

# Surgical Repair of Triangular Fibrocartilage Complex Tears: A Systematic Review

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## Abstract

**Objective** This study systematically reviews the outcomes of surgical repair of triangular fibrocartilage complex (TFCC) tears. Existing surgical techniques include capsular sutures, suture anchors, and transosseous sutures. However, there is still no consensus as to which is the most reliable method for ulnar-sided peripheral and foveal TFCC tears.

**Methods** A systematic review of MEDLINE and EMBASE was performed according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The focus was on traumatic Palmer 1B ulna-sided tears. Twenty-seven studies were included, including three comparative cohort studies.

**Results** There was improvement in all functional outcome measures after repair of TFCC tears. The outcomes following peripheral and foveal repairs were good overall: Mayo Modified Wrist Evaluation (MMWE) score of 80.1 and 85.1, Disabilities of the Arm, Shoulder and Hand (DASH) score of 15.7 and 15.8, grip strength of 80.3 and 92.7% (of the nonoperated hand), and pain intensity score of 2.1 and 1.7, respectively. For peripheral tears, transosseous suture technique achieved better outcomes compared with capsular sutures in terms of grip strength, pain, Patient-Rated Wrist Evaluation (PRWE), and DASH scores (grip 85.8 vs. 77.7%; pain 1.5 vs. 2.2; PRWE 11.6 vs. 15.8; DASH 14.4 vs. 16.1). For foveal tears, transosseous sutures achieved overall better functional outcomes compared with suture anchors (MMWE 85.4 vs. 84.9, DASH 10.9 vs. 20.6, pain score 1.3 vs. 2.1), but did report slightly lower grip strength than the group with suture anchors (90.2 vs. 96.2%). Arthroscopic techniques achieved overall better outcomes compared with open repair technique.

**Conclusion** Current evidence demonstrates that TFCC repair achieves good clinical outcomes, with low complication rates.

**Level of Evidence** This is a Level IV, therapeutic study.

## Keywords

- ▶ triangular fibrocartilage
- ▶ TFCC
- ▶ repair
- ▶ foveal
- ▶ peripheral tear
- ▶ systematic review

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Triangular fibrocartilage complex (TFCC) tears are a common source of pain on the ulnar side of the wrist and is often associated with decreased grip strength and impaired function. In addition, the TFCC, especially through its foveal attachment, contributes to the stability of the distal radioulnar joint (DRUJ).<sup>1–3</sup> TFCC tears can be classified according to the location and cause.<sup>4</sup> The Palmer classification delineates tears into two categories—acute/traumatic (Type 1) and degenerative tears (Type 2). Type 1 tears are further divided into four subtypes (1A to 1D) depending on the location of the tear. Type 1B injuries are tears located at the ulnar side of the TFCC. These tears may be repairable due to the vascularity in the peripheral one-third of the TFCC.<sup>4,5</sup>

The TFCC is composed of superficial and deep components. The superficial or distal component is a hammock structure attached to the ulnar collateral ligament and the deep or proximal component is a triangular ligament, or ligamentum subcruratum, attached to the ulnar fovea by palmar and dorsal limbs, forming the volar and dorsal distal radioulnar ligaments.<sup>6</sup> Previous anatomical and biomechanical studies have shown that the deep component plays a greater role in stability of the DRUJ compared with the superficial component of the TFCC.<sup>7</sup> As the Palmer classification does not divide Type 1B tears into foveal or superficial tears, there can be a lack of standardization of nomenclature between studies. Atzei et al proposed a more clinically relevant, treatment-based classification of Type 1B tears. In this classification, the distal (peripheral) and proximal (foveal) components of the TFCC are incorporated and contrasted. Class 1 tears consist of a repairable distal tear, class 2: a repairable complete tear, class 3: a repairable proximal tear, class 4: a nonrepairable tear, and class 5: an arthritic DRUJ.<sup>8–10</sup>

Pain caused by TFCC tears may be treated by nonoperative means including rest, splinting, cortisone injections, and activity modification.<sup>11</sup> However, surgery is considered when nonoperative measures fail and this includes arthroscopic debridement, arthroscopic/arthroscopic-assisted repair (outside-in, inside-out, all-inside), or open repair.<sup>8</sup> Ulnar shortening osteotomy (USO) can also be performed to unload the ulnocarpal joint; in the event there is associated ulna abutment from ulna positive variance.<sup>12</sup>

Various TFCC repair techniques have been discussed and the type of repair chosen depends on the location of the TFCC tear.<sup>8</sup> Peripheral tears are often repaired using traditional suture techniques to reattach the superficial portion of the TFCC to the dorsal ulnocarpal capsule and the extensor carpi ulnaris (ECU) tendon subsheath.<sup>13</sup> Foveal avulsions are frequently repaired by reattachment to the foveal insertion using transosseous sutures passed through drill holes or suture anchors.<sup>8,14,15</sup> Both repairs can be performed with either open or arthroscopic techniques. However, to date, despite the various techniques that have been described, there is still no clear consensus as to which technique provides the most optimum results.<sup>3,16,17</sup> Therefore, it was the aim of this study to systematically review the current literature and examine the functional and clinical outcomes as well as complications of surgical repair techniques for traumatic Palmer Type 1B TFCC tears.

**Table 1** Search strategy

1	Triangular fibrocartilage/or TFCC.mp.
2	repair.mp.
3	treatment.mp.
4	surgery.mp.
5	opera*.mp.
6	result.mp.
7	outcome.mp.
8	2 or 3 or 4 or 5 or 6 or 7
9	1 and 8
10	limit 9 to english language

Abbreviation: TFCC, triangular fibrocartilage complex.

## Methods

### Study Selection Protocol

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Two authors (E.H.L., K. S.) systematically searched the electronic databases PubMed MEDLINE and Ovid MEDLINE (1946–2020) and Ovid EMBASE (1980–2020) using the search strategy in **Table 1**. The search results were up to date as of March 2020. Two authors independently selected studies which met the inclusion criteria based on title and abstract. Both authors reviewed the full-text versions of selected studies and independently extracted the outcome data. Any discrepancies were resolved by a third author (E.T.E.).

### Eligibility Criteria

Clinical studies were considered if they included adult patients over the age of 16 years with a Palmer Type 1B TFCC tear treated by surgical repair. All clinical studies or case series which included subjective or objective outcome measures were considered. Studies were excluded if (1) clinical outcomes were not reported, (2) study patients had nonrepairable tears or (3) study patients suffered concomitant injuries such as distal radius fractures or underwent DRUJ reconstruction, (4) the article is not in the English language, and (5) the article is an editorial, conference abstract, or review article.

### Data Exaction/Outcome Measures

Data were extracted using standardized forms, which included patient characteristics, intervention, comparisons, outcomes, study setting, sample size, and follow-up. Validated patient-reported outcomes and functional outcomes were collected. This included data on the patient's preoperative and postoperative pain level based on the visual analogue scale (VAS) and numerical rating scale (NRS), grip strength as measured by a dynamometer, functional outcome based on the Modified Mayo Wrist Evaluation (MMWE) score, the Patient-Rated Wrist Evaluation (PRWE) score, and Disabilities of the Arm, Shoulder, and Hand (DASH) score. Grip strength was reported as a percentage of the contralateral side. Both preoperative and postoperative measurements were collected.

VAS and NRS are both validated patient-reported measures of pain intensity consisting of a continuous scale that ranges

from 0, representing “no pain,” to 10, which represents “worst imaginable pain.” The NRS is a segmented numeric version of the VAS.<sup>18,19</sup> The MMWE assesses the patient’s (1) pain, (2) grip strength, (3) range of motion, and (4) return to employment. The total score, based on the clinician’s assessments, ranges from 0 to 100, with higher scores indicating a better result.<sup>20</sup> PRWE is a 15-item questionnaire that allows patients to rate their wrist pain and disability. It consists of two subscales: (1) pain intensity, and (2) function in specific activity and function in usual activity. The maximum score tallied is 100 which represents the greatest disability.<sup>21</sup> The DASH is a validated self-administered questionnaire designed to measure pain symptoms and disability related to the upper extremity. The QuickDASH is an abbreviated version of DASH, and contains 11 questions to measure the severity of symptoms. In both DASH and QuickDASH, the total score is placed on a scale between 0 (no disability) and 100 (most severe disability).<sup>22–24</sup>

Grip strength as measured by a dynamometer was reported as a percentage of the strength on the contralateral, unoperated hand. Data on postoperative complications were also extracted from the included studies. This includes reoperations, altered sensation, and recurrent DRUJ instability.

### Assessment of Study Quality

The Moga tool was specifically developed to assess the methodological quality of case series using the Modified Delphi technique. Using this tool, each study was scored out of 18 points. A study with 14 or more points was of acceptable quality.<sup>25</sup>

SPSS Statistics (IBM, New York, NY) was used for calculation of weighted averages of the continuous data we collected. Meta-analysis was not done due to heterogeneity of our sample.

## Results

### Study Selection

A total of 1,390 articles were found from both databases. After removing duplicates, 1,027 records were screened based on title and abstract. A total of 178 articles were selected for full-text review. One hundred and fifty articles were excluded with reasons provided. ► **Fig. 1** demonstrates the PRISMA diagram for the systematic review.

### Quality Assessment

A total of 27 articles met the inclusion criteria.<sup>26–52</sup> All studies were retrospective cohort or case series and achieved a Moga score of 14 or higher. There were five Level III and 22 Level IV studies. Characteristics of the included studies are shown in ► **Tables 2** and **3**.

### Study and Patient Characteristics

There was a total of 825 patients (mean age = 32.2 years) reported from 27 articles. Three papers were comparative studies and included two study groups.<sup>26,40,48</sup> Fourteen studies reported peripheral TFCC repairs<sup>26–39</sup> and 13 studies reported foveal avulsions of the TFCC.<sup>40–52</sup> As the pathoanatomy

of these tears and repair techniques differ, the outcomes of peripheral and foveal tears were analyzed separately.

## Clinical Outcome Measures

### Repair Techniques and Pooled Analysis of Outcome Measures

#### Peripheral Tears of the TFCC

Fourteen studies reported peripheral TFCC repairs in 517 patients (► **Table 2**). The mean age of study patients was 33.1 years; their average follow-up time is 34.8 months. The time between injury and surgical repair was reported in six papers, and the average is 19.1 months. Repair techniques include a combination of outside-in and inside-out capsular sutures, and sutures pulled through a bone tunnel in the ulna (transosseous suture). Thirteen studies reported only arthroscopic techniques and one study compared arthroscopic and open techniques. Thus, there was a sample size of 478 patients who underwent arthroscopic repair and 39 who had open repair. Thirteen studies<sup>26–30,32–39</sup> consisting of 398 patients reported on an outside-in or inside-out suture secured to the joint capsule. Two studies<sup>26,31</sup> (119 patients) described sutures secured through ulnar transosseous tunnels.

#### Outcomes of Peripheral Repair

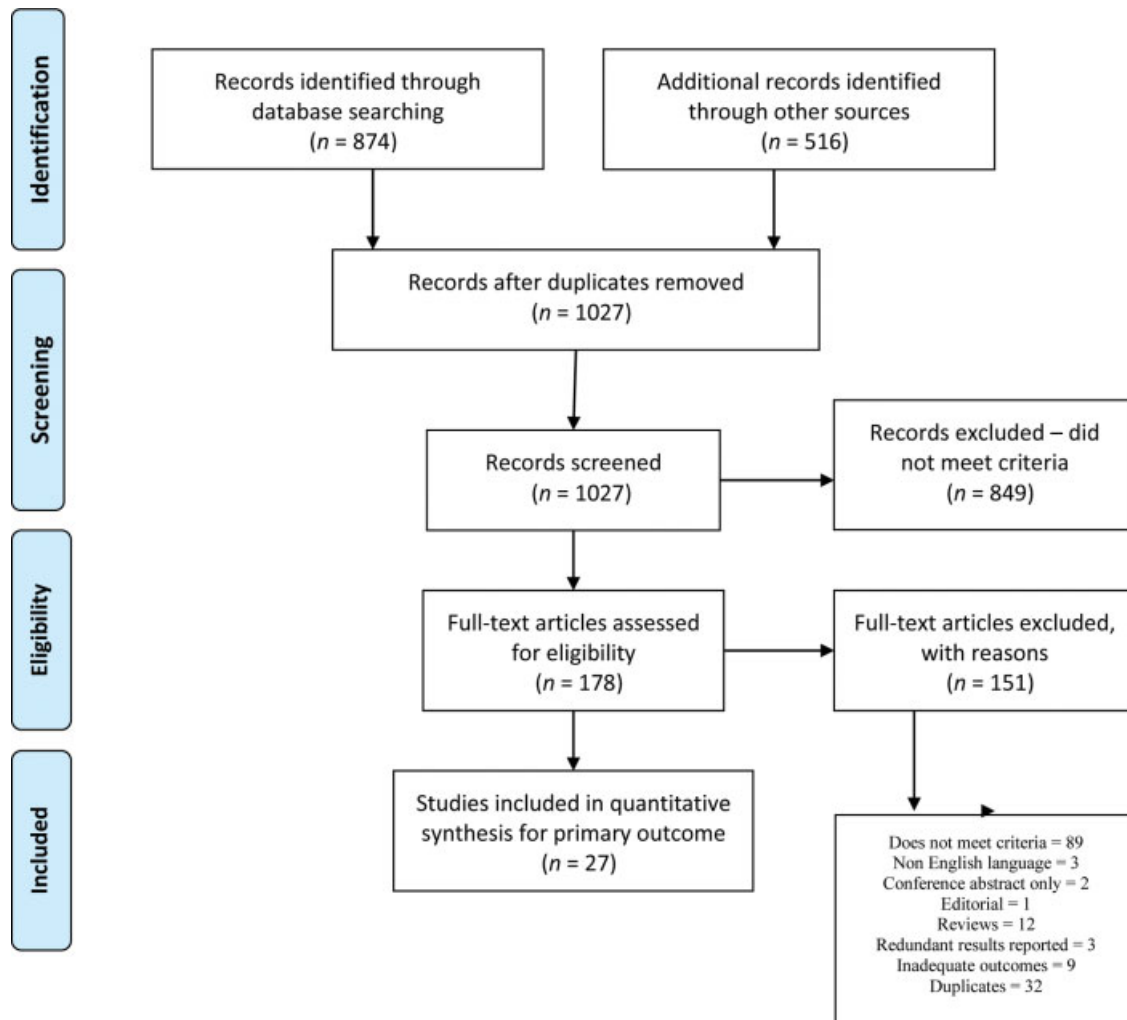
► **Fig. 2** demonstrates an improvement in the pooled preoperative to postoperative functional outcomes for peripheral repairs for all measures. MMWE showed an improvement from a mean of 63.8 preoperatively to 80.1 postoperatively. Furthermore, the DASH score improved from 41.1 to 15.7. There was a gain in grip strength from 74.9 to 80.3% of the contralateral side. Reported pain intensity decreased from 7.1 to 2.1 (► **Table 4**).

As aforementioned, 13 studies reported capsular repair techniques, which were all done arthroscopically. The only study that reported an open repair approach used a transosseous repair technique.<sup>26</sup> The other study that repaired the TFCC injury using a bone tunnel did so via an arthroscopic-assisted technique.<sup>31</sup>

Compared with transosseous sutures ( $n = 119$ ), arthroscopic capsular suture repair ( $n = 398$ ) achieved better MMWE scores (82.9 vs. 71.2). However, transosseous technique demonstrated a slightly better DASH score (14.4 vs. 16.1), better postoperative grip strength (85.8 vs. 77.7%), and better postoperative pain (1.5 vs. 2.2). Postoperative outcomes of different techniques of peripheral TFCC repair are shown in ► **Figs. 3** and **4**.

#### Foveal Avulsion of the TFCC

Thirteen studies reported outcomes of foveal repairs in 308 patients (► **Table 5**). The patients’ mean age was 31.3 years; they were followed up for an average period of 33.7 months. The period before surgical repair was reported in 10 studies, and the average duration was 12.7 months. Foveal avulsions were reattached using either suture anchors (six studies,  $n = 165$ )<sup>41–43,47–49</sup> or sutures through ulnar transosseous tunnels (seven studies,  $n = 143$ ).<sup>40,44–46,50–52</sup> Twelve studies with



**Fig. 1** PRISMA diagram. PRISMA, preferred reporting items for systematic reviews and meta-analyses.<sup>57</sup>

255 patients reported arthroscopic techniques, and three studies with 53 patients reported open techniques. Two of the three papers on open repair were comparative studies involving both arthroscopic and open approach groups.<sup>40,48</sup> One study reported only an open technique.<sup>49</sup>

#### *Suture Anchor Foveal Repair (n = 165 Patients)*

Atzei et al, Luchetti et al, and Kim et al described an arthroscopic-assisted foveal repair of the two dorsal and volar radioulnar ligament limbs via a suture anchor to the fovea.<sup>41,47,48</sup> This was performed via suture shuttles using an outside-in technique through a direct foveal portal. Atzei et al described the direct foveal portal to be 1 cm proximal to the 6U portal, on the volar ulnar aspect of the wrist. A 2-cm mini-open incision over the ECU tendon may be used to avoid the dorsal sensory branch of the ulnar nerve.<sup>41</sup>

Luchetti et al compared the outcomes of open and arthroscopic foveal repair.<sup>48</sup> The open foveal repair was done via an open dorsal approach described by Garcia-Elias using a 4-cm central dorsal skin incision and a suture anchor into the ulnar fovea.<sup>53</sup> Both groups had improvement of pain scores, MMWE, DASH, and PRWE scores, and significantly better

DASH scores in the arthroscopic group compared with the open group.

#### *Transosseous Foveal Repair (n = 143 Patients)*

Seven papers reported a transosseous repair technique.<sup>40,44–46,50–52</sup> Iwasaki et al performed arthroscopic-assisted transosseous repair using a guiding device through the four to five portal, targeting the fovea. An outside-in technique for the suture shuttle was then utilized, with the sutures finally tied onto the ulnar periosteum over the proximal entrance of the osseous tunnel.<sup>45</sup> Jegal et al reported a similar technique, utilizing an Aiming Guide inserted through the four to five portal directed at the fovea to create bone tunnels from proximal ulnar cortex. The sutures entering through these transosseous tunnels would be tied down and fixed by knotting over the joint capsule.<sup>46</sup> Park et al and Jung et al inserted the aiming guide through 6R portal toward the fovea. Under arthroscopic control, they passed the suture which grasped the TFCC through the transosseous tunnel and secured with a suture anchor proximal to the trajectory of the bone tunnel.<sup>50,52</sup>

**Table 2** Studies characteristics of peripheral TFCC repairs

Author/Study	Study design	Level of evidence	Sample size	Mean age (years)	Mean follow-up time (months)	Time from injury to surgery (months)	Type of TFCC injury	Type of repair	Repair technique
Anderson et al 2008	Retrospective cohort study	III	O: 39 A: 37	33	O: 53 A: 32		Peripheral	Open and Arthroscopic	O: Transosseous suture A: Capsular suture (outside in)
Badia and Khanchandani 2007	Retrospective case series	IV	23	35	17		Peripheral	Arthroscopic	Capsular suture (outside in)
Bayoumy et al 2015	Retrospective case series	IV	37	23.3	24	11.1	Peripheral	Arthroscopic	Capsular suture (outside in)
Degreef et al 2005	Retrospective case series	IV	52	32	16		Peripheral	Arthroscopic	Capsular suture (outside in)
Haugstvedt and Husby 1999	Retrospective case series	IV	20	32	42	25	Peripheral	Arthroscopic	Capsular suture (outside in)
Lee et al 2019	Retrospective cohort study	III	80	37	23.7	6.4	Peripheral	Arthroscopic	Transosseous suture
McAdams et al 2009*	Retrospective case series	IV	9	20.8	32.2	52.1	Peripheral	Arthroscopic	Capsular suture (inside out)
Millants et al 2002	Retrospective case series	IV	35	31	58		Peripheral	Arthroscopic	Capsular suture
Papapetropoulos et al 2010	Retrospective cohort study	IV	27	37	24	15	Peripheral	Arthroscopic	Capsular suture (outside in)
Roh et al 2018	Retrospective case series	IV	60	32	12	5	Peripheral	Arthroscopic	Capsular suture (outside in)
Ruch et al 2005	Retrospective case series	IV	35	34	29		Peripheral	Arthroscopic	Capsular suture (outside in)
Sarkissian et al 2019	Retrospective case series	IV	11	36	84		Peripheral	Arthroscopic	Capsular suture
Wolf et al 2012	Retrospective case series	IV	40	38	58		Peripheral	Arthroscopic	Capsular suture
Yao and Lee 2011	Retrospective case series	IV	12	42	17.5		Peripheral	Arthroscopic	Capsular suture

Abbreviations: A, arthroscopic; O, open; TFCC, triangular fibrocartilage complex.

Note: In the above studies, only ulnar-sided TFCC repairs were included.

Shinohara et al and Abe et al both utilized a small incision to expose the ulnar side of ulnar neck and drilled two parallel osseous bone tunnels directed at fovea. Suture fed through tunnels via the portals then tied to the entrance of the bone tunnels, thus directly attaching the TFCC to the fovea.<sup>40,51</sup> Dunn et al performed the reattachment in a similar technique, securing the TFCC in a horizontal mattress, tensioning through the tunnel and fixed it with a suture anchor proximal to the bone tunnel.<sup>44</sup>

#### Outcomes of Foveal Repair

The weighted averages of preoperative to postoperative functional outcomes for foveal repairs are shown in ►Fig. 5. The MMWE and PRWE scores improved from a mean of 56 to 85.1, and 63.2 to 26.3, respectively. The DASH score improved from 43.8 to 15.8. Grip strength improved from 76.9 to 92.7%. Reported pain intensity as measured by VAS or NRS scores improved from 5.8 to 1.7 (►Table 5).

Transosseous sutures achieved a similar outcome compared with suture anchors, with respect to MMWE (85.4 vs. 84.9), but overall had a much better DASH score (10.9 vs. 20.6) and reported pain (1.3 vs. 2.1). On the other hand, the

suture anchor group reported slightly better postoperative grip strength (96.2 vs. 90.2% of the contralateral side), and PRWE score (24.7 vs. 28.1). Postoperative outcomes of different techniques of peripheral TFCC repair are shown in ►Figs. 6 and 7.

#### Postoperative Immobilization and Rehabilitation (For Both Peripheral and Foveal Repairs)

All studies immobilized patients from a range of 3 to 8 weeks, using long arm or sugar tong splints, or cast, with some authors changing to a short arm cast or removable wrist splint after 2 to 4 weeks.<sup>27-29,32,34,39-42,45,47,49,52</sup> Four studies immobilized the DRUJ with K-wires for 3 to 6 weeks after a peripheral repair.<sup>26,29,33,47</sup> Return to heavy activities and sport was at 3 to 6 months after surgery.<sup>28,32,40,41,43,46,48,50</sup>

#### Complications

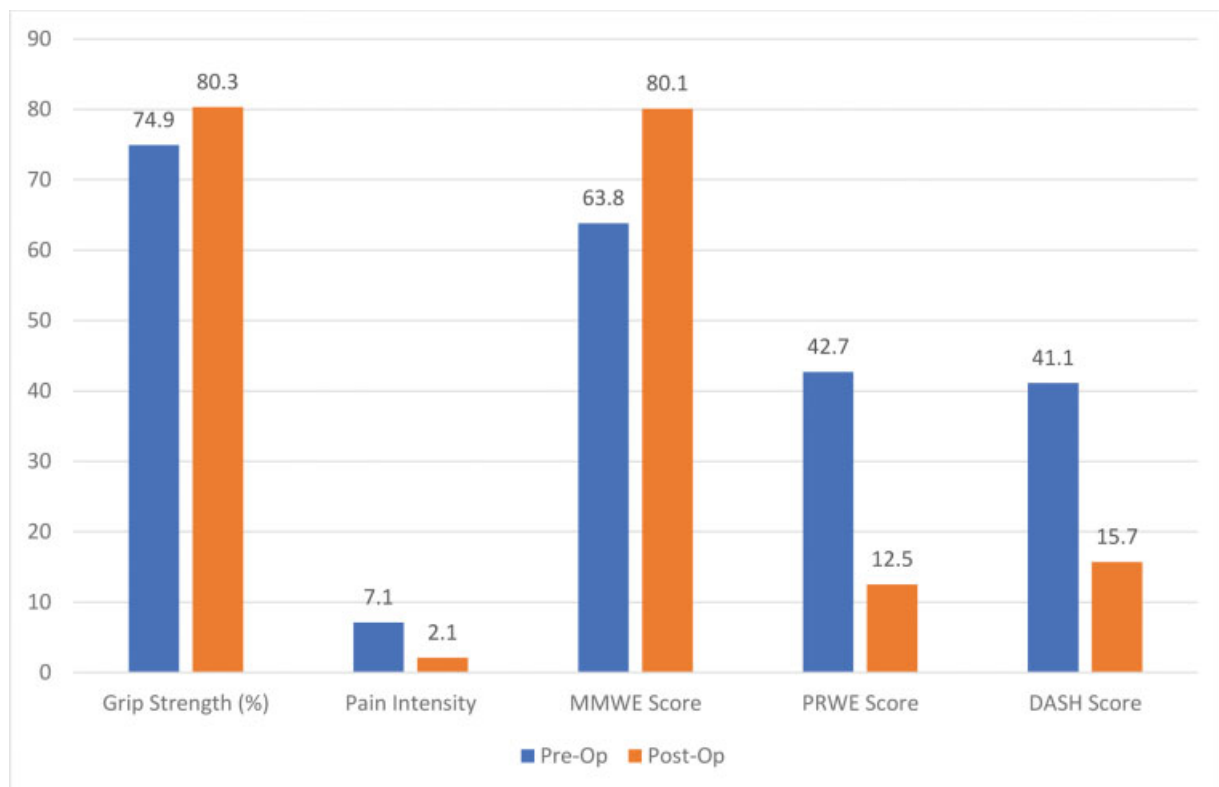
##### Reoperation

Reoperation case incidence was reported in 23 papers—11 involving peripheral tears, and 12 involving foveal injuries (►Tables 4, 5, 6). While 14 studies reported no reoperations,

**Table 3** Studies characteristics of foveal TFCC repairs

Author/Study	Study design	Level of evidence	Sample size	Mean age (years)	Mean follow-up time (months)	Time from injury to surgery (months)	Type of TFCC injury	Type of repair	Repair technique
Abe et al 2018	Retrospective case series	III	O: 8 A: 21	O: 22 A: 34	34.4	O: 11 A: 8.5	Foveal	Open and arthroscopic	Transosseous suture
Atzei et al 2015	Retrospective case series	IV	48	34	33	11	Foveal	Arthroscopic	Suture anchor
Auzias et al 2020	Retrospective case series	IV	24	41	44		Foveal	Arthroscopic	Suture anchor
Chou et al 2003	Retrospective case series	IV	8	31	48	45.3	Foveal	Arthroscopic	Suture anchor
Dunn et al 2019	Retrospective case series	IV	15	21	46	3.8	Foveal	Arthroscopic	Transosseous suture
Iwasaki et al 2011	Retrospective case series	IV	12	31	30	8	Foveal	Arthroscopic	Transosseous suture
Jegal et al 2016	Retrospective case series	IV	19	37	31	6	Foveal	Arthroscopic	Transosseous suture
Jung et al 2019	Retrospective cohort study	III	42	35.3	26		Foveal	Arthroscopic	Transosseous suture
Kim et al 2013	Retrospective case series	IV	15	30	29	12.7	Foveal	Arthroscopic	Suture anchor
Luchetti et al 2014	Retrospective cohort study	III	O: 24 A: 25	33	31		Foveal	Open and arthroscopic	Suture anchor
Moritomo 2015	Retrospective case series	IV	21	31	26		Foveal	Open	Suture anchor
Park et al 2018	Retrospective case series	IV	16	29.8	31.1	11	Foveal	Arthroscopic	Transosseous suture
Shinohara et al 2013	Retrospective case series	IV	10	27	31	10	Foveal	Arthroscopic	Transosseous suture

Abbreviations: A, arthroscopic; O, open; TFCC, triangular fibrocartilage complex.  
Note: In the above studies, only ulnar-sided TFCC repairs were included.

**Fig. 2** Peripheral tear repair outcomes—preoperative versus postoperative.

**Table 4** Outcomes of peripheral TFCC repairs

Author/Study	Pain score (VAS/NRS)		Grip strength (% of contralateral)		MMWS		PRWE		DASH		Complications		
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Reoperations	Neuropraxia	DRUJ instability
Anderson et al 2008 (Open)		1.5	72	73	65.6	71.2				16.7	11	14	8
Anderson et al 2008 (Arthroscopic)		2.6	66	71	63.5	70.6				20.7	9	8	5
Badia and Khanchandani 2007				81							0	0	Excluded
Bayoumy et al 2015	7.6	2.9	82.5	89	62.1	91.2			29.9	10.2	0	1	
Degreef et al 2005		2.4		80						17.3	0	2	
Haugstvedt and Husby 1999		3.1		83		Excellent: 35% Good: 35% Fair: 20% Poor: 10%					5		
Lee et al 2019			72.5	92.1			42.7	11.6	34.4	13.3	0	0	
McAdams et al 2009 <sup>a</sup>									50.7	0	0		
Millants et al 2002		0.6								15			
Papapetropoulos et al 2010	6.3	1.4	85.5	64					31.7	9.8	0	1	0
Roh et al 2018	6.8	2.1							63.8	27.8	2	3	8
Ruch et al 2005				73						12			
Sarkissian et al 2019		1.7		98		81		12.3	41	10	0	0	Excluded
Wolf et al 2012	7.5	2.5				87			35	14	0	5	Excluded
Yao and Lee 2011				64.4				19		11	1		Excluded

Abbreviation: DASH, Disabilities of the Arm, Shoulder and Hand; DRUJ, distal radioulnar joint; MMWS, modified Mayo Wrist score; NRS, numerical rating scale; PRWE, patient-rated wrist evaluation; TFCC, triangular fibrocartilage complex; VAS, visual analogue scale.

Note: In the above studies, only ulnar-sided TFCC repairs were included.

nine studies outlined the secondary procedures that were required. Studies on peripheral injuries saw a higher incidence of reoperation than studies on foveal avulsions (28 cases, 7.9% vs. 12 cases, 5.5%).

Five patients required subsequent USO.<sup>30,39,47</sup> Ten patients underwent diagnostic arthroscopy for persistent wrist symptoms.<sup>30,39,48</sup> During the secondary arthroscopy, it was shown that six of these patients had healing of the TFCC repair.<sup>30,39</sup> Four of these patients needed additional operations to correct other abnormalities—Darrach's procedure, proximal row carpectomy due to Kienbock's disease, and USO ( $n = 2$ ). In the two remaining patients, no cause for pain was identified.

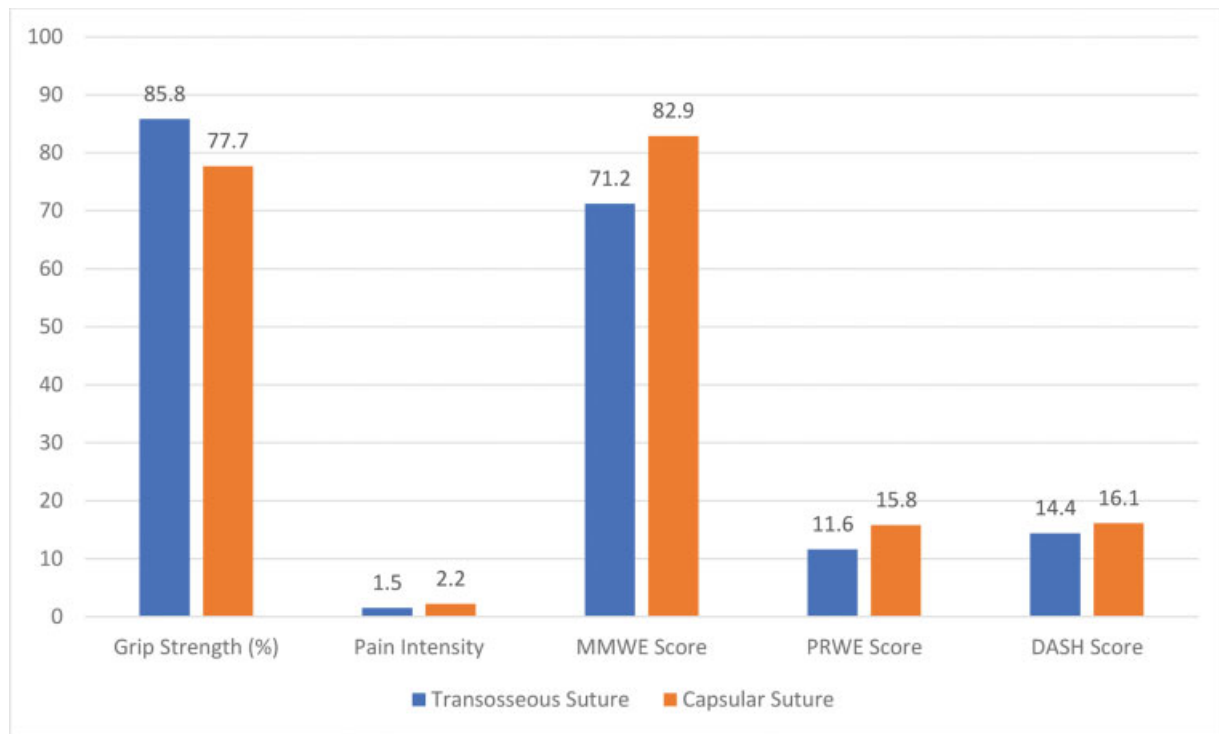
In four cases (three with open approach, one arthroscopically) reported by Luchetti et al, the patient underwent diagnostic arthroscopy due to persistent DRUJ instability.<sup>48</sup> The arthroscopy showed suture rupture with radioulnar ligament detachment at the site of previous repair. Subsequent reconstruction of the DRUJ was needed in 13 patients as reported by Anderson et al due to persistent DRUJ instability—eight of 39 patients (2.1%) in the open repair group, five of 36 patients (1.4%) in the arthroscopic repair group.<sup>26</sup>

Chou et al reported one patient who continued to experience persistent pain after arthroscopic reattachment of a foveal injury using a suture anchor. The patient needed multiple procedures including excision of an incisional neuroma, an eventually DRUJ arthrodesis.<sup>43</sup> Only one patient needed a complete re-operation of his TFCC repair due to re-injury from boxing 4 months following the initial procedure.<sup>44</sup> In 14 patients (10 with open approach, four arthroscopically), ECU tendonitis was noted in follow-up and required exploration and tenosynovectomy.<sup>26</sup> Two studies—both using the arthroscopic approach—reported suture removal in five patients due to irritation.<sup>35,51</sup>

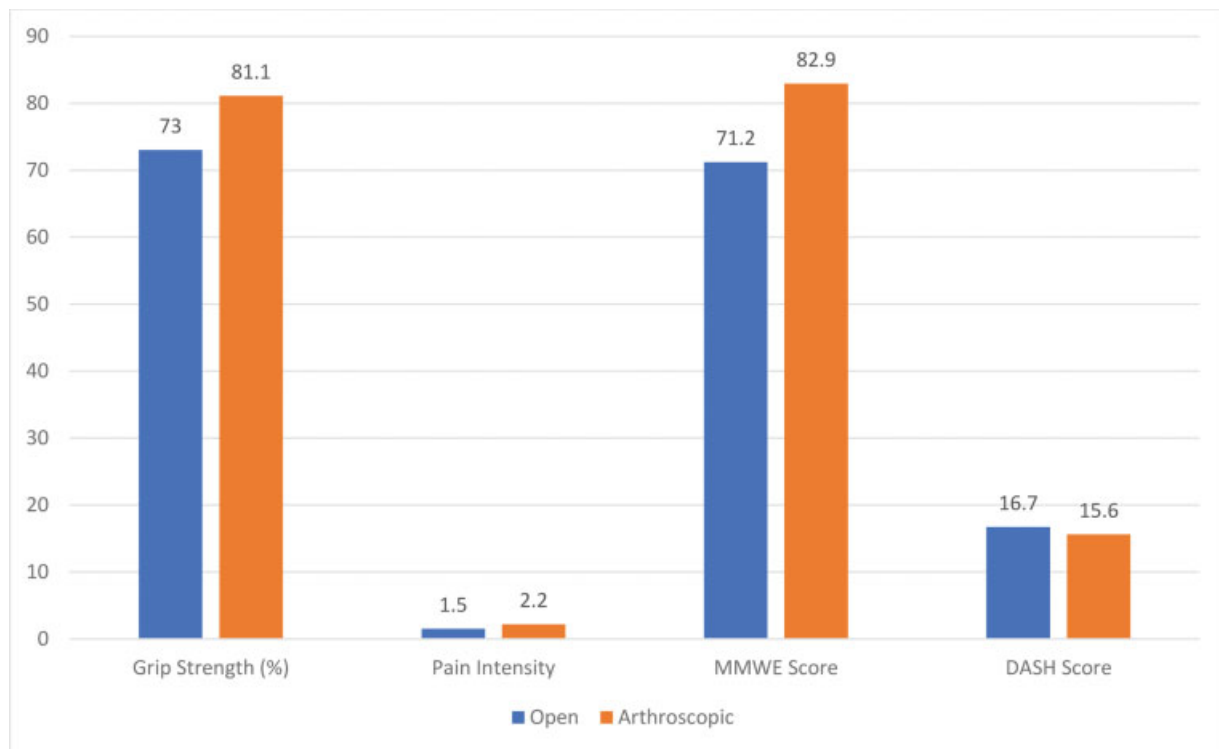
#### Altered Sensation

Neuropraxia of the dorsal cutaneous branch of ulnar nerve was a reported complication in 11 studies with peripheral repairs totalling 34 patients (8.0%), and in 14 papers with foveal repairs totalling 23 patients (8.0%), with nearly all resolved with conservative management at the final follow-up.

One of the three comparative studies noted higher incidence of postoperative hyperesthesia in the dorsal cutaneous branch of ulnar nerve in patients who had open repair compared with arthroscopic repair (35.9 vs. 22.2%).<sup>26</sup> The other two comparative studies did not note any nerve lesions.<sup>40,48</sup>



**Fig. 3** Peripheral tear repair outcomes—transosseous sutures versus capsular sutures.



**Fig. 4** Peripheral tear repair outcomes—arthroscopic versus open.

#### Recurrent DRUJ Instability

Five studies ( $n=21$ ) reported recurrent instability in patients with peripheral repairs, with an incidence of 12.1%. Thirteen patients had recurrent DRUJ instability after capsular repair and eight patients had recurrent

DRUJ instability after transosseous suture repair. Twelve studies of foveal repairs reported recurrent DRUJ instability in 24 patients (10.3%)—21 cases with suture anchors and three cases with transosseous sutures.



**Table 5** Outcomes of foveal TFCC repairs

Author/Study	Pain score (VAS/NRS)		Grip strength (% of contralateral)		MMWS		PRWE		DASH		Complications		
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Reoperations	Neuropraxia	DRUJ instability
Abe et al 2018 (Open)	10	0	81.6	96.9		100% Excellent				7.8	0	0	0
Abe et al 2018 (Arthroscopic)	10	0.2	80.2	97.6		Excellent: 85.7% Good: 14.3%				5.7	0	0	3
Atzei et al 2015	3	1	92.7	103.6	48	87			42	15	0	5	4
Auzias et al 2020	7.4	1.3					83.7	9.3	52.1	21.7	0	6	4
Chou et al 2003			55	88	62	88					1	0	0
Dunn et al 2019		1.3				84.3				9.7	1		Excluded
Iwasaki et al 2011	7.2	1.0	92.7	106.3		92.5			59.5	7.7	0		0
Jegal et al 2016			71	89		Excellent: 36.8% Good: 52.6% Fair: 10.5%	53	19	44	11			0
Jung et al 2019	4.3	2.4	69.5	83.4	72	82.5	58.2	32.2	40.3	15.9	0	0	
Kim et al 2013			79.3	82.9	64	84			28.4	16.6	3	2	3
Luchetti et al 2014 (Open)	7	4			48	78	69	42	58	36	3	0	4
Luchetti et al 2014 (Arthroscopic)	7	3			47	81	54	23	39	18	1	0	1
Moritomo 2015		2	65	92	43	92						10	Mild: 4 Moderate: 1
Park et al 2018	3.7	0.8	57.3	79.6	61.8	83.4			35	9.9	0	0	0
Shinohara et al 2013			84	98	70	94					3	0	3

Abbreviation: DASH, Disabilities of the Arm, Shoulder and Hand; DRUJ, distal radioulnar joint; NRS, numerical rating scale; PRWE, patient-rated wrist evaluation; TFCC, triangular fibrocartilage complex; VAS, visual analogue scale.

In four papers, the DRUJ instability was noted to be mild in 14 of the 15 patients with this complication—being described as slightly looser than the contralateral side.<sup>40,42,49,51</sup> The remaining patient was reported to have moderate instability.<sup>49</sup>

Five studies listed DRUJ instability as an exclusion criterion.<sup>27,37–39,44</sup> In Badia and Khanchandani, DRUJ instability was an indication for a different approach of repair than the one studied.<sup>27</sup>

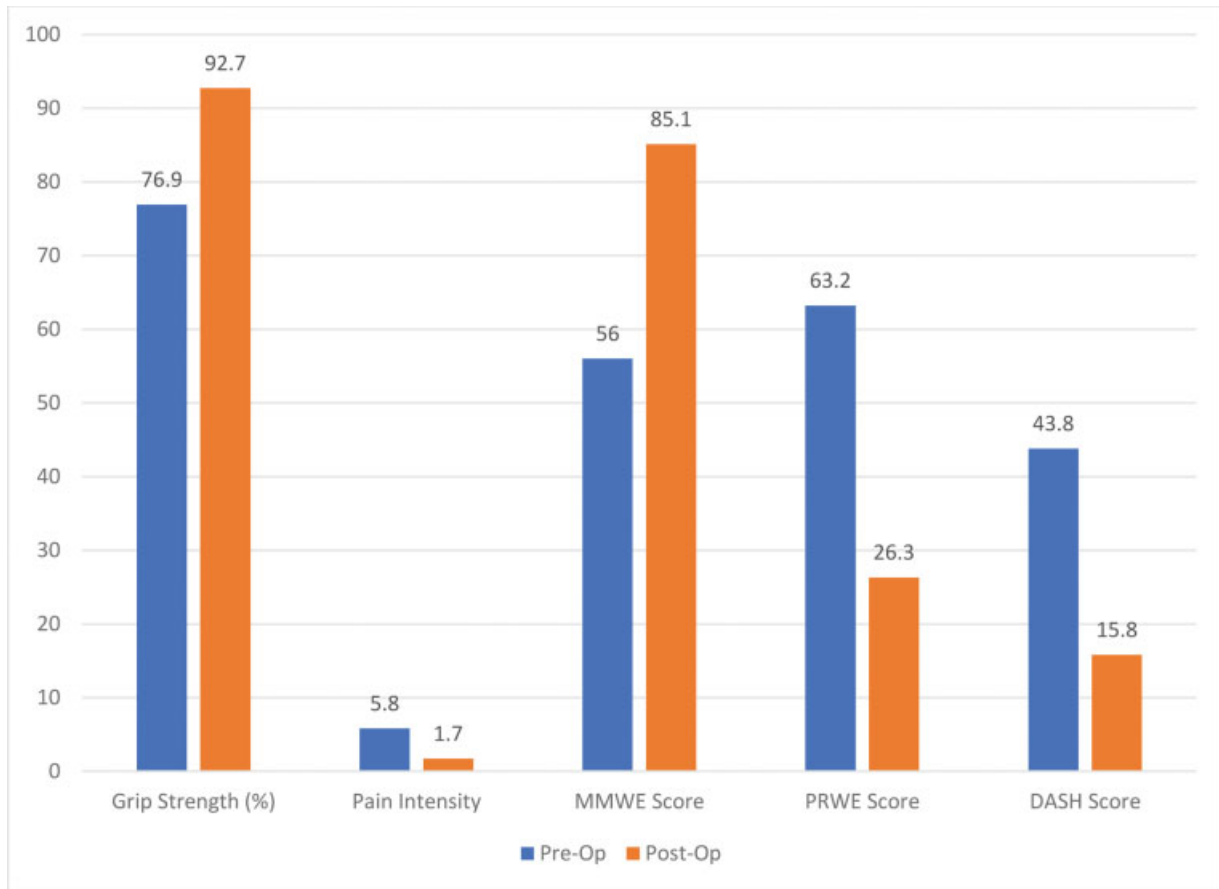
#### Soft Tissue Complications

Iwasaki et al and Kim et al reported postoperative ECU tendonitis in three patients of their cohorts (11.1%)—all resolved with conservative management or cortisone injection.<sup>45,47</sup> Extensor digiti minimi irritation (2.7%,  $n = 1$ )<sup>28</sup> and mild irritation surrounding suture knots (47.4%,  $n = 9$ )<sup>46</sup> were noted, and resolved without surgical intervention. Other complications included chronic regional pain syndrome (8.3%,  $n = 2$ )<sup>42</sup> and hypertrophic scarring (2.5%,  $n = 1$ ).<sup>38</sup>

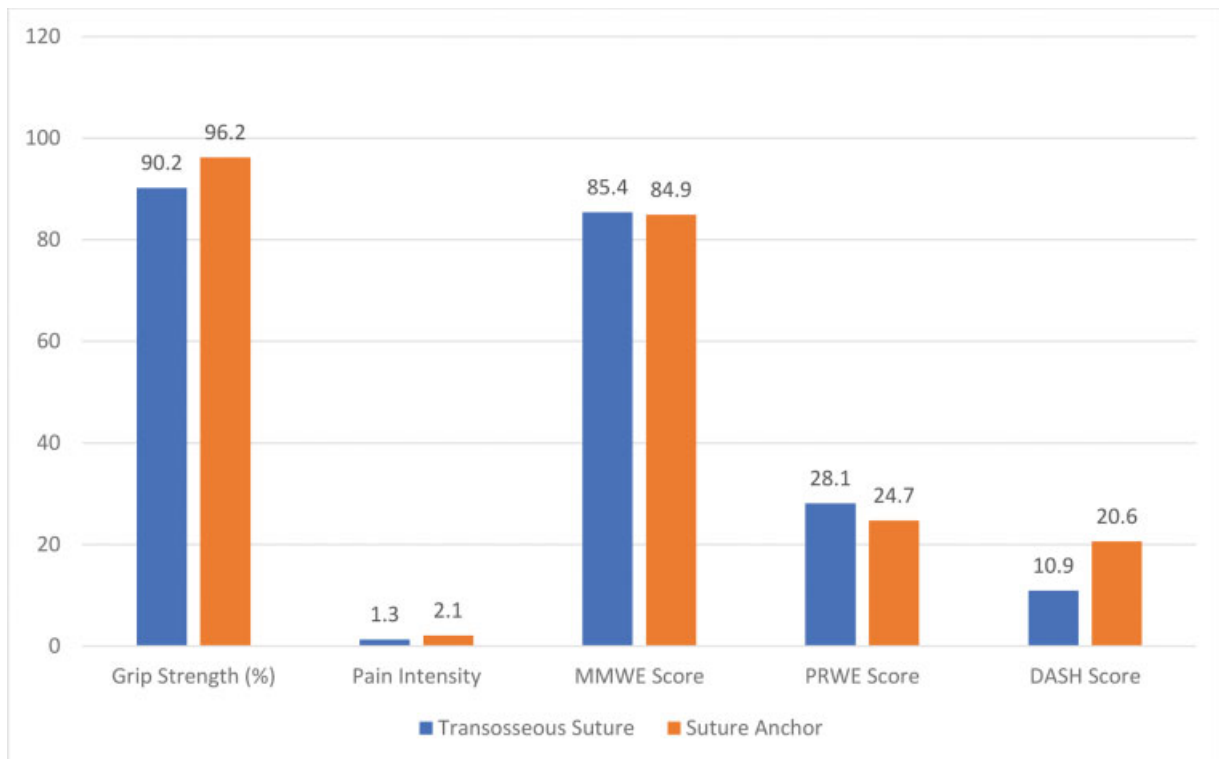
## Discussion

This systematic review of surgical repair of peripheral and foveal TFCC tears shows that surgery can achieve good functional outcomes and a low complication rate. In peripheral tears, transosseous suture repair achieved improved outcomes compared with capsular sutures in most functional outcomes. In foveal tears, transosseous sutures achieved improved outcomes compared with suture anchors in DASH and pain scores, while patients who underwent suture anchors had slightly higher grip strength and PRWE scores. Overall, arthroscopic techniques demonstrated overall better functional outcomes compared with open techniques.

The foveal component of the TFCC contributes to the stability of the DRUJ.<sup>3,8</sup> Hence, evidence of DRUJ laxity is often associated with avulsion or attenuation of the foveal attachment of the TFCC.<sup>54</sup> Accordingly, in 11 of the 13 studies of patients with foveal avulsions, all patients had evidence of DRUJ instability. One paper on arthroscopic repair of foveal injuries excluded

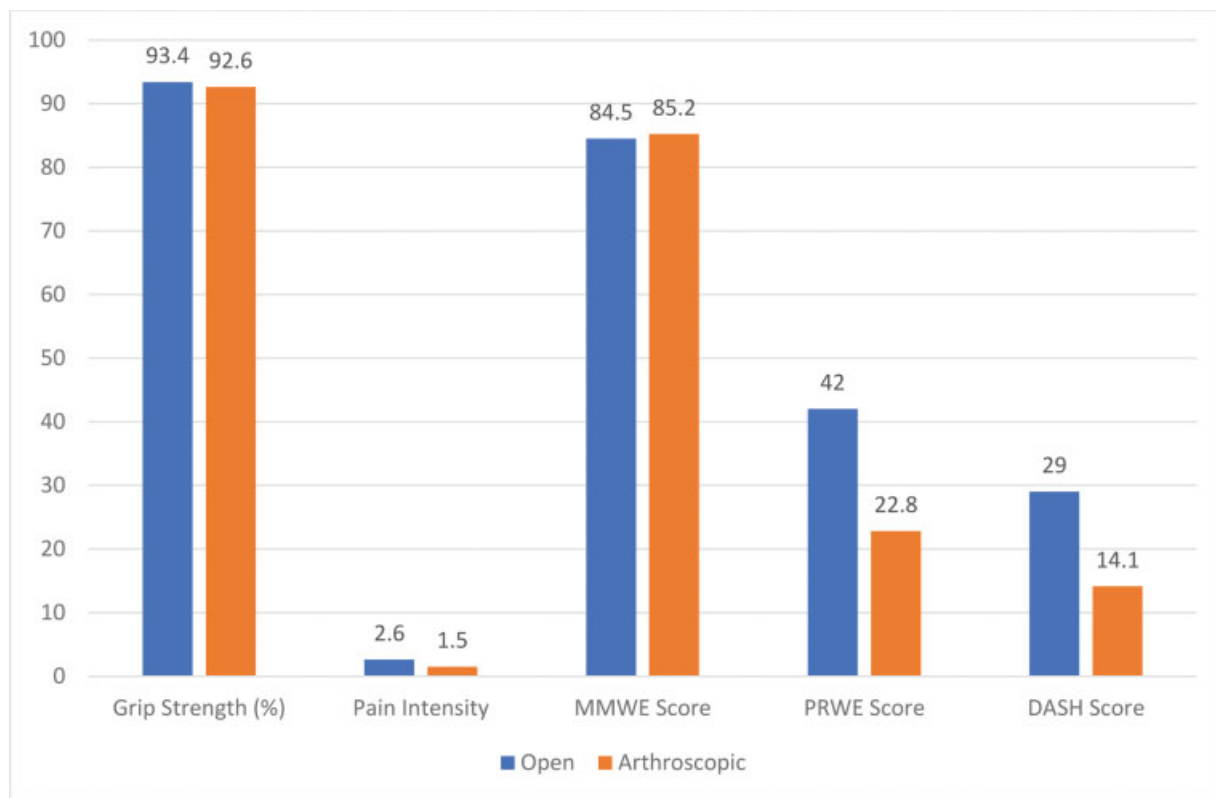


**Fig. 5** Foveal tear repair outcomes—preoperative and postoperative.



**Fig. 6** Foveal tear repair outcomes—suture anchor versus transosseous suture.

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**Fig. 7** Foveal tear repair outcomes—arthroscopic versus open.

**Table 6** Complications

Peripheral	Reoperations	Altered sensation	Recurrent DRUJ instability
Total cases in peripheral	28	34	21
No. of studies reported	11	11	5
No. of pts in studies reported	355	426	174
% Complication rate	7.9%	8.0%	12.1%
Total no. of patients	517		
Foveal	Reoperations	Altered sensation	Recurrent DRUJ instability
Total cases in foveal	12	23	24
No. of studies reported	12	14	12
No. of pts in studies reported	220	289	232
% Complication rate	5.5%	8.0%	10.3%
Total no. of patients	308		

Abbreviation: DRUJ, distal radioulnar joint.

patients with DRUJ instability, due to their preference for open techniques in foveal reattachment surgery.<sup>44</sup>

The distal or peripheral component contributes less to the stability of the DRUJ. In the Atzei classification, class 1 distal or peripheral tears should demonstrate no or slight DRUJ instability with the ballottement test.<sup>9</sup> In the studies describing peripheral tears, only six of 14 studies included patients with DRUJ instability.<sup>26,29–32,35</sup> In three studies, DRUJ instability was not examined or reported.<sup>33,34,36</sup> Recurrent instability after TFCC repair was reported in five

studies as a complication, and a higher recurrence rate was found in patients managed with capsular sutures compared with transosseous sutures ( $n = 13$  vs.  $n = 8$ ). This suggests that capsular sutures may be inadequate for management if a foveal tear was inadvertently missed.

This study is a current and comprehensive systematic review of the literature on functional and clinical outcomes of peripheral and foveal TFCC repairs. However, the current evidence is based on retrospective cohort studies and case series. Thus, our conclusions are limited by the overall low

levels of evidence from the included studies. Surgical techniques vary considerably between authors. Variations exist within repair types (e.g., knotless or knotted capsular sutures and knotless or knotted suture anchors). Some authors use all-arthroscopic or arthroscopic-assisted methods, and some utilize mini-open approaches. Outcome reporting between studies was heterogeneous as not all studies reported all the functional outcomes studied. The limitation of using the Palmer classification which does not include a separate class for foveal avulsions leads to a lack of standardization in the nomenclature surrounding peripheral tears. It should be noted that the included studies tried to control for confounding factors by excluding patients with concomitant injuries from the study population, and by using validated tools for measuring outcome. However, there remains a significant heterogeneity in demographics of the patients, inclusion criteria, duration of symptoms prior to surgery, and postoperative follow-up. This is a limitation that should be considered when interpreting the conclusions on outcomes and complication rates.

Recent reviews on surgical management of TFCC injuries observed that both open and arthroscopic repair techniques achieved improvement in patient-reported and functional outcomes, and there was no evidence of one technique being superior to another.<sup>3,16,17</sup> Nakamura et al also found that both open and arthroscopic transosseous repair techniques were reliable and successful in treating foveal detachments of the TFCC.<sup>15</sup> Although they reported better overall outcomes in the group that underwent arthroscopic repair compared with open repair, it should be noted that there was a significant discrepancy in their sample sizes—733 patients in arthroscopic repair group and 92 in the open repair group. As such, observations from a direct comparison between these two groups should be interpreted with caution. The relative scarcity of studies on open repair techniques and comparative studies between the two techniques is also noted in recent publications.<sup>3,11,17</sup>

DRUJ instability, both as a preoperative finding and postoperative outcome, was assessed with only clinical maneuvers such as the ballottement test.<sup>55</sup> Determination of the severity of DRUJ instability or subluxation continues to be difficult to standardize, due to the lack of an objective and validated measure. Axial MRI imaging was used as a tool to measure DRUJ subluxation by measuring the displacement of the ulnar head with respect to the radius.<sup>56</sup> Furthermore, a Push Pull gauge (NK-100, HANDPI, China) was a tool utilized by Lee et al to apply uniform stress in anteroposterior and posteroanterior directions to the ulnar head while taking lateral stress views in both injured and uninjured wrists. Therefore, the authors were confident that their measurement of ulnar translation was more reliable and objective.<sup>31</sup>

In summary, available evidence demonstrates that the various approaches to ulnar-sided TFCC repair achieve good functional and clinical outcomes, with low complication rates. However, prospective, comparative studies of high methodological quality are needed to allow for standardized

evaluations between different repair techniques for ulnar-sided TFCC tears.

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#### Conflict of Interest

None declared.

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