Musculoskelet Surg (2016) 100:157–163
DOI 10.1007/s12306-016-0426-z

REVIEW

Biomechanical testing of the reconstructed ulnar collateral ligament: a systematic review of the literature

B. M. Saltzman[1] · B. J. Erickson[1] · J. M. Frank[2] · J. D. Harris[3] · G. P. Nicholson[1] · B. R. Bach[1] · N. N. Verma[1] · A. A. Romeo[1]

Received: 25 August 2016 / Accepted: 4 September 2016 / Published online: 14 September 2016

Abstract
Purpose The purpose was to perform a systematic review of the literature investigating biomechanical studies of ulnar collateral ligament reconstruction (UCLR) techniques to summarize the most commonly analyzed methods of fixation (at both the ulna and humerus), the degree of elbow flexion at the time of fixation, graft characteristics, and modes of failure with these techniques.
Materials and methods A systematic review was performed. All cadaveric biomechanical studies that tested a reconstruction method for UCLR were included. Descriptive statistics were calculated for each study and parameter/variable analyzed.
Results Twenty-three studies were included with a total of 397 elbows in 242 cadavers (mean age 54.8 ± 20 years, range 16–96). The majority of studies (65 %) used a palmaris longus graft. The docking technique (37.2 %) was the most commonly tested reconstruction method. Significant heterogeneity between studies precluded assimilation of specific techniques (each of the 23 studies utilized a unique technique). Fixation was performed at 30°–90° of elbow flexion. The most common mode of failure was suture failure (51 %), followed by midsubstance rupture (27.00 %), and bone tunnel fracture (14.00 %). No significant differences were observed amongst techniques for all measures analyzed.
Conclusion This study found the docking technique to be the most commonly tested technique, while the mode of reconstruction failure was most commonly at the suture interface. If the graft failed at the bone interface, it was most likely to occur at the ulna. Surgeon preference and comfort level with a specific technique should dictate choice.

Keywords Ulnar collateral ligament (UCL) · Tommy John · Elbow · Biomechanical · Systematic review · Ulnar collateral ligament reconstruction (UCLR)

✉ B. M. Saltzman
bryan.m.saltzman@gmail.com

B. J. Erickson
berickso.24@gmail.com

J. M. Frank
Jon.m.frank@gmail.com

J. D. Harris
joshuaharrismd@gmail.com

G. P. Nicholson
gnicholson@rushortho.com

B. R. Bach
bbach@rushortho.com

N. N. Verma
nverma@rushortho.com

A. A. Romeo
aromeo@rushortho.com

1 Department of Orthopedic Surgery, Rush University Medical Center, 1611 W Harrison St Suite 300, Chicago, IL 60612, USA

2 Division of Sports Medicine, The Steadman Clinic, 181 W Meadow Dr., Vail, CO 81657, USA

3 Department of Orthopedics and Sports Medicine, Houston Methodist Hospital, 6550 Fannin, Smith Tower, Suite 2500, Houston, TX 77030, USA

Introduction

Injury to the ulnar collateral ligament (UCL) of the elbow has become a common injury in throwing athletes, especially baseball pitchers, with an increasing number of ulnar collateral ligament reconstructions (UCLR) performed

Table 1 Summary of ulnar collateral ligament reconstruction techniques

Technique	Ulna	Humerus	Ulnar fixation	Humeral fixation	Graft configuration	Management of FP mass	Management of ulnar nerve	Routine arthroscopy
Jobe	Tunnel	Tunnel	None	Sutured to itself	Figure-of-eight	Transection	Submuscular transposition	No
Modified Jobe	Tunnel	Tunnel	None	Sutured to itself	Figure-of-eight	Split	No transposition	No
Docking	Tunnel	Socket	None	Sutured over bone bridge	Triangle	Split	No transposition	Yes
Docking plus	Tunnel	Socket	None	Sutured and graft over bone bridge	Figure-of-eight	Split	No transposition	No
DANE TJ	Socket	Socket	Interference screw	Docking over bone bridge	Linear	Split	No transposition	No
Hybrid	Tunnel	Anchor	None	Suture anchor, sutured to itself	Triangle	Split	No transposition	No
ASMI modification	Tunnel	Tunnel	None	Sutured to itself	Figure-of-eight	Split	Anterior subcutaneous transposition	Yes
Tension slide	Socket	n/a	Suspensory cortical, interference screw	n/a	n/a	n/a	n/a	n/a
Bisuspensory	Socket	Socket	Suspensory cortical	Suspensory cortical	Linear	n/a	n/a	n/a
Ziploop	Socket	Socket	Suspensory cortical	Interference screw	Linear	n/a	n/a	n/a

FP flexor–pronator mass, *n/a* not applicable

each year [1–6]. The UCL provides medial support to valgus loads and comes under tremendous amounts of stress during throwing sports such as baseball and javelin [7–10]. The majority of stress, up to 32 N-m, is imparted on the UCL during the late cocking and early acceleration phases of pitching [8]. This amount of stress pushes the UCL toward failure with each pitch; surrounding osseous and muscular restraints aid the UCL in combatting the valgus moment during certain overhead activities [11]. While the UCL is made up of three distinct bundles, the anterior bundle, made up of anterior and posterior bands, is the strongest, stiffest, and most important part of the UCL with overhead activities [10, 12]. These bands function in reciprocal fashion with the anterior band tight at lesser degrees of elbow flexion and the posterior band tighter at higher degrees of elbow flexion [10].

Ulnar collateral ligament reconstruction (UCLR), commonly referred to as “Tommy John surgery,” was first performed by Dr. Frank Jobe in 1974 and published in the literature in 1986 [13]. Since then, the initial Jobe technique has undergone several modifications, with claimed benefits and advantages for each modification [2, 14–18]. Clinical experience and early biomechanical studies have dictated that reconstruction of the torn UCL provides superior outcomes versus primary repair in the majority of patients [13, 19]. UCLR is commonly performed in both professional and amateur athletes [1, 3, 5]. There are several different surgical techniques utilized by surgeons based on humeral and ulnar methods of fixation, graft configuration, management of the flexor–pronator mass, and treatment of ulnar nerve (Table 1) [2, 6, 11, 16, 19–23].

Currently, there is no consensus regarding the optimal UCLR technique and means of failure. The purpose was to perform a systematic review of the literature investigating biomechanical studies of UCL reconstruction (UCLR) techniques to summarize the most commonly analyzed methods of fixation (at both the ulna and humerus), the degree of elbow flexion at the time of fixation, graft characteristics, and modes of failure with these techniques. Our hypothesis was that the docking technique would be the most favored surgical technique to analyze given its more recent widespread utilization and that the most common location for failure would be at the suture interface.

Materials and methods

A systematic review was performed using Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines with a PRISMA checklist [24].

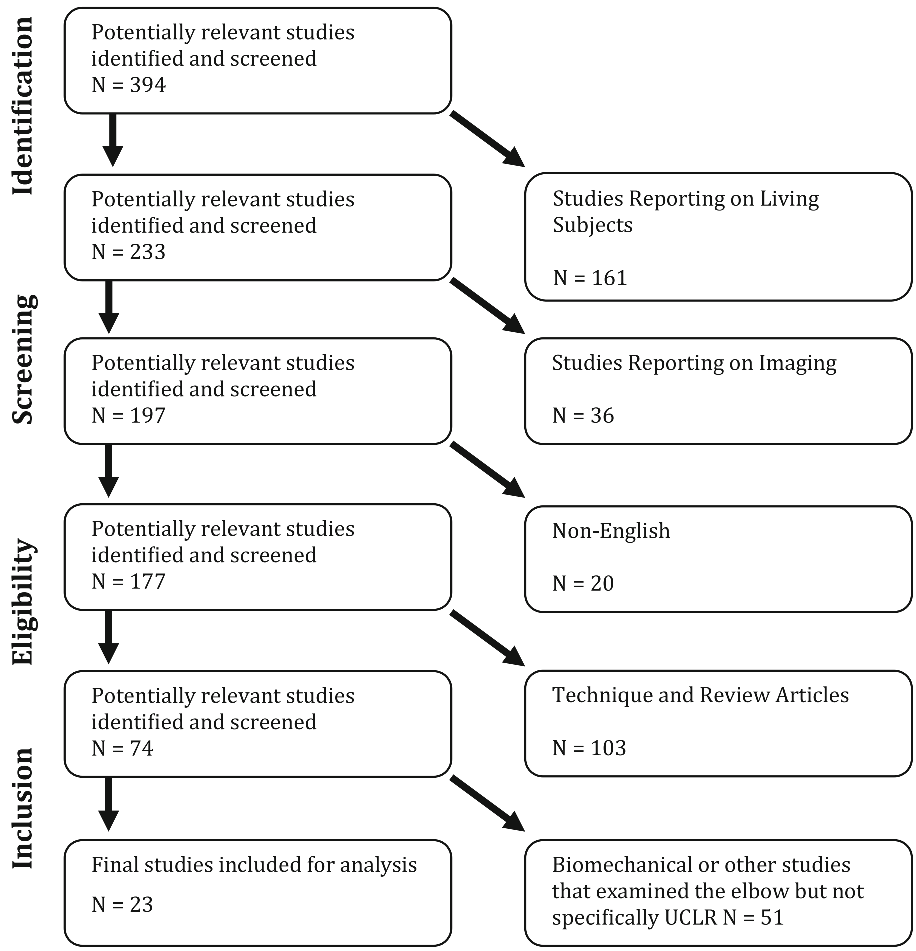

Fig. 1 Systematic review search algorithm within MEDLINE database according to PRISMA guidelines. After application of all exclusion criteria, 23 studies were identified for inclusion and further analysis; *UCLR* ulnar collateral ligament reconstruction

The protocol has been registered in the PROSPERO database (registration number: CRD42013003743, available at http://www.crd.york.ac.uk/PROSPERO). Three independent reviewers (one board-eligible orthopedic surgeon and two orthopedic surgery residents) completed the search. The search was performed on February 15, 2016, using the following search algorithm: (((((ulnar[Title/Abstract] AND collateral[Title/Abstract]) AND ligament[Title/Abstract]) AND elbow[Title/Abstract]) NOT thumb[Title/Abstract]) NOT lateral[Title), in the following databases: Medline, SportDiscus, CINAHL, and Cochrane Central Register of Controlled Trials. Inclusion criteria were any English language studies analyzing biomechanical outcomes for reconstruction of the UCL of the elbow using any reported technique. Exclusion criteria included studies that used living subjects, non-English language, imaging only, surgical technique, systematic reviews or meta-analyses, letters to the editor, topic reviews, and articles dealing with non-medial UCL aspects of the elbow. Exclusively biomechanical evidence was deemed inclusive. Both electronically published and print journal articles were acceptable, but meeting abstracts and proceedings were disallowed. All references within included studies were cross-referenced for potential inclusion if omitted from the initial search. Figure 1 demonstrates our search algorithm to generate the final studies for inclusion and analysis.

Each study was analyzed for several variables that may affect the outcome of each technique reported. The primary focus of the review compares methods of fixation; this was therefore recorded for both the ulna and the humerus. Similarly, the degree of elbow flexion at the time of fixation was also noted. Graft characteristics were identified, extracted, and analyzed. Demographic data including cadaver sex, age, and side were recorded. In addition, we report the various modes of failure found in each study. The authors also noted whether a study reported any financial conflicts of interest.

Descriptive statistics were calculated for each study and parameter or variable analyzed. Continuous variable data were reported as mean ± standard deviation (weighted means where applicable). Categorical data were reported as frequencies with percentages. For all statistical analysis, $p < 0.05$ was deemed statistically significant.

Results

Prior to screening, 394 studies were identified. Following eligibility screening and filtering via exclusion criteria, 23 studies remained (Fig. 1). Of these 23 studies, 12 reported the presence of a conflict of interest, while 9 had no conflict, and the remaining 2 made no mention. Combined, 242 cadaver specimens and 397 elbows were used. Of these elbows, 116 were male and 69 were female; 142 were right elbows and 139 were left elbows. The mean age of these specimens was 54.8 ± 20 years (range 16–96) (Table 2).

The overwhelming majority of grafts (65 %) were palmaris longus, followed by gracilis (10 %), and extensor tendon (8 %). Sixty-seven percent of reconstructed elbows were completed using autograft. The majority of grafts were tensioned with the elbow flexed at either 70° (32.4 %) or 90° (34.4 %) (Table 2). A wide variety of techniques were utilized, with 32 % using the docking technique (Table 3).

The most common mode of failure was suture failure (51 % of elbows, 80.1 % of which were secondary to suture pullout). There was no standard method of testing amongst studies.

Table 2 Summary of data collected

	n (%)
# of studies	23
Conflict of interest	
Present	12 (52 %)
Absent	9 (39 %)
Not reported	2 (9 %)
# of cadavers	242
Mean cadaver age	54.8 ± 20 years (16–96)
# of elbows	397
Male	116 (62.3 %)
Female	69 (37.7 %)
# of right elbows	142 (50.1 %)
# of left elbows	139 (49.9 %)
Graft type	
Palmaris longus	279 (65 %)
Extensor tendon	33 (8 %)
Flexor tendon	4 (1 %)
Semitendinosus	24 (6 %)
Gracilis	40 (10 %)
Triceps tendon	10 (2 %)
Bovine extensor	17 (4 %)
Unspecified	18 (4 %)
Donor source (#grafts)	
Autograft	222 (67 %)
Allograft	96 (30 %)
Xenograft	12 (3 %)
Elbow flexion angle upon fixation (# studies)	
30	2 (53 elbows) (13 %)
45	1 (31 elbows) (7.7 %)
50	1 (18 elbows) (4.5 %)
70	9 (131 elbows) (32.4 %)
90	7 (139 elbows) (34.4 %)
Not specified	2 (32 elbows) (8 %)
Modes of failure	
Midsubstance rupture	27.00 %
Suture failure	51 %
Pullout	80.10 %
Rupture	4.50 %
Slippage	9.10 %
Knot Failure	5.50 %
Bone tunnel fracture	14.00 %
Humeral	27 %
Ulnar	73 %
Anchor/screw pullout	2.60 %
Graft pullout	5.40 %

Discussion

Medial UCL reconstruction is a successful operation for symptomatic UCL deficiency that has undergone several modifications since its initial description by Dr. Jobe in 1986 [13]. This study found the docking technique to be the most commonly tested technique, while the mode of reconstruction failure was most commonly at the suture interface. If the graft failed at the bone interface, it was most likely to occur at the ulna.

Clinical outcomes following UCLR are generally favorable, starting with a reported 63 % return to previous level of play in Dr. Jobe's original paper [13]. The modified Jobe utilizes a muscle-splitting approach and has been reported to have up to 93 % return to play [23]. The ASMI modification, using a flexor carpi ulnaris split, also has favorable outcomes, ranging from 79 to 87.5 % [1, 14]. These three approaches have a figure-of-eight configuration to the graft. The docking technique utilizes a muscle-splitting approach and a triangular configuration to its graft [22, 25]. An over 90 % return to play has been reported with this technique [25]. The DANE TJ modifies the docking technique by using an interference screw [2]. It has been associated with an 86 % rate of excellent outcome [2]. With an up to 85 % favorable outcome, the hybrid technique uses suture anchors in an attempt to decrease the risk of tunnel fracture [26]. The double-docking technique which fixes the graft over a bone tunnel in the ulna and button device on the humerus has >90 % RTS rate [3]. Overall, excellent outcomes have ranged from 68 % to as high as 95 % [1–4, 6, 14, 15, 19, 20, 26–28]. When results

Table 3 List of techniques evaluated broken down by number of elbows included in this review

Technique	# Elbows (%)
Docking	147 (37.2 %)
Humeral and ulnar sockets with metal interference screws	30 (7.6 %)
Jobe	29 (7.4 %)
Docking with a humeral interference knot	20 (5.1 %)
Modified Jobe	29 (7.4 %)
Docking with suspensory cortical fixation on ulna	19 (4.9 %)
Humeral and ulnar bone anchors	17 (4.4 %)
Single Strand	11 (2.8 %)
Docking plus	10 (2.6 %)
Humeral and ulnar bone tunnels with interference screws	9 (2.3 %)
Docking with a humeral bioabsorbable interference screw	21 (5.4 %)
Humeral and ulnar sockets with bioabsorbable interference screw fixation	8 (2.0 %)
Ziploop technique	8 (2.0 %)
Tension slide	6 (1.5 %)
Humeral and ulnar bisuspensory cortical fixation	6 (1.5 %)
UCL repair augmented with internal brace	9 (2.3 %)
GraftLink	7 (1.8 %)
Tightrope	7 (1.8 %)

of multiple techniques were compared, a recent systematic review of the literature did find a significantly higher return to sport rate following the docking technique (97 %) compared with the Jobe (66.7) and ASMI (93.3 %) techniques [15]. Hence, from a clinical perspective, it seems that the docking and double-docking techniques may provide a slight advantage in RTS rates [15, 18].

The results of this study show that the most common mode of failure following UCLR in a laboratory setting is suture failure. While failure of the graft represented 27 % of the failure, suture failure was much higher at 51 %. The various modes of suture failure included pullout, slippage, and suture rupture. One technique that tries to offset the ability of the sutures to fail is the double-docking technique, in which a button device is used on the humerus to secure the docked graft in place [3]. Despite an encouraging RTS rate, no biomechanical studies have been conducted to date to test the double-docking technique in isolation, or in comparison with other techniques [3]. Biomechanical studies evaluating this technique are necessary to determine whether this offers a superior mode of fixation to some of the other techniques that were evaluated in this study. Furthermore, the clinical implications of these modes of failure need to be better understood as the number of revision UCLR has been rising in recent years [29–32]. If the common modes of failure can be prevented, the number of revision UCLR can be decreased.

The most commonly reported complication of UCL reconstruction, regardless of technique, is ulnar neuropraxia [15, 18, 33]. For this reason, many techniques include a routine anterior subcutaneous ulnar nerve transposition [14]. There are also many techniques, however, that will not routinely transpose the ulnar nerve if the patient lacks preoperative ulnar nerve symptoms [3]. No evidence to date has shown clear superiority of either routine or selective ulnar nerve transposition with UCLR, although reviews have found slightly lower rates of postoperative ulnar neuropraxia in patients treated with selective ulnar nerve transposition (4 %) compared with obligatory ulnar nerve transposition (9 %) [15]. Other complications reported in the literature include stiffness, ulnar tunnel fracture, synovitis, and infection [15]. For those that undergo revision reconstruction, complication rates of up to 40 % have been reported, primarily involving loss of motion or re-tear [30]. As no technique showed biomechanical superiority in this review, the surgeon should choose the technique with which he/she is most familiar to reduce the likelihood of operative complications. Future biomechanical studies should standardize several variables that make comparison between studies difficult including elbow flexion angle at time of graft fixation and biomechanical testing protocol.

Conclusion

This study found the docking technique to be the most commonly tested technique, while the mode of reconstruction failure was most commonly at the suture interface. If the graft failed at the bone interface, it was most likely to occur at the ulna. Surgeon preference and comfort level with a specific technique should dictate choice.

Limitations

The limitations inherent to a systematic review include the limitations of the studies themselves. This includes selection bias, present in that this review only analyzed cadaveric, older, both male and female specimens. This is in contrast to most UCLR in vivo, which are in young male throwers. Performance bias was present in that the biomechanical testing protocols were vastly different between studies, with large amounts of heterogeneity in grafts, techniques, and fixation methods. It was this heterogeneity that precluded study data assimilation and meta-analysis. Detection bias was present given the significant heterogeneity in assessment of strength and other biomechanical parameters.

Funding There was no funding for this project.

Compliance with ethical standards

Conflict of interest There are no conflicts of interest or disclosures of or pertaining to the completion of this manuscript. Beyond the scope of this manuscript, the following disclosures are noted for the authors: Bryan M. Saltzman receives publishing royalties, financial or material support from Nova Science Publishers and Postgraduate institute for Medicine. Brandon Erickson declares that he has no conflict of interest. Jonathan Frank declares that he has no conflict of interest. Joshua Harris is a board or committee member of AAOS and AOSSM and AANA, is on the editorial board of Arthroscopy and Frontiers in Surgery, receives research support from DePuy A Johnson & Johnson Company, is a paid consultant for NIA Magellan, receives publishing royalties/financial/material support from SLACK Incorporated, and a paid presented or speaker with research support for Smith & Nephew. Gregory Nicholson receives IP royalties from Innomed, receives Publishing royalties, financial or material support from SLACK Incorporated, is a paid consultant with research support from Tornier, and receives stock options from Zimmer. Bernard Bach is on the board of AOSSM, receives research support from Arthrex, Inc, CONMED Linvatec, DJ Orthopaedics, Ossur, Smith & Nephew, and Tornier, and receives publishing royalties from SLACK Incorporated. Nikhil Verma is on the board of AOSSM and ASES and AANA and Arthroscopy and Journal of Knee Surgery, receives publishing royalties from Arthroscopy, receives research support from Arthrex Inc and Arthrosurface and DJ Orthopaedics, receives stock options from Cymedica, is a paid consultant with stock options for Minivasive, is a paid consultant for Orthospace, receives stock options for Omeros, receives research support from Ossur, is on the governing board of SLACK Incorporated, receives IP royalties, is a paid consultant for Smith & Nephew, receives research support from Smith & Nephew, Athletico, ConMed Linvatec, Miomed, Mitek, and receives publishing royalties from Vindico Medical-Orthopedics Hyperguide. Anthony Romeo is on the board of AOSSM and ASES, receives royalties, is a paid consultant and presenter for Arthrex, Inc., receives research support from DJO Surgical, is on the editorial or governing board of Orthopedics and Orthopedics Today, receives research support from Ossur, is on the editorial board of SAGE, receives publishing royalties from Saunders/Mosby-Elseview, is on the editorial or governing board with publishing royalties from SLACK Incorporated, receives research support from Smith & Nephew, and is on editorial board of Wolters Kluwer Health–Lippincott Williams & Wilkins.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent No humans were involved.

References

1. Cain EL Jr, Andrews JR, Dugas JR, Wilk KE, McMichael CS, Walter JC 2nd et al (2010) Outcome of ulnar collateral ligament reconstruction of the elbow in 1281 athletes: results in 743 athletes with minimum 2-year follow-up. Am J Sports Med 38:2426–2434. doi:10.1177/0363546510378100
2. Dines JS, ElAttrache NS, Conway JE, Smith W, Ahmad CS (2007) Clinical outcomes of the DANE TJ technique to treat ulnar collateral ligament insufficiency of the elbow. Am J Sports Med 35:2039–2044. doi:10.1177/0363546507305802
3. Erickson BJ, Bach BR Jr, Cohen MS, Bush-Joseph CA, Cole BJ, Verma NN et al (2016) Ulnar collateral ligament reconstruction: the rush experience. Orthop J Sports Med 4:2325967115626876. doi:10.1177/2325967115626876
4. Erickson BJ, Gupta AK, Harris JD, Bush-Joseph C, Bach BR, Abrams GD et al (2013) Rate of return to pitching and performance after tommy john surgery in major league baseball pitchers. Am J Sports Med. doi:10.1177/0363546513510890
5. Erickson BJ, Nwachukwu BU, Rosas S, Schairer WW, McCormick FM, Bach BR Jr et al (2015) Trends in medial ulnar collateral ligament reconstruction in the united states: a retrospective review of a large private-payer database from 2007 to 2011. Am J Sports Med 43:1770–1774. doi:10.1177/0363546515580304
6. O'Brien DF, O'Hagan T, Stewart R, Atanda AW Jr, Hammoud S, Cohen SB et al (2015) Outcomes for ulnar collateral ligament reconstruction: a retrospective review using the KJOC assessment score with two-year follow-up in an overhead throwing population. J Shoulder Elbow Surg. doi:10.1016/j.jse.2015.01.020
7. Erickson BJ, Harris JD, Chalmers PN, Bach BR Jr, Verma NN, Bush-Joseph CA et al (2015) Ulnar collateral ligament reconstruction: anatomy, indications, techniques, and outcomes. Sports Health 7:511–517. doi:10.1177/1941738115607208
8. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF (1995) Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med 23:233–239
9. Fleisig GS, Barrentine SW, Zheng N, Escamilla RF, Andrews JR (1999) Kinematic and kinetic comparison of baseball pitching among various levels of development. J Biomech 32:1371–1375
10. Morrey BF (1986) Applied anatomy and biomechanics of the elbow joint. Instr Course Lect 35:59–68
11. Morrey BF, An KN (1983) Articular and ligamentous contributions to the stability of the elbow joint. Am J Sports Med 11:315–319
12. Cohen MS, Bruno RJ (2001) The collateral ligaments of the elbow: anatomy and clinical correlation. Clin Orthop Relat Res 383:123–130
13. Jobe FW, Stark H, Lombardo SJ (1986) Reconstruction of the ulnar collateral ligament in athletes. J Bone Joint Surg Am 68:1158–1163
14. Azar FM, Andrews JR, Wilk KE, Groh D (2000) Operative treatment of ulnar collateral ligament injuries of the elbow in athletes. Am J Sports Med 28:16–23
15. Erickson BJ, Chalmers PN, Bush-Joseph CA, Verma NN, Romeo AA (2015) Ulnar collateral ligament reconstruction of the elbow: a systematic review of the literature. Orthop J Sports Med 3:2325967115618914. doi:10.1177/2325967115618914

16. McGraw MA, Kremchek TE, Hooks TR, Papangelou C (2013) Biomechanical evaluation of the docking plus ulnar collateral ligament reconstruction technique compared with the docking technique. Am J Sports Med 41:313–320. doi:10.1177/0363546512466375
17. Paletta GA Jr, Klepps SJ, Difelice GS, Allen T, Brodt MD, Burns ME et al (2006) Biomechanical evaluation of 2 techniques for ulnar collateral ligament reconstruction of the elbow. Am J Sports Med 34:1599–1603. doi:10.1177/0363546506289340
18. Vitale MA, Ahmad CS (2008) The outcome of elbow ulnar collateral ligament reconstruction in overhead athletes: a systematic review. Am J Sports Med 36:1193–1205. doi:10.1177/0363546508319053
19. Conway JE, Jobe FW, Glousman RE, Pink M (1992) Medial instability of the elbow in throwing athletes. Treatment by repair or reconstruction of the ulnar collateral ligament. J Bone Joint Surg Am 74:67–83
20. Andrews JR, Timmerman LA (1995) Outcome of elbow surgery in professional baseball players. Am J Sports Med 23:407–413
21. Morgan RJ, Starman JS, Habet NA, Peindl RD, Bankston LS Jr, D'Alessandro DD et al (2010) A biomechanical evaluation of ulnar collateral ligament reconstruction using a novel technique for ulnar-sided fixation. Am J Sports Med 38:1448–1455. doi:10.1177/0363546510363463
22. Rohrbough JT, Altchek DW, Hyman J, Williams RJ 3rd, Botts JD (2002) Medial collateral ligament reconstruction of the elbow using the docking technique. Am J Sports Med 30:541–548
23. Thompson WH, Jobe FW, Yocum LA, Pink MM (2001) Ulnar collateral ligament reconstruction in athletes: muscle-splitting approach without transposition of the ulnar nerve. J Shoulder Elbow Surg 10:152–157. doi:10.1067/mse.2001.112881
24. Moher D, Cook DJ, Eastwood S, Olkin I, Rennie D, Stroup DF (1999) Improving the quality of reports of meta-analyses of randomised controlled trials: the QUOROM statement. Quality of Reporting of Meta-analyses. Lancet 354:1896–1900
25. Dodson CC, Thomas A, Dines JS, Nho SJ, Williams RJ 3rd, Altchek DW (2006) Medial ulnar collateral ligament reconstruction of the elbow in throwing athletes. Am J Sports Med 34:1926–1932. doi:10.1177/0363546506290988
26. Hechtman KS, Zvijac JE, Wells ME, Botto-van Bemden A (2011) Long-term results of ulnar collateral ligament reconstruction in throwing athletes based on a hybrid technique. Am J Sports Med 39:342–347. doi:10.1177/0363546510385401
27. Dodson CC, Slenker N, Cohen SB, Ciccotti MG, DeLuca P (2010) Ulnar collateral ligament injuries of the elbow in professional football quarterbacks. J Shoulder Elbow Surg 19:1276–1280. doi:10.1016/j.jse.2010.05.028
28. Koh JL, Schafer MF, Keuter G, Hsu JE (2006) Ulnar collateral ligament reconstruction in elite throwing athletes. Arthroscopy 22:1187–1191. doi:10.1016/j.arthro.2006.07.024
29. Conte SA, Fleisig GS, Dines JS, Wilk KE, Aune KT, Patterson-Flynn N et al (2015) Prevalence of ulnar collateral ligament surgery in professional baseball players. Am J Sports Med 43:1764–1769. doi:10.1177/0363546515580792
30. Dines JS, Yocum LA, Frank JB, ElAttrache NS, Gambardella RA, Jobe FW (2008) Revision surgery for failed elbow medial collateral ligament reconstruction. Am J Sports Med 36:1061–1065. doi:10.1177/0363546508314796
31. Marshall NE, Keller RA, Lynch JR, Bey MJ, Moutzouros V (2015) pitching performance and longevity after revision ulnar collateral ligament reconstruction in major league baseball pitchers. Am J Sports Med. doi:10.1177/0363546515579636
32. Wilson AT, Pidgeon TS, Morrell NT, DaSilva MF (2015) Trends in revision elbow ulnar collateral ligament reconstruction in professional baseball pitchers. J Hand Surg. doi:10.1016/j.jhsa.2015.07.024
33. Watson JN, McQueen P, Hutchinson MR (2013) A systematic review of ulnar collateral ligament reconstruction techniques. Am J Sports Med. doi:10.1177/0363546513509051