Title

Open versus arthroscopic repair of 1B ulnar-sided triangular fibrocartilage complex (TFCC) tears: a systematic review

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HAND

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Abstract:

Background
Peripheral 1B tears of the Triangular Fibrocartilage Complex (TFCC) can result in distal radio-ulnar joint (DRUJ) instability. Peripheral tears are amenable to both open and arthroscopic surgical repair. In the context of associated DRUJ instability; combined evidence supports successful outcomes for peripheral tear repair.
Methods
The aim of this systematic review (SR) was to compare the surgical treatment of 1B TFCC tears via arthroscopic versus open methods of repair. The primary outcome measure was restored DRUJ stability. The secondary outcome measures included patient-reported outcomes and clinical outcome measures. An electronic database search of Ovid Embase, PubMed and the Cochrane Central Register of Controlled Trials (CENTRAL) was performed to cover a 20 year period. Two authors independently screened records for eligibility and extracted data.
Results
Only three studies met the strict inclusion criteria highlighting the poor evidence base for TFCC IB repairs. A "secondary analysis" group was developed with modified inclusion criteria which included a further seven studies for analysis. Pooled data from the primary and secondary analysis groups demonstrated that post-operative DRUJ stability was achieved following open repair in approximately 84.4% (76/90) of cases and following arthroscopic repair in approximately 86% (129/150).
Conclusions
This SR demonstrates a current lack of the high quality evidence required to draw firm conclusions on the merits of arthroscopic versus open repair of IB TFCC tears. On the basis of the limited available comparative literature, there is no evidence to suggest superiority of one technique over the other.
(Level 3 evidence)

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Only three studies met the strict inclusion criteria highlighting the poor evidence base for TFCC IB repairs. Hence, a "secondary analysis" group was developed with modified inclusion criteria which included a further seven studies for analysis. Pooled data from the primary and secondary analysis groups demonstrated that post-operative DRUJ stability was achieved following open repair in 84% (76/90) of cases and in 86% (129/150) following arthroscopic repair.

Conclusions

This SR demonstrates a current lack of the high quality evidence required to draw firm conclusions on the merits of arthroscopic versus open repair of IB TFCC tears. There is no scientific evidence to suggest superiority of one technique over the other, albeit some surgeons and authors may express a strong personal view.

(Level 3 evidence)

INTRODUCTION

Triangular Fibro-Cartilage Complex (TFCC) tears are a common cause of ulnar-sided wrist pain [1, 32]. They were originally described by Palmer [30] and categorised into two main types. Type 1 lesions are acute traumatic tears; sub-divided from 1A to 1D and usually involve mechanisms of rotational stress with axial load-bearing from falling on an outstretched hand [34]. Traumatic Type 1 injuries occur more commonly at the periphery. Type 2 lesions are degenerative and central in location with increasing secondary changes [36].

Palmer 1A is a central perforation tear to the TFCC disc. 1B, 1C and 1D tears are classed as "peripheral" tears (Figure I). 1C tears lead to ulno-carpal instability, whereas 1B and 1D tears lead to instability of the Distal Radio-Ulnar Joint (DRUJ). Palmer 1B tears involve an avulsion of the ulnar foveal attachment of the TFCC, whereas Palmer 1D tears, which are rare [14], involve an avulsion of the radial attachment. In Palmer 1B tears, injury to the distal limb does not itself lead to DRUJ instability; however disruption to the proximal limb which inserts into the fovea will cause instability [3, 40].

[Insert here: **Figure I.**]

Peripheral tears are amenable to surgical repair [1, 28] because the peripheral TFCC [8] is vascular, as opposed to the central membranous portion [1].

In DRUJ instability, the evidence supports successful outcomes for peripheral repair/reattachment [3, 5, 13, 38]. However, the key question of whether arthroscopic techniques are superior to open repair remains unclear [2, 22]. A further controversy pertaining to the treatment of symptomatic peripheral 1B tears is whether surgical repair is necessary in the context of a stable DRUJ. Several studies support favourable outcomes in this setting [33, 42, 47, 48], supported by early papers suturing the detached surface to the peripheral capsule rather than to the fovea [17, 42]. However, arthroscopic debridement without repair had comparable results to repair in this context [11].

The main advantages of arthroscopic repair are superior visualisation of the TFCC and proposed improved wrist function by avoiding further injury to surrounding soft tissue structures [9]. In general, the arthroscopic techniques employed are either described as "inside-out" or "outside-in"

84 depending upon how the re-attachment is performed [12]. The perceived limitation of arthroscopic
85 repair of 1B tears is the inability to anatomically restore the foveal attachment [37, 42].

86 The aim of this systematic review (SR) is to compare the surgical treatment of 1B TFCC tears via
87 arthroscopic versus open methods of repair.

88

89 ## MATERIALS AND METHODS

90 ### Literature search

91 An electronic database search of Ovid Embase, PubMed and the Cochrane Central Register of
92 Controlled Trials (CENTRAL) was performed in April 2017. Studies published between the 1st
93 January 1997 and the 31st December 2016 were included, covering 20 years of research. The
94 search terms were developed with the help of an information analyst (D.G) to include the key
95 concepts of TFCC, DRUJ instability and ulnar avulsion (Supplementary material 1).

96 Additional articles were sourced by manually checking reference lists of articles identified via the
97 search. Studies other than in English or Spanish were excluded. The review protocol is registered
98 on the international prospective register of systematic reviews (PROSPERO). ID:
99 CRD42017033327 available via
100 http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42017033327. Preferred
101 Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed
102 [24]. The selection process is demonstrated in the study PRISMA flowchart (Figure II).

103

104 ### Inclusion and exclusion criteria

105 The inclusion and exclusion criteria used to assess the full-text articles for eligibility are
106 summarised below:

107 Inclusion criteria:

108 • Studies of patients suffering 1B TFCC tears treated via arthroscopic or open surgical repair
109 • Age 18 to 65 years
110 • Reporting the pre-operative and post-operative DRUJ stability status

- Reporting at least one patient-reported outcome measure or clinical outcome measure
- Minimum follow-up 12 months
- Randomised controlled trials, cohort studies, case-control studies, case series

Exclusion criteria:

- Central TFCC tears
- Peripheral tears other than type 1B
- Associated injuries
- Studies including surgical procedures in addition to repair of the TFCC
- Studies published prior to 01/01/1997 or after 31/12/2016
- Abstract only publications
- Case reports, editorials, letters, cadaveric studies and review articles
- Full text study reports other than in English or Spanish

Outcome measures

The primary outcome measure was restored stability of the DRUJ at a minimum post-operative follow-up period of 12 months. The secondary outcome measures included patient-reported outcomes and clinical outcome measures. The patient-reported outcomes were the Modified Mayo Wrist Score (MMWS), the Disabilities of the Arm, Shoulder, and Hand (DASH), the Patient Rated Wrist Evaluation (PRWE) score and the Visual Analogue Score (VAS). Clinical measures reviewed were grip strength, range of movement (ROM) and treatment complications.

Data management and quality assessment

Two authors (VR, AF) independently screened records for eligibility and extracted data. Quality assessment of studies was performed using the Joanna Briggs Institute critical appraisal tool checklist for case series studies [25] (supplementary tables II & III). Disagreements were reviewed by the senior authors (TL, AK).

RESULTS

The results of the search and selection process are presented in a PRISMA flowchart [24] (Fig. II).

[Insert here**: Figure II.**]

Three studies fully met all the strict pre-defined inclusion criteria for this review [7, 18, 20]. There were no comparative studies (RCTs, cohorts or case series). The three included studies were case series exclusively of arthroscopic results. These studies were entered into the "primary analysis group" (Table I).

[Insert here**: Table I**. Primary analysis group (demographic details, follow up and outcome measures)]

We further identified five studies [5, 19, 46, 47, 48], which would have met the inclusion criteria bar the strict age range applied and/or reporting of certain follow-up parameters. Most importantly, these five studies report the DRUJ stability status (primary outcome). We therefore also present a separate post-hoc "secondary analysis group" of studies fulfilling the modified inclusion criteria below:

Modified inclusion criteria:

- Studies with a mixed age population (age range <18 or >65), if the mean age of participants was within the 18 to 65 range.
- Studies where the minimum follow-up for some patients was less than 12 months, provided that the mean study follow-up was at least 12 months.

Two further studies were also entered into the "secondary analysis group" (Table II) [22, 29]. Nakamura et al, [29] did not report PROM or clinical measurement outcomes; however, it was included because it met the modified inclusion criteria and included both arthroscopic and open techniques. Luchetti et al, [22] was also included, despite having patients with an associated injury or additional interventional procedures, because it is the only published study where the design was such that a direct comparison of arthroscopic versus open 1B repairs was reported.

[Insert here: **Table II**. Secondary analysis group (demographic details, follow up and outcome measures]

A common reason for study exclusion in the primary analysis was that different TFCC tear sub-types were often grouped together in the analysis, [2, 10, 15, 31, 35, 38, 41]. Several studies were excluded due to ambiguity regarding which of their subjects had associated injuries or concurrent procedures [23, 26, 27, 39, 43, 44, 45]. However, for one study [29], we were able to contact the senior author to clarify their methodology and include the study in the "secondary analysis group" (Table II).

180

181 **Results in the primary analysis group**

182 These three studies only included arthroscopic repairs [7, 18, 20].

183 The 27 subjects included in Kim et al. [20] (n=15) and Iwasaki et al. [18] (n=12) had an
184 unstable DRUJ pre-operatively. In all 27 cases, DRUJ instability was restored at follow up
185 (Table I). In terms of secondary outcome measures, both studies showed an improvement
186 in DASH scores and grip strength post-operatively, however a statistically significant
187 difference for these outcomes was only reported in the smaller study (n=12; Iwasaki et al.
188 [18]). The latter also showed a statistically significant improvement post-operatively in VAS
189 scores, from 72.1 to 10 ($p<0.0001$). Kim et al. [20] demonstrated a significant
190 improvement in MAYO score from 64 to 84 ($p=0.007$), and overall, both studies reported an
191 "excellent" or "good" result in 24/27 cases and a "fair" or "poor" result in 3/27 cases for the
192 arthroscopic procedure (Table I).

193 The third study in the "primary analysis group" (Bayoumy et al. [7]; (n=37)) included
194 patients with ulnar-sided wrist pain, which worsened on grasping or ulnar deviation, but
195 without instability of the DRUJ pre-operatively. This suggests a distal 1B peripheral tear, not
196 a destabilising proximal 1B tear [3, 40]. Hence, the primary outcome measure of regained
197 stability could not be assessed, however the study showed statistically significant
198 improvements in the secondary outcome measurements; DASH, grip strength, VAS and
199 MAYO scores post-operatively (Table I).

200 **Results in the secondary analysis group**

201 Of the seven studies entered into the "secondary analysis group" (Table II), two studies
202 included non-randomised comparisons of arthroscopic and open treatment of 1B TFCC tears
203 (Nakamura et al. [29] (n=90) and Luchetti et al. [22] (n=49)). By combining data from
204 these studies, open repair techniques restored DRUJ stability in 76/90 patients (84%) and
205 arthroscopic repair in 41/49 cases (84%). The secondary outcome measures of interest were
206 reported only by Luchetti et al. [22] with statistically significant improvements in DASH
207 ($p<0.001$), VAS during activity ($p<0.001$) and PRWE ($p<0.001$).

The remaining five studies in the "secondary analysis group" (Table II) were case series of arthroscopic only repair of 1B tears [5, 19, 46, 47, 48]. Three studies included 74 patients who presented with DRUJ instability pre-operatively (Woo et al. [46] (12/12), Atzei et al. [5] (48/48) and Jegal et al. [19] (14/19). In total, when combined with arthroscopic repairs in the above cohorts (Nakamura et al. [29] and Luchetti et al. [22]), 102/123 (83%) regained DRUJ stability. In terms of secondary outcome measures, these authors reported an improvement (Table II). All patients presented by Wysocki et al. [47] (n=29) and Yao and Lee. [48] (n=12), had a stable DRUJ pre-operatively; which is similar to Bayoumi et al. [7] (n=37) in the "primary analysis group" suggesting a distal 1B tear. There was limited data available on secondary outcome scores for these studies.

Open versus arthroscopic treatment in relation to resolving DRUJ instability.

By pooling data from the primary and secondary analyses groups (Table III) the SR suggests that post-operative stability can be expected following open repair in 84% (76/90) of cases and following arthroscopic repair in 86% (129/150) of cases; i.e. comparable results.

[Insert here**: Table III.** Combined assessment of cases with DRUJ instability pre-operatively for both primary and secondary analysis groups, comparing open and arthroscopic treatment.]

Complications

Documented complication rates were low and all complications were reported to resolve. The two studies which assessed both arthroscopic and open techniques reported no complications at all [22, 29] (Table II).

DISCUSSION

The aim of this SR was to assess the merits of arthroscopic repair versus open repair for peripheral 1B tears in the context of DRUJ instability. This SR demonstrates that the current evidence for surgical management of peripheral 1B TFCC tears consists primarily of low level studies (retrospective case series). Our overall evidence-based conclusion is that both techniques give similar good outcomes.

The study's predefined inclusion and exclusion criteria reflect what we felt should be the ideal study population, aiming to eliminate confounding factors such as concomitant injuries and other surgical procedures. An age range between 18 to 65 years covers the working age population and excludes patients with skeletally immature wrists and older patients where the presence of osteoporosis and co-existing arthritic changes is more likely [6]. Also, a minimum follow up period of 12 months was deemed important to ensure outcomes for each subject were assessed at a reasonable time post-operatively allowing maximum recovery. Another important strength is that we only included studies that clearly defined whether the TFCC tear had caused instability to the DRUJ, It is essential to know the "stability status" of the DRUJ as instability entails a 1B peripheral tear to the proximal part of the TFCC making a reattachment to the fovea of the ulnar head necessary [4], as opposed to a stable joint where the distal part is torn and the need for repair remains questionable [11].

In accordance with these strict pre-defined inclusion criteria, only three case series of arthroscopic repair techniques were reported in our "primary analysis group" making any comparison redundant. As described in the methods, we further identified seven studies which marginally missed the inclusion criteria; our "secondary analysis group". Most importantly, these seven studies did report the DRUJ stability status (primary outcome). We felt that not considering these "suboptimal" studies altogether, despite their limitations, would consist of underreporting the existing literature.

The secondary analysis group allowed comparison of arthroscopic and open repair of Type 1B peripheral TFCC tears, showing no gross differences in outcomes and complications; the majority of cases regained post-operative stability, irrespective of technique. The complication risk may be weakly in favour of open procedures as they had no reported complications, as opposed to a number of minor transient complications after arthroscopic procedures (Tables I and II). Interestingly, arthroscopic repair of TFCC tears in patients with a stable DRUJ [7, 47, 48] resulted in statistically significant improvements in DASH and VAS scores suggesting that all Type 1B peripheral tears may merit a repair, at least regarding pain relief and overall function. However these results must be interpreted with great caution, due to the biases introduced by any non-randomised comparison (primarily selection bias) and the poor methodological quality of the studies.

The main limitation of this study was the lack of good quality comparative studies of open repair to arthroscopic procedures. Many TFCC lesions reported in the literature are associated with distal radius fractures. These fractures have an impact on wrist function per se, whether or not they require operative fixation [16]. We identified several weaknesses of the included studies, which limit the reliability of their results (Supplementary tables II & III): the methodology, in particular the inclusion criteria, was not always clear; the majority did not clarify whether consecutive inclusion of participants occurred, which may have led to selection biasFurthermore, a variety of differing techniques of assessing DRUJ stability were described across studies: each study implemented one or more clinical tests combined with, in some studies, an arthroscopic assessment of instability features. Although accepted as current practice, this lack of a clear and standardised assessment of stability status is a major limitation in pooling results. Furthermore, an array of different repair techniques was described by the authors under "umbrella terms" of open or arthroscopic repair.

CONCLUSION

This SR demonstrates current lack of the high quality evidence required to draw firm conclusions on the merits of arthroscopic versus open repair of IB TFCC tears with DRUJ instability preoperatively. This is due to the design and methodological flaws of existing studies, but also the fact that type IB tears are a difficult condition to research in isolation, as they often present with associated injuries that may require concurrent surgical procedures.

The available evidence suggests that both open and arthroscopic methods of repair adequately address DRUJ instability in the majority of cases (over 80%), with similar rates of persisting instability. Secondary outcome measures were also seen to improve for both techniques. In cases with no pre-operative DRUJ instability, where the need for repair is controversial [11], secondary outcome scores also improved post-operatively.

It is brutally obvious, based on this SR that we have to improve our evidence-based knowledge by setting up prospective, preferably randomised studies, where there is no bias from the researchers/surgeons in the study design. It is well known that keen "wrist arthroscopists" are mostly in favour of an arthroscopically assisted approach as opposed to "anatomists" who with excellent dissection will favour an open approach. There are obvious

advantages and disadvantages with both techniques, but it is reassuring that the current literature supports the surgeon to use any of the two options as outcome and complications will be very similar.

Conflict of Interest Statement: The authors confirm that they have no conflicts of interest to declare.

Statement of Human and Animal Rights: The above work is a systematic review of literature and we did not carry out experiments on human or animal subjects.

Statement of Informed Consent: We confirm there to be no identifying information about participants in the article.

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References

1. Ahn AK, Chang D. and Plate AM. Triangular fibrocartilage complex tears. Jt Dis. 2006;64(3): 114-119.

2. Anderson ML, Larson AN, Moran SL, Cooney WP, Amrami KK, Berger RA. Clinical comparison of arthroscopic versus open repair of triangular fibrocartilage complex tears. J Hand Surg [AM]. 2008;33 (5): 675-82.

3. Atzei A. New trends in arthroscopic management of type 1-B TFCC injuries with DRUJ instability. J Hand Surg [Eur]. 2009;34(5): 582-591.

4. Atzei A. and Luchetti R. Foveal TFCC tear classification and treatment. Hand Clin. 2011;27(3): 263-272.

5. Atzei A., Luchetti R. and Braidotti F. Arthroscopic foveal repair of the triangular fibrocartilage complex. J Wrist Surg. 2015;4(01): 22-30.

6. Banks LN and Lindau TR. Epidemiology of osteoarthritis of the hand and wrist. OA Musculoskeletal Medicine. 2013;1(3): 23.

7. Bayoumy M, Elkady HA, Said HG, El-Sayed A, Saleh WR. Short-term evaluation of arthroscopic outside-in repair of Type 1B TFCC tear with vertical mattress suture. Int J Multidiscip Res Dev. 2015;7: 679-683.

8. Bednar MS, Arnoczky SP and Weiland AJ. The microvasculature of the triangular fibrocartilage complex: its clinical significance. J Hand Surg [Am]. 1991;16(6): 1101-1105.

9. Bednar JM and Osterman AL. The role of arthroscopy in the treatment of traumatic triangular fibrocartilage injuries. Hand Clin. 1994;10: 605–14.

10. Buterbaugh GA, Brown TR, Horn PC. Ulnar-sided wrist pain in athletes. Clin Sports Med. 1998;17(3): 567-83

11. Cardenas-Montemayor E, Hartl JF, Wolf MB, Leclère FM, Dreyhaupt J, Hahn P and Unglaub F. Subjective and objective results of arthroscopic debridement of ulnar-sided TFCC (Palmer type 1B) lesions with stable distal radio-ulnar joint. Arch Orthop Trauma Surg. 2013;133(2): 287-293.

12. Cober SR and Trumble TE. Arthroscopic repair of triangular fibrocartilage injuries. Orthop Clin North Am. 2001;32: 279–294.

13. Corso SJ, Savoie FH, Geissler WB, Whipple TL, Jiminez W and Jenkins N. Arthroscopic repair of peripheral avulsions of the triangular fibrocartilage complex of the wrist: a multicenter study. Arthroscopy. 1997;13(1): 78-84.

14. Dalal S, and Murali SR. The distal radio-ulnar joint. Orthop Trauma. 2012;26 (1): 44-52.

15. Estrella EP, Hung LK, Ho PC, Tse WL. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007;23 (7): 729-37

16. Gliatis JD, Plessas SJ and Davis TRC. Outcome of distal radial fractures in young adults. J Hand Surg [Br]. 2000;25B: 6: 535-543.

17. Haugstvedt JR and Husby T. Results of repair of peripheral tears in the triangular fibrocartilage complex using an arthroscopic suture technique. Scand J Plast Reconstr Surg Hand Surg. 1999;33(4): 439-47.

18. Iwasaki N, Nishida K, Motomiya M, Funakoshi T, Minami A. Arthroscopic-assisted repair of avulsed triangular fibrocartilage complex to the fovea of the ulnar head: a 2- to 4-year follow-up study. Arthroscopy. 2011;10: 1371-8.

19. Jegal M, Heo K, Kim JP. Arthroscopic trans-osseous suture of peripheral triangular fibrocartilage complex tear. J Hand Surg Asian-Pac. 2016;21; 300-306

20. Kim B, Yoon HK, Nho Jh, Park KH, Park SY, Yoon JH, Song HS. Arthroscopically assisted reconstruction of triangular fibrocartilage complex foveal avulsion in the ulnar variance-positive patient. Arthroscopy. 2013;29: 1762-8

21. Lindau T. Arthroscopic Evaluation of Associated Soft Tissue Injuries in Distal Radius Fractures. Hand Clin. 2017;33(4): 651-658.

22. Luchetti R, Atzei A, Cozzolino R, Fairplay T and Badur N. Comparison between open and arthroscopic-assisted foveal triangular fibrocartilage complex repair for post-traumatic distal radio-ulnar joint instability. J Hand Surg [Eur]. 2014;39(8): 845-855.

23. McAdams TR, Swan J, Yao J. Arthroscopic treatment of triangular fibrocartilage wrist injuries in the athlete. Am J Sports Med. 2009;37 (2): 291-7

24. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009; 339:b2535

25. Moola S, Munn Z, Tufanaru C, et al. Chapter 7: Systematic reviews of etiology and risk. In: Aromataris E, Munn Z (Editors). Joanna Briggs Institute Reviewer's Manual.

The Joanna Briggs Institute. 2017. Available from https://reviewersmanual.joannabriggs.org

26. Moritomo H, Masatomi T, Murase T, Miyake J, Okada K, Yoshikawa H. Open repair of foveal avulsion of the triangular fibrocartilage complex and comparison by types of injury mechanism. J Hand Surg [Am]. 2010;35 (12): 1955-63

27. Moritomo H. Open repair of the triangular fibrocartilage complex from palmar aspect. J Wrist Surg. 2015;4(1): 2-8

28. Nagle DJ. Triangular fibrocartilage complex tears in the athlete. Clin Sports Med. 2001;20(1), 155-166.

29. Nakamura T, Sato K, Okazaki M, Toyama Y, Ikegami H. Repair of Foveal Detachment of the Triangular Fibrocartilage Complex: Open and Arthroscopic Transosseous Techniques. Hand Clin. 2011;27: 281-90.

30. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg [Am]. 1989;14A: 594–606.

31. Park MJ, Jagadish A, Yao J. The rate of triangular fibrocartilage injuries requiring surgical intervention. Orthopedics. 2010;3(11): 806

32. Read J. Ulnar-sided wrist pain is not the only cause of TFCC injury: a clinical perspective on other diagnoses in the sport setting. Br J Sports Med. 2013;47(17): 1061-1062.

33. Reiter A, Wolf MB, Schmid U, Frigge A, Dreyhaupt J, Hahn P and Unglaub F. Arthroscopic repair of Palmer 1B triangular fibrocartilage complex tears. Arthroscopy. 2008;24(11): 1244-1250.

34. Rettig AC. Athletic injuries of the wrist and hand part i: traumatic injuries of the wrist. Am J Sports Med. 2003; 31(6): 1038-1048.

35. Ruch DS and Papadonikolakis A. Arthroscopically assisted repair of peripheral triangular fibrocartilage complex tears; factors affecting outcome. Arthroscopy. 2005;21(9): 1126-30

36. Sachar K. Ulnar-sided wrist pain: evaluation and treatment of triangular fibrocartilage complex tears, ulnocarpal impaction syndrome, and lunotriquetral ligament tears. J Hand Surg [Am]. 2008;33(9): 1669-1679.

37. Sagerman SD and Short W. Arthroscopic repair of radial-sided triangular fibrocartilage complex tears. Arthroscopy. 1996;12: 339–342

38. Shih JT, Lee HM and Tan CM.. Early isolated triangular fibrocartilage complex tears: management by arthroscopic repair. J Trauma. 2002;53(5): 922-927.

39. Shinohara T, Tatebe M, Okui N, Yamamoto M, Kurimoto S, Hirata H. Arthroscopically assisted repair of triangular fibrocartilage complex foveal tears. J Hand Surg [Am]. 2013;38(2): 271-7

40. Skalski MR, White EA, Patel DB, Schein AJ, RiveraMelo H and Matcuk GR. The Traumatized TFCC: An Illustrated Review of the Anatomy and Injury Patterns of the Triangular Fibrocartilage Complex. Curr Probl Diagn Radiol. 2016;45(1): 39-50.

41. Tang CY, Fung B, Rebecca C, Lung CP. Another light in the dark: review of a new method for the arthroscopic repair of triangular fibrocartilage complex. J Hand Surg [Am]. 2012;37 (6): 1263-8

42. Trumble TE, Gilbert M and Vedder N. Arthroscopic repair of the triangular fibrocartilage complex. Arthroscopy. 1996;12(5): 588-597.

43. Trumble TE, Gilbert M, Vedder N. Isolated tears of the triangular fibrocartilage: management by early arthroscopic repair. J Hand Surg [Am]. 1997;22 (1): 57-65

44. Wolf MB, Kroeber MW, Reiter A, et al.. Ulnar shortening after TFCC suture repair of Palmar type 1B lesions. Arch Orthop Trauma Surg. 2010;130(3): 301-6

45. Wolf MB, Haas A, Dragu A, Leclere FM, Dreyhaupt J, Hahn P, Unglaub F. Arthroscopic repair of ulnar-sided triangular fibrocartilage complex (Palmar Type 1B) tears: a comparison between short-and midterm results. J Hand Surg [Am]. 2012;37 (11): 2325-30

46. Woo SJ, Jegal M, Park MJ. Arthroscopic-assisted repair of triangular fibrocartilage complex foveal avulsion in distal radioulnar joint injury. Indian J Orthop. 2016;50 (3): 263-268.

47. Wysocki RW, Richard MJ, Crowe MM, Leversedge FJ and Ruch DS. Arthroscopic treatment of peripheral triangular fibrocartilage complex tears with the deep fibers intact. J Hand Surg [Eur]. 2012;37(3): 509-516.

48. Yao J and Lee AT. All-arthroscopic repair of Palmer 1B triangular fibrocartilage complex tears using the FasT-Fix device. J Hand Surg [Am]. 2011;36(5): 836-842.

Figure I. Peripheral TFCC tear (reproduced with permission from Elsevier, from Lindau T. Arthroscopic Evaluation of Associated Soft Tissue Injuries in Distal Radius Fractures. Hand Clinics. 2017;33(4):651-658 [23]

Figure II. PRISMA flowchart

452

Title

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The aim of this systematic review (SR) was to compare the surgical treatment of 1B TFCC tears via arthroscopic versus open methods of repair. The primary outcome measure was restored DRUJ stability. The secondary outcome measures included patient-reported outcomes and clinical outcome measures. An electronic database search of Ovid Embase, PubMed and the Cochrane Central Register of Controlled Trials (CENTRAL) was performed to cover a 20 year period. Two authors independently screened records for eligibility and extracted data.

Results

Only three studies met the strict inclusion criteria highlighting the poor evidence base for TFCC IB repairs. Hence a ~~A~~ "secondary analysis" group was developed with modified inclusion criteria which included a further seven studies for analysis. Pooled data from the primary and secondary analysis groups demonstrated that post-operative DRUJ stability was achieved following open repair in ~~approximately~~ 84~~.4%~~ (76/90) of cases and in 86%(129/150) following arthroscopic repair ~~in approximately 86% (129/150).~~

Conclusions

This SR demonstrates a current lack of the high quality evidence required to draw firm conclusions on the merits of arthroscopic versus open repair of IB TFCC tears. ~~On the basis of the limited available comparative literature,~~ There is no evidence to suggest superiority of one technique over the other, albeit some surgeons and authors may express a strong personal view.

(Level 3 evidence)

INTRODUCTION

~~The Triangular Fibrocartilage Complex (TFCC) has an important role in load-bearing of the wrist, cushioning the ulnar carpal bones and facilitating rotation via the distal radio-ulnar joint (DRUJ) [1]. The main portion of the TFCC is the triangular fibrocartilage disc proper (TFC), commencing from the palmar and dorsal distal sigmoid notch to create a proximal and distal limb at insertion into the distal ulna [3]. The proximal limb inserts into the fovea and the distal limb inserts into the ulnar capsule with continuity into the distal styloid. These limbs are integrated parts of the dorsal and volar radioulnar ligaments (RULs). The TFC and RULs are the main components stabilising the DRUJ [43].~~

Triangular fibrocartilage complex (TFCC) tears are a common cause~~s~~ of ulnar-sided wrist pain [1, 3~~2~~5]. They were originally described by Palmer [3~~0~~3] and categorised into two main types ~~(Types 1 and 2).~~ Type 1 lesions are acute traumatic tears; sub-divided from 1A to 1D and usually involve mechanisms of rotational stress with axial load-bearing from falling on an outstretched hand [3~~4~~7]. Traumatic Type 1 injuries occur more commonly at the periphery. Type 2 lesions are degenerative and central in location with increasing secondary changes [3~~6~~9]. ~~Type 2 lesions, sub-classified from 2A to 2E, occur from various degrees of ulnocarpal abutment/impaction [16].~~

Palmer 1A is a central perforation tear to the TFCC disc. 1B, 1C and 1D tears are classed as "peripheral" tears (Figure I). 1C tears lead to ulno-carpal instability, whereas 1B and 1D tears lead to instability of the distal radioulnar joint (DRUJ). Palmer 1B tears involve an avulsion of the ulnar foveal attachment of the TFCC, whereas Palmer 1D tears, which are rare ~~less common~~ [14], involve an avulsion of the radial attachment. In Palmer 1B tears, injury to the distal limb does not itself lead to DRUJ instability; however disruption to the proximal limb which inserts into the fovea will cause instability [3, 4~~0~~3].

[Insert here: **Figure I.**]

Peripheral tears are amenable to surgical repair [1, 28~~3~~1] because the peripheral ~~10-40% of the~~ TFCC [8] is vascular, as opposed to the central membranous portion of the TFCC ~~which is avascular~~ [1].

In DRUJ instability, the evidence supports successful outcomes for peripheral repair/reattachment [3, 5, 13, 38~~41~~]. However, the key question of whether arthroscopic techniques are superior to open repair remains unclear [2, 2~~24~~]. A further controversy pertaining to the treatment of symptomatic peripheral 1B tears is whether surgical repair is necessary in the context of a stable DRUJ. Several studies support favourable outcomes in this setting [3~~36~~, 4~~25~~, 47~~50~~, 48~~51~~], supported by early papers suturing the detached surface to the peripheral capsule rather than to the fovea [1~~78~~, 4~~25~~]. However, arthroscopic debridement without repair had comparable results to repair in this context [11].

The main advantages of arthroscopic repair are superior visualisation of the TFCC and proposed improved wrist function by avoiding further injury to surrounding soft tissue structures [9]. In general, the arthroscopic techniques employed are either described as "inside-out" or "outside-in" depending upon how the re-attachment is performed [12]. The perceived limitation of arthroscopic repair of 1B tears is the inability to anatomically restore the foveal attachment [37~~40~~, 4~~25~~].

The aim of this systematic review (SR) is to compare the surgical treatment of 1B TFCC tears via arthroscopic versus open methods of repair.

MATERIALS AND METHODS

Literature search

An electronic database search of Ovid Embase, PubMed and the Cochrane Central Register of Controlled Trials (CENTRAL) was performed in April 2017. Studies published between the 1st January 1997 and the 31st December 2016 were included, covering 20 years of research. The search terms were developed with the help of an information analyst (D.G) to include the key concepts of TFCC, DRUJ instability and ulnar avulsion (Supplementary material 1).

Additional articles were sourced by manually checking reference lists of articles identified via the search. Studies other than in English or Spanish were excluded. The review protocol is registered on the international prospective register of systematic reviews (PROSPERO). ID: CRD42017033327 available via http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42017033327. Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed [2~~4~~6]. The selection process is demonstrated in the study PRISMA flowchart (Figure II).

Inclusion and exclusion criteria

The inclusion and exclusion criteria used to assess the full-text articles for eligibility are summarised below:

Inclusion criteria:

- Studies of patients suffering 1B TFCC tears treated via arthroscopic or open surgical repair
- Age 18 to 65 years
- Reporting the pre-operative and post-operative DRUJ stability status
- Reporting at least one patient-reported outcome measure or clinical outcome measure
- Minimum follow-up 12 months
- Randomised controlled trials, cohort studies, case-control studies, case series

Exclusion criteria:

- Central TFCC tears
- Peripheral tears other than type 1B
- Associated injuries
- Studies including surgical procedures in addition to repair of the TFCC
- Studies published prior to 01/01/1997 or after 31/12/2016
- Abstract only publications
- Case reports, editorials, letters, cadaveric studies and review articles
- Full text study reports other than in English or Spanish

Outcome measures

The primary outcome measure was restored stability of the DRUJ at a minimum post-operative follow-up period of 12 months. The secondary outcome measures included patient-reported

outcomes and clinical outcome measures. The patient-reported outcomes were the Modified Mayo Wrist Score (MMWS), the Disabilities of the Arm, Shoulder, and Hand (DASH), the Patient Rated Wrist Evaluation (PRWE) score and the Visual Analogue Score (VAS). Clinical measures reviewed were grip strength, range of movement (ROM) and treatment complications.

Data management and quality assessment

Two authors (VR, AF) independently screened records for eligibility and extracted data. Quality assessment of studies was performed using the Joanna Briggs Institute critical appraisal tool checklist for case series studies [257] (supplementary tables II & III). Disagreements were reviewed by the senior authors (TL, AK).

~~Quality assessment of studies was performed using the Joanna Briggs Institute critical appraisal tool checklist for case series studies [27]. This was conducted independently by two authors (VR, AF). In case of disagreement this was resolved by consensus and discussion with the senior author (TL).~~

RESULTS

The results of the search and selection process are presented in a PRISMA flowchart [(2426])) (Fig. II).

[Insert here**: Figure II.**]

Three studies fully met all the strict pre-defined inclusion criteria for this review [7, 189, 202]. There were no comparative studies (RCTs, cohorts or case series). The three included studies were case series exclusively of arthroscopic results ~~and therefore do not allow any comparisons~~. These studies were entered into the "primary analysis group" (Table I).

[Insert here**: Table I**. Primary analysis group (demographic details, follow up and outcome measures)]

We further identified five studies [5, 1920, 469, 4750, 4851] which would have met the inclusion criteria bar the strict age range applied and/or reporting of certain follow-up parameters. Most

importantly, these five studies ~~do~~ report the DRUJ stability status (primary outcome). We therefore also present a separate post-hoc "secondary analysis group" of studies fulfilling the modified inclusion criteria below:

Modified inclusion criteria:

- Studies with a mixed age population (age range <18 or >65), if the mean age of participants was within the 18 to 65 range.
- Studies where the minimum follow-up for some patients was less than 12 months, provided that the mean study follow-up was at least 12 months.

Two further studies were also entered into the "secondary analysis group" (Table II) [2~~4~~, ~~32~~]. Nakamura et al, [~~32~~] did not report PROM or clinical measurement outcomes; however, it was included because it met the modified inclusion criteria and included both arthroscopic and open techniques. Luchetti et al, [2~~4~~] was also included, despite having patients with an associated injury or additional interventional procedures, because it is the only published study where the design was such that a direct comparison of arthroscopic versus open 1B repairs was reported.

[Insert here: **Table II**. Secondary analysis group (demographic details, follow up and outcome measures]

A common reason for study exclusion in the primary analysis was that different TFCC tear sub-types were often grouped together in the analysis, ~~with no differentiation of outcome scores between tear types~~ [2, 10, 15, 3~~4~~, 3~~8~~, 3~~8~~~~1~~, 4~~4~~, 4~~4~~~~4~~]. Several studies were excluded due to ambiguity regarding which of their subjects had associated injuries or concurrent procedures [2~~5~~,

2~~6~~8, 2~~7~~9, 39~~4~~2, 4~~3~~6, 4~~4~~7, 4~~5~~8]. However, for one study [29~~3~~32], we were able to contact the senior author ~~to confirm that the subjects underwent no concurrent surgical procedures, and also that they were all skeletally mature, which also allowed this study to be included~~ to clarify their methodology and include the study ~~-~~in the "secondary analysis group" (Table II).

198

199 **Results in the p~~P~~rimary analysis group**

200 These three studies ~~entered into the primary analysis group~~ only included arthroscopic
201 repairs [7, 1~~8~~9, 2~~0~~2].

202 The 27 subjects included in Kim et al. [2~~2~~0] (n=15) and Iwasaki et al. [1~~8~~9] (n=12) had an
203 unstable DRUJ pre-operatively. In all 27 cases, DRUJ instability was restored at follow up
204 (Table I). In terms of secondary outcome measures, both studies showed an improvement
205 in DASH scores and grip strength post-operatively, however a statistically significant
206 difference for these outcomes was only reported in the smaller study (n=12; Iwasaki et al.
207 [1~~8~~9]). The latter also showed a statistically significant improvement post-operatively in VAS
208 scores, from 72.1 to 10 ($p<0.0001$). Kim et al. [2~~0~~2] demonstrated a significant
209 improvement in MAYO score from 64 to 84 ($p=0.007$), and ~~Iwasaki et al. [19] also returned~~
210 ~~a high MAYO score of 92.5 but had no pre-operative score for comparison, yet likely to be~~
211 ~~significant given the score of 92.5.~~ o~~O~~verall, both studies reported an "excellent" or "good"
212 result in 24/27 cases and a "fair" or "poor" result in 3/27 cases for the arthroscopic
213 procedure (Table I).

214 The third study in the "primary analysis group" (Bayoumy et al. [7]; (n=37)) included
215 patients with ulnar-sided wrist pain, which worsened on grasping or ulnar deviation, but
216 without instability of the DRUJ pre-operatively. This suggests a distal 1B peripheral tear, not
217 a destabilising proximal 1B tear [3, 4~~0~~3]. Hence, the primary outcome measure of regained
218 stability could not be assessed, however the study showed statistically significant
219 improvements in the secondary outcome measurements; DASH, grip strength, VAS and
220 MAYO scores post-operatively (Table I).

221 **Results in the s~~S~~econdary analysis group**

222 Of the seven studies entered into the "secondary analysis group" (Table II), two studies
223 included non-randomised comparisons of arthroscopic and open treatment of 1B TFCC tears
224 (Nakamura et al. [~~3~~29] (n=90) and Luchetti et al. [224] (n=49)). By combining data from
225 these studies, open repair techniques restored DRUJ stability in 76/90 patients (84~~.4~~%) and
226 arthroscopic repair in 41/49 cases (8~~43.7~~%). The secondary outcome measures of interest

were reported only by Luchetti et al. [224] with statistically significant improvements in DASH (p<0.001), VAS during activity (p<0.001) and PRWE (p<0.001).

The remaining five studies in the "secondary analysis group" (Table II) were case series of arthroscopic only repair of 1B tears [5, 1920, 469, 4750, 5481]. Three studies included 74 patients who presented with DRUJ instability pre-operatively (Woo et al. [469] (12/12), Atzei et al. [5] (48/48) and Jegal et al. [1920] (14/19). In total, when combined with arthroscopic repairs in the above cohorts (Nakamura et al. [2932] and Luchetti et al. [224]), 102/123 (832.9%) regained DRUJ stability. In terms of secondary outcome measures, these authors reported an improvement (Table II). All patients presented by Wysocki et al. [4750] (n=29) and Yao and Lee. [4851] (n=12), had a stable DRUJ pre-operatively; which is similar to Bayoumi et al. [7] (n=37) in the "primary analysis group" suggesting a distal 1B tear. There was limited data available on secondary outcome scores for these studies.

Open versus arthroscopic treatment in relation to resolving DRUJ instability.

~~This SR was unable to directly compare arthroscopic and open procedures within the "primary analysis group" with very strict inclusion criteria. However,~~ By pooling data from the primary and secondary analyses groups (Table III) the SR suggests that post-operative stability can be expected following open repair in ~~approximately~~ 84.4% (76/90) of cases and following arthroscopic repair in ~~approximately~~ 86% (129/150) of cases; i.e. comparable results.

[Insert here: **Table III.** Combined assessment of cases with DRUJ instability pre-operatively for both primary and secondary analysis groups, comparing open and arthroscopic treatment.]

Complications

Documented complication rates were low and all complications were reported to resolve. ~~These included extensor carpi ulnaris (ECU) tendonitis, extensor digiti minimi (EDM) extensor lag, neurapraxia of the dorsal sensory branch of the ulnar nerve, mild irritation at the repair site due to the suture knot and flexor carpi radialis (FCR) tendonitis.~~ The two studies which assessed both arthroscopic and open techniques reported no complications at all [224, 2932] (Table II).

~~**Quality assessment**~~

~~The term "quality" refers to the degree to which a study employs measures to minimize bias and error in its design, conduct and analysis [21]. We used the Joanna Briggs Institute critical appraisal tool checklist, which revealed several areas of poor methodology within our included papers (Supplementary tables II & III). As an example; Kim et al. [22] excluded patients with a previous history of surgery (including ulnar shortening osteotomy). In spite of this the authors included a secondary ulnar shortening osteotomy within their dataset [22].~~

~~There were no level I or II studies found by this SR, only one level III study [24] and the remaining studies were "level IV" evidence.~~

DISCUSSION

The aim of this SR was to assess the merits of arthroscopic repair versus open repair for peripheral 1B tears in the context of DRUJ instability. This SR demonstrates that the current evidence for surgical management of peripheral 1B TFCC tears consists primarily of low level studies (retrospective case series). Our overall evidence-based conclusion is that both techniques give similar good outcomes.

The study's predefined inclusion and exclusion criteria reflect what we felt should be the ideal study population, aiming to eliminate confounding factors such as concomitant injuries and other surgical procedures. An age range between 18 to 65 years covers the working age population and excludes patients with skeletally immature wrists and older patients where the presence of co-existing osteoporosis arthritic changes is more likely [6]. Also, a minimum follow up period of 12 months was deemed important to ensure outcomes for each subject were assessed at a reasonable time post-operatively allowing maximum recovery ~~from the procedure and not just based on data-driven opportunistic follow-up typical of many retrospective studies~~. Another important strength is that we only included studies that clearly defined whether the TFCC tear had caused instability to the DRUJ, ~~in order to reliably compare outcomes for open and arthroscopic interventions.~~ It is essential to know the "stability status" of the DRUJ as instability entails a 1B peripheral tear to the proximal part of the TFCC making a reattachment to the fovea of the ulnar head necessary [4], as opposed to a stable joint where the distal part is torn and the need for repair remains questionable [11].

~~This is paramount in assessing the patient and planning the non-surgical or surgical management.~~

In accordance with these strict pre-defined inclusion criteria, only three case series of arthroscopic repair techniques were reported in our "primary analysis group" making any comparison redundant. As described in the methods, we further identified seven studies which marginally missed the inclusion criteria; our "secondary analysis group". Most importantly, these seven studies did report the DRUJ stability status (primary outcome). We felt that not considering these "suboptimal" studies altogether, despite their limitations, would consist of underreporting ~~of~~ the existing literature.

~~We therefore presented an additional "secondary group" of included studies. This did allow~~ The secondary analysis group allowed a ~~a descriptive~~ comparison of arthroscopic and open repair of Type 1B peripheral TFCC tears, showing no gross differences in outcomes and complications; the majority of cases regained post-operative stability, irrespective of technique. The complication risk may be weakly in favour of open procedures as they had no reported complications, as opposed to a number of minor transient complications after arthroscopic procedures (Tables I and II). Interestingly, arthroscopic repair of TFCC tears in patients with a stable DRUJ [7, 47~~50~~, 48~~51~~] resulted in statistically significant improvements in DASH and VAS scores suggesting that all Type 1B peripheral tears may merit a repair at least regarding pain relief and overall function. However these results must be interpreted with great caution, due to the biases introduced by any non-randomised comparison (primarily selection bias) and the poor methodological quality of the studies.

~~The interpretation of any conclusions should also be made in the greater context of a comparison against non-surgical treatments, whether therapy, injections or no intervention at all. The pertinent question here is "what is the natural history of type IB tears?" and if, in the long term, patients with 1B TFCC tears (whether causing instability or not) improve regardless of intervention. Mrkonjic et al. [30] reported type 1B peripheral tears sustained in association with a distal radius fracture caused DRUJ instability, but most did not require repair.~~

The main limitation of this study was the lack of good quality comparative studies of open repair to arthroscopic procedures. ~~This reflects the limited quality of existing studies and~~

~~their heterogenicity~~. ~~In particular,~~ ~~m~~Many TFCC lesions reported in the literature are associated with distal radius fractures. These fractures have an impact on wrist function per se, whether or not they require operative fixation [16~~7~~]. We identified several weaknesses of the included studies, which limit the reliability of their results (Supplementary tables II & III): the methodology, in particular the inclusion criteria, was not always clear; the majority did not clarify whether consecutive inclusion of participants occurred, which may have led to selection bias~~. Kim et al. [22] excluded patients with a previous history of surgery (including ulnar shortening osteotomy). In spite of this the authors included a secondary ulnar shortening osteotomy in their dataset [22].~~ Furthermore, a variety of differing techniques of assessing DRUJ stability were described across studies: each study implemented one or more clinical tests combined with, in some studies, an arthroscopic assessment of instability features. Although accepted as current practice, ~~T~~this lack of a clear and standardised assessment of stability status is a major limitation in pooling results. Furthermore, an array of different repair techniques was described by the authors under "umbrella terms" of open or arthroscopic repair.

CONCLUSION

This SR demonstrates current lack of the high quality evidence required to draw firm conclusions on the merits of arthroscopic versus open repair of IB TFCC tears with DRUJ instability preoperatively. This is due to the design and methodological flaws of existing studies, but also the fact that type IB tears are a difficult condition to research in isolation, as they often present with associated injuries that may require concurrent surgical procedures. ~~Furthermore, as demonstrated in our SR, 1B TFCC lesions may be proximal causing instability or distal only causing pain.~~

The available evidence suggests that both open and arthroscopic methods of repair adequately address DRUJ instability in the majority of cases (over 80%), with similar rates of persisting instability. Secondary outcome measures were also seen to improve for both techniques. In cases with no pre-operative DRUJ instability, where the need for repair is controversial [11], secondary outcome scores also improved post-operatively. ~~Surgical complications were only observed in cases treated arthroscopically, though all complications resolved over time.~~

It is brutally obvious, based on this SR that we have to improve our evidence-based knowledge by setting up prospective, preferably randomised studies, where there is no bias from the researchers/surgeons in the study design. It is well known that keen "wrist arthroscopists" are mostly in favour of an arthroscopically assisted approach as opposed to "anatomists" who with excellent dissection will favour an open approach. There are obvious advantages and disadvantages with both techniques, but it is reassuring that the current literature supports the surgeon to use any of the two options as outcome and complications will be very similar.

~~A key remaining point of controversy is that the natural history of TFCC tears is still unclear, which poses the question of whether symptoms of pain and/or DRUJ instability would improve over time, without surgical intervention [30].~~

~~We would recommend further structured research in this area to allow stronger conclusions. To improve the quality of future research, an assessment of pre and post-surgical DRUJ stability should always be included in reports and a standardised agreed method of assessing and documenting DRUJ instability is required. Patient-reported outcome measures at set-time points (including baseline) should be reported. Prospectively recording procedures and standardised outcomes in a centralised database would facilitate this and inform future management of patients with these injuries.~~

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376 **References**

377 1. Ahn AK, Chang D. and Plate AM. Triangular fibrocartilage complex tears. Joint
378 Diseases. 2006;64(3): 114-119.

379 2. Anderson ML, Larson AN, Moran SL, Cooney WP, Amrami KK, Berger RA. Clinical
380 comparison of arthroscopic versus open repair of triangular fibrocartilage complex
381 tears. J Hand Surg [AM]. 2008;33 (5): 675-82.

382 3. Atzei A. New trends in arthroscopic management of type 1-B TFCC injuries with DRUJ
383 instability. Journal of Hand Surgery (European Volume). 2009;34(5): 582-591.

384 4. Atzei A. and Luchetti R. Foveal TFCC tear classification and treatment. Hand clinics.
385 2011;27(3): 263-272.

386 5. Atzei A., Luchetti R. and Braidotti F. Arthroscopic foveal repair of the triangular
387 fibrocartilage complex. Journal of wrist surgery. 2015;4(01): 22-30.

388 6. Banks LN and Lindau TR. Epidemiology of osteoarthritis of the hand and wrist. OA
389 Musculoskeletal Medicine. 2013;1(3): 23.

390 7. Bayoumy M, Elkady HA, Said HG, El-Sayed A, Saleh WR. Short-term evaluation of
391 arthroscopic outside-in repair of Type 1B TFCC tear with vertical mattress suture.
392 International journal of multidisciplinary research and development. 2015;7: 679-
393 683.

394 8. Bednar MS, Arnoczky SP and Weiland AJ. The microvasculature of the triangular
395 fibrocartilage complex: its clinical significance. The Journal of hand surgery.
396 1991;16(6): 1101-1105.

397 9. Bednar JM and Osterman AL. The role of arthroscopy in the treatment of traumatic
398 triangular fibrocartilage injuries. Hand Clin. 1994;10: 605–14.

10. Buterbaugh GA, Brown TR, Horn PC. Ulnar-sided wrist pain in athletes. Clin Sports Med. 1998;17(3): 567-83

11. Cardenas-Montemayor E, Hartl JF, Wolf MB, Leclère FM, Dreyhaupt J, Hahn P and Unglaub F. Subjective and objective results of arthroscopic debridement of ulnar-sided TFCC (Palmer type 1B) lesions with stable distal radio-ulnar joint. Archives of orthopaedic and trauma surgery. 2013;133(2): 287-293.

12. Cober SR and Trumble TE. Arthroscopic repair of triangular fibrocartilage injuries. Orthop Clin North Am. 2001;32: 279–294.

13. Corso SJ, Savoie FH, Geissler WB, Whipple TL, Jiminez W and Jenkins N. Arthroscopic repair of peripheral avulsions of the triangular fibrocartilage complex of the wrist: a multicenter study.Arthroscopy: The Journal of Arthroscopic & Related Surgery. 1997;13(1): 78-84.

14. Dalal S, and Murali SR. The distal radio-ulnar joint. Orthopaedics and Trauma. 2012;26 (1): 44-52.

15. Estrella EP, Hung LK, Ho PC, Tse WL. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007;23 (7): 729-37

~~16. Friedman SL and Palmer AK. The ulnar impaction syndrome. Hand clinics. 1991;7(2); 295-310.~~

~~17.~~16. Gliatis JD, Plessas SJ and Davis TRC. Outcome of distal radial fractures in young adults. Journal of Hand Surgery. 2000;25B: 6: 535-543.

~~18.~~17. Haugstvedt JR and Husby T. Results of repair of peripheral tears in the triangular fibrocartilage complex using an arthroscopic suture technique. Scand J Plast Reconstr Surg Hand Surg. 1999;33(4): 439-47.

~~19.~~18. Iwasaki N, Nishida K, Motomiya M, Funakoshi T, Minami A. Arthroscopic-assisted repair of avulsed triangular fibrocartilage complex to the fovea of the ulnar head: a 2- to 4-year follow-up study. Arthroscopy. 2011;10: 1371-8.

~~20.~~19. Jegal M, Heo K, Kim JP. Arthroscopic trans-osseous suture of peripheral triangular fibrocartilage complex tear. J Hand Surg Asian-Pac. 2016;21; 300-306

~~21. Khan, KS, Khan, KS (ed.), Kunz, R (ed.), Kleijnen, J (ed.) & Antes, G (ed.) Systematic Reviews to Support Evidence-based Medicine: how to review and apply findings of healthcare research. Royal Society of Medicine Press; London: 2003.~~

~~22.~~20. Kim B, Yoon HK, Nho Jh, Park KH, Park SY, Yoon JH, Song HS. Arthroscopically assisted reconstruction of triangular fibrocartilage complex foveal avulsion in the ulnar variance-positive patient. Arthroscopy. 2013;29: 1762-8

~~23.~~21. Lindau T. Arthroscopic Evaluation of Associated Soft Tissue Injuries in Distal Radius Fractures. Hand Clinics. 2017;33(4): 651-658.

~~24.~~22. Luchetti R, Atzei A, Cozzolino R, Fairplay T and Badur N. Comparison between open and arthroscopic-assisted foveal triangular fibrocartilage complex repair for post-traumatic distal radio-ulnar joint instability. Journal of Hand Surgery (European Volume), 2014;39(8): 845-855.

~~25.~~23. McAdams TR, Swan J, Yao J. Arthroscopic treatment of triangular fibrocartilage wrist injuries in the athlete. Am J Sports Med. 2009;37 (2): 291-7

~~26.~~24. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement BMJ. 2009; 339:b2535

~~27.~~25. Moola S, Munn Z, Tufanaru C, et al. Chapter 7: Systematic reviews of etiology and risk. In: Aromataris E, Munn Z (Editors). Joanna Briggs Institute Reviewer's Manual. The Joanna Briggs Institute. 2017. Available from https://reviewersmanual.joannabriggs.org

~~28.~~26. Moritomo H, Masatomi T, Murase T, Miyake J, Okada K, Yoshikawa H. Open repair of foveal avulsion of the triangular fibrocartilage complex and comparison by types of injury mechanism. J Hand Surg Am. 2010;35 (12): 1955-63

~~29.~~27. Moritomo H. Open repair of the triangular fibrocartilage complex from palmar aspect. J Wrist Surg. 2015;4(1): 2-8

~~30. Mrkonjic A, Geijer M, Lindau T and Tägil M. The natural course of traumatic triangular fibrocartilage complex tears in distal radial fractures: a 13–15 year follow-up of arthroscopically diagnosed but untreated injuries. The Journal of hand surgery, 2012;37(8): 1555-1560.~~

~~31.~~28. Nagle DJ. Triangular fibrocartilage complex tears in the athlete. Clinics in sports medicine, 2001;20(1), 155-166.

~~32.~~29. Nakamura T, Sato K, Okazaki M, Toyama Y, Ikegami H. Repair of Foveal Detachment of the Triangular Fibrocartilage Complex: Open and Arthroscopic Transosseous Techniques. Hand clinics. 2011;27: 281-90.

~~33.~~30. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg; 1989;14A: 594–606.

~~34.~~31. Park MJ, Jagadish A, Yao J. The rate of triangular fibrocartilage injuries requiring surgical intervention. Orthopedics. 2010;3(11): 806

~~35.~~32. Read J. Ulnar-sided wrist pain is not the only cause of TFCC injury: a clinical perspective on other diagnoses in the sport setting. British journal of sports medicine. 2013;47(17): 1061-1062.

~~36.~~33. Reiter A, Wolf MB, Schmid U, Frigge A, Dreyhaupt J, Hahn P and Unglaub F. Arthroscopic repair of Palmer 1B triangular fibrocartilage complex tears. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2008;24(11): 1244-1250.

~~37.~~34. Rettig AC. Athletic injuries of the wrist and hand part i: traumatic injuries of the wrist. The American journal of sports medicine, 2003; 31(6): 1038-1048.

~~38.~~35. Ruch DS and Papadonikolakis A. Arthroscopically assisted repair of peripheral triangular fibrocartilage complex tears; factors affecting outcome. Arthroscopy. 2005;21(9): 1126-30

~~39.~~36. Sachar K. Ulnar-sided wrist pain: evaluation and treatment of triangular fibrocartilage complex tears, ulnocarpal impaction syndrome, and lunotriquetral ligament tears. The Journal of hand surgery. 2008;33(9): 1669-1679.

~~40.~~37. Sagerman SD and Short W. Arthroscopic repair of radial-sided triangular fibrocartilage complex tears. Arthroscopy. 1996;12: 339–342

~~41.~~38. Shih JT, Lee HM and Tan CM.. Early isolated triangular fibrocartilage complex tears: management by arthroscopic repair. Journal of Trauma and Acute Care Surgery. 2002;53(5): 922-927.

~~42.~~39. Shinohara T, Tatebe M, Okui N, Yamamoto M, Kurimoto S, Hirata H. Arthroscopically assisted repair of triangular fibrocartilage complex foveal tears. J Hand Surg Am. 2013;38(2): 271-7

~~43.~~40. Skalski MR, White EA, Patel DB, Schein AJ, RiveraMelo H and Matcuk GR. The Traumatized TFCC: An Illustrated Review of the Anatomy and Injury Patterns of the Triangular Fibrocartilage Complex. Current problems in diagnostic radiology. 2016;45(1): 39-50.

~~44.~~41. Tang CY, Fung B, Rebecca C, Lung CP. Another light in the dark: review of a new method for the arthroscopic repair of triangular fibrocartilage complex. J Hand Surg Am. 2012;37 (6): 1263-8

~~45.~~42. Trumble TE, Gilbert M and Vedder N. Arthroscopic repair of the triangular fibrocartilage complex. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 1996;12(5): 588-597.

~~46.~~43. Trumble TE, Gilbert M, Vedder N. Isolated tears of the triangular fibrocartilage: management by early arthroscopic repair. J Hand Surg Am. 1997;22 (1): 57-65

~~47.~~44. Wolf MB, Kroeber MW, Reiter A, et al.. Ulnar shortening after TFCC suture repair of Palmar type 1B lesions. Arch Orthop Trauma Surg. 2010;130(3): 301-6

48.45. Wolf MB, Haas A, Dragu A, Leclere FM, Dreyhaupt J, Hahn P, Unglaub F. Arthroscopic repair of ulnar-sided triangular fibrocartilage complex (Palmar Type 1B) tears: a comparison between short-and midterm results. J Hand Surg Am. 2012;37 (11): 2325-30

49.46. Woo SJ, Jegal M, Park MJ. Arthroscopic-assisted repair of triangular fibrocartilage complex foveal avulsion in distal radioulnar joint injury. Indian J Orthop. 2016;50 (3): 263-268.

50.47. Wysocki RW, Richard MJ, Crowe MM, Leversedge FJ and Ruch DS. Arthroscopic treatment of peripheral triangular fibrocartilage complex tears with the deep fibers intact. The Journal of hand surgery. 2012;37(3): 509-516.

51.48. Yao J and Lee AT. All-arthroscopic repair of Palmer 1B triangular fibrocartilage complex tears using the FasT-Fix device. The Journal of hand surgery. 2011;36(5): 836-842.

Figure I. Peripheral TFCC tear (reproduced with permission from Elsevier, from Lindau T. Arthroscopic Evaluation of Associated Soft Tissue Injuries in Distal Radius Fractures. Hand Clinics. 2017;33(4):651-658 [23]

Figure II. PRISMA flowchart

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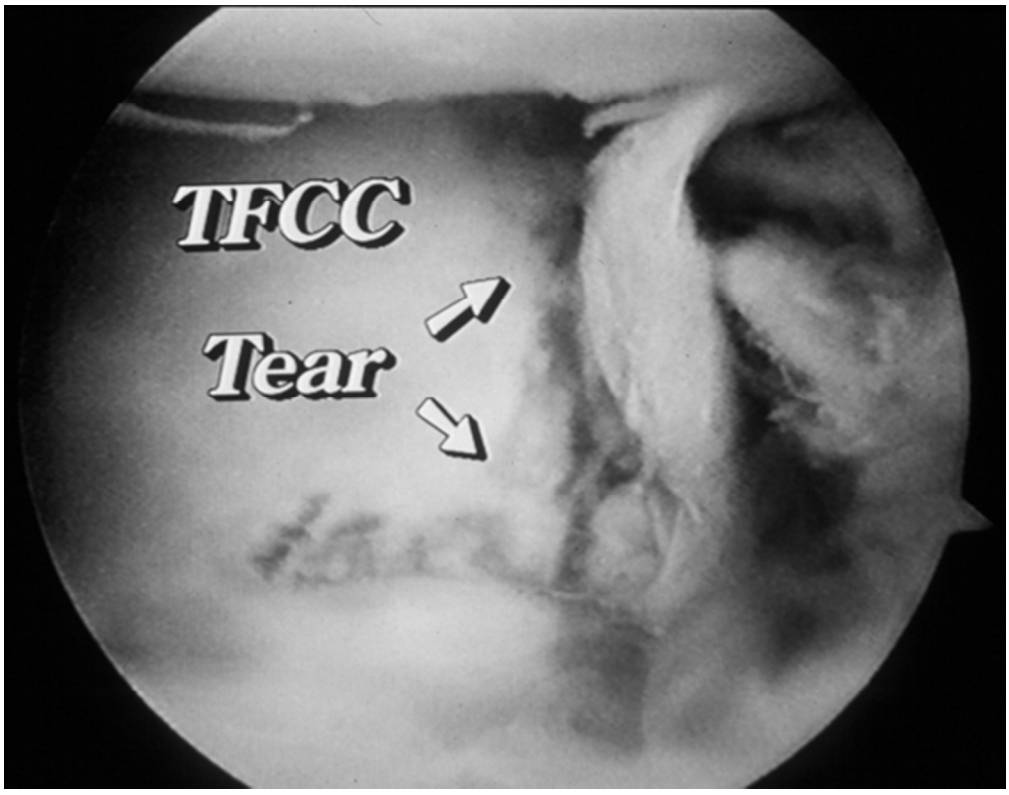
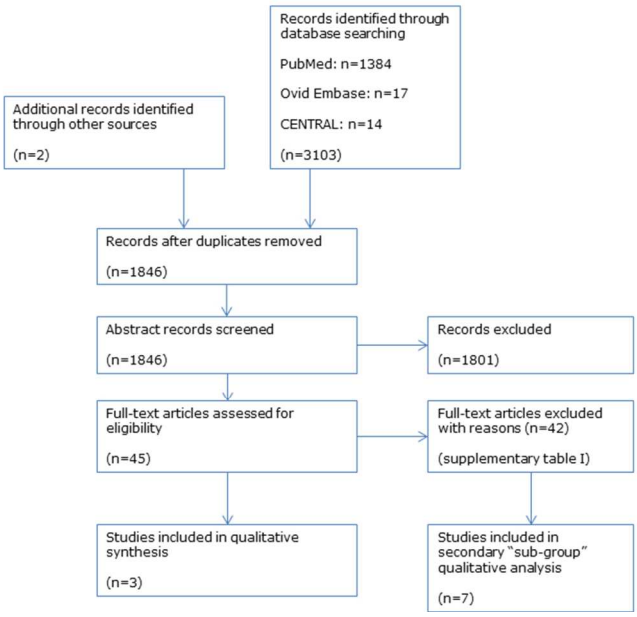


Peripheral TFCC tear (reproduced with permission from Elsevier, from Lindau T. Arthroscopic Evaluation of Associated Soft Tissue Injuries in Distal Radius Fractures. Hand Clinics. 2017;33(4):651-658 [23]

23x18mm (600 x 600 DPI)



PRISMA flowchart

254x190mm (96 x 96 DPI)

Table I. Primary analysis group (demographic details, follow up and outcome measures)

Primary analysis group – Demographic details, follow up and outcome measures				
	Open	**Arthroscopic**		
	N/A	**Kim et al, 2013 [22] (n=15)**	**Iwasaki et al, 2011 [19] (n=12)**	***Bayoumy et al, 2015* [7] *(n=37)***
Mean age (range)		30.5 (19-54)	31 (20-50)	*23.3 (18-34)*
Mean follow up (months)		29	30	*24*
Unstable Pre-op (%)		100% (15/15)	100% (12/12)	*0% (0/37)*
Unstable Post-op (%)		0% (0/15)	0% (0/12)	*N/A*
% remaining unstable		0%	0%	*N/A*
DASH: Pre-op		28.4	59.5	*29.9*
DASH: Post-op		16.6 (p=0.06)	7.7 (p<0.0001)	*10.2 (p<0.05)*
VAS: Pre-op		-	72.1	*7.6*
VAS: Post-op		-	10 (p<0.0001)	*2.9 (p<0.05)*
MAYO: Pre-op		64	Unknown	*62.1*
MAYO: Post-op		84 (p=0.007)	92.5	*91.2 (p<0.05)*
MAYO post-op results:				
-Excellent & Good		n=12	n=12	-
-Fair & Poor		n=3	n=0	-
Grip strength (% of contralateral)				
-Pre-op		79.3%	92.7%	*82.5%*
-Post-op		82.9% (p=0.086)	106.3% (p=0.003)	*89%*
Complications				
-ECU tendonitis		n=1	n=2	-
-DSBUN neurapraxia		-	-	*n=1*
-EDM extensor lag		-	-	*n=1*

*1B tears with a stable DRUJ

DSBUN= Dorsal sensory branch ulna nerve

Table II. Secondary analysis group (demographic details, follow up and outcome measures)

Secondary analysis group – Demographic details, follow up and outcome measures									
	Open		**Arthroscopic**						
	Nakamura et al 2011 [32] (n=66)	**Luchetti et al 2014 [24] (n=24)**	**Nakamura et al 2011 [32] (n=24)**	**Luchetti et al 2014 [24] (n=25)**	**Woo et al 2016 [49] (n=12)**	**Jegal et al 2016 [20] (n=19)**	**Atzei et al 2015 [5] (n=48)**	***Wysocki et al* [50] *2012 (n=29) 4 Lost to F/U***	***Yao & Lee 2011* [51] *(n=12)***
Mean follow up (months)	36	31	42	31	19	31	33	*31*	*17.5*
Minimum follow up	24	6	12	6	14	18	6	*16*	*11*
Mean age (range)	31 (16-68)**	32 (13-49)	27 (16-53)**	33 (13-69)	24.7 (17-34)	37 (16-60)	34 (17-54)	*30 (13-61)*	*42 (19-69)*
Additional injury/surgery	0	9 DR# 5 wafers	0	16 DR#	0	0	0	*0*	*0*
Unstable Pre-op (%)	100% (66/66)	100% (24/24)	100% (24/24)	100% (25/25)	100% (12/12)	74% (14/19)	100% (48/48)	*0% (0/29)*	*0% (0/12)*
Unstable Post-op (%)	15% (10/66)	17% (4/24)	29% (7/24)	4% (1/25)	58% (7/12)	11% (2/19)	8% (4/48)	*0% (0/25)*	*0% (0/12)*
% remaining unstable	15% (10/66)	17% (4/24)	29% (7/24)	4% (1/25)	58% (7/12)	14% (2/14)	8% (4/48)	*0% (0/25)*	*0% (0/12)*
DASH: Pre-op	-	58	-	39	48.4	44	42	*38*	-
DASH: Post-op	-	36 (p<0.001)	-	18	24.6 (p=0.005)	11	15	*9 (p=0.003)*	*11 (Quick D)*
VAS (Rest): Pre-op	-	2	-	2	5.3 ***	-	3	*5.4 ****	-
VAS (Rest): Post-op	-	1 (NS)	-	1 (NS)	1.7 (p=0.003)	-	1	*0.9 (p<0.001)*	-
VAS (Active): Pre-op	-	7	-	7	-	-	8	-	-
VAS (Active): Post-op	-	4 (p<0.001)	-	3 (p<0.001)	-	-	3	-	-

MAYO: Pre-op	-	-	-	-	-	-	48	-	-
MAYO: Post-op	-	-	-	-	-	-	87	-	-
-Excellent & Good	-	-	-	-	-	n=17	n=40	-	-
-Fair & Poor	-	-	-	-	-	n=2	n=6	-	-
Grip strength (% of contralateral/Kg)									
-Pre-op	-	20 Kg	-	22Kg	54.9%	71%	92.7%	-	-
-Post-op	-	22 Kg (NS)	-	24Kg (NS)	72.8%	89%	103.6% (p<0.05)	*35Kg*	*64%*
PRWE: Pre-op	-	69	-	54	58.7	53	-	-	-
PRWE: Post-op	-	42 (p<0.001)	-	23 (p<0.001)	30.2 (p=0.007)	19	-	-	*19*
Complications									
-DSBUN neurapraxia	-	-	-	-	-	-	n=5	*n=2*	-
-Suture knot irritation	-	-	-	-	-	n=9	-	-	-
-ECU tendonitis	-	-	-	-	-	-	-	*n=1*	-
-FCR tendonitis	-	-	-	-	-	-	-	*n=1*	-

NS = not significant

DR# = distal radius fracture

DUSBN= Dorsal sensory branch ulna nerve

*1B tears with a stable DRUJ

** Cases aged <18y were skeletally mature (confirmed with author)

*** Unclear whether VAS score was done at rest or active – therefore assumed to be at rest.

Table III. Combined assessment of cases with DRUJ instability pre-operatively for both primary and secondary analysis groups, comparing open and arthroscopic treatment.

Pre-op (all Unstable)	**Post-op STABLE**	**Post-op UNSTABLE**
Open (n=90)	76 (84.4%)	14 (15.6%)
Arthroscopic (n=150)	129 (86%)	21 (14%)

Supplementary material 1. Database Search strategies

PubMed (search date 24/04/2017):

"triangular fibrocartilage"[MeSH Terms] OR "triangular fibrocartilage" OR "triangular cartilage" OR "triangular fibrocartilaginous" OR TFCC OR (("distal radioulnar joint" OR "distal radioulnar joints" OR DRUJ) AND (instability OR unstable)) OR "ulnar avulsion" OR "ulnar avulsions"

Ovid Embase (search date 25/04/2017):

1 triangular fibrocartilage/

2 "triangular fibrocartilage".mp.

3 "triangular cartilage".mp.

4 "triangular fibrocartilaginous".mp.

5 TFCC.mp.

6 (radioulnar joint/ or "distal radioulnar joint".mp. or "distal radioulnar joints".mp. or DRUJ.mp.) and (instability or stability or unstable or stable).mp.

7 "ulnar avulsion".mp.

8 "ulnar avulsions".mp.

9 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8

Cochrane Central Register of Controlled Trials (CENTRAL) (search date 25/04/2017):

[mh "triangular fibrocartilage"] OR "triangular fibrocartilage" OR "triangular cartilage" OR "triangular fibrocartilaginous" OR TFCC OR (("distal radioulnar joint" OR "distal radioulnar joints" OR DRUJ) AND (instability OR stability OR unstable OR stable)) OR "ulnar avulsion" OR "ulnar avulsions"

Supplementary table I. References for full text articles excluded, with key reasons for exclusion.

Full text article excluded	**Key reason for exclusion**
Abe et al, [1]	No DRUJ stability status documented
Anderson et al, [2]	No differentiation between peripheral types
Andersson et al, [3]	Associated injuries
Atzei et al, [4]	No DRUJ stability status documented post-op
Atzei, [5]	Overlap with 2008 paper and included reconstruction with PL
Badia and Khanchandani, [6]	No DRUJ stability status documented
Baehser-Griffith et al, [7]	No DRUJ stability status documented
Buterbaugh et al, [8]	No DRUJ stability status documented No differentiation between peripheral tear type Associated injuries
Chou and Lee, [9]	Only four isolated 1B tears included - sample size considered to be too small for inclusion by senior author (TL)
Chou et al, [10]	Associated injuries and procedures
Corso et al, [11]	Associated injuries
Dailey and Palmer, [12]	No primary data available
Degreef et al, [13]	No Pre-op DRUJ stability documented Previous treatments unknown Age range: 16-56 Follow up: 7-36m
De Smet et al, [14]	No DRUJ stability status documented
Estrella et al, [15]	No differentiation between tear types
Hess et al, [16]	Reconstruction with tendon graft
Kovachevich and Elhassan, [17]	No primary data available
Luchetti et al, [18]	Associated injuries
McAdams et al, [19]	Associated ECU tendinosis in 1 DRUJ instability in 4 - unclear which patients they were

Millants et al, [20]	No DRUJ stability status documented
Miwa et al, [21]	Pre-op DRUJ status unclear Age range 14-55
Moritomo et al, [22]	4 subjects had simultaneous USO
Moritomo, [23]	3 subjects had LT 11 subjects had simultaneous USO
Nakamura et al, [24]	Limited patient information (Age, outcome scores, mean follow up)
Nakamura et al, [25]	Ambiguity regarding whether positive UV had corrective osteotomy first
Papapetropoulos et al, [26]	No DRUJ stability status documented
Park et al, [27]	No differentiation of outcomes for tear types. No post op DRUJ stability status (stable pre-op)
Reiter et al, [28]	Mean follow up of 11 months
Ruch & Papadonikolakis, [29]	No DRUJ stability status Associated injuries No differentiation between tear types
Shih et al, [30]	No differentiation between tear types.
Shinohara et al, [31]	Unclear which patient had distal radius fracture
Soreide et al, [32]	No DRUJ stability status documented
Tang et al, [33]	Mean follow up 8.2 months
Tang et al, [34]	Mean follow up 8 months. No differentiation between tear types
Trumble et al, [35]	Four patients were included with distal radius fractures
Wolf et al, [36]	5 subjects had USO post TFCC repair
Wolf et al, [37]	5 subjects had USO before mid-term results (overlap with Wolf et al, 2010)
Woo et al, [38]	Age range 17-34
Yao, [39]	No DRUJ stability status documented
Yao and Lee, [40]	No DRUJ stability status documented

1. Abe Y, Moriya A, Tominaga Y, Yoshida K. Dorsal Tear of Triangular Fibrocartilage Complex: Clinical Features and Treatment. J Wrist Surg. 2016;5(1): 42-6

2. Anderson ML, Larson AN, Moran SL, Cooney WP, Amrami KK, Berger RA. Clinical comparison of arthroscopic versus open repair of triangular fibrocartilage complex tears. J Hand Surg [AM]. 2008;33 (5): 675-82.

3. Andersson JK, Axelsson P, Stromberg J, Karlsson J, Friden J. Patients with triangular fibrocartilage complex injuries and distal radioulnar joint instability have reduced rotational torque in the forearm. J Hand Surg Eur Vol. 2016;41(7): 732-8

4. Atzei A, Rizzo A, Luchetti R, Fairplay T. Arthroscopic foveal repair of triangular fibrocartilage complex peripheral lesion with distal radioulnar joint instability. Tech Hand Up Extrem Surg. 2008;12(4): 226-35

5. Atzei A. New trends in arthroscopic management of type 1-B TFCC injuries with DRUJ instability. Journal of Hand Surgery (European Volume). 2009;34(5): 582-591.

6. Badia A and Khanchandani P. Suture welding for arthroscopic repair of peripheral triangular fibrocartilage complex tears. Tech Hand up Extrem Surg. 2007;11(1): 45-50

7. Baehser-Griffith P, Bednar JM, Osterman AL, Culp R. Arthroscopic repairs of triangular fibrocartilage complex tears. AORN J. 1997;66(1): 101-2

8. Buterbaugh GA, Brown TR, Horn PC. Ulnar-sided wrist pain in athletes. Clin Sports Med. 1998;17(3): 567-83

9. Chou CH and Lee TS. Peripheral tears of triangular fibrocartilage complex: results of primary repair. Int Orthop. 2001;25(6): 392-5.

10. Chou KH, Sarris IK, Sotereanos DG. Suture anchor repair of ulnar-sided triangular fibrocartilage complex tears. J Hand Surg Br. 2003;28(6): 546-50

11. Corso SJ, Savoie FH, Geissler WB, Whipple TL, Jiminez W and Jenkins N. Arthroscopic repair of peripheral avulsions of the triangular fibrocartilage complex of the wrist: a multicenter study.Arthroscopy: The Journal of Arthroscopic & Related Surgery. 1997;13(1): 78-84.

12. Dailey SW and Palmer AK. The role of arthroscopy in the evaluation and treatment of triangular fibrocartilage complex injuries in athletes. Hand Clin. 2000;16(3): 461-76

13. Degreef I, Welters H, Millants P, Van Ransbeeck H, De Smet L. Disability and function after arthroscopic repair of ulnar avulsions of the triangular fibrocartilage complex of the wrist. Acta Orthop Belg. 2005;71(3): 289-93

14. De Smet L. Van De Meulebroucke B. Van Ransbeeck H, Zachee B, Fabry G. Arthroscopic suturing of ulnar avulsions (Type 1-B) of the triangular fibrocartilage complex of the wrist. Hand Surg. 1998;3(1): 35-39

15. Estrella EP, Hung LK, Ho PC, Tse WL. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007;23 (7): 729-37

16. Hess F, Sutter R, Nagy L, Schweizer A. Stability and clinical outcome after reconstruction of complete triangular fibrocartilage disruption. J Wrist Surg. 2016;5 (2): 124-130

17. Kovachevich R and Elhassan BT. Arthroscopic and open repair of the TFCC. Hand Clin. 2010;26 (4):485-94

18. Luchetti R, Atzei A, Cozzolino R, Fairplay T and Badur N. Comparison between open and arthroscopic-assisted foveal triangular fibrocartilage complex repair for post-traumatic distal radio-ulnar joint instability. Journal of Hand Surgery (European Volume), 2014;39(8): 845-855.

19. McAdams TR, Swan J, Yao J. Arthroscopic treatment of triangular fibrocartilage wrist injuries in the athlete. Am J Sports Med. 2009;37 (2): 291-7

20. Millants P, De Smet L, Van Ransbeeck H. Outcome study of arthroscopic suturing of ulnar avulsions of the triangular fibrocartilage complex of the wrist. Chir Main. 2002;21(5): 298-300

21. Miwa H, Hashizume H, Fujiwara K, Nishida K, Inoue H. Arthroscopic surgery for traumatic triangular fibrocartilage complex injury. J Orthop Sci. 2004;9(4): 354-9

22. Moritomo H, Masatomi T, Murase T, Miyake J, Okada K, Yoshikawa H. Open repair of foveal avulsion of the triangular fibrocartilage complex and comparison by types of injury mechanism. J Hand Surg Am. 2010;35 (12): 1955-63

23. Moritomo H. Open repair of the triangular fibrocartilage complex from palmar aspect. J Wrist Surg. 2015;4(1): 2-8

24. Nakamura T, Nakao Y, Ikegami H, Sato K, Takayama S. Open repair of the ulnar disruption of the triangular fibrocartilage complex with double three-dimensional mattress suturing technique. Tech Hand Up Extrem Surg. 2004;8(2): 116-23

25. Nakamura T, Sato K, Okazaki M, Toyama Y, Ikegami H. Repair of Foveal Detachment of the Triangular Fibrocartilage Complex: Open and Arthroscopic Transosseous Techniques. Hand clinics. 2011;27: 281-90

26. Papapetropoulos PA, Wartinbee DA, Richard MJ, Leversedge FJ, Ruch DS. Management of peripheral triangular fibrocartilage complex tears in the ulnar positive patient: arthroscopic repair versus ulnar shortening osteotomy. J Hand Surg Am. 2010;35(10):1607-13.

27. Park MJ, Jagadish A, Yao J. The rate of triangular fibrocartilage injuries requiring surgical intervention. Orthopedics. 2010;3(11): 806

28. Reiter A, Wolf MB, Schmid U, Frigge A, Dreyhaupt J, Hahn P and Unglaub F. Arthroscopic repair of Palmer 1B triangular fibrocartilage complex tears. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2008;24(11): 1244-1250.

29. Ruch DS and Papadonikolakis A. Arthroscopically assisted repair of peripheral triangular fibrocartilage complex tears; factors affecting outcome. Arthroscopy. 2005;21(9): 1126-30

30. Shih JT, Lee HM and Tan CM.. Early isolated triangular fibrocartilage complex tears: management by arthroscopic repair. Journal of Trauma and Acute Care Surgery. 2002;53(5): 922-927.

31. Shinohara T, Tatebe M, Okui N, Yamamoto M, Kurimoto S, Hirata H. Arthroscopically assisted repair of triangular fibrocartilage complex foveal tears. J Hand Surg Am. 2013;38(2): 271-7

32. Soreide E, Husby T, Haugstvedt JR.. A long-term (20 years") follow-up after arthroscopically assisted repair of the TFCC. J Plast Surg Hand Surg. 2016;1-5

33. Tang C, Fung B., Chan R, Fok M. The beauty of stability: distal radioulnar joint stability in arthroscopic triangular fibrocartilage complex repair. Hand Surg. 2013;18(1): 21-26

34. Tang CY, Fung B, Rebecca C, Lung CP. Another light in the dark: review of a new method for the arthroscopic repair of triangular fibrocartilage complex. J Hand Surg Am. 2012;37 (6): 1263-8

35. Trumble TE, Gilbert M, Vedder N. Isolated tears of the triangular fibrocartilage: management by early arthroscopic repair. J Hand Surg Am. 1997;22 (1): 57-65

36. Wolf MB, Kroeber MW, Reiter A, et al.. Ulnar shortening after TFCC suture repair of Palmar type 1B lesions. Arch Orthop Trauma Surg. 2010;130(3): 301-6

37. Wolf MB, Haas A, Dragu A, Leclere FM, Dreyhaupt J, Hahn P, Unglaub F. Arthroscopic repair of ulnar-sided triangular fibrocartilage complex (Palmar Type 1B) tears: a comparison between short-and midterm results. J Hand Surg Am. 2012;37 (11): 2325-30

38. Woo SJ, Jegal M, Park MJ. Arthroscopic-assisted repair of triangular fibrocartilage complex foveal avulsion in distal radioulnar joint injury. Indian J Orthop. 2016;50 (3): 263-268.

39. Yao J. All-arthroscopic repair of peripheral triangular fibrocartilage complex tears. Operative techniques in sports medicine. 2010;18(3): 168-172

40. Yao J and Lee AT. All-arthroscopic repair of Palmer 1B triangular fibrocartilage complex tears using the FasT-Fix device. The Journal of hand surgery. 2011;36(5): 836-842.

Supplementary table II. Joanna Briggs Checklist Results – Primary Analysis Group

	Iwasaki et al, 2011	Kim et al, 2013	Bayoumy et al, 2015
1. Were there clear criteria for inclusion in the case series?	Yes	Yes	No
2. Was the condition measured in a standard, reliable way for all participants included in the case series?	Yes	Yes	Yes
3. Were valid methods used for identification of the condition for all participants included in the case series?	Yes	Yes	Yes
4. Did the case series have consecutive inclusion of participants?	Yes	Unclear	Yes
5. Did the case series have complete inclusion of participants?	Unclear	Yes	Yes
6. Was there clear reporting of the demographics of the participants in the study?	Yes	Yes	Yes
7. Was there clear reporting of clinical information of the participants?	Yes	Yes	Unclear
8. Were the outcomes or follow up results of cases clearly reported?	Yes	Yes	Yes
9. Was there clear reporting of the presenting site(s)/clinic(s) demographic information?	N/a	N/A	N/A
10. Was statistical analysis appropriate?	Yes	Yes	Yes

Supplementary table III. Joanna Briggs Checklist results – Secondary analysis group

	Wysocki et al 2012	Jegal et al 2016	Woo et al 2016	Atzei et al 2015	Nakamura et al 2011	Yao & Lee 2011	Luchetti et al 2014
1. Were there clear criteria for inclusion in the case series?	Yes	Unclear	No	Yes	Unclear	Yes	Yes
2. Was the condition measured in a standard, reliable way for all participants included in the case series?	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
3. Were valid methods used for identification of the condition for all participants included in the case series?	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
4. Did the case series have consecutive inclusion of participants?	Unclear	Unclear	Unclear	Unclear	No	Unclear	Unclear
5. Did the case series have complete inclusion of participants?	Yes	Unclear	Unclear	Unclear	No	Unclear	Unclear
6. Was there clear reporting of the	Yes	Yes	Yes	Yes	Yes	Yes	Yes

demographics of the participants in the study?							
7. Was there clear reporting of clinical information of the participants?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8. Were the outcomes or follow up results of cases clearly reported?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9. Was there clear reporting of the presenting site(s)/clinic(s) demographic information?	N/a	N/a	N/a	N/a	N/a	N/a	N/a
10. Was statistical analysis appropriate?	Yes	N/a	Yes	Yes	N/a	N/a	Yes