Systematic Review

Elbow Ulnar Collateral Ligament Repair With Suture Augmentation Is Biomechanically Equivalent to Reconstruction and Clinically Demonstrates Excellent Outcomes: A Systematic Review

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Purpose: To systematically review (1) biomechanical properties of augmented elbow ulnar collateral ligament (UCL) repair compared with reconstruction and (2) clinical efficacy and complication rates of UCL repair with and without augmentation. **Methods:** A systematic review was completed August 15, 2023, identifying articles that (1) biomechanically compared suture augmented UCL repair and reconstruction and (2) clinically evaluated medial elbow UCL repairs. Search terms included: "UCL repair" OR "internal brace" OR "suture augmentation" AND "UCL reconstruction." For inclusion, biomechanical studies compared augmented repair with reconstruction; clinical studies required clinical outcomes with minimum 6-month follow-up. Biomechanical data included torsional stiffness, gap formation, peak torque, and failure torque. Clinical data included return to previous level of play, time to return, functional outcomes, and complications. **Results:** In total, 8 biomechanical and 9 clinical studies were included (5 with and 4 without augmentation). In most biomechanical studies, augmented repairs demonstrated less gap formation, with equivalent torsional stiffness, failure load, and peak torque compared with reconstruction. Clinical outcomes in 104 patients without augmentation demonstrated return to previous level of 50% to 94% for nonprofessional athletes and 29% for professional baseball pitchers. Suture augmented repairs in 554 patients demonstrated return to previous level from 92% to 96%, at 3.8 to 7.4 months, with Kerlan Jobe Orthopaedic Clinic scores of 86 to 95. The overall complication rate for augmented UCL repair was 8.7%; most commonly ulnar neuropraxia (6%). **Conclusions:** Biomechanically, UCL repair with augmentation provided less gapping with equivalent torsional stiffness and failure compared with reconstruction. Clinically, augmented UCL repair demonstrated excellent return to previous level of play and Kerlan Jobe Orthopaedic Clinic scores with modest complications and time to return. Augmented UCL repair is biomechanically equivalent to reconstruction and may be a viable alternative to reconstruction in indicated athletes. **Clinical Relevance:** UCL repair with suture augmentation is biomechanically equivalent to reconstruction and clinically demonstrates excellent outcomes.

Introduction

The medial ulnar collateral ligament (UCL) of the elbow is the primary restraint against excessive valgus force. A significant increase in risk of injury occurs with increasing pitch velocity.[1] Due to increased early specialization, injuries to the UCL are occurring at younger ages.[2,3] There has been an increase in the number of reconstructions performed in adolescent overhead athletes, with their incidence projected to rise to 14.6 per 100,000 by 2025.[4-6]

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Overhead throwing athletes are particularly susceptible to UCL injuries due to repetitive valgus stress, exposing the anterior bundle of the UCL to supraphysiological tensile forces. UCL injuries typically manifest as medial elbow pain with attenuated throwing velocity and endurance.[7] Over time, degradation of the tissue may result in partial-thickness tears or complete ruptures. If nonoperative measures including rest and rehabilitation fail, surgical intervention may be indicated to allow the athlete to return to their sport. An estimated 5% of baseball pitchers ages 9 to 14 years suffer UCL injuries severe enough to require surgical intervention.[8]

Traditionally, UCL reconstruction has been the gold standard for UCL injuries in overhead athletes. First introduced by Frank Jobe in 1974 and subsequently modified, UCL reconstruction has excellent surgical outcomes across all levels of competition.[2,9] Return to play after reconstruction to the same level has been reported at rates between 80% and 97%.[10-14] Despite the high success rate, the biggest drawback of UCL reconstruction is the 12- to 18-month recovery, which can result in loss of 1 to 2 competitive seasons.[15]

UCL repair with suture augmentation is an emerging alternative to UCL reconstruction with promising early results for a faster return to play with proper indications, excluding mid-substance tears and severely degenerated ligaments.[16] Historically, UCL repair outcomes were inferior to UCL reconstruction in professional athletes.[17-19] However, there was a renewed interest in repairs after Savoie et al.[20,21] demonstrated improved return to previous level of sport in shorter time, using suture anchors. Dugas et al.[16] improved repair techniques by adding suture augmentation to create an "internal brace" (IB). An IB uses a collagen-coated suture tape that is inserted alongside the repaired UCL to protect the ligament. This acts as a brace, or "backstop" to resist valgus stress and to provide a biologic augment to ligament healing.[22,23] Biomechanical cadaveric studies using suture augmentation have shown comparable or superior results when compared with the traditional reconstructions.

For augmented UCL repairs, return to play and time to return continue to be elucidated with recent studies. In addition, to date there has been no compiled literature on complication rates using UCL repair with suture augmentation. Hence, the purpose of the study was to systematically review (1) the biomechanical properties of suture augmented elbow UCL repair compared with UCL reconstruction, and (2) the clinical efficacy and complication rates of UCL repair with and without augmentation. We hypothesize that UCL repair with suture augmentation will demonstrate at least equivalent biomechanical properties compared with UCL reconstruction and that, clinically, augmented UCL repair will produce overall excellent results with mean return to sport of 6 months, and <10% complication rate.

Methods

Literature Search and Study Selection

This review was performed August 15, 2023, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The primary search was used to identify any studies that directly compared UCL repair augmented with IB to UCL reconstruction. A search of the literature was completed using MEDLINE (PubMed), Embase, Cochrane library, Science Direct, and Scopus. Primary search terms used included ("UCL repair" OR "internal brace" OR "suture augmentation") AND "UCL reconstruction." A more detailed list of search terms can be found in Appendix 1, available at www.arthroscopyjournal.org. The initial search string yielded 478 results: 126 PubMed, 21 ScienceDirect, 159 Embase, 7 Cochrane, and 165 SCOPUS. After 262 duplicates were removed, the remaining 216 abstracts were screened independently by 2 orthopaedic board-certified reviewers (T.M.S. and E.N.B.). A third sports medicine fellowship-trained reviewer was available for any disputes. Studies were removed when they failed to make a direct comparison of augmented repair to reconstruction, when they explored the wrong anatomical region (ie, thumb, lateral ulnar collateral ligament, etc), when they did not pertain to orthopaedic sports medicine (ie, traumatic elbow dislocations or non-human studies) or when they were the wrong article type (review, conference abstract, technique guide, etc). Included studies were published in the English language in peer-reviewed journals. This left 9 articles for full-text screening, in which one article was excluded for lack of information regarding gapping and torque. Eight biomechanical articles remained. No clinical articles directly comparing IB augmented UCL repair with UCL reconstruction were identified. Figure 1 depicts the PRISMA flow chart.

Secondary Literature Search and Study Selection

A secondary search was performed with the goal of identifying studies with outcome data after UCL repair. This search included the same databases previously used: MEDLINE (PubMed), Embase, Cochrane Library, Science Direct, and Scopus. Search terms included "UCL repair" OR "internal brace" or "augmentation." Appendix 1 lists the specific search strategy. The secondary search string revealed 1989 results: 374 PubMed, 644 from ScienceDirect, 470 Embase, 15 Cochrane, and 486 SCOPUS. After the 799 duplicates were removed, the remaining 1190 abstracts were screened by the aforementioned process. Articles

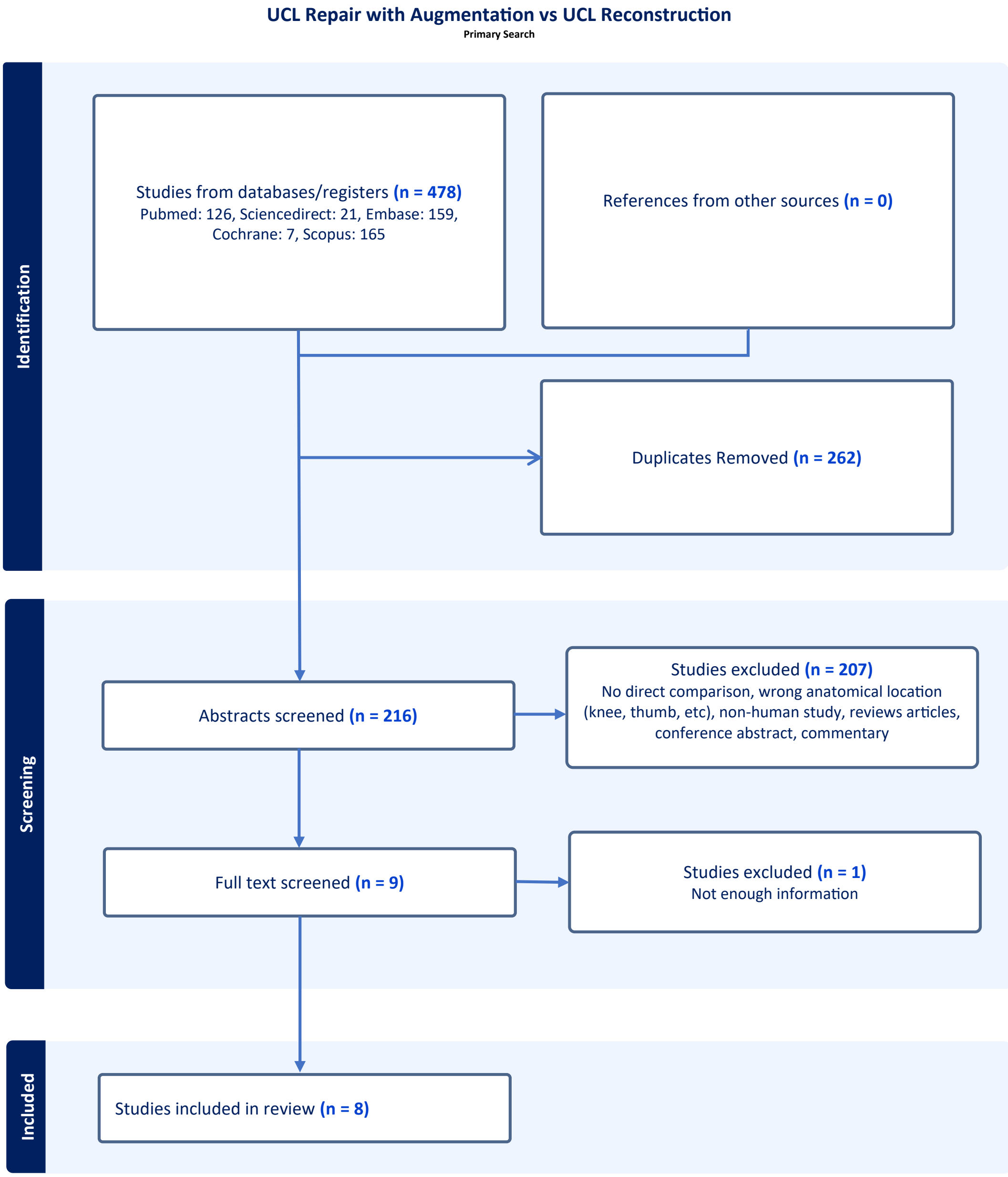

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart for primary search.

focused on the wrong anatomic location (knee, thumb, lateral UCL, etc), non-human studies, review articles, and commentaries were excluded. This left 22 articles for full text screening, in which 13 studies were excluded for lack of either outcome or complication data, lack of demographic data, incorrect design, or revision setting. The remaining 9 articles were included in this systemic review. Figure 2 depicts the PRISMA flow chart.

Outcome Measurements

For biomechanical studies, information was collected regarding the number of cadaveric elbows that underwent augmented UCL repair and the type of reconstruction compared. Dependent variables collected included gap formation, yield torque, torsional stiffness at failure and torque at failure. All biomechanical studies occurred in a controlled laboratory environment with appropriate randomization on axial-torsional testing machines to determine stiffness, torque, and gapping.

For clinical studies, we collected surgical techniques for UCL repair along with patient age, sex, dominant arm, type of sport, and the level of competition. Outcome variables included the Kerlan Jobe Orthopaedic Clinic (KJOC) shoulder and elbow score,[24] rate of return to previous level of play, time to return, and additional outcome measures (Andrew—Carson, American Shoulder and Elbow Score, and Disabilities

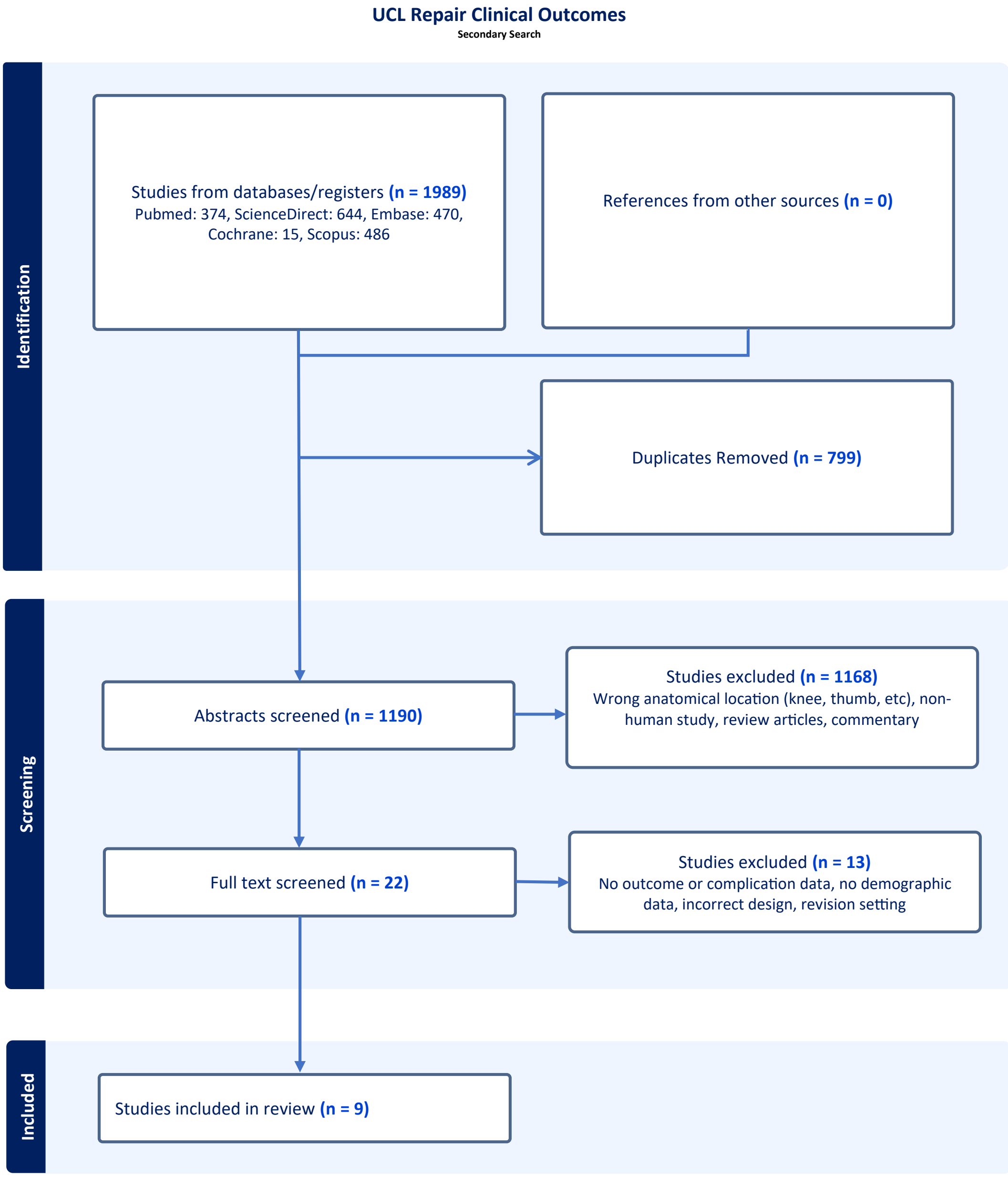

Fig 2. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart for secondary search.

of the Arm, Shoulder, and Hand). Finally, we compiled complication data across the clinical studies and reported ranges. We also assigned MINORS (Methodological Index for NOn-Randomized Studies) criteria to each study as a way to appraise the risk of bias among the largely nonrandomized studies reported in the literature.[25] Minimal clinically important difference, patient acceptable symptomatic state, substantial clinical benefit, and maximal outcome improvement data were searched but not reported in the included articles.

Surgical Technique

The biomechanical reconstruction techniques for comparison consisted of the modified Jobe, modified docking, and 3-strand docking techniques.[7,26,27] For UCL repair with suture augmentation, a similar technique was used in all of the cadaveric samples and clinical studies, as described by Dugas et al.[16,28] To summarize, after superficial dissection and splitting of the flexor−pronator, the UCL was split in line with its fibers and intraoperative evaluation was performed to evaluate the ligamentous tissue (confirm absence of midsubstance tear, bony fragments, tissue deficiency, or extensive degeneration). The ulnar nerve was only released distally to visualize; transposition was only performed for preoperative symptoms. A suture anchor with collagen-dipped suture tape was first placed proximal or distal based on the location of the avulsion and the repair stitch was used to repair the ligament to

Table 1. Biomechanical Properties of UCL IB Augmentation With Comparison With UCL Reconstruction

Study	Study Type	Cadaver Elbow #	Techniques Compared	Torsional Stiffness, Nm/deg	Gap Formation, °	Peak Torque, Nm	Failure Torque, (Nm)/Load(N)
Otto et al. (2023)[33]*	Controlled lab study	14	Repair aUCL vs modified Jobe	–	Lower at 120°	–	No difference
Mead et al. (2021)[32]	Controlled lab study	18	Suspensory fixation repair vs docking reconstruction	No difference	No difference	No difference	Lower
Roth et al. (2021)[23]	Controlled lab study	20	Repair vs modified Jobe	No difference at failure	–	No difference	–
Bachmaier et al. (2020)[31]	Controlled lab study	16	Repair vs modified docking	Higher	Lower	Higher	No difference
Urch et al. (2019)[27]	Controlled lab study	16	Repair vs 3-strand docking	No difference at failure	• Restored to intact state at all angles • Lower at 30° and 90°	Lower	Lower
Bodendorfer et al. (2018)[30]	Controlled lab study	18	Repair vs docking Reconstruction	–	• No difference	–	No difference
Jones et al. (2018)[29]	Controlled lab study	20	Repair vs modified Jobe	No difference at failure	• Lower at 10th, 100th, and 500th cycle 2-10 Nm • No difference for gap till failure	-	No difference
Dugas et al. (2016)[16]	Controlled lab study	18	Repair vs modified Jobe	No difference at failure	• Lower at 10 cycles between 2 and 5 Nm • No difference for gap till failure	–	No difference

NOTE. This table is made with respect to IB repair. Comparisons made at significance of $P < .05$.
aUCL, anterior band of ulnar collateral ligament; IB, internal bracing; UCL, ulnar collateral ligament.
*Results for isolated aUCL bracing compared with reconstruction; results from dual bracing not included.

bone. Next, the remaining ligament was repaired side-to-side and a second suture anchor, loaded with the suture tape, was placed either proximal or distal with the elbow at 20° of flexion and slight varus pressure. The suture tape was then sutured to the native ligament. The elbow was taken through range of motion to ensure the elbow was not over-constrained.

Results

A total of 8 biomechanical studies were included comparing medial UCL repairs augmented with IB with that of UCL reconstructions. These studies were published from 2016 to 2023 and included a total of 140 elbows, 70 in both the reconstruction and augmented repair groups.

With regards to clinical outcomes, 658 UCL repairs were identified in the literature between 1992 and 2022. Between 1992 and 2009, 104 repairs were performed without the use of suture augmentation (102 of these on athletes). Upon the advent of suture augmentation, between 2016 and 2022, 554 repairs with suture augmentation were identified. These repairs were performed in both male and female patients, across various sports and multiple levels of competition.

Biomechanical Studies

The summary of biomechanical studies is found in Table 1.[16,23,27,29-33] Dugas et al.[16] first compared the modified Jobe reconstruction with UCL repair with suture augmentation in 18 cadaveric elbows and found no statistical difference in torsional stiffness at failure and torque at failure. However, gap formation was significantly less for the repair group at 10 cycles between 2 and 5 Nm, with no difference at failure. This was further explored by Jones at al.,[29] who performed cyclic testing of elbows at 10, 100, and 500 cycles and demonstrated significantly less gap formation between 2 and 10 Nm in the augmented repair groups, again noting no difference at failure. Mirroring Dugas et al., failure testing showed no statistical difference for torsional stiffness or torque. Bodendorfer et al.[30] compared differences at 90° of elbow flexion and found similar load to failure, gapping, and valgus opening angle between both surgical techniques.

A more comprehensive study was performed by Bachmaier et al.,[31] who creatively used 24 elbows to compare the mechanical properties of native elbows to those of repaired, repaired with suture augmentation, and reconstruction. The results demonstrated that augmented repair possessed the greatest torsional stiffness and load to failure with lower gap formation compared with reconstruction or repair without augmentation. Further, suture augmentation restored valgus stability most similarly to that of the intact ligament. Roth et al.[23] found that augmented UCL repairs and reconstruction both restored normal joint contact mechanics, torque, and stiffness to that of the intact ligament in 10 matched pairs of elbows. Although nonsignificant, there was a trend toward lower torque in the reconstruction group, indicating repair may better mimic the intact ligament. Urch et al.[27] sought to compare repair of the posterior band of the anterior bundle with a 3-ply docking technique. Here, the augmented repair had significantly less yield torque (9.1 Nm vs 19.1 Nm), yield angle (5.4° vs 10.2°), and ultimate torque (17.6 vs 23.9 Nm). However, the valgus laxity was re-established to intact states at all angles of elbow flexion in the repair group which was not seen in the reconstruction group at full extension and 30° of flexion. Similarly, Mead at al.[32] found that suspensory fixation repair restored valgus stability to levels not significantly different from reconstruction at all angles of flexion with no differences in ultimate torque to failure. Otto et al.[33] demonstrated less joint gapping at 120° of elbow flexion in the suture augmented repair group compared with that of reconstructed UCLs. There were no significant differences noted in valgus laxity, cycles to failure, or failure load.

In the 6 studies specifically evaluating torsional stiffness, 5 noted no significant differences and one study noted slightly higher torsional stiffness in the augmented repair group. In the 7 studies evaluating gap formation, the augmented repair group was found to demonstrate less gap formation (in at least one angle) in 5 studies and performed equal to reconstruction in the remaining 2 studies. In the 4 studies evaluating peak torque, two studies demonstrated no significant difference, one study demonstrated higher peak torque, and one study demonstrated lower peak torque (posterior band repair only). In the 7 studies evaluating the failure load, 5 studies found no significant difference, whereas 2 studies demonstrated a lower failure load in the suture augmented repair group.

Clinical Studies

Return to Play

A summary of clinical studies is found in Tables 2 and 3.[18,20,21,34-39] Before the advent of suture augmentation, multiple studies evaluated clinical outcomes for UCL repair. Conway et al.[18] demonstrated inferior return to previous level of play in baseball players after UCL repairs when compared with reconstructions (50% vs 68%). It was especially poor in professional athletes, with only 29% (2/7) repairs returning to previous level of play compared with 75% (12/16) for reconstructions. Argo et al.[20] was able to demonstrate a high success rate for primary repairs in females participating in softball, tennis, and gymnastics. The return to previous level of play across all levels of play was 94% (17/18), with an average return time of 2.5

Table 2. Demographic and Technique Summary of Studies Evaluating UCL Repairs

Study	MINORS Score	LoE	Repair # (N)	Sex (M/F)	Dominant Arm, %	Mean Age, y, range	Sport	Level of Competition	Mean F/U, mo
UCL repairs with internal brace augmentation									
Rothermich et al. (2022)[37]	11	IV	28	12/16	16 (57)	17.5 ± 3.7	1 – basketball; 7 – cheerleading; 10 – FB; 8 – gymnastics; 1 – VB; 1 – wrestling	1 – youth; 21 – HS; 5 – college; 1 – pro	44.4
O'Connell et al. (2021)[36]	12	IV	40	35/5	35 (88)	17.8 ± 3.7 (14-28)	35 – baseball; 4 – tumblers; 1 – VB	22 – HS; 17 – college; 1 – coach	23.8
Rothermich et al. (2021)[39]	13	IV	353	309/44	–	19.1 ± 4.9 (12-68)	272 – baseball; 22 – FB; 18 – gymnastics; 14 – softball; 6 – fall; 6 – javelin; 4 – wrestling; 3 – weightlifting; 2 – VB; 1 – basketball; 1 – horseback riding; 4 – unknown	–	6
Dugas et al. (2019)[38]	11	IV	111	107/4	–	18.3 ± 2.7 (13-26)	102 - Baseball (90 pitchers); 4 – other softball; 4 – FB quarterbacks; 1 – javelin	74 – HS; 31 – college; 4 – rec; 1 – MS; 1 – pro	Not specified (12-24)
Walters et al. (2016)[35]	10	IV	22	19/3	–	17.8	19 – baseball (13 pitchers); 2 – football; 1 – javelin; 1 – cheerleader	22 – HS	Not specified (6-12)
UCL repairs without internal brace augmentation									
Richard et al. (2009)[34]	11	IV	11	10/1	–	23 (20-37)	5 – FB; 1 – golf; 1 – baseball; 1 – VB; 1 – wrestling; 1 – swimming; 1 – coach	10 – college; 1- coach	16+
Savoie et al. (2008)[21]	13	IV	60	47/13	53 (83)	17.2 (14.8-22)	51 – throwing athlete (47 baseball); 9 – nonthrowing	13 – MS; 25 – HS; 22 – college	59
Argo et al. (2006)[20]*	11	IV	19	0/19	12 (63)	22 (15-37.2)	8 – softball; 4 – gymnastics; 2 – tennis; 1 – skier; 1 – calf roper; 1 –cheerleader; 1 – baton; 1 – MVC	1 – nonathlete; 4 – rec; 5 – HS; 9 – college	39
Conway et al. (1992)[18]	NA	IV	14	14/0	–	26.5 (19-38)	14 – baseball (13 pitchers)	4 – college; 3 – minor league; 7 –pro	76

FB, football; F/U, follow up; HS, high school; LoE, Level of Evidence; M/F, male/female; MINORS, Methodological Items for NOn-Randomized Studies; MS: middle school; MVC, motor vehicle collision; NA, not applicable: not enough information; Pro, professional; Rec, recreational; UCL, ulnar collateral ligament; VB, volleyball.

*This study includes one patient who underwent a reconstruction with palmaris autograft.

months (range 2-3.5 months), with an Andrews–Carson score increase from 120 to 191.3. In 2008, Savoie et al.[21] found a high return to previous level of play in 93% (56/60) of athletes using suture anchors and bone tunnels in baseball, basketball, and cheerleading athletes. The return to play was an average of 6 months (range 4-11.7 months) for these collegiate and lower-level athletes. Similarly, Richard et al.[34] found a high return to previous level of play, 90% (9/10), between 4 and 6 months.

Of the 102 athletes (excluding nonathletes) who underwent UCL repair without augmentation in the 4 included studies, 94 (92%) were able to return to play at their preoperative level. The repairs were performed on 71 (68%) males and 33 (32%) females. The athletic level included 7 professional (6.9%), 3 minor league (2.9%), 45 college (44%), 30 high school (29%), and 17 others (17%). The majority played baseball (60%), and the remaining athletes played a variety of other sports. The mean time to return ranged from 2.5 to 6 months. KJOC scores were not recorded in any of the studies, but Savoie et al.[21] and Argo et al.[20] demonstrated Andrew–Carson scores of 188 and 191, respectively. Richard et al.[34] demonstrated a postoperative DASH score of 6.

Regarding UCL repairs with suture augmentation, Walters et al.[35] published outcomes of 22 UCL repairs with the suture augmentation construct in 2016. They demonstrated a 96% return to previous level of play after a mean of 21 weeks with a mean KJOC score of 93 in adolescent athletes. In 2019, Dugas et al.[28] published their outcomes using the IB technique for suture augmentation with collagen-dipped sutures. In 111 repairs across all levels of athletes for baseball, football, softball, and javelin they demonstrated a 92% (102/111) return to play at a mean return of 6.7 months, with a mean KJOC score of 88.2. This success has since been replicated by O'Connell et al.[36] in 2021 with a 92.5% return to previous level of play at mean 6.9 months, with mean KJOC scores of 95.3 in 22 high school athletes and 93.9 in 17 collegiate athletes. Finally, Rothermich et al.[37] evaluated 28 nonthrowing athletes in 2022 and found a return to same level of play of 93% (26/28), with a mean time of 7.4 months.

The 4 included studies contained return to play and outcome data overall for 201 suture-augmented UCL repairs. Of these patients, 187 (93%) were able to return to sport at their previous level or greater. This included repair on 173 (86%) male and 28 (14%) female athletes. These repairs were predominately performed on baseball players (78%). The data included 2 (1%) professional, 53 (26%) college, 139 (69%) high school, and 7 (3%) other levels of play (coach, recreational, youth, and middle school). The mean time to return to sport was reported in 4 studies, ranging from 3.8 to 7.4 months. KJOC scores were reported in 3 studies, ranging from 86.2 to 95.3. One study, Rothermich et al.,[37] reported an ASES score of 94.4.

Rehabilitation

Dugas et al.[38] provided the most detailed rehabilitation discussion, which appears similar to the other studies for suture augmentation repairs. The elbow was immobilized for 2 weeks, followed by gradual restoration of full motion with a brace to resist valgus stress. At 3 to 4 weeks, light isotonic strengthening was started followed by The Thrower's Ten Program. With improved strength and neuromuscular control, the Advanced Thrower's Ten Program was initiated, followed by a 2-hand, then 1-hand plyometric program (week 6). The brace was removed at this point. Hitting was permitted at week 10 and an interval-throwing program was initiated at week 11 if the athlete was advancing appropriately. After 10 weeks of progressive long-toss, baseball pitchers were allowed to throw from a mound, starting at 50% maximal intensity and increasing until full-competitive ability attained.

Complications

Results for complications are described in Table 4. In the 4 studies without suture augmentation (104 UCL repairs), complications were noted in 11 (11%) patients. Six (5.8%) of these patients had postoperative ulnar nerve paresthesia, 4 of which resolved without needing surgical intervention. There were 4 (3.8%) patients requiring subsequent return to the operating room (OR). Two to address ulnar neuropathy (primary or revision ulnar nerve transposition), 1 for capsular release to address arthrofibrosis, and 1 for irrigation and debridement to address an infection.

Four studies described complications in UCL repairs with IB augmentation. Rothermich et al.[39] performed a retrospective chart review for their 353 patients. 84.7% reported no complications, 11.9% reported minor complication such as ulnar nerve paresthesia, medial elbow pain, or a superficial wound complication. 3.4% required a return to OR secondary to a major complication requiring ulnar nerve exploration, debridement, ulnar nerve transposition, or heterotopic ossification excision. Dugas at al.[38] in 111 athletes reported 4.5% return to OR rate for complications (5 cases); 3 cases of ulnar neuropathy, 1 heterotopic bone formation, and 1 retear. O'Connell et al.[36] reported 1 ulnar paresthesia in 39 cases (2.5%), which completely resolved.

In the 4 studies exploring suture augmented UCL repairs, there were 532 procedures associated with complication data. The complication rate per study ranged from 2.5% to 12% among all repairs, with a combined complication rate of 8.7%. Ulnar nerve paresthesias were observed in 32 (6.0%) patients, 11 (2.1%) experienced medial elbow pain, 2 (0.04%) had superficial wound complications, and 1 (0.02%) had a

Table 3. Return-to-Play and Outcome Summary of Studies Evaluating UCL Repairs

Study	RTP # (%) (Same Level or Higher)	RTP Time, mo	KJOC Score, range	Other Outcome Measurements
UCL repairs with internal brace augmentation				
Rothermich et al. (2022)[37]	26 (93)	7.4 ± 3.8	–	ASES score: 94.4
O'Connell et al. (2021)[36]	37 (93) – Overall 21 (95) – HS 15 (88) –College	6.9 (2-12 mo)	92.6 (64-100) – Overall 95.3 (64-100) – HS 93.9 (71-100) – college	–
Rothermich et al. (2021)[39]	–	–	–	–
Dugas et al. (2019)[38]	102 (92)	6.7	88.2 overall 86.2 – 12 mo 91.1 – 24 mo	–
Walters et al. (2016)[35]	4 (100) –Non-baseball 18 (95) – Baseball	3.8 – Non-baseball 4.9– baseball	88.3 – 6 mo 93 – 12 mo	–
UCL repairs without internal brace augmentation				
Richard et al. (2009)[34]	9 (90) – college athletes 1 (100) – coach	4-6 mo	–	DASH– 6 (2-12)
Savoie et al. (2008)[21]	56 (93)	6 (4-11.7)	–	Andrew– Carson rating 188 (from 132 preoperatively)
Argo et al. (2006)[20]*	17/18 (94) athletes	2.5 (2.0-3.5)	–	Andrew– Carson rating 191 (from 120 preoperatively)
Conway et al. (1992)[18]	7 (50) – at same level 3 (21)– at lower level 2 (14) – at recreational level	–	–	–

ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder and Hand; HS, high school; KJOC, Kerlan-Jobe Orthopaedic Clinic; RTP, return to play; UCL, ulnar collateral ligament.
*This study includes one patient who underwent a reconstruction with palmaris autograft.

subsequent UCL retear. Return to OR was noted in 19 patients (5.3%). The majority of these reoperations were performed to address the ulnar nerve (15), followed by excision of heterotopic ossification (3), and exploration of medial elbow (1).

Discussion

Biomechanically, suture augmented UCL repair demonstrated equivalent or better mechanical properties compared with UCL reconstruction, approximating the function of the native ligament. Clinically, suture augmented UCL repairs demonstrated excellent KJOC scores, >90% return to previous level of play within 4 to 7 months, with an 8.7% complication rate. UCL repairs are becoming an increasingly utilized option for overhead athletes given recent favorable results and this study supports it as an option for certain UCL injuries. However, further studies are needed to directly compare augmented UCL repair and reconstruction in order to better define surgical indications and outcomes.

Augmented UCL repair from a biomechanical standpoint was at least equivalent to reconstruction and better mimicked the native laxity of the intact ligament. In a study evaluating the real-time collagen alignment of the native UCL under load, Smith et al.[40] showed that the native UCL collagen does not reorganize significantly with load. This suggests that the native UCL is a check-reign ligament against valgus force with little compliance in the tissue with loading. Therefore, an IB construct that reinforces the check-reign effect of the UCL is likely to better replicate the biomechanics of the native UCL. The biomechanical studies in this review demonstrated significantly less gapping with no difference in torsional stiffness or failure torque compared with reconstructions. The only study showing lower torque for repairs (Urch et al.[27]) addressed only the posterior band of the anterior bundle repair, verifying the anterior band is most important for resisting torque. In summary, suture augmented UCL outperformed reconstructions regarding gapping with comparable stiffness and failure torque.

A biomechanical concern regarding augmented UCL repair is the potential for over-constraint of the joint. However, Kouk et al.[41] has shown consistency biomechanically between single-surgeon and multiple-surgeon groups performing augmented UCL repair regarding contact-area, contact-force, and peak pressure. Elbow peak torque and stiffness were not significantly different between surgeon groups. Bachmaier et al.[31] was able to demonstrate the suture augmented repair essentially replicated the native UCL for all load levels. Thus far, biomechanical results have demonstrated a return to near-intact levels following augmented repair while not causing over-constraint of the joint.[41]

Clinical outcomes for UCL repair have significantly improved with the advancement of repair techniques.

Table 4. Complications Summary of Studies Evaluating UCL Repairs

Study	Ulnar Nerve Paresthesia #, %	Other Complications, %	Reoperation
UCL repairs with internal brace augmentation			
Rothermich et al. (2022)[37]	2 (7)	0	2 – Ulnar neurolysis and revision ulnar transposition
O'Connell et al. (2021)[36]	1 (3)	–	–
Rothermich et al. (2021)[39]	29 (8)	11 – Medial elbow pain 2 – Superficial wound complications	6 – Ulnar nerve explorations/debridements 4 – Primary ulnar nerve transpositions 2 – Heterotopic ossification excisions
Dugas et al. (2019)[38]	–	1 – subsequent UCL retear (3 years out)	2 – primary ulnar nerve transposition 1 – revision ulnar nerve transposition 1 – Exploration of medial elbow pain 1 – Heterotopic ossification excision
Walters et al. (2016)[35]	–	–	–
UCL repairs without internal brace augmentation			
Richard et al. (2009)[34]	–	1 – 20° flexion contracture	–
Savoie et al. (2008)[21]	3 (5)	1 – Arthrofibrosis 1 – Stitch abscess 1 – Superficial wound complication	1 – Capsular release 1 – Irrigation and debridement
Argo et al. (2006)[20]*	–	1 – Stitch abscess	–
Conway et al. (1992)[18]	3 (21)	0	1 – Revision ulnar nerve transposition 1 – Primary ulnar nerve transposition

UCL, ulnar collateral ligament.
*This study includes one patient who underwent a reconstruction with palmaris autograft.

In 1981, Norwood et al.[19] first described direct UCL repair in 2 softball and 2 nonthrowing athletes with 100% return to play. Azar et al.[17] in 2000 described a 63% return to play for direct repair compared with 81% for reconstructions. However, both studies were excluded from our review due to the lack of sufficient clinical data. A series by Conway et al.[18] in 1992, demonstrated an inferior return to previous level of play in professional and collegiate baseball players for repairs when compared with reconstructions (50% vs 68%). It was especially poor in professional athletes, with only 29% of repairs returning to their previous level of play compared with 75% of reconstructions. Given better outcomes with reconstruction, UCL repairs were largely abandoned until Argo et al.[20] reported Savoie's UCL repair technique using suture anchors in female athletes (58% throwers) with 94% return to any level of play. Savoie et al.[21] in 2008 reported on 60 repairs in athletes (51 throwers), with 93% return to any level of play. In 2016, Walters et al.[35] first described the clinical outcomes of the Dugas UCL repair technique with suture augmentation. Subsequent clinical studies evaluated in this review have demonstrated excellent clinical outcomes in 554 patients with suture augmented UCL repair with return to play rates of 92% to 96%, at a mean of 3.8 to 7.4 months, with KJOC scores of 86 to 95.

The majority of the athletes in the included studies played baseball. As previously noted, without suture augmentation Conway et al.[18] had only a 29% return to previous level of sport in professional pitchers. Initial data is promising for baseball players in this study; however, the 92% to 96% return to previous level was primarily in high school and college athletes. A study by Paletta and Milner[42] was not included due to the preliminary nature of the data but mirrored previous studies with a 94% (74/78) return to play at mean 7.5 months, with mean KJOC score of 90.4, among high school and collegiate baseball players. They also reported preliminary data in professional baseball players demonstrating an 88% (15/17) return to play, with 2 requiring conversion to UCL reconstruction (1 retear, 1 continued pain).

Comparative clinical studies evaluating UCL repair and reconstruction are lacking. UCL reconstructions have long been the gold standard for UCL injuries.[43] In Major League Baseball pitchers, return to any level of play after UCL reconstruction ranges from 80% to 97% in 12 months on average, with return to previous level of play ranging from 67% to 87% at 15 months.[43,44] KJOC scores in a systematic analysis done by Glogovac et al.[15] ranged from 76 to 89, Conway scores ranged from 81 to 87, and Andrews Timmerman scores ranged from 84 to 93. Outcomes for augmented UCL repair from this review demonstrated comparable results. There has been expressed reservation regarding UCL repair in midsubstance injuries and ligaments with significant degenerative changes.[28,42] Since the majority of repairs have been performed in nonprofessional athletes, it remains to be seen how UCL repairs will fair in an elite population with greater degenerative changes in the UCL. At this point, a direct comparison cannot be performed comparing UCL repairs and reconstructions due to these dissimilar populations.

Circumspection should accompany any new surgical technique. In a systematic review by Somerson et al.,[45] the mean complication rate for UCL reconstructions was 10.2%, with the majority being ulnar neurapraxias. The complication rate for repairs from this review was 8.7%, most commonly ulnar paresthesias, typically resolving within several weeks to months. Complication rates thus appear to be comparable between the techniques. Additional factors should be considered regarding repairs. Close attention should be placed on joint range of motion and overconstraint, which can negatively affect outcomes. A new technique may also incur a learning curve for the surgeon before outcomes and complications are optimized. In addition, future study will be needed to evaluate the long-term outcomes and complications associated with the IB itself, such as stress-shielding, tissue abrasion, or reaction to wear particles from the suture tape.[39] Hardware complications may occur including loosening, migration, irritation, or failure. The durability of the procedure has yet to be seen, and as few revisions have been performed to date, the outcomes for revision of a repair to a reconstruction remain largely unknown. However, it appears that the IB repair technique is relatively bone sparing, leaving sufficient bone for a subsequent revision.[46] A prospective comparative cohort study is necessary to better define the indications for UCL repair and reconstruction through direct comparison. Further investigation is warranted to evaluate repair outcomes in higher level athletes, including the professional level and those with variable quality UCL tissue.

Limitations

One limitation of this systematic review is the lack of direct clinical comparison between UCL repair and reconstruction, which presents an avenue for further research. Direct comparison studies are not currently available, and given an inherent selection bias (repairs performed in younger, nonprofessional athletes with good UCL tissue), indirect comparison is limited. Moreover, most results were in baseball athletes, which limits generalizability to other sports. Clinical data including range of motion, specifics regarding tear patterns (location and severity), previous treatments, limited follow-up, and rehabilitation were not routinely recorded, which are important factors to consider. In addition, this review did not evaluate surgeon experience and case volume, as experience instituting a new technique may drive outcomes. Thus, the generalizability of these outcomes remains to be seen when implemented by a diversity of surgeons in a variety of athletes.

Conclusions

UCL repair with augmentation provided less gapping with equivalent torsional stiffness and failure compared with reconstruction in biomechanical studies. Clinically, UCL repair with augmentation demonstrated high KJOC scores and return to previous level of play with low complications and quick return to play. Based on available data, augmented UCL repair is biomechanically equivalent to reconstruction and may be a viable alternative to reconstruction in indicated athletes.

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Appendix A

Primary search:

("ulnar collateral ligament" OR "medial ulnar collateral ligament" OR "medial collateral ligament") AND ("UCL repair" OR "internal brace" OR "augmentation" OR "suture tape") AND ("UCL reconstruction" OR "Tommy John" OR "docking" OR "Jobe").

Secondary search (no clinical studies were identified when including "reconstruction"; therefore, this additional search was performed to find clinical studies):

("UCL repair" OR "ulnar collateral ligament repair" OR "medial collateral ligament") AND ("internal brace" OR "suture augmentation" OR "suture tape" or "repair").