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Chronological and geographic trends of TFCC Repair

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SYNOPSIS

This review shows trends in triangular fibrocartilage complex (TFCC) repair since 1990 by geographic area and year. The repair methods presented in the literature were inside-out, outside-in, all-inside, and open repair. The outside-in technique was reported most often for ulnar-side tears whereas the inside-out technique was reported most frequently for radial-side tears. Recently, a foveal reattachment technique for ulnar-side tears has garnered attention and has been reported with increasing frequency, especially in Asia, because the deepest portion of TFCC, attached to fovea, plays a key role in stabilizing the distal radioulnar joint (DRUJ). Understanding these trends can help us to best treat TFCC tears.

Keywords

wrist; arthroscopy; TFCC repair; chronological trends; geographic trends

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DISCLOSURE STATEMENT

None

Introduction

The triangular fibrocartilage complex (TFCC) is an important stabilizer of the wrist joint, specifically the distal radioulnar joint (DRUJ). Disorders of the TFCC are one of the most common causes of ulnar-side wrist pain that interferes with daily activities such as opening a door or shaking hands.¹

The TFCC consists of 4 main components: the triangular fibrocartilage proper (the fibrocartilage articular disk), the distal radioulnar ligaments (volar and dorsal), the meniscus homolog, and the floor of the tendon sheath of the extensor carpi ulnaris tendon. The articular disk rises from the hyaline cartilage of the sigmoid notch and the lunate facet of the distal radius. The disk becomes thicker along its ulnar attachment, and is wedge shaped at the coronal section. The distal volar and dorsal radioulnar ligaments conjoin and insert into the base of the ulnar styloid. The meniscus homolog is a connective layer between the articular disk and the triquetrum. The floor of the sheath of the extensor tendon is incorporated into the TFCC on its dorsoulnar side. The ulnar aspect of the disk has two portions; one portion inserts into the ulnar styloid, and the other inserts at the fovea of the ulnar head (Figure 1).^{2,3} The deepest portion has been called the ligamentum subcruentum.⁴ The foveal attachment does more than the styloid insertion to stabilize the distal radioulnar joint (DRUJ) because it has a closer relationship to the rotational axis of the forearm.⁵ Therefore, a foveal detachment of the TFCC often results in DRUJ instability.^{2,6}

The anatomy of the blood supply to the TFCC was revealed using latex injections.⁷ There are three main arterial supplies to the TFCC: 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. Several studies have showed penetration of the vessels into about 10% to 20% of the peripheral articular disk using ink injections.^{7,8} The peripheral palmar, ulnar, and dorsal areas have good healing ability because they have sufficient vascularization, whereas the central and radial areas typically need debridement in cases of injury because they have poor blood supply.

TFCC injuries are managed initially using nonsurgical measures, such as the immobilization of the wrist and forearm, activity modification, and analgesics, for the first 2 or 3 months. Morimoto et al. reported that 46% of patients with avulsion of the TFCC from the fovea were pain-free after conservative treatment.⁹ Operative treatment is considered in cases of persistent pain, DRUJ instability, and/or concomitant fractures. Operative treatment consists of open or arthroscopic debridement, and open or arthroscopic repair. These operative treatments are contraindicated for cases with severe ulnocarpal arthritis, or severe DRUJ arthritis associated with DRUJ instability.

This article reviewed the classification of TFCC injuries and some repair methods based on the location of the tissue disruption. We also assessed trends of TFCC repair organized by year and geographic area using literature published between 1990 and 2016 to provide current practice patterns of TFCC management around the world.

Classification

TFCC tears were categorized into two main classes by Palmer. These are class 1: Traumatic lesions and Class 2: Degenerative lesions (Table 1). These were further divided into subtypes.

Class 1 tears are identified based on the anatomic location of tissue disruption. Class 1A (central) tears are the most common type of traumatic TFCC tears and are debrided if conservative treatment fails. Class 1B tears are peripheral tears in the vascular zone that are often the most appropriate to repair surgically as they often cause instability of the DRUJ. Class 1C tears are avulsions of the TFCC attachment to the ulnar carpus arising from the disruption of the volar ulnar extrinsic ligament complex. This ligamentous disruption often results in DRUJ instability. Class 1D tears are an avulsion of the TFCC from its radial attachment. This tear is often involved with marginal sigmoid notch fractures and the insertion sites of the dorsal and volar radioulnar ligaments that also cause instability of the DRUJ.

Class 2 tears are identified based on their point in the degenerative process. Degenerative tears are the result of chronic loading on the ulnar side of the wrist. These changes start with TFCC wear and chondromalacia of the ulnar lunate and ulnar head. TFCC perforation, lunotriquetral ligament perforation, and ulnocarpal arthritis develop sequentially.

Literature review

We performed a literature search using the MEDLINE (pubmed) and EMBASE databases for articles that demonstrated a TFCC repair technique. The TFCC injury area and method of repair were extracted and categorized by geographic region and year. TFCC repair methods consist of arthroscopic inside-out, outside-in, all-inside, and open surgical repair. There are also two sites that the ulnar stump of the TFCC can be attached to after the injury; one is soft tissue such as the joint capsule, and the other is the ulnar fovea. Therefore, we extracted the information about the area that the ulnar-side tears were attached to. If an article showed a technique that had been previously reported by the same author, the article was excluded.

We identified 41 articles written about the repair of ulnar TFCC tears and 10 articles written about the repair of radial TFCC tears. Conservative treatments were attempted for all cases reported in this review before undergoing TFCC repair. The mean time from the initial injury to operation was 8.9 months (range 2–49, mean weighted value based on the number of patients). All patients underwent surgeries after failed conservative treatments and continuous wrist pain. It was reported that, prior to surgery, 9% of the patients complained of reduced grip strength, and that 15% of the patients had distal radio-ulnar joint instability such as clicking or clunking. These symptoms were also indications for surgery. There were two studies that reported how many patients underwent open surgeries after failed conservative treatments.^{9,10} Overall, 44% (52/119) of patients with a TFCC injury had surgeries after conservative treatments.

Repair of the ulnar side (Palmer 1B)

Trends in chronological order

The annual number of articles that reported TFCC repairs increased gradually from 1991 to 2010 (Figure 2). Although some authors began to report the repair of volar side-tears and dorsal-side tears more recently, articles that show the repair of ulnar TFCC tears have been the most frequent since 1991. These articles revealed that the ulnar side of the TFCC plays an important role in DRUJ stability.

Four surgical repair techniques have been reported: inside-out, outside-in, all-inside (all-arthroscopic), and open repair. To date, no direct-comparative study between these techniques has been published. The most described technique throughout the time period analyzed was outside-in (Figure 3). The outside-in technique was first reported in the first half of the 1990's. For this technique, a 1.5cm incision is initially made volar to the extensor carpi ulnaris (ECU) tendon. A needle is then advanced through the ulnar capsule and into the torn TFCC (Figure 4), after which a second needle is inserted adjacent to the first one. The suture end from the first needle is retrieved and brought out via the second needle using a wire loop. The suture ends are then tied over the wrist capsule under tension.

The inside-out technique was originally reported by de Araujo et al. in 1996.¹¹ For this technique, a Tuohy needle is placed into the 3–4 or 1–2 portal to pass sutures in a radial to ulnar direction (Figure 5). The needle is passed through the torn TFCC and advanced through a 1.5cm longitudinal incision on the ulnar side of the wrist. A 2-0 PDS suture is then inserted through the needle and out the ulnar incision. A second pass through the TFCC tear is performed by moving the needle a few millimeters in the volar or dorsal direction. The second suture end is pulled through the needle, keeping the 2 suture ends free on the ulnar side of the wrist, and tied.

All-inside techniques, in which the entire repair is performed arthroscopically, were first demonstrated in the 2000's (Figure 3).^{12,13–15} These techniques do not require an extra longitudinal incision and a subcutaneous suture knot. Yao et al. reported on this technique using the FasT-Fix system (Smith and Nephew Endoscopy, Andover MA) with excellent results in 92% of their patients based on the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) and Patient-Rated Wrist Evaluation (PRWE) questionnaires.^{16,17} The system has 2 absorbable poly-L-lactate (PLLA) blocks that are pre-threaded and pre-tied in a self-sliding knot. The 2 PLLA blocks are deployed through the capsule on either side of the TFCC tear and tightening the suture provides a re-approximation of the tear edge (Figure 6).

Open repair techniques were the first established treatment method for TFCC tears.¹⁸ Cooney et al. demonstrated an open repair technique using a dorsal ulnar incision between the fourth and fifth extensor compartments.¹⁸ After inversion of the extensor retinaculum, the wrist capsule is incised parallel to the TFCC. Nakamura et al. reported that open repair techniques are used if the fovea and the DRUJ are poorly visualized from a DRUJ arthroscopic view, or if the TFCC is in poor condition such that arthroscopic repair may cause the sutures to cut through the TFCC.⁶ However, in the dorsal approach, the ECU tendon sheath floor and the superficial dorsal limb of the radioulnar ligament block the view

of the fovea. Thus, Moritomo et al. recommended a palmar surgical approach for open TFCC repair and reported excellent results in 86% of their patients.¹⁹ In this palmar approach, a curvilinear or zig-zag incision is made along the medial side of the flexor carpi ulnaris (FCU) tendon. The FCU tendon and the ulnar nerve are retracted to the radial side. The palmar capsule is then incised transversely from the palmar sigmoid notch of the radius to the base of the ulnar styloid.

With regard to the areas that ulnar-side TFCC tears were attached to, attachments to the soft tissue have been demonstrated since the 1990s and are the most commonly reported (Figure 7). In these conventional repair methods, peripheral TFCC tears are attached to the dorsal or ulnar joint capsule. A multicenter study revealed that 41 of 45 patients with an average follow-up of 37 months had good to excellent results by using a capsular repair of a peripheral TFCC tear.²⁰ However, TFCC tears originating at the fovea are not restored to the original site by this method, and instability of DRUJ may remain in some cases. Estrella et al. demonstrated that results were poor in 14% of all patients who were treated by capsular repair, 40% of whom had persistent DRUJ instability.²¹

Recently, the concept of the site where ulnar-side tears are attached during repair is changing. Reports on TFCC repair by attachment to the fovea have been increasing gradually since 2000. Between 2011 and 2016, more articles were published on the method of repair involving foveal reattachment than attachment to the soft tissue (Figure 7). This is likely because it was revealed that the foveal insertion of the TFCC plays a key role in the DRUJ stability.²² Bain et al. demonstrated that if the foveal footprint remains unattached, it becomes soaked in synovial fluid, leading to synovitis. Furthermore, they showed that this synovitis may inhibit healing of the foveal insertion, and lead to persistent DRUJ instability, wrist pain, and decreased grip strength.²³

Two methods of reattachment of the TFCC to the fovea are suture anchors and transosseous sutures.^{6,24–26} Atzai reported results for the use of suture anchors for reattachment. In this study, the mean pain score improved from 8.3 to 1.2, and the Modified Mayo Wrist Score was excellent or good in 94% of all patients.²⁵ Nakamura et al. showed the results of reattachment by a transosseous suture through a bone tunnel. The study revealed that 15 among 24 wrists resulted in no pain, and that the clinical outcome was excellent or good in 79% of patients.⁶

Trends by geographic area

Articles that described TFCC repairs were mainly published in North America and Asia; fewer articles were reported in Europe (Table 2 and Figure 8). Similarly, methods of repair for ulnar TFCC tears were mainly shown in North America and Asia. (Figure 9) Outside-in techniques were most reported worldwide, and both open and inside-out repair were not reported in any publications from Europe.

Most articles from North America and Europe demonstrated the way that TFCC tears attach to soft tissue, such as a joint capsule (Figure 10). (Article number, North America: 14/17, Europe: 8/9) On the other hand, over half of the articles from Asia, mainly Japan and Korea, showed the way that ulnar-side TFCC tears attach to the fovea. (Asia: 8/15)

Recently, Atzei proposed a new classification subgroup, type 1-B, in Europe.²⁷ This classification was endorsed by The European Wrist Arthroscopy Society (EWAS). Type 1-B is further divided into five classes that provide differentiation between distal and proximal, and repairable and irreparable lesions (Table 3). Indications for treatment are also defined in this classification system. Foveal reattachments are required for complete and isolated proximal repairable tears (class 2 and 3) with DRUJ instability; conventional reattachments to the capsule are performed for isolated distal repairable tears (class 1). Considering that TFCC avulsion from the foveal insertion can cause DRUJ instability, these classifications and indications are rational. However, for an accurate diagnosis based on this classification, DRUJ arthroscopy is needed.

DRUJ arthroscopy was first reported by Whipple et al. in 1994.²⁸ The procedure has rarely been performed because of its difficulty and the small size of the joint. Radiocarpal and mid-carpal arthroscopies were often performed instead. Recently, several studies, mainly from Japan, have reported that DRUJ arthroscopies are important^{29–33} because radiocarpal arthroscopies cannot visualize the foveal insertion of the deep fibers in the cases where the superficial portion of TFCC was not torn. The deep fibers are the main stabilizers of the TFCC so it is critical that they can be visualized to make an accurate diagnosis; DRUJ arthroscopies can be used to diagnose a rupture of the deep fibers. Nakamura et al. reported that a DRUJ arthroscopy should be performed in any patients who have acute or chronic TFCC tears with DRUJ instability.³⁰ Yamamoto et al. demonstrated that pathological findings of the proximal surface of the articular disk tended to relate to ulnar wrist pain,²⁹ and that, in 30% of all patients, DRUJ arthroscopies revealed pathological findings that could not be identified with a radiocarpal arthroscopy.³¹

Repair on radial side (Palmer 1D)

Trends in chronological order

We identified only 10 articles that reported on the repair of radial-side TFCC tears.^{34–41} The repair of radial-side tears has been reported since the 1990s. However, the annual number of articles that reported the repair of radial side tears did not increase over the time period covered in our literature search (Figure 2 and Figure 11). A radial side tear is more uncommon and the repair methods are controversial. On the other hand, the repair of ulnar-side TFCC tears has better healing potential and results in good clinical outcomes. Some studies have reported that radial side TFCC tears cannot heal because of a lack of blood supply.^{7,8,42} However, other studies have showed good outcomes in healing radial-side tears.^{35,37,39} Trumble et al. reported that the repair of radial-side TFCC tears decreases pain significantly.⁴³ Shih et al. demonstrated that patients with radial-side TFCC tears had the same results as those with ulnar-side tears.³⁷ They hypothesized that a combination of vascular ingrowth and synovial fluid can supply enough nutritional support to heal the tear. Therefore, TFCC repair may be performed for cases of radial-side tear with DRUJ instability.

Four repair methods were reported for radial-side tears: outside-in, inside-out, all-inside, and open repair techniques (Figure 11). The inside-out technique was most commonly used (6/10 articles).^{34,35,37,41,44} The inside-out technique is performed by using trans-osseous

sutures through the distal radius in ulnar to radial direction (Figure 12). The suture is passed through the cannula, central rim of the TFCC, and bone tunnel, and then tied over the radius. The outside-in technique is also performed using trans-osseous sutures, but in the radial to ulnar direction (Figure 13).^{36,38} Recently, two all-inside repair techniques have been reported (Figure 11).^{39,40} Trumble first demonstrated one of them, an arthroscopic direct-repair technique, using an anchor to the radius in 2011.³⁹ Cho et al. noted another new all-inside technique using a small curved suture hook in 2012.⁴⁰ In this technique, trans-osseous sutures are not necessary, and therefore, no extra skin incision is made to avoid the risk of irritating subcutaneous suture knot stacks over the radial side of the radius.

Trends by geographic area

Table 4 and Figure 14 show the number of papers describing each suture technique for radial-side TFCC tears organized by geographic regions. The repair of radial-side TFCC tear was mainly reported in North America and Asia.^{34,35,37–41,43} Only one paper was from Europe, showing the outside-in technique.³⁶

Repair in other areas

In regard to TFCC repair in other areas, we identified 2 articles that discussed volar TFCC tears (Palmer class 1C)^{37,45} and 2 articles that demonstrated dorsal TFCC tears.^{21,46} All four articles were published in Asia (Figure 8). The volar TFCC tears were repaired the same way as ulnar-side TFCC repairs (open or outside-in technique).^{37,45} In both articles discussing dorsal tears, the outside-in technique was used.^{21,46} Dorsal tears of the TFCC are not included in the original Palmer classification system. Dorsal tears were first discussed by Estrella et al. in 2007²¹; other authors have also reported the existence of dorsal TFCC tears.^{46,47} Abe et al. stated that a dorsal tear can entrap the ulnar head and cause restricted rotation of the forearm⁴⁷.

Summary

This review showed the classification and repair methods of TFCC tears organized by tear area and in chronological order. The outside-in technique for the ulnar-side repair was presented the most often. Although good results were revealed with each technique, the all-inside technique may be advantageous because this technique does not need a skin incision or a subcutaneous suture knot. Thus, the all-inside technique is a good option to decrease the risks of cutaneous nerve injury and irritation below the skin from the suture knot.

Soft tissue attachments were demonstrated most often in regards to the area that the stumps of ulnar-side TFCC tears were attached to. However, it has recently been recognized that the foveal attachment of the TFCC plays an important role in the DRUJ stability; reports of repair by attachment to the fovea have been gradually increasing. With soft tissue attachments, TFCC instability may remain in cases with torn proximal components. Therefore, surgeons should know the importance of foveal attachment methods. In cases with DRUJ instability but no TFCC tear findings after a radiocarpal arthroscopy, surgeons should consider performing DRUJ arthroscopies for a precise diagnosis because normal radiocarpal arthroscopies cannot detect a tear of the foveal attachment from the deep fibers.

The Atzai classification is useful to determine a treatment strategy for peripheral TFCC tears.

Articles that showed methods of radial-side TFCC tear repair were scarce and were published mostly in North America and Asia. The outside-in technique for radial-side tear repair was demonstrated most frequently while all-inside techniques have begun to emerge in recent years. Although the effectiveness of radial-side TFCC tear repair is controversial, radial-side repair may be indicated for the case with DRUJ instability.

With increasing globalization, the cultural diversity in local populations is bound to increase. Understanding differences in treatment methods or strategies provides information so that physicians can give their patients better options adapted to their cultural circumstances such as health insurance and health infrastructure.

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KEY POINTS

- The repair methods for ulnar tears were noted as inside-out, outside-in, all-inside, and open repair, with the outside-in technique being the most common.
- Although the most reported method of TFCC repair is by attachment to the joint capsule, repair of ulnar side tears by foveal attachment has been demonstrated recently.
- The effectiveness of the repair of radial-side tears was controversial and the methods of repair reported were inside-out, outside-in, all-inside, and open repair.

Figure 1.

Axial illustration of the TFCC.

From Michelotti B, Brown M, Chung KC. Wrist Arthroscopy. In: Chung KC, editor. Operative Techniques: Hand and Wrist Surgery, 3rd edition. Philadelphia: Elsevier; 2018; with permission.

Figure 2.
Number of papers organized by year and the site of TFCC tears.

Figure 3.
Number of papers organized by year and suture technique for ulnar-side TFCC tears.

Figure 4. Outside-in technique for ulnar-side TFCC tears. (A) A curved needle is penetrated through the capsule and the distal portion of the tear. A second needle is inserted parallel to the first. (B) A 2-0 or 3-0 PDS suture is passed through the needle and the suture is secured with the suture passer from the other needle. (C) The suture passer is withdrawn with the suture. (D) The needles are withdrawn and the suture ends are tied over the joint capsule.

Figure 5.

Inside-out technique for ulnar-side TFCC tears. (A) The Tuohy needle is advanced to the ulnar wrist and a PDS suture is passed through the needle. (B) The needle is withdrawn and the second needle is penetrated through the triangular fibrocartilage (TFC) at a point a few millimeters from the first. Both free suture ends are pulled out and tied over the ulnar capsule.

Figure 6.

All-inside technique for ulnar-side TFCC tears. (A) The first PLLA (poly-L-lactate) block is penetrated through the tear and advanced through the ulnar capsule. The needle introducer is then backed out to release the block outside the capsule. The second block is passed through the capsule and placed in the same manner. (B) The needle introducer is withdrawn, leaving the pre-tied suture. The suture is tightened, and the knot is cut by the knot pusher and cutter.

Figure 7.
Number of papers organized by attachment site and year for ulnar-side TFCC tears.

Figure 8.
Number of papers categorized by geographic region and the site of TFCC tear.

Figure 9.
Number of papers categorized by suture technique and geographic region for ulnar-side TFCC tears.

Figure 10.

Number of papers categorized by attachment site and geographic region for ulnar-side TFCC tears.

Figure 11.
Number of papers categorized by suture technique and year for radial-side TFCC tears.

Figure 12.

Inside-out technique for radial-side TFCC tears. (A) A cannula is inserted into the joint. A meniscal needle is then passed through the triangular fibrocartilage (TFC) and the radius after making a bone tunnel with a K-wire. (B) A second needle is advanced in the same manner. The suture is tied over the radius.

Figure 13.

Outside-in technique for radial-side TFCC tears. A special anchor system is used in this method. (A) The T-fix application device preset an anchor is advanced until the triangular fibrocartilage (TFC) is perforated after making a bone canal with a reamer. (B) The anchor is pushed out, unfolded, and retracted after removal of the application. The thread is tied periostally through a small incision.

Figure 14.
Number of papers organized by suture technique and geographic region for radial-side tears.

Table 1

Palmer classifications of TFCC tears

Class	Description
Class 1	Acute traumatic
1A	Central TFCC perforation
1B	Peripheral ulnar side TFCC tear (with or without ulnar styloid fracture)
1C	Distal TFCC disruption (disruption from distal ulnocarpal ligaments)
1D	Radial TFCC disruption (with or without sigmoid notch fracture)
Class 2	Degenerative
2A	TFCC wear
2B	TFCC wear with lunate and/or ulnar chondromalacia
2C	TFCC perforation with lunate and/or ulnar chondromalacia
2D	TFCC perforation with lunate and or ulnar chondromalacia with lunotriquetral ligament perforation
2E	2D + ulnocarpal arthritis

Table 2
Number of papers for each repair method for ulnar-side TFCC tears categorized by geographic region

Area	country	No. of paper	Attached area		Suture technique			All-inside	Open
			Fovea	Soft tissue	Outside-in	Inside-out	Inside-out		
North America	USA	17	3	14	9	3	2	3	
Asia	Japan	5	4	1	3	0	0	2	
	Korea	5	3	2	4	0	1	0	
	Taiwan	2	0	2	0	1	0	1	
	China	1	0	1	1	0	0	0	
	Hong Kong	1	1	0	0	1	0	0	
Europe	Philippines	1	0	1	1	0	0	0	
	Italy	3	1	2	1	0	2	0	
	Belgium	3	0	3	3	0	0	0	
	Austria	1	0	1	1	0	0	0	
	Germany	1	0	1	0	0	1	0	
	Norway	1	0	1	1	0	0	0	
	Total	41	12	29	24	5	6	6	

Table 3

Triangular fibrocartilage Complex Peripheral Tear Classification

	Clinical DRUJ Instability	Appearance of TFCC distal component	Status of TFCC proximal component	TFCC healing potential	Status of DRUJ cartilage	Treatment
Class 1: repairable distal tear	None/Slight	Torn	Intact	Good	Good	REPAIR Suture (Ligament-to-capsule)
Class 2: repairable complete tear	Mild/Severe	Torn	Torn	Good	Good	REPAIR Foveal Refixation
Class 3: repairable proximal Tear		Intact	Torn	Good	Good	
Class 4: non-repairable	Severe	Torn	Torn	Poor	Good	RECONSTRUCTION Tendon Graft
Class 5: arthritic DRUJ	Mild/Severe	Variable				SALVAGE Arthroplasty or Joint Replacement

Table 4
Number of papers organized by repair method and geographic region for radial-side TFCC tears

Area	country	No. of paper	Suture technique			
			Outside-in	Inside-out	All-arthroscopic	Open
North America	USA	5	0	3	1	1
			0	1	0	0
Asia	Korea	1	0	0	1	0
	Taiwan	1	0	1	0	0
	Hong Kong	1	0	1	0	0
	Austria	1	1	0	0	0
Total		10	1	6	2	1