Review Article

# Open and Arthroscopic Triangular Fibrocartilage Complex (TFCC) Repair

Ramesh C. Srinivasan, MD
Jason J. Shrouder-Henry, MD, MBA, FRCS(C)
Marc J. Richard, MD
David S. Ruch, MD

ASSOCIATED VIDEO

## ABSTRACT

Triangular fibrocartilage complex (TFCC) tears, whether acute or chronic, can result in persistent ulnar-sided wrist pain. Although diagnosis and nonsurgical management of TFCC tears is well described, there remains ongoing discussion about the optimal surgical technique, specifically open or arthroscopic. This article reviews the most up-to-date literature regarding TFCC injury including demographics, risk factors for TFCC injury, classification of acute and chronic TFCC tears, history and physical examination, appropriate diagnostic imaging, surgical indications, pertinent surgical anatomy, open and arthroscopic TFCC repair, fixation biomechanics and techniques, postoperative rehabilitation, and clinical outcomes.

From the The Hand Center of San Antonio (Srinivasan), San Antonio, TX, the Illinois Bone and Joint Institute (Shrouder-Henry), Hinsdale, IL, and the Department of Orthopaedic Surgery (Richard, Ruch), Duke University Medical Center, Durham, NC.

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Triangular fibrocartilage complex (TFCC) injury is a frequent cause of ulnar-sided wrist pain. The TFCC acts both as a cushion for the ulnar side of the wrist preventing discomfort with ulnar deviation and as a stabilizer for the distal radioulnar joint (DRUJ). Injury to the TFCC may result in pain and DRUJ instability, leading to loss of motion, grip strength, clicking, and/or popping requiring surgical repair. Several studies have demonstrated an increase in prevalence with aging. In a recent systematic review, Chan et al[1] similarly found that asymptomatic TFCC tears were more common in older patients: 15% of patients were younger than the age of 30, 27% of patients were from 30 to 49 years, 38% of patients were from 50 to 69 years, and 49% of patients were older than 70 years. Given the frequency of asymptomatic tears and the increase in its prevalence with older age, the authors cautioned that these tears may be an incidental finding in many patients. Although surgical treatment could be successful, the perceived improvement in symptoms may actually be due to a placebo effect. They concluded that careful history and physical examination are required to determine whether the TFCC tear is symptomatic and that it was important to quantify the severity of symptoms related to TFCC pathology to determine whether surgical treatment is necessary.[1]

## Surgical Anatomy

The TFCC is made up of six major components: the radioulnar ligaments (dorsal and volar), central articular disk, meniscus homolog, ulnar collateral

ligament, extensor carpi ulnaris (ECU) subsheath, and the ulnolunate and ulnotriquetral ligaments. Dorsal and volar radioulnar ligaments originate at the sigmoid notch of the radius and insert at the base of the ulnar styloid. These ligaments, as well as the triangular fibrocartilage (TFC), represent the primary stabilizers of the DRUJ. The articular disk originates from the hyaline cartilage of the sigmoid notch and the lunate facet of the distal radius. This disk is thicker along its ulnar attachment and is wedge shaped in the coronal plane. The meniscus homolog is a connective layer of tissue between the articular disk and triquetrum. The floor of the ECU subsheath is incorporated into the TFCC on its dorsoulnar side. The ulnar aspect of the disk has two components. One component inserts on the ulnar styloid, whereas the second component inserts at the foveal of the ulnar head via the ligamentum subcruentum.[2-4] This foveal attachment provides a greater contribution to DRUJ stability because it is closer to the rotational axis of the forearm.[5] Thus, foveal detachment of the TFCC often results in DRUJ instability.[6]

The blood supply for the TFCC has been well delineated with latex injections.[7] Three main arterial branches for the TFCC exist: the palmar and dorsal branches of the ulnar artery, the dorsal branch of the anterior interosseous artery, and the palmar branch of the anterior interosseous artery. Ink injections have demonstrated penetration of these vessels into 10% to 20% of the peripheral disk.[7,8] The peripheral palmar, ulnar, and dorsal portions of the TFCC can heal via repair because of this vascularity. By contrast, tears of the central and radial portions of the TFCC are best treated with débridement because of poor blood supply.

## Classification of TFCC Injury

TFCC injury is characterized as acute or degenerative. Acute TFCC tears are subcategorized into central perforation of the cartilage disk with no DRUJ instability (type 1A); injury to the ulnar attachment of TFCC by ligament avulsion from fovea or via fracture through ulnar styloid (type 1B); distal avulsion at the origin of ulnolunate, ulnocapitate, and ulnotriquetral ligaments (type 1C); or radial avulsion(type 1D) (Figure 1).[9] Degenerative TFCC tears have several patterns: TFCC wear and thinning (type 2A), TFCC wear with lunate and/or ulna chondromalacia (type 2B), TFCC perforation with lunate and/or ulna chondromalacia (type 2C), TFCC perforation with lunate and/or ulna chondromalacia and lunotriquetral ligament disruption (type 2D), TFCC perforation with lunate and/or ulna chondromalacia, or lunotriquetral ligament perforation and ulnocarpal arthritis (type 2E).[9]

## History and Physical Examination

TFCC mechanism of injury typically involves forced axial loading, ulnar deviation, or forearm rotation. Patients with TFCC injury often present with a chief report of persistent mechanical ulnar-sided wrist pain that causes reproducible discomfort with forearm rotation and ulnar deviation.[10] Physical examination involves visual inspection to assess for ulnar sided swelling and/or dorsal prominence of the distal ulna (the "piano key" sign). The wrist is then examined for DRUJ instability, foveal tenderness, clicking, and crepitus. Direct comparison to the contralateral wrist is helpful for delineating subtle findings.

The differential diagnoses for ulnar-sided wrist pain are extensive, and concomitant pathology should be ruled out including hook of hamate injuries, pisotriquetral arthritis, lunotriquetral instability, and ECU tendinitis or subluxation.[10] The ulnocarpal stress test (with the wrist in maximal ulnar deviation, an axial load is applied, followed by rotation through forearm pronation and supination) may be used to localize pathology to the ulnocarpal joint (ulnocarpal abutment, traumatic TFCC tear, lunotriquetral ligament tears, wrist arthritis, and loose bodies may lead to a positive test).[10] The ECU synergy test (the patient is asked to radially deviate the thumb against resistance with the elbow flexed and the forearm supinated which causes the ECU tendon to bowstring against the skin) may be used to differentiate between ECU tendinitis, subluxation, and intra-articular pathology.

A diagnostic steroid injection into the ECU subsheath proximal to the DRUJ and wrist joint may be done to confirm the presence or absence of ECU tendinitis. If the injection for the subsheath fails to provide lasting relief, a second "diagnostic injection" may be done into the DRUJ or ulnocarpal joint. Alternatively, additional imaging may be pursued to obtain a diagnosis.[11]

## Risk Factors for TFCC Injury

Risk factors regarding TFCC injury include ulnar positive variance. Traumatic TFCC tears are more common in patients playing sports requiring frequent pronation/supination, radial/ulnar deviation, and axial loading of the forearm such as racquet sports or golf.[2] Recently, the shape of the sigmoid notch (flat-face, C-, S-, and ski-slope types) has also been

## Figure 1

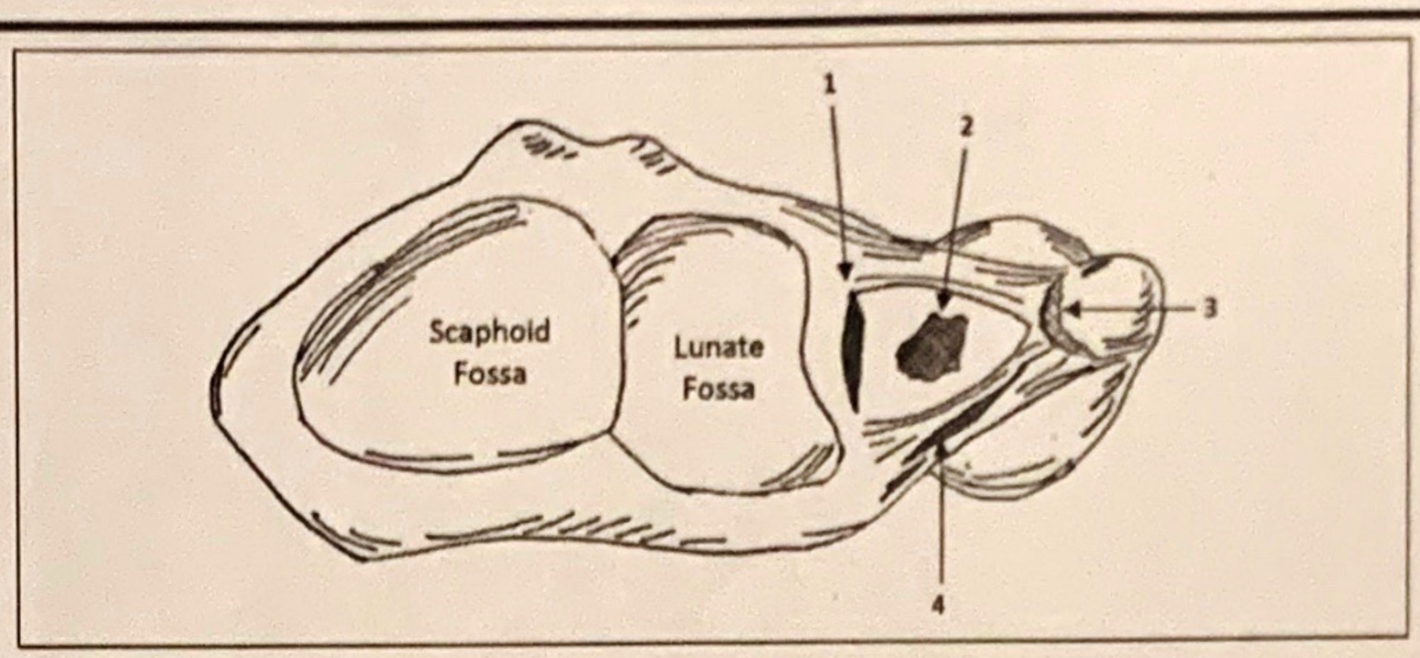



Figure demonstrating the Palmer classification of acute tears of the triangular fibrocartilage complex. Class 1A: Central tear of the fibrocartilage disk tissue (1). Class 1B: ulnar-sided peripheral attachment or avulsion (2). Class 1C: tear of the volar ulnar extrinsic ligaments (3). Class 1D: radial-sided peripheral detachment (4) (Courtesy of Victoria L. G. Thompson, DDS).

investigated regarding propensity for TFCC injury. Univariate analysis demonstrated that a flat-face sigmoid notch was more common in patients with TFCC foveal tears.[12]

## Diagnostics

Lateral and PA radiographs are initially obtained to assess the DRUJ, ulnar variance, and associated fractures and arthritis. Ulnar variance is most sensitively assessed in a dynamic fashion with pronated grip PA x-rays of the wrist.[13] Bilateral x-rays allow for direct comparison of a symptomatic and asymptomatic wrist in the same patient.[14] Recently, the lateral wrist radiograph has been shown to be most accurate with assessing ulnar variance regarding the actual clinical anatomy of the wrist.[14] However, dynamic PA x-rays may be best for simulating activities of daily living that may cause ulnocarpal impaction and associated ulnar-sided wrist pain.[14] If radiographs are negative in the context of persistent ulnar-sided wrist pain, advanced imaging is indicated. Magnetic resonance imaging (MRI), magnetic resonance arthrography, CT, and computed tomographic arthrography may be considered. Sensitivity and specificity for diagnosis of TFCC lesions has been reported as best for computed tomographic arthrography (0.89 and 0.89), followed by magnetic resonance arthrography (0.89 and 0.78), and then MRI (0.76 and 0.82).[15] Diagnostic accuracy was higher for central TFCC tears (sensitivity of 0.92 and specificity of 0.93) compared with peripheral lesions (sensitivity of 0.71 and specificity of 0.98).[15]

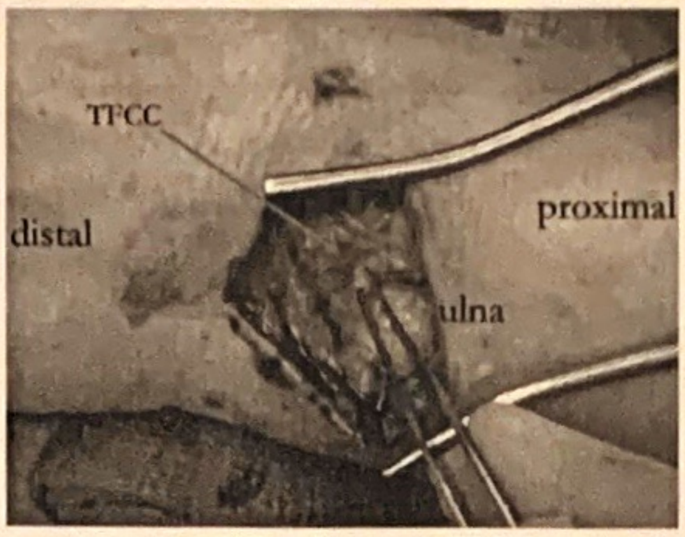
Intraoperative assessment using an arthroscopic probe to do the "trampoline test" historically has been the most commonly used technique for assessing the TFCC tension before and after repair. Recently, Trehan et al[16] have demonstrated that the "hook test" to be 90% specific and sensitive for identifying TFCC foveal disruption and subsequent return to baseline tension after TFCC foveal repair.

## Nonsurgical Treatment

TFCC tears without DRUJ instability are typically treated conservatively for 3 to 6 months before considering surgical treatment. Management includes wrist immobilization, oral nonsteroidal anti-inflammatory medication, corticosteroid injections into the ulnocarpal joint, and occupational therapy.[17,18] However, little evidence exists to support a general consensus regarding the specifics of conservative treatment: length of time, type of immobilization (short or long arm splint), the type of occupational therapy exercises, and the type, amount, and/or number of steroid injections. In 2019, Lee et al[19] published their results evaluating the natural history of TFCC tears without DRUJ instability and the results of nonsurgical treatment. Patients were treated with a short-arm splint for 4 to 12 weeks after diagnosis of the TFCC tear confirmed by MRI examination. They found that 30% of patients recovered completely (PRWE score ≤ to 20 points) by 6 months after injury, and 50% of patients recovered completely after 1 year. The authors concluded that TFCC tears without DRUJ instability should be treated nonsurgically for a minimum of 6 months before considering repair. Of note, the authors were unable to identify predictors of persistent pain with nonsurgical treatment to avoid unnecessary surgical delay.[19]

For TFCC tears with instability of the DRUJ, immobilization with forearm in supination for 4 to 6 weeks may be necessary to achieve a successful result. Moritomo

**Figure 2**




Intraoperative photograph demonstrating open TFCC foveal repair (Courtesy of Edward Chan, MD and Ramesh C. Srinivasan, MD). TFCC = Triangular fibrocartilage complex

et al[17] demonstrated that 46% of patients with foveal TFCC disruptions could be successfully treated with nonsurgical treatment.

## Surgical Indications and Contraindications

Surgical management is recommended for acute injuries in high-demand patients, chronic degenerative tears with ulnar impaction, and persistent DRUJ instability.[18] Although most TFCC tears are treated nonoperatively, one study indicated that more than 40% of patients with a TFCC injury may eventually require surgical management.[20] Contraindications to surgical intervention include patients who have degenerative changes about the DRUJ or radiocarpal joints, mild symptoms even in the setting of radiographic changes, and the low demand, medically unfit elderly cohort.[21] Indications for surgical treatment in the form of TFCC débridement versus repair include persistent pain and patients who have failed 3 to 6 months of conservative treatment (oral NSAIDS, splinting, occupational therapy, and steroid injections).[17,18] If the patient is ulnar positive (2 mm or greater), then strong consideration should be given to ulnar shortening osteotomy rather than TFCC débridement or repair. These patients are more likely to fail surgical treatment that only addresses the TFCC and frequently require subsequent ulnar shortening osteotomy.[18,22,23]

## Surgical Technique Descriptions

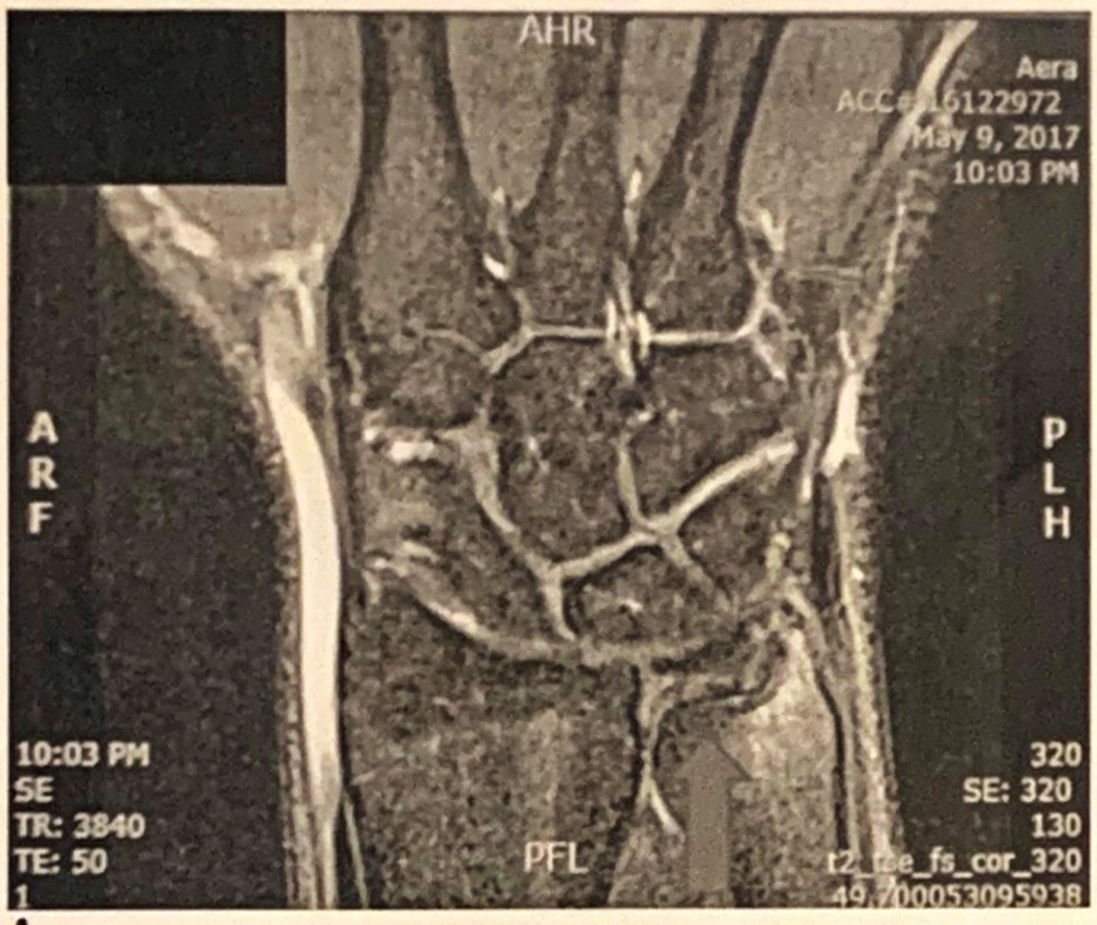
Surgical management of TFCC tears is divided into open or arthroscopic treatments. The open technique begins with a longitudinal dorsal ulnar incision over the fifth extensor compartment. Of note, the dorsal ulnar sensory nerve should be identified and protected. Deep to the skin, the extensor retinaculum is incised, and the extensor digiti quinti tendons are temporarily transposed. The ulnocarpal wrist capsule is incised longitudinally or with an inverted L-shaped incision. The fovea and torn TFCC is then visualized and repaired with a suture anchor or with horizontal mattress sutures through bone tunnels. Specifically, the suture anchor may be drilled into the fovea, and then, the detached fibers are tied down to the anchor. Alternatively, a knotless suture anchor may be used. In the transosseous tunnel technique, a 4-0 nylon stitch is passed through the torn TFCC and then tied over two drill holes in the ulnar cortex. Before definitive fixation of the TFCC, the DRUJ is reduced, and the forearm is placed in a neutral to slightly supinated position.[24] The capsule, retinaculum, and skin are then closed sequentially in layers. Figure 2 illustrates an intraoperative photograph of a TFCC repair using an open foveal technique.

Arthroscopic-assisted TFCC repair has become an increasingly popular method for surgical management of TFCC tears. For patients with peripheral tears without DRUJ instability, TFCC repairs may be done repairing the torn TFCC to the wrist capsule.[25] Alternatively, for patients with peripheral TFCC tears and DRUJ instability, an arthroscopic or open foveal repair can be done.[26]

For arthroscopic-assisted TFCC repair, the patient is placed in a supine position with the arm on a hand table and 10 lbs. of longitudinal traction applied with the elbow at 90 degrees. Traction with the wrist in slight flexion allows for ideal visualization and portal placement. Standard diagnostic wrist arthroscopy portals are then placed: 3-4, 6R, and 6U, if necessary. Diagnostic arthroscopy is completed to confirm TFCC injury and any other associated wrist ligamentous injuries. The 6R portal allows for instrumentation to débride poor quality tissue about the TFCC and improve visualization. Outside-in suture repair of the TFCC to the ulnar capsule may be done arthroscopically using the technique described by Wysocki, Richard, and Ruch et al. Initially, the peripheral tear is débrided to stable edges with the use of an arthroscopic shaver. Sutures (2-0 PDS) are passed through the wrist capsule with a Tuohy needle. A second Tuohy needle passed through the TFCC loaded with a nitinol wire is used to retrieve the 2-0 PDS sutures. A formal incision is made before knot tying to ensure that the knots are tied securely directly over the capsule away from the dorsal cutaneous branch of the ulnar nerve (Video 1; arthroscopic-assisted TFCC capsular repair).[25]

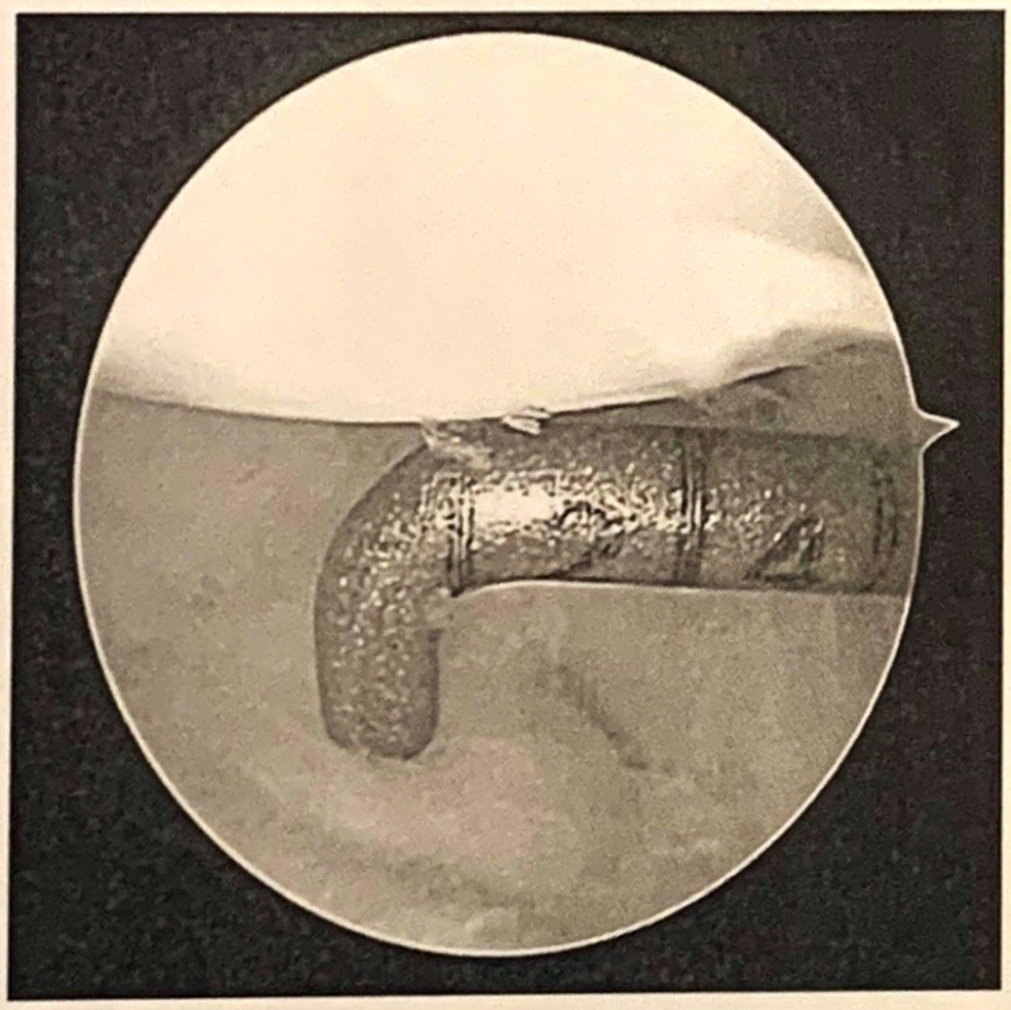
For foveal repairs, diagnostic wrist arthroscopy is completed as described above. The peripheral tear is confirmed with a positive trampoline or hook test. A subcutaneous incision is made along the ulna approximately

## Figure 3




A

B



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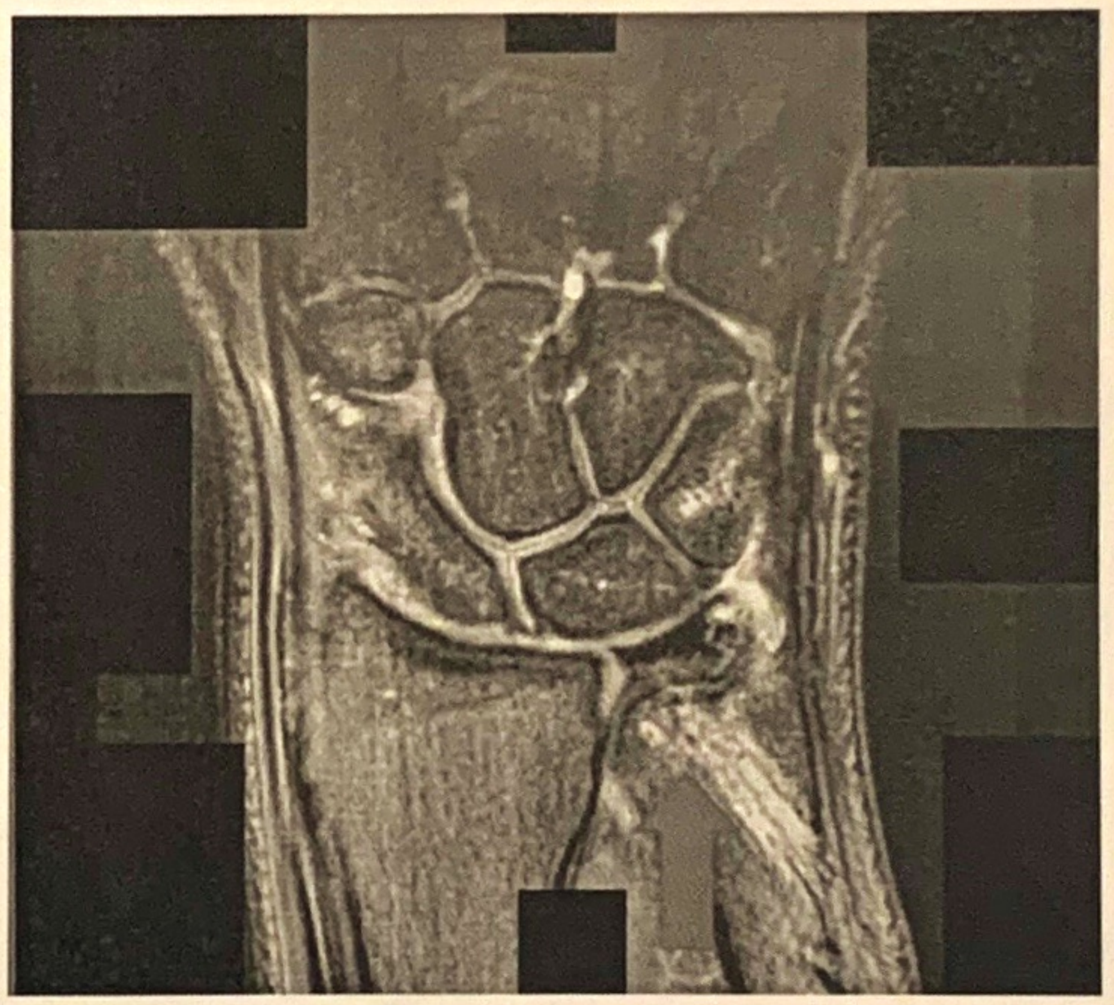

D

This 19-year-old man is a collegiate division 1 tennis player who presented with persistent ulnar-sided wrist pain after hitting an awkward forehand. Two steroid injections and splinting for greater than 6 months failed to alleviate symptoms. On physical examination, he had tenderness over the fovea and a positive TFC compression test. Preoperative MRI demonstrated peripheral tear of the TFCC on the T2 coronal cuts (**A**). The patient elected for arthroscopic TFCC foveal repair using the ulnar tunnel technique with a knotless suture anchor and 2-0 fiberwire (Video 2). Intraoperative photograph demonstrating TFCC repair (**B**) and restoration of tension and normal trampoline test (**C**). Postoperative MRI demonstrates TFCC repair with anatomic seating of the TFCC on the ulnar head (**D**) (Courtesy of Ramesh C. Srinivasan, MD). MRI = magnetic resonance imaging; TFC = triangular fibrocartilage; TFCC = triangular fibrocartilage complex

2 cm proximal to the ulnocarpal joint. The central aspect of the TFCC is localized via arthroscopy to achieve correct guidewire placement. A guidewire is advanced with approximately 45 degrees of obliquity from the subcutaneous border of the ulna into the wrist joint at the foveal insertion of the TFCC. Once appropriate positioning of the guidewire is confirmed, the guidewire is over drilled with a 3.5 mm cannulated drill to create an ulnar bone tunnel from the subcutaneous border of the ulna to the fovea. Using the outside-in technique, the suture passing needle is passed through the ulnar bone tunnel into the volar portion of the TFC. The needle is initially turned clockwise; then the needle is turned counter clockwise while slowly removing it from the joint. This technique allows the suture

**Table 1.** Postoperative Rehabilitation Protocols

| Capsular Repair of Peripheral TFCC Tears W/Deep Fibers Intact | | | |
|---|---|---|---|
| **0–3 Weeks** | **3+ weeks** | **12+ Weeks** | |
| Sugar tong or Muenster splint in full supination | Short removable splint, working on pronation | Return to sport | |
| **DRUJ Instability With TFCC Tear Treated With Foveal Repair** | | | |
| **0–6 Weeks** | **6–10 Weeks** | **10+ Weeks** | **12+ Weeks** |
| Restrict forearm rotation | Discontinue splinting and initiate active/passive wrist range of motion | Resume gradual light strengthening | Return to sport |

DRUJ = distal radioulnar joint; TFCC = Triangular fibrocartilage complex

to stay within the ulnocarpal joint for later retrieval. The arthroscopic probe is used to move the suture dorsally. Subsequently, a suture lasso is placed through the ulnar bone tunnel through the dorsal portion of the TFC. The lasso and suture are then retrieved with a hemostat and brought together out the 6R portal. Once outside the joint, exterior to the skin, the suture is passed though the lasso, and the lasso is then pulled back out the ulnar bone tunnel, which results in a mattress suture repair, restoring tension to the TFC. This suture is secured to the ulnar shaft with a knotless suture anchor through a second drill hole 1 cm proximal to the ulnar bone tunnel. The TFC may then be probed through the 6R portal to assess for appropriate restoration of tension via the trampoline test (Video 2; arthroscopic-assisted ulnar foveal bone tunnel repair).[26] Figure 3, A–D demonstrate clinical and MRI images of a patient preoperatively and postoperatively treated with this technique.

## Fixation Biomechanics and Techniques

Many open and arthroscopic fixation techniques of TFCC tears have been described including the outside-in technique originally described by Whipple and Geissler,[27] inside-out techniques,[28,29] the all-inside arthroscopic (FasT-Fix, Smith and Nephew Endoscopy, Andover, MA),[30] suture anchor,[31] and the mini-push lock anchor with 2-0 Fiber wire.[32] In a cadaveric study by Desai et al, the suture anchor technique (73N) was found to have a statistically notable higher load to failure of repair than outside-in soft-tissue repair (54 N). The load to 2-mm gap formation was notably higher, as well, for the suture anchor technique (10 ± 3 N) compared with the outside-in repairs.[33] Johnson et al[26] demonstrated that the Arthrex ulnar tunnel (foveal) repair with a knotless suture anchor resulted in DRUJ stiffness and ulnar translation similar to native tissue in pronation and supination. Thus, TFCC tears, from a biomechanical standpoint, may be best treated with a direct open or arthroscopic direct foveal repair with the use of a suture anchor (particularly those with preoperative DRUJ instability).

## Postoperative Rehabilitation

Postoperative rehabilitation protocols may vary depending on surgical technique and intraoperative findings. After capsular repair of peripheral TFCC tears with the deep fibers intact, patients are treated with a sugar tong or Muenster splint for 3 weeks in full supination. After 3 weeks, patients are allowed to work on pronation in a short removable splint.[25] For patients with DRUJ instability with TFCC tear treated with a foveal repair, forearm rotation may be restricted for up to 6 weeks postoperatively. At week 6, splinting is discontinued and active/passive wrist range of motion is initiated. Gradual light strengthening is resumed at the 10-week mark.[34] Return to sport is generally not allowed until 12 weeks postoperatively[35] (Table 1).

## Complications

The complications associated with open and arthroscopic-assisted techniques include dorsal sensory nerve injury, ECU tendinitis from the suture knot, persistent DRUJ instability, and recurrent pain.[36,37] Dorsal ulnar cutaneous sensory nerve injury can be avoided with meticulous dissection, identification and protection of the dorsal sensory nerve branches, and the ECU tendon and its subsheath before knot or implant placement. Once the TFCC is repaired, DRUJ stability should be carefully assessed via intraoperative physical examination with comparison to the contralateral extremity before wound closure and splint placement.

## Outcomes

Limited high-quality evidence exists comparing open versus arthroscopic TFCC repair. In general, TFCC repair, regardless of open or arthroscopic technique, results in improved pain scores and functional outcomes. In a 2018 systematic review conducted by Andersson et al,[37] comparable results exist between the two procedures regarding postoperative residual DRUJ instability, range of motion, grip strength, and Disability of Arm, Shoulder, and Hand (DASH) score. A prospective cohort study of 75 patients with a 43-month follow-up in 2008 reported improvement in grip strength, Mayo Modified Wrist Scores (MMWS), and pain scores with no notable difference between arthroscopic and open TFCC repair. This study did note lower rates of superficial ulnar nerve pain (22% vs. 26%), ECU tendinitis (11% vs. 26%), and revision surgery because of persistent DRUJ instability (14% vs. 21%) in the arthroscopic versus open repair groups, respectively. However, none of these differences reached statistical significance. Of note, this study was only powered to detect a difference for the MMWS.[38]

Seo et al[39] compared arthroscopic repair (AR) versus débridement (AD) for chronic unstable TFCC tears in patients undergoing concomitant ulnar shortening osteotomy. Both cohorts demonstrated improvements in grip strength and subjective scores at the final follow-up. However, the AR group had better grip strength, DASH, PRWE (Patient-rated Wrist Evaluation), and superior recovery from DRUJ instability. The authors concluded that arthroscopic repair should be done if concomitant DRUJ instability is present.[39]

Recently, Wu et al[40] reported decreased pain, improved motion and stability, and excellent functional outcomes for 149 children and adolescents treated surgically with TFCC débridement, TFCC repair, concomitant ulnar styloid nonunion excision, and/or ulnar shortening osteotomy. Trehan et al reported good functional outcomes in 43 pediatric and adolescent patients treated with TFCC repair. However, seven patients remained dissatisfied and went on to ulnar shortening osteotomy.[41]

## Conclusions

Injury to the TFCC complex continues to be a source of notable and debilitating ulnar-sided wrist pain for active patients. Open and arthroscopic repair to the capsule or fovea has resulted in favorable clinical outcomes, regardless of the specific technique used. Preoperative DRUJ instability is likely best treated with a direct foveal repair restoring DRUJ stability. Notable preoperative ulnar positivity (>2 mm) may be the greatest risk factor for TFCC repair failure. Ulnar variance should be carefully assessed preoperatively. Patients with ulnar variance > 2 mm may be best treated with ulnar shortening osteotomy.

Future research is needed in the form of adequately powered prospective trials accurately comparing clinical and functional outcomes of open and arthroscopic TFCC repair with specific attention to patient age, peripheral versus foveal repair, postoperative complications, and the presence of preoperative DRUJ instability and ulnar variance.

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