be exercised in unstable DRUJs since the instability will be exacerbated postoperatively. Patients with ulnar-positive variance may experience styloid-carpal impingement after this procedure. Patients with malunited distal radius fractures do well with this technique when a radial osteotomy is performed in conjunction. HIT generally provides pain relief but doesn't consistently improve motion due to altered DRUJ kinematics. Long term pain relief and improvement in forearm rotation are more likely in rheumatoid arthritis patients. Failures are often due to residual ulnocarpal impaction.

The Sauve-Kapandji procedure was created as an alternative to resection arthroplasties. It is indicated in patients with rheumatoid arthritis, post-traumatic arthritis and osteoarthritis. It combines radioulnar fusion with creation of a pseudoarthrosis proximal to the fusion. Fixation with two screws as well as use of cannulated screw system improve the efficiency of the procedure. Tenuous fixation and insufficient bone stock increase the likelihood of fixation failure or nonunion. Tenodesis of the distal ulnar stump is performed if there is instability especially in the young patient. By avoiding substantial ulnar head resection, the ulnar column and carpal articulation are preserved. This prevents the ulnar translation of the carpus that is seen in rheumatoid wrists that undergo the Darrach procedure. Limited bone resection also prevents styloid-carpal impingement. Soft-tissue preservation is crucial for stability. Some patients report subjective instability after this procedure. Despite this, the majority of patients experience pain relief and restoration of forearm rotation. Through a series of 105 patients, Zimmerman et al. found that all patient had improved forearm rotation while 97% of patients experience pain relief. Grip strength also improved. [1, 3]

Minami et al. performed a retrospective study with 61 patients with DRUJ osteoarthritis who received either the Darrach procedure, the Sauve-Kapandji procedure or hemiresection-interposition athroplasty to determine the long-term outcomes of these procedures. 20 patients had the Darrach procedure while 16 patients had HIT. 25 patients had the Sauve-Kapandji procedure. There were 38 primary osteoarthritis cases and the rest were secondary. 25 women and 36 men comprised the study population. Pain scores, grip strength, range of motion and return to work status were the outcome measures that were studied. At an average of 10 years (R, 5-14years) postoperatively, relief of pain from Sauvé-Kapandji procedure and HIT was superior to the Darrach procedure although this was not statistically significant. Supination and pronation of the forearm showed statistical significant improvement after all procedures. Statistically significant improvements in flexion and extension of the wrist were seen with the HIT and Sauvé-Kapandji procedures. Grip strength improvements in the HIT and Sauvé-Kapandji procedures were statistically superior to those with a Darrach's procedure. This was also the case for return to work status.

Post-operative complications such as distal radioulnar convergence and impingement of the ulna were common following the Darrach's procedure. They concluded that the Darrach's procedure was best for elderly patients with severe osteoarthritic changes of the distal radioulnar joint in elderly patients. They felt that the decision between HIT and the Sauvé-Kapandji procedure should be determined by the existence and status of the triangular fibrocartilage complex and the amount of the positive ulnar variance. The Sauvé-Kapandji procedure was preferred when there was positive ulnar variance of more than 5 mm even with a functional TFCC or when the TFCC could not be reconstructed. HIT was indicated when the TFCC was intact or could be adequately reconstructed. The Sauvé-Kapandji procedure was preferred when there was positive ulnar variance of more than 5 mm even with a functional TFCC or when the TFCC could not be reconstructed. Future studies that are prospective with more patients need to be performed to further the understanding of these three arthroplasty options. [16]

Implant arthroplasty provide an intact ulnar head replacement which is critical for normal stability and forearm rotation. Soft tissue stabilization procedures that are used in resection arthroplasty to reduce radioulnar impingement can be unpredictable. As an alternative to a soft tissue stabilization procedure, the intact ulnar head replacement that implant arthroplasty provides restores load transmission and alleviates radioulnar impingement. Originally, implant arthroplasty was used for patients with failed resection arthroplasty. Now, indications also include irreparable ulnar head fractures as well as treatment of arthritic DRUJs. Implant arthroplasty ranges from partial ulnar head replacements to self-constrained DRUJ systems.

Partial ulnar head implants are available in various forms such as pyrocarbon spacers. They are best for patients with isolated DRUJ arthritis without instability. It is the least intrusive implant arthroplasty since only the focal pathologic site is resected and replaced. DRUJ biomechanics are minimally altered. It is generally considered after a failed hemiresection-interposition athroplasty. Complete distal ulnar resection such as the Darrach procedure precludes the possibility of using a partial ulnar head implant in the future. It is also contraindicated in patients with more than 3 mm of positive ulnar variance. Patients experience pain relief with these partial ulnar head replacements without significant complications.

Total ulnar head arthroplasty requires replacement of the ulnar head with a stemmed implant. Two examples include a ceramic head with a porous-coated titanium stem inserted intramedullary in the distal ulnar and a metallic, modular ulnar head with a stem and extended collar for ulnar neck deficiencies. The ceramic implant has a concave distal surface that helps decrease pressure across the ulnocarpal joint. Van Shoonhoven et al. studied the ceramic implant in 23 patients suffering from painful DRUJ instability following failed ulnar resection arthroplasty. Pain relief and stability were accomplished in all patients except two that had recurrent instability. Revision of the implant for these 2 patients was successful. [17]The metallic implant has sites for reattachment of the major soft-tissue stabilizers including the ulnocarpal ligaments, TFCC and ECU sheath. This improves DRUJ stability. It was studied in 17 patients with multiple previous operations for radioulnar convergence, impingement or arthritis. Grip strength increased by 16%, pain scores scores were halved while forearm rotation was unchanged. There were two failures within a 1.5 years. [18, 19]

Although failure is a concern, total ulnar head replacement can be efficacious when successfully implanted. They are indicated for arthritic DRUJs, isolated instability, radioulnar impingement or painful instability after failed partial or complete distal ulnar resection. By replacing the entire ulnar head, some of the soft-tissue stabilizers are disturbed ensuring that DRUJ biomechanics are more altered than with partial ulnar head implants. The remaining soft-tissue stabilizers are critical since these ulnar head implants do not have an intrinsic DRUJ stabilizing mechanism. Therefore, implants with attachment sites for soft tissues such as the TFCC are quite valuable. However care should be taken to avoid overzealous soft tissue attachment to the implant since that can lead to joint subluxation as well as stiffness. [1, 3]

Total DRUJ arthroplasties were developed as salvage options for degenerative DRUJs without native soft tissue support. They tend to be performed after failed resection arthroplasties. The Scheker semi-constrained distal radioulnar joint prosthesis (APTIS Medical, Louisville, KY, USA), which is the total DRUJ arthroplasty being evaluated by this project, is a self-stabilizing spheroidal joint composed of a radial and an ulnar component that are both made of made of 316 medical grade stainless steel **[Figure 1A-1D].** This prosthesis is indicated in skeletally mature patients who have had traumatic, rheumatoid or degenerative arthritis of the DRUJ, especially if it is accompanied by instability or a compromised sigmoid notch. It is strongly indicated in those with unsuccessful Darrach, Sauve-Kapandji or other resection arthroplasties as well as those with unstable and painful ulnar head implants. It is also indicated in patients with developmental DRUJ pathology such as Madelung deformity or those that have undergone distal ulnar resection to remove a tumor. The contraindications include a proximal ulna measuring less than 11cm, titanium or nickel allergies, severe osteoporosis or an active infection.

Fig. 1 (A, B) Preoperative posteroanterior (PA) and lateral X-ray views showing post-traumatic DRUJ arthritis with a hemiarthroplasty.
(C, D) PA and lateral views 2 years after implantation of a total DRUJ arthroplasty.

Implantation of this prosthesis has been described previously. First, an incision is made on the dorsoulnar aspect of the distal forearm, radial to the ECU tendon. The ulna is mobilized from the radius and freed from the surrounding tissue. A template is placed at the sigmoid notch on the long axis of the radius. Resection of the distal ulna allows access to the ulnar aspect of the distal radius. A 2-cm gap is created between the ulna and the distal articulating surface of the radius to make room for the radial side plate, the flare of the ulnar stem, and the socket of the prosthesis. The template guide is fixed to the radius through the middle screw hole. A 2-cm long transverse tunnel in the distal radius is created. The peg at the distal end of the radial plate is then inserted in this tunnel. The middle screw and the adjacent screws are then secured. The fluted end of the stem is press-fit into the medullary cavity of the ulna. The polyethylene ball is placed on the peg of the stem when the flare of the stem is 5 mm past the proximal border of the socket. Once the ball is in the socket, the ulnar portion of the radial plate cover is secured with 2 small screws. The range of pronation and supination is examined for stability and limitations in motion. The interosseous membrane should be divided partially until satisfactory motion is achieved. Although there are few studies on the implant, outcomes in terms of pain relief, grip strength and forearm rotation are favorable especially for degenerative DRUJs without native soft tissue support. [1, 3, 21, 22]

In summary, DRUJ anatomy and biomechanics inform our recognition and understanding of DRUJ pathology. DRUJ dysfunction can result from traumatic, degenerative, developmental, inflammatory or neoplastic etiologies. Symptomatic DRUJ disease is initially managed conservatively and medically. Surgical intervention is generally required for post-traumatic and degenerative DRUJ dysfunction that's recalcitrant to medical therapy. Surgical options range from traditional resection arthroplasty to total self-stabilizing DRUJ implants. Decision-making regarding the proper surgical option depends on the anatomic deficits of each pathologic DRUJ as well as patient preference.

STATEMENT OF PURPOSE

The goal of this study is to assess wrist functionality of patients who have received the Scheker total distal radioulnar joint prosthesis. The specific aims are listed below.

Specific Aims:

1. Perform a retrospective chart review to attain the preoperative range of motion, grip strength and pain score of the wrist that received the Scheker total distal radioulnar joint prosthesis for all patients
2. Assess the postoperative range of motion and grip strength of the wrist that received the Scheker total distal radioulnar joint prosthesis for all patients
3. Assess the postoperative pain of the wrist that received the Scheker total distal radioulnar joint prosthesis for all patients using a pain score questionnaire
4. Compare the postoperative range of motion, grip strength and pain score of the wrist that received the Scheker total distal radioulnar joint prosthesis for all patients to the preoperative range of motion and grip strength. Assess for significance with a student's independent, 2-tailed T-test for unequal variance

Hypotheses:

1. On average, patients will have postoperative range of motion and grip strength that are significantly increased compared to preoperative values.
2. On average, patients will be in significantly less pain postoperatively versus preoperatively

METHODS

The author of this thesis performed a retrospective chart review, approved by Yale's institutional review board (IRB), to gather data on patients of Dr. Seth Dodds and Dr. Joseph Slade at Yale-New Haven Hospital that underwent implantation of the Scheker total distal radioulnar joint prosthesis (APTIS Medical, Louisville, Kentucky) from 2005 to 2010. The following data was collected from the medical records of all patients: age, sex, diagnosis, dates of surgeries and follow ups, specifics of surgeries, complications, preoperative and postoperative wrist range of motion measurements including pronation, supination, flexion, extension, radial deviation and ulnar deviation, grip strength and visual analog scale (VAS) pain scores (0-10 scale).

The only inclusion criterion for this study was having the Scheker total distal radioulnar joint prosthesis for greater than 2 years. Exclusion criteria included removal of the implant postoperatively, concurrent implantation of another prosthesis in the wrist with the Scheker implant and incomplete preoperative data sets. One patient was excluded for removal of the prosthesis shortly after implantation due to infection. Another patient was excluded for concurrent implantation of the Scheker prosthesis and the UNI 2 total wrist implant (Integra, Plainsboro, New Jersey). The total wrist implant was considered a confounder in assessing the efficacy of the Scheker implant. 8 patients with less than 2 years of follow up and/or incomplete data sets were excluded. After these exclusion criteria, there were a total of 10 patients for this study.

The author of this thesis sent an introductory letter briefly explaining the purpose of the study. After a period of time, these potential study subjects were contacted by phone to fully explain the purpose, detail the clinical situation, formally invite them to participate in the study, and answer any questions the subject may have regarding the study. Consent was documented with signed assents/consent forms by subjects. This recruitment procedure was approved by Yale's IRB.

All 10 patients were brought into clinic for final follow up. The author of this thesis performed these clinical evaluations with supervisory assistance from Dr. Seth Dodds. The degree of pronation, supination, flexion, extension, radial deviation and ulnar deviation were measured. [23] A goniometer was used for these measurements. Grip strength was measured using these with a dynamometer. A student's independent, 2-tailed T-test for unequal variance was performed to compare preoperative to postoperative outcome measures. A p value < 0.05 denotes statistical significance.

RESULTS

Our cohort of 10 patients with mean age was diverse in terms of DRUJ pathology and demographics. 7 patients had post traumatic DRUJ arthritis and/or instability, 1patient had DRUJ osteoarthritis, 1 patient had Madelung's deformity and another had cancerous destruction of the distal ulna [**Figure 2A-2D**]. The group was split evenly in terms of gender. The average age was 56.2±16.1 years. The average time from injury or presentation for DRUJ osteoarthritis to Scheker prosthesis implantation was 30.3 months (R, 4.4-44.2 months). 4 patients had an unsuccessful ulnar resection or ulnar head implant prior to receiving the Scheker prosthesis. The mean time from surgery to final follow up was 5 years (R, 2.8-6 years). As far as complications, one patient with post-traumatic arthritis after a distal radius fracture had repair of their distal radius nonunion twice after Scheker implantation. He also had heterotopic ossification. One patient with ulnar impaction secondary to madelung's deformity also had heterotopic ossification.

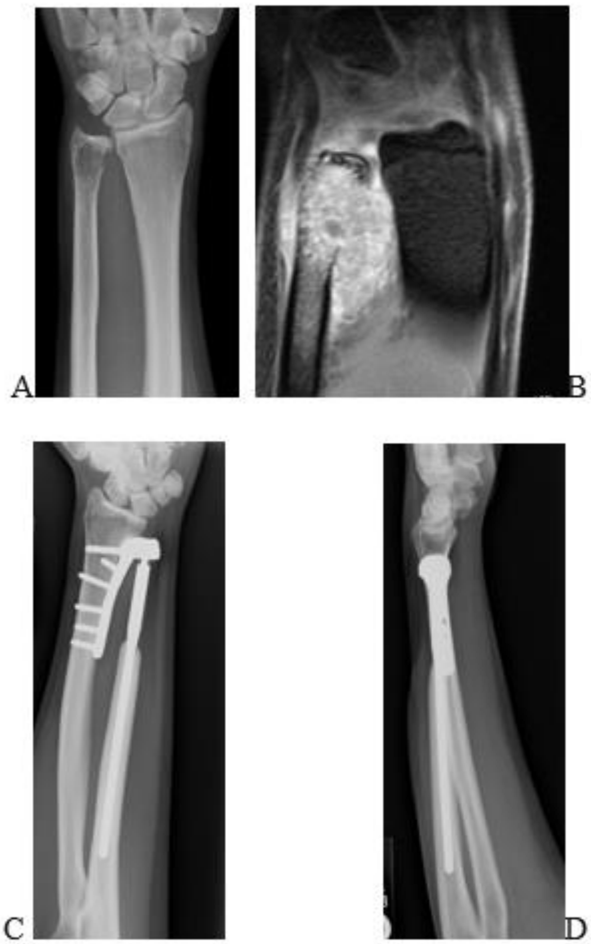

Fig. 2 (A) Preoperative PA view of a wrist with metastatic melanoma of the distal ulna. (B) Preoperative MRI showing the tumor. (C and D) PA and lateral views of the forearm 2 years postoperatively after total DRUJ arthroplasty.

Mean preoperative wrist range of motion measurements, grip strength and pain scores were collected from medical records and compared to the postoperative measurements from final follow up at 5±1.1years in our clinic [**Table 1**]. Mean wrist flexion decreased postoperatively from 45±21.4° (n=7) to 32.1±22.8° (n=10) while extension increased from 35±14.6 ° (n=7) to44.8±13.9° (n=10). Mean supination increased from 63.6±16.6° (n=7) to 72.5±14.4 (n=10). Pronation increased from 64.3±21.3° (n=7) to 69.5±14.6° (n=10). Average ulnar deviation increased from

21.7±11.4° (n=6) to 25.3±5.4° (n=10) while radial deviation increased from 10.8±5.3 ° (n=6) to 13±8.8° (n=10). Average grip strength decreased slightly from 55.5±25.6 lbs (n=3) to 54.9±23.7 lbs (n=10) postoperatively. The average VAS pain score decreased from 4.8±2 (n=6) to 3.6±3.1 (n=10). None of these changes in these outcome measures were statistically significant. In general, there was an increase in range of motion with the exception of wrist flexion while pain decreased. Grip strength measurements were nearly identical preoperatively and postoperatively.

Table 1 Preoperative to postoperative comparison of outcome measures (5 ± 1.1 years follow-up)

Outcome measure	Average preoperative measurement	Average postoperative measurement	*P* value
Wrist flexion (°)	45 ± 21.4, *n* = 7	32.1 ± 22.8, *n* = 10	.29
Wrist extension (°)	35 ± 14.6, *n* = 7	44.8 ± 13.9, *n* = 10	.22
Supination (°)	63.6 ± 16.6, *n* = 7	72.5 ± 14.4, *n* = 10	.30
Pronation (°)	64.3 ± 21.3, *n* = 7	69.5 ± 14.6, *n* = 10	.61
Ulnar deviation (°)	21.7 ± 11.4, *n* = 6	25.3 ± 5.4, *n* = 10	.53
Radial Deviation (°)	10.8 ± 5.3, *n* = 6	13 ± 8.8, *n* = 10	.58
Grip Strength (lb)	55.5 ± 25.6, *n* = 3	54.9 ± 23.7, *n* = 10	.98
Pain (0–10 scale)	4.75 ± 2, *n* = 6	3.6 ± 3.1, *n* = 10	.40

DISCUSSION

Traditional partial and complete resections of the distal ulna have not been routinely satisfactory in treating painful and dysfunctional DRUJ problems outside of the low demand patient population. [11] Hemiarthroplasties such as ulnar head implants have produced reasonable outcomes in retrospective reviews but require an intact radial sigmoid notch as well as ligamentous support to stabilize the DRUJ. [12, 14] Total DRUJ arthroplasties were developed as salvage options for degenerative DRUJs without native soft tissue support. They are typically performed after failed resection arthroplasties.

The Scheker prosthesis is one of these few total DRUJ implants. It was created by Dr. Luis Scheker and was cleared by the FDA in 2005. Its self-stabilizing design allows it to functionally replace the ulnar head, the sigmoid notch, and the soft-tissue stabilizers. It consists of an endomedullary ulnar stem and an ultrahigh molecular weight (UHMW) polyethylene ball that fits into a socket on a plate that is fixed to the radius. [20-22] This prosthesis is indicated in skeletally mature patients who have had traumatic, rheumatoid or degenerative arthritis of the DRUJ, especially if it is accompanied by instability or a compromised sigmoid notch. It is strongly indicated in those with unsuccessful Darrach, Sauve-Kapandji or other resection arthroplasties as well as those with unstable and painful ulnar head implants. It is also indicated in patients with developmental DRUJ pathology such as Madelung deformity or those that have undergone distal ulnar resection to remove a tumor. The contraindications include a proximal ulna measuring less than 11cm, titanium or nickel allergies, severe osteoporosis or an active infection. [11]

Our patient cohort with the Scheker prosthesis demonstrated a postoperative improvement in pain scores and range of motion with the exception of wrist flexion. The average wrist flexion of 32.1±22.8° in our study was skewed by one patient who developed an extension contracture of the wrist postoperatively secondary to concomitant extensor tendon repairs. Grip strength decreased by less than a pound. However, none of these changes were statistically significant.

There are three studies on the Scheker prosthesis, one by Zimmerman and Jupiter, one by Axelsson and Sollerman and the other by Scheker et al. [24, 25, 26] At an average follow up of 2.4±0.7 years, Zimmerman and Jupiter reported that 6 patients had mean postoperative 80±8.9° supination (R 60–90°) and 86.7±5.2° pronation (R 80–90°).These final measurements are higher than the 72.5±14.4 ° supination and 69.5±14.6 ° pronation that we reported at 5±1.1 years postoperatively. They only reported postoperative wrist range of motion measurements which makes it difficult to elucidate the effect of this prosthesis on these outcome measures.

Scheker et al. reported an increase in supination postoperatively from 52±29.1° (n=16) to 75±17.9° (n=20) and increase in pronation from 66±30.6° (n=15) to 81±11.2° (n=20) at a follow up of 5 years for 35 patients. Both of these improvements were statistically significant ($P<.05$). Our cohort had higher mean grip strength of 54.9±23.7 lbs than the mean grip strength of 48.6±35.8 lbs reported by Zimmerman and Jupiter. Scheker's cohort demonstrated a statistically significant increase in preserved grip strength (% contralateral side) from 48% (SD 29.5, n=13) to 90% (SD 57.1, n=22) postoperatively while our cohort's mean grip strength decreased slightly from 55.5±25.6 lbs (n=3) to 54.9±23.7 lbs (n=10).

At an average follow up of 3.7 yrs (R, 2-5), Axelsson and Sollerman reported that 9 patients had a 25% median increase in their grip strength (P=.09). Although these studies used different grip strength outcome measures, they demonstrate that most patients' grip strength remained relatively the same or increased postoperatively.

The mean VAS pain score (0-10 scale) in our cohort decreased from 4.8±2 (n=6) to 3.6±3.1 (n=10). In Scheker et al.'s cohort, pain with activity significantly decreased from 8.25 (SD 1.2, n=8) to 2.71 (SD 2.7, n=24) after surgery ($P<.05$). Only 2 of the 6 patients in Zimmerman and Jupiter's study reported pain postoperatively. Axelsson and Sollerman's cohort had a median postoperative VAS score of .3 versus a preoperative VAS score of 6 (P=.01). Overall, pain decreased due to this prosthesis. [24, 2, 26]

Scheker et al. reported a 100% 5-year survival rate among the 27 patients at the 5 year follow-up. In the immediate postoperative period, there were two minor soft tissue infections promptly resolved with antibiotics. No prostheses were infected. In contrast, one patient was excluded from our study for removal of the prosthesis shortly after implantation due to infection. Of the 36 prostheses implanted by Scheker et al., 11 of the prostheses had symptomatic complications. There was one screw/cap loosening, five cases of ectopic bone formation and six cases of ECU tendinitis. These complications were all managed surgically to each patient's satisfaction. 4 years postoperatively, one patient suffered from ECU hypersensitivity which was attributed to failed tendon repairs prior to prosthesis implantation. This was subsequently treated with injections. 25 of the 36 implanted prostheses were free of symptomatic complications.

Radiographs of 24 patients were compared with images obtained immediately following implantation. Two prostheses showed slight evidence of stem loosening while another prosthesis had loosening of a screw on the prosthesis cap as well as ectopic bone growth over the proximal part of the radial plate. All patients showing radiographic evidence of loosening or bone growth were asymptomatic. They had minimal pain and were satisfied with their prostheses. [24]

Axelsson and Sollerman reported 4 minor adverse events following Scheker implantation. Radiographic evaluation showed that 6 patients showed distal ulnar bone resorption around the implant stem exceeding 2 mm. One patient developed bone resorption around a screw tip of the radial component. However, there were no signs of loosening. Two patients reported lateral elbow pain that was treated conservatively with success. One patient required surgery for De Quervain disease a year after implantation. Another patient experienced transient carpal tunnel syndrome postoperatively. [26]

Although we didn't not report subjective outcomes, Scheker et al. used a variety of metrics to grade their patients' subjective outcomes. At 5 years postoperatively, mean PRWE (Patient rated wrist evaluation) score was 24 out of 100 (n= 19) and mean DASH (Disabilities of arm, shoulder & hand) score was 16 out of 100 (n=20) and. These scores reflect minimal difficulty with activities of daily living and pain. There were no preoperative DASH and PRWE scores to truly ascertain the effect of the Scheker implant. On a scale from 0 to 10, with 10 being completely satisfied, patients reported an average satisfaction score of 9.8 out of 10 with their prostheses (n= 26, SD= 0.49). [24]

Zimmerman et al. used a novel ten-item questionnaire that they developed to assess subjective outcomes for their study population. One of the 6 pts was lost to follow-up and therefore was unable to take the questionnaire. At their final follow-up, patients reported generally mild to moderate disability. When asked about their ability to lift everyday objects, two patients felt very limited, one patient reported not being limited while another felt mildly limited. With regard to wrist stability, three denied any instability, one patient reported a somewhat unstable wrist and one reported mild instability. In terms of pain, 4 patients reported their pain to be "much better", while the others reported unchanged pain.

Four out five patients reported being either slightly or much better postoperatively with regard to motion and strength. Patients were asked to score their wrists preoperatively and postoperatively from 0 to 100. The average preoperative score was 33±12 and the average postoperative score was 73±12 which means that the average change was 40 (R, 15–55). Four out of the five patients said they would undergo the procedure again to get this total DRUJ implant. The patient with the unrelated chronic pain syndrome had lowest subjective outcomes and would not choose the Scheker implant if he had to choose a treatment option again. [25]

Other than the Scheker prosthesis, the only other available total DRUJ prosthesis is the Stability Sigmoid Notch Total DRUJ system (Small Bone Innovations, Morrisville, PA) (Ewald, 2012). The Stability prosthesis consists of the U-Head ulnar head prosthesis (Small Bone Innovations, Morrisville, PA) and a polyethylene sigmoid notch resurfacing implant. At a follow up of 46 months, Ewald and Moran report that a cohort of 4 patients had a final mean of 80 (R, 60-90) pronation and 64 (R, 45-90) supination. Grip strength increased from 16.53lbs preoperatively to 56.22 lbs postoperatively while pain scores decreased from 8 to 2.5. These mean postoperative outcome measures are comparable to those from the aforementioned studies on the Scheker prosthesis. However, this prosthesis requires capsular and soft-tissue stability for good outcomes since it's not constrained like the Scheker prosthesis. [27]

This study is limited by the small sample size and its retrospective nature. There is no control group which introduces bias and there is no power analysis. However, this total joint prosthesis is promising due to its self-stabilizing design alleviating the need for an intact sigmoid notch or intact ligamentous support. 4 of the 10 patients had 1 prior unsuccessful ulnar resection or replacement before implantation of the Scheker prosthesis which further highlights its utility in situations where traditional arthroplasties or other implants have failed. The other 6 study subjects either had distal ulna arthritis with instability or DRUJ arthritis with a dysfunctional sigmoid notch. These are strong indications for Scheker implantation. The length of implant survivorship is still unknown but Dr. Scheker's cohort had a 100% 5 year implant survival rate while only 1 of the 20 patients who have received the Scheker prosthesis at our institution has had it removed (for infection).[24]

The revision options for a failed Scheker prosthesis are unknown and will require further study. It is clear that this prosthesis has produced satisfactory postoperative range of motion, pain score and grip strength outcomes. Our study along with previous studies demonstrates that this prosthesis is a suitable solution for patients with dysfunctional distal radioulnar joints as well as those that have not responded to other arthroplasties. Based on the experience gained from this cohort of patients, it is our preference to use this prosthesis when there are no other reasonable alternatives to treat severe DRUJ arthritis.

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