Clinical Outcomes of Ulnar Collateral Ligament Repair With Internal Brace Versus Ulnar Collateral Ligament Reconstruction in Competitive Athletes

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Background: The increasing prevalence of ulnar collateral ligament (UCL) injuries, particularly in young athletes, necessitates optimization of treatment options. The introduction of UCL repair with internal bracing offers an exciting alternative to traditional UCL reconstruction.

Purpose: To compare midterm outcomes between UCL repair with internal bracing and UCL reconstruction in competitive athletes.

Study Design: Cohort study; Level of evidence, 3.

Methods: The authors identified competitive athletes who underwent primary UCL repair with internal bracing or UCL reconstruction between 2013 and 2021 and were at least 2 years postsurgery. To have qualified for repair, patients must have shown complete or partial UCL avulsion from the sublime tubercle or medial epicondyle. Relevant patient, injury, operative, and revision surgery data were collected via chart review. Preoperative American Shoulder and Elbow Surgeons Elbow assessment form (ASES-E), Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow (KJOC), and Andrews-Carson scores were obtained from an ongoing data repository. ASES-E, KJOC, and Andrews-Carson scores, and return-to-sport (RTS) data were collected at follow-up. Linear regression modeling controlling for relevant covariates was utilized to compare patient-reported outcome (PRO) scores between groups. Proportions of athletes who successfully returned to sport and proportions of subsequent revision procedures between groups were compared using chi-square tests. Lastly, for those with baseline questionnaire data, the authors compared magnitude of change between preoperative and postoperative scores between groups using linear regression modeling with baseline scores and follow-up time as the covariates, and follow-up scores as the dependent variable.

Results: A total of 461 athletes were eligible for inclusion with complete clinical and outcome data available (mean age at surgery, 19.1 years; 92% male). The UCL repair group had a significantly shorter follow-up time than the UCL reconstruction group (4.4 vs 6.3 years; $P < .01$). When controlling for follow-up time, the groups did not differ in ASES-E, KJOC, or Andrews-Carson scores at follow-up. There was no significant difference in proportion of revisions between UCL repair (9%) and UCL reconstruction (8%) ($P = .77$). Of the 268 athletes with complete follow-up in the repair group, 247 attempted to return to their preinjury sport, and 241 (98%) were able to RTS. Six athletes reported that they were unable to RTS due to limitations from their surgery. Of the 155 athletes with follow-up in the reconstruction group, 147 attempted to return to their preinjury sport; 145 (99%) were able to successfully RTS, and 2 were unable to return due to limitations from their surgery. The 2 groups, repair with internal brace versus reconstruction, did not statistically differ in the proportions that returned to preinjury sport ($P = .20$) but did differ regarding time in months to return to practice (6.7 ± 3.5 vs 10.2 ± 11.7) ($P < .01$) and time in months to return to competition (9.2 ± 4.6 vs 13.4 ± 13.3) ($P < .01$).

Conclusion: Athletes who underwent UCL repair with internal brace reported excellent midterm PROs statistically similar to those after UCL reconstruction, including proportion successfully returning to preinjury sport. There was no significant difference in revision rates between procedures. However, athletes who underwent UCL repair had a statistically significantly shorter time to RTS.

Keywords: elbow; ulnar collateral ligament; internal brace; reconstruction; repair; return to play; Tommy John surgery

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Since Dr. Jobe's first medial ulnar collateral ligament (UCL) reconstruction on former Major League Baseball (MLB) player Tommy John in 1974, the same procedure, known colloquially as "Tommy John" surgery, is a staple operative treatment for grade 1, 2, and 3 injuries of the UCL not amenable to nonoperative treatment in competitive athletes.[24,28] Between 2000 and 2017, UCL reconstructions in MLB players nearly doubled, increasing from approximately 20 per year to approximately 40 per year.[11] Perhaps even more alarmingly, in that same time frame, UCL surgeries increased from approximately 10 per year to nearly 140 per year in Minor League Baseball.[11] The incidence of UCL injuries and need for surgical reconstruction in competitive amateur baseball is also of concern, with nearly 1 procedure per team each year (0.86/team/year) in National Collegiate Athletic Association baseball (Divisions I, II, and III).[18,20,22,35] Mahure and colleagues extrapolated that between 2015 and 2025, the yearly rate of primary UCL reconstruction in patients 15 to 24 years of age would increase by >50%.[35]

The conventional method for UCL reconstruction involves use of an autologous palmaris longus graft.[10] As surgical techniques have been refined, complications, including injury to the ulnar nerve, have been reduced, while outcomes have improved.[33] One outcome of particular interest is the patient's ability to return to sport (RTS). Current RTS rates for primary UCL reconstructions range from 83% to 95%, with athletes competing at the same or higher levels of play.[9,15,16,20,31,38,39,45] In one of the largest case series currently published, by Cain and colleagues,[9] athletes were able to RTS at a mean of 11.6 months postoperatively. For MLB players specifically, the mean time to RTS was reported to be 16.8 months.[36]

While UCL reconstruction has been widely accepted and implemented for decades, UCL repair has only recently reentered clinical practice as a viable surgical technique.[18,19,29,41,46] Although once considered an option through the 1990s, UCL repair quickly declined in popularity due to less favorable outcomes when compared with UCL reconstruction.[6,14] In 1992, Conway and colleagues[14] compared RTS rates 12 months postoperatively and found that 68% of patients who underwent UCL reconstruction returned to sport at the same level of play or higher, while only 50% of patients who underwent UCL repair returned to sport. Similarly, in 2000, Azar and colleagues[6] reported that 81% of patients who underwent UCL reconstruction had successful RTS, as compared with 63% of those after UCL repair. However, in the early 2000s, surgeons began to reassess the clinical utility of UCL repair, after the demonstration by Argo and colleagues[4] of satisfactory outcomes in a small cohort of female athletes. Savoie and colleagues[46] demonstrated positive outcomes with a UCL repair technique using only suture anchors, reporting RTS within 6 months for 56 of 60 high school and collegiate athletes, the majority (85%) of whom competed in throwing sports. Dugas and colleagues[19] modified the repair procedure by augmenting the UCL repair with an internal brace. The addition of the internal brace created a valgus stress backstop and a biological scaffold for improved healing of the ligament. Biomechanical studies have demonstrated that the UCL repair with internal bracing possesses similar time-zero failure properties to those of the modified Jobe and docking UCL reconstruction techniques and increased resistance to gapping with cyclic/fatigue loading.[7,8,29] Dugas and colleagues[18] later reported on early outcomes of 111 overhead throwing athletes after UCL repair with internal brace at a minimum follow-up of 1 year, finding that 92% returned to the same or higher level of competitive sports at a mean of 6.7 months after surgery and with a mean Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow (KJOC) score of 88 out of 100 at follow-up.

Whereas these previous studies have examined complications and early outcomes after UCL repair with internal brace, to our knowledge, few (if any) previous studies have compared midterm outcomes between UCL repair and UCL reconstruction.[18,43,44] Our study compares clinical outcomes between competitive athletes who underwent UCL repair with internal brace augmentation and those who underwent UCL modified Jobe reconstruction with a minimum postoperative follow-up of 2 years. We hypothesized that athletes undergoing repair with internal bracing would demonstrate similar subsequent reoperation rates, similar proportions of successful return to preinjury sport, and shorter RTS time compared with those who underwent UCL reconstruction. We further hypothesized that elbow- and upper extremity–related function and residual ulnar nerve paresthesia symptoms would be similar between competitive athletes who underwent UCL repair versus those who underwent UCL reconstruction.

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METHODS

Patient Population

After institutional review board approval (Sterling IRB; No. 9503), we performed a Current Procedural Terminology code search using codes 24345 and 24346 at Andrews Sports Medicine and Orthopaedic Center in Birmingham, Alabama, to identify patients who had been operatively treated with a UCL reconstruction or UCL repair with internal brace during an 8-year period from June 11, 2013, to May 1, 2021, yielding 862 potentially eligible patients. We subsequently performed chart reviews of the electronic health record (EHR) for each potential participant. Inclusion criteria included the following: (1) documented UCL reconstruction or UCL repair with internal brace for UCL grade 1, 2, or 3 insufficiency that was not amenable to nonoperative treatment; (2) participants were at least 2 years postoperative from their UCL procedure; and (3) participants had been a competitive athlete at the time of their injury and subsequent surgical treatment. Exclusion criteria included the following: (1) history of ipsilateral elbow surgery before the primary/index UCL procedure; (2) UCL repairs without internal bracing; (3) age <15 or >45 years at the time of surgery; (4) concomitant intraoperative treatment of any of the following: elbow fracture, elbow osteochondritis dissecans lesion, and/or injury to an elbow ligament outside the UCL complex; or (5) absent or incomplete chart information. We did not exclude potential patients based on sex/gender, race/ethnicity, or level of athletic competition at the time of injury.

Demographics, Injury Characteristics, and Patient Evaluation

We performed chart reviews within the EHR for all eligible patients and collected data including patient information, injury details, sport-related information at the time of injury and surgery, intraoperative pathology and procedure details, and subsequent surgical history. Demographic data collected included date of birth, date of injury (defined as when pain first began and whether this date was exact or estimated by the patient), age at the time of surgery, sex, and body mass index. Sport-related information collected included whether the patient was an athlete or nonathlete at the time of injury, level of competition, sport(s), and position(s). Intraoperative pathology data collected included whether the UCL tear was partial or complete, as well as the location of tear. Additionally, we identified whether the native UCL was noted to be calcified, contained an ossicle, or had any other form of heterotopic ossification. Surgical procedure data collected included what UCL procedure was performed (reconstruction or repair with internal brace), graft source and type, whether an ulnar nerve transposition (UNT) or decompression was performed, and any other concomitant operative procedures performed during the index procedure. Subsequent surgical history was assessed via chart review and recorded for all patients before initial attempts for follow-up outcome data collection. Patients who underwent subsequent elbow surgeries were contacted to determine if the procedure was a complication or revision of the index UCL procedure. These patients were not included in the collection of patient-reported outcome (PRO) data.

Patient Selection for Surgery

Potential surgical candidates typically underwent initial nonoperative treatment after clinical confirmation of UCL insufficiency. Despite nonoperative efforts, including rest, rehabilitation, bracing, and, in selected cases, platelet-rich plasma injections, these patients were unable to resume sports and/or achieve sufficient symptomatic relief. For competitive athletes, determining failure of nonoperative treatment was case specific, influenced by factors such as the timing within their sport's season, the athlete's level of competition, and their response to early nonoperative care. UCL tears were confirmed in all cases through examination, including a positive milking maneuver and/or a moving valgus stress test, along with magnetic resonance imaging (MRI).[10,25] Our institution conducted MRI studies with intra-articular contrast, but in specific cases, patients were referred from outside providers with nonarthrographic MRI.

After UCL insufficiency was confirmed through clinical and radiographic evaluations, patients underwent a thorough assessment to determine the most appropriate surgical procedure for their individual needs. In order to be a candidate for repair, patients must have exhibited complete or partial avulsion of the UCL from the sublime tubercle or medial epicondyle. Furthermore, remaining UCL tissue was examined for intrasubstance signal, thickening, or degeneration, which might suggest poor tissue quality and serve as a relative contraindication to repair. In our initial experience, patient selection for UCL repair generally included athletes seeking faster RTS than UCL reconstruction typically allows. However, with increased procedural experience, this decision-making criterion became less stringent. In general, patients with perceived UCL tissue deficiency, including those with bony fragments in the UCL, were not considered candidates for UCL repair. Attritional ruptures with unhealthy-appearing tissue on MRI were also indications of inadequate tissue for repair. Patients preoperatively deemed eligible for repair were prepared for both repair and reconstruction, with the final decision for repair or reconstruction made during intraoperative examination of the UCL.

Operative Technique

Each index surgical procedure assessed in this study was performed similarly by 5 fellowship-trained sports medicine orthopaedic surgeons (J.R.D., E.L.C., B.A.E., M.A.R., and M.K.R.) at Andrews Sports Medicine and Orthopaedic Center in Birmingham, Alabama. The operative technique for UCL repair was performed utilizing a collagen-dipped internal brace (FiberTape; Arthrex), as previously described by Dugas and colleagues.[18] UCL reconstructions were performed using the modified Jobe technique as previously described by Azar and colleagues[6] and Cain and colleagues.[9,10]

Postoperative Rehabilitation

Full postoperative rehabilitation protocols for both UCL reconstruction and UCL repair have been previously described, each involving a structured protocol, with several defined phases, each with unique rehabilitative goals.[9,18,52] While each protocol worked toward regaining full range of motion, preventing muscle atrophy, and redeveloping upper extremity strength, the timeline of rehabilitation after UCL repair was accelerated compared with that after UCL reconstruction (approximately 2-3 weeks accelerated for range of motion progression, strengthening, and initiation of plyometrics; approximately 5 to 9 weeks accelerated for the initiation of an interval throwing program). For example, after UCL repair, the brace was mobilized at postoperative week 2, with patients allowed 0° to 145° of motion at postoperative week 4. In comparison, patients did not progress to 0° to 145° of motion until week 6 after UCL reconstruction. Athletes began the Thrower's Ten Program at postoperative week 6 after UCL repair versus postoperative week 8 after UCL reconstruction. Similarly, 2-hand plyometric drills and initial throwing were typically initiated at postoperative weeks 9 to 10 after UCL repair versus postoperative week 12 after UCL reconstruction. Lastly, interval throwing programs were typically initiated at postoperative week 11 after UCL repair as compared with postoperative weeks 16 to 20 after UCL reconstruction.

Subsequent Operative Procedures

For each potential participant who met preliminary inclusion criteria for this study, we assessed their EHR for any subsequent operations to the ipsilateral elbow. Those who were determined to have had a subsequent procedure met a primary outcome of our study (ie, having had a revision/subsequent procedure), and thus we did not collect PROs. Subsequent procedures were placed into one of the following categories: UCL revision, ulnar nerve (either transposition or decompression), intra-articular, or other procedure. All reoperations for patients who would otherwise be eligible for follow-up can be classified as grade 3 on the adapted Clavien-Dindo classification system as described by Sink et al.[48] In addition, we asked all patients whom we successfully followed up with if they had undergone any subsequent ipsilateral elbow procedures outside of our institution and to describe the reoperation, if applicable.

Baseline and Follow-up Patient-Reported and Return-to-Sport Outcomes

Three primary questionnaires were utilized to evaluate patient-reported elbow function at both baseline and follow-up: the American Shoulder and Elbow Surgeons Elbow assessment form (ASES-E), Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow (KJOC), and Andrews-Carson scores. The PRO portion of the ASES-E is a validated tool that assesses a patient's level of elbow pain and level of difficulty in completing a variety of tasks.[30] The ASES-E has pain and function subscores, scored from 0 to 100 and 0 to 36, respectively, with lower pain scores indicating lower (better) elbow-related pain and higher function scores indicating better elbow-related function.[30] Similarly, the KJOC is a validated questionnaire that is designed to assess function in athletes competing in overhead sports, scored from 0 (worst) to 100 (best).[1,21] Lastly, the Andrews-Carson score is a PRO tool designed to assess outcomes after elbow arthroscopy. Patients are asked to describe their current elbow symptoms through a series of multiple-choice questions, from which a numeric score is calculated, ranging from 0 (worst upper extremity function) to 100 (best upper extremity function).[3] Beginning in 2016, our institution prospectively enrolled patients in an outcome data repository (OBERD; Universal Research Solutions, LLC), collecting both baseline and follow-up (automated) questionnaires for those enrolled. For patients with UCL surgical procedures before 2016, baseline/presurgical questionnaire data were not collected. Follow-up outcome data were collected through the OBERD platform, with additional data obtained via telephone calls or survey links if needed. Study data were gathered and managed using REDCap, an electronic data capture tool hosted at The American Sports Medicine Institute and Ascension St. Vincent's.[26,27] During follow-up, we also collected additional data, including (1) the Patient Rated Ulnar Nerve Evaluation (PRUNE) questionnaire sensorimotor subscore; (2) questions related to preoperative and postoperative sports participation, level of competition, and RTS success/timing; and (3) questions related to subsequent ipsilateral elbow surgeries at outside institutions.[34] RTS was defined as the date when the athlete returned to team practice. For baseball pitchers specifically, return to practice was determined as the date when they first participated in throwing off of a mound during team practice. Return to competition was defined as the date when the athlete returned to competition against other teams. For both return to practice and return to competition, athletes were asked to provide the specific dates they returned to practice and competition during the follow-up survey. These dates were then used to calculate the return time for both practice and competition from the date of their surgery. This information was collected directly from the athletes during follow-up data collection and was based on their actual participation dates rather than dates when they were medically cleared in the EHR. The sensorimotor subscore of the PRUNE survey assesses the patient's current sensorimotor symptoms, and patients are assigned a score between 0 (no symptoms) and 40 (most symptoms).[34]

Statistical Analysis

We calculated summary statistics for patient, injury, surgical, and outcome data within both the UCL repair and reconstruction groups. We compared key demographic, injury, and surgical data between UCL repair and reconstruction groups using independent t tests for continuous variables and chi-square tests for categorical data. For outcome data, we used linear regression modeling, controlling for group differences in follow-up time, to compare patient-reported function measures (ASES-E, KJOC, Andrews-Carson, and PRUNE scores) between groups. Regarding RTS, we summarized the proportions that returned to preinjury sport and reasons for the inability to return and compared the proportions of successful return to preinjury sport between groups using a chi-square test. To examine clinically relevant subgroups, we summarized outcome data within baseball athletes only and in athletes participating at the high school or collegiate level and compared these between repair and reconstruction groups using independent *t* tests and chi-square tests for patient-reported function measures and RTS, respectively. We further compared outcomes between surgical types (ie, repair and reconstruction) in subgroups of those with partial UCL tears only and those with complete UCL tears only, using independent *t* tests and chi-square tests for patient-reported function measures and RTS, respectively. Lastly, within those with baseline questionnaire data, we calculated effect sizes (Cohen *d*) for the magnitude of change within each group and compared the amount of change between groups using linear regression modeling with presurgery scores and follow-up time as the covariates and follow-up scores as the dependent variable. For all analyses, we considered *P* values <.05 to be statistically significant. All statistical analyses were performed using SPSS Version 28.0 (IBM Corp).

RESULTS

A total of 862 patients who underwent either UCL reconstruction or UCL repair were identified from the billing code database search (Figure 1). From these 862 patients, 210 patients were excluded for the following reasons: nonathlete at the time of injury/surgery, history of ipsilateral elbow surgery before the index UCL procedure, UCL repair performed without an internal brace, age <15 or >45 years at the time of the index procedure, subsequent ipsilateral shoulder surgery after the index UCL procedure, nonworking contact information, or other reasons (Figure 1). From the remaining 652 eligible athletes, we successfully collected either PRO data (for those without subsequent elbow procedures) or elbow reoperation data in 461 athletes (71% of total eligible patients; mean age at surgery, 19.1 years; 92% male) (Figure 1). Overall proportions of successful follow-up were similar between the UCL repair and UCL reconstruction groups (UCL repair, 70%; UCL reconstruction, 72%). For those with PRO data and without subsequent elbow reoperations (n = 423; mean follow-up time, 5.1 ± 2.3 years), 268 (63%) had UCL repair with internal brace and 155 (37%) had UCL reconstruction (Table 1). Athletes with successful follow-up for PRO data collection (n = 423) did not differ from athletes with unsuccessful follow-up (n = 191) in age (successful follow-up, 19.0 ± 2.9 years; unsuccessful follow-up, 19.0 ± 2.6 years; *P* = .69), sex distribution (successful follow-up, 93% male; unsuccessful follow-up, 93% male; *P* = .84), or proportions of UCL repair with internal brace versus

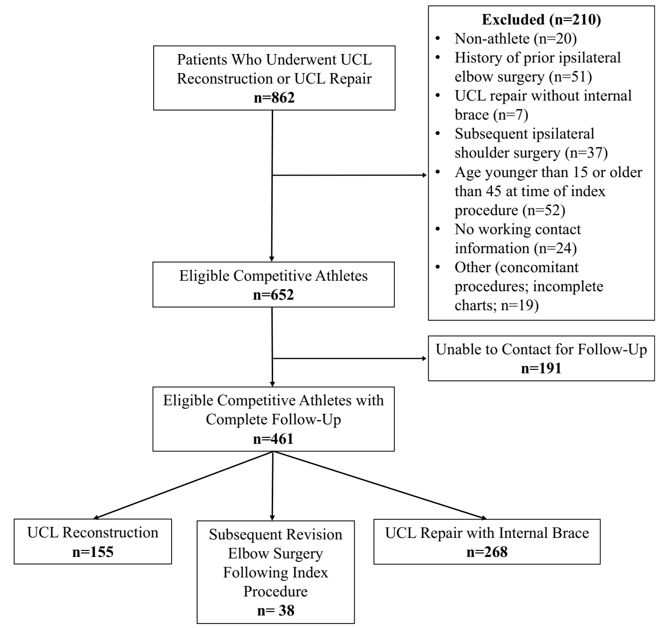

Figure 1. Inclusion and exclusion criteria. UCL, ulnar collateral ligament.

UCL reconstruction (successful follow-up, 63% UCL repair; unsuccessful follow-up, 62% UCL repair; *P* = .81).

Subsequent Operative Procedures and Categories With Proportions

A total of 38 subsequent reoperations were identified among the included cohort of 461 UCL procedures (8% total), with only 9 (2%) being UCL revision procedures. Of the 38 reoperations, 25 (25/293; 9%) were performed after primary UCL repair with internal brace and 13 (13/168; 8%) were performed after primary UCL reconstruction. For those with reoperations after UCL repair with internal brace (n = 25), the corresponding categories and proportions were as follows: 4 (16%) were UCL revisions, 4 (16%) were ulnar nerve decompressions, 15 (60%) were UNTs, 2 (8%) were classified as other, and none were performed to address intra-articular pathology. For those with reoperations after UCL reconstruction (n = 13), the corresponding categories and proportions were as follows: 6 (46%) were UCL revisions, 1 (8%) was an ulnar nerve decompression, 4 (31%) were UNTs, 1 (8%) was classified as other, and 1 (8%) was to address intra-articular pathology. There were no statistical differences in the proportions of subsequent elbow procedures between the UCL repair with internal brace and UCL reconstruction groups (*P* = .77).

Included Cohort Characteristics

For those with PRO data and no subsequent reoperations (n = 423), demographic, injury, and surgery data are shown in Table 1 by UCL procedure group. The groups did not

TABLE 1
Patient, Injury, and Surgery Data and Comparisons Between Groups[a]

Variable	Repair Group (n = 268)	Reconstruction Group (n = 155)	*P* Value
Age at surgery, y	18.8 ± 2.7	19.4 ± 3.1	.06[b]
Follow-up time, y	4.4 ± 1.9	6.3 ± 2.5	<.01[b]
Sex distribution			.07[c]
Female	23 (8.6)	6 (3.9)	
Male	245 (91.4)	149 (96.1)	
Primary sport at time of injury			
Baseball	216 (80.6)	137 (88.4)	
American football	20 (7.5)	4 (2.6)	
Softball	11 (4.1)	2 (1.3)	
Track and field	7 (2.6)	6 (3.9)	
Gymnastics	4 (1.5)	1 (0.6)	
Wrestling	1 (0.4)	2 (1.3)	
Basketball	1 (0.4)	1 (0.6)	
Cheerleading	5 (1.9)	0	
Other	3 (1.1)	2 (1.3)	
Level of competition at time of injury			
Professional	7 (2.6)	5 (3.2)	
Collegiate	107 (39.9)	82 (52.9)	
High school	144 (53.7)	65 (41.9)	
Club/travel	8 (3.0)	2 (1.3)	
Adult recreational	2 (0.7)	0	
Youth recreational	0	1 (0.6)	
UCL tear grade			<.01[c]
Complete	49 (18.3)	63 (40.6)	
Partial	207 (76.1)	86 (55.5)	
Insufficiency/ossicle	1 (0.4)	1 (0.6)	
Not reported	11 (4.1)	5 (3.2)	
Ulnar nerve transposition			<.01[c]
Yes	162 (60.4)	148 (95.5)	
Decompression	106 (39.6)	7 (4.5)	
Osteophyte excision			.99[c]
Yes	19 (7.1)	11 (7.1)	
No	249 (92.9)	144 (92.9)	

[a]Data are presented as n (%) or mean ± SD. UCL, ulnar collateral ligament.
[b]Comparison with independent *t* test.
[c]Comparison with chi-square test.

significantly differ in age or sex distribution, but the UCL repair group had a shorter follow-up time than the UCL reconstruction group (Table 1). Table 1 also shows the primary sport at the time of UCL injury and level of competition for both groups. The most common primary sport at the time of surgery was baseball in both groups. Within the UCL repair group, the majority of athletes competed at the high school level (54%), with the next highest proportion competing at the collegiate level (40%). Within the UCL reconstruction group, the majority of athletes competed at the collegiate level (53%), with the next highest proportion competing at the high school level (42%). There was a significantly higher proportion of partial UCL tears and a significantly lower proportion of complete UCL tears in the UCL with internal brace group when compared with the UCL reconstruction group ($P < .01$) (Table 1). Additionally, within the UCL repair group, there was a significantly lower proportion of concomitant UNTs when compared with the UCL reconstruction group ($P < .01$) (Table 1). There were no significant differences between groups in the proportions of concomitant osteophyte excisions (Table 1).

Patient-Reported Outcomes

PRO-related data are shown in Table 2. We controlled for differences in follow-up time when comparing PROs between groups. After controlling for follow-up time, the groups did not differ in ASES-E, KJOC, Andrews-Carson, or PRUNE scores at follow-up (Table 2). Of the 268 athletes in the repair group, 247 attempted to return to their preinjury level of sport. Among the 247 that attempted to return, 241 (98%) were able to return to their preinjury level of sport. Only 6 athletes were unable to return due to limitations from their UCL repair. Of the 155 athletes in the reconstruction group, 147 attempted to return to their preinjury level of sport. Among the 147 who attempted to return, 145 (99%) were able to return to their preinjury level of sport, with 2 athletes unable to return due to limitations from their UCL reconstruction. Reasons for the

TABLE 2
Patient-Reported and Return-to-Sport Outcomes Between Groups[a]

Variable	Repair Group (n = 268)	Reconstruction Group (n = 155)	*P* Value
ASES-E function score at follow-up[b]	35.3 ± 2.3	35.6 ± 1.2	.14[g]
ASES-E pain score at follow-up[c]	3.4 ± 11.2	1.8 ± 7.2	.17[g]
KJOC score at follow-up[d]	84.5 ± 18.8	86.1 ± 15.8	.41[g]
AC score at follow-up[e]	90.3 ± 13.3	92.5 ± 11.6	.34[g]
PRUNE score at follow-up[f]	2.1 ± 4.6	2.2 ± 4.8	.77[g]
Overall proportion of athletes who returned to preinjury level of sport, % (n)	89.9 (241/268)	93.5 (145/155)	.20[h]
Reasons for not returning to preinjury sport, n			
Graduated and not talented enough for next level	11/27	4/10	
Limited by their UCL surgery	6/27	2/10	
Personal reasons or decreased interest	5/27	3/10	
Other	5/27	1/10	
Proportion of athletes able to return to preinjury level of sport who attempted to return after surgery % (n)	97.6 (241/247)[i]	98.6 (145/147)[j]	
Time to return to practice, mo	6.7 ± 3.5	10.2 ± 11.7	<.01[k]
Time to return to competition, mo	9.2 ± 4.6	13.4 ± 13.3	<.01[k]

[a]Data are presented as mean ± SD unless otherwise indicated. AC, Andrews-Carson; ASES-E, American Shoulder and Elbow Surgeons Elbow assessment form; KJOC, Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow; PRUNE, Patient Rated Ulnar Nerve Evaluation; UCL, ulnar collateral ligament.
[b]Out of 36; 36 = best elbow-related function.
[c]Out of 100; 0 = best/lowest elbow-related pain.
[d]Out of 100; 100 = best elbow-related function.
[e]Out of 100; 100 = best elbow-related function.
[f]Out of 40; 0 no ulnar nerve–related symptoms.
[g]Comparison with linear regression (group as independent variable; controlling for follow-up time).
[h]Comparison with chi-square test.
[i]A total of 22 athletes in the repair group did not attempt to return to sport.
[j]Eight athletes in the reconstruction group did not attempt to return to sport.
[k]Comparison with independent *t* test.

inability to RTS are also shown in Table 2. The 2 groups did not statistically differ in the proportions that returned to sport. Athletes who underwent UCL repair reported statistically significant decreases in time from surgery to return to practice and return to competition when compared with athletes who underwent UCL reconstruction (Table 2).

Subgroup Comparisons

Table 3 demonstrates PRO data within competitive baseball athletes only (n = 353), as well as stratified by baseball athletes participating at the high school or collegiate level. Within baseball athletes only, UCL repair and reconstruction groups did not differ in any outcome measure across the entire sample, as well as within high school and collegiate athletes (Table 3).

Across the entire cohort of athletes with partial UCL tears (n = 293), there were 207 in the UCL repair group and 86 in the UCL reconstruction group. Within those with partial tears (n = 293), there were no differences in any of the PRO measures (ASES-E, KJOC, and Andrews-Carson scores) at follow-up or in the proportions able to return to preinjury sport between those who underwent UCL repair and those who underwent UCL reconstruction (all $P > .26$). Additionally, across the entire cohort of athletes with complete UCL tears (n = 112), there were 49 in the UCL repair group and 63 in the UCL reconstruction group. Within those with complete UCL tears (n = 112), there were no differences in any of the PRO measures (ASES-E, KJOC, and Andrews-Carson scores) at follow-up or in the proportions able to return to preinjury sport between those who underwent UCL repair and UCL reconstruction (all $P > .13$).

Baseline to Follow-Up Questionnaire Data Comparisons

For those with follow-up data, baseline (presurgical) questionnaire data were also collected in 221 athletes with UCL repair with internal brace and 69 athletes with UCL reconstruction. Table 4 shows baseline and follow-up questionnaire data within each group. Within both groups, large effect sizes (all $d > 1.2$) were observed for baseline to follow-up improvements for each questionnaire (Table 4). The amount of change did not differ between groups for any questionnaire (Table 4).

DISCUSSION

As UCL repair with internal brace has become established as a viable procedure for treating UCL injuries, direct

TABLE 3
Outcome Data in Baseball Athletes Only (n = 353), Stratified by Level of Competition[a]

Variable	Repair Group (n = 216)	Reconstruction Group (n = 137)	*P* Value
ASES-E function score[b]			
Overall	35.5 ± 1.3	35.7 ± 1.0	.27
HS	35.6 ± 0.9	35.7 ± 0.7	.43
Collegiate	35.3 ± 1.8	35.7 ± 1.1	.13
ASES-E pain score[c]			
Overall	1.1 ± 3.8	0.7 ± 3.4	.35
HS	1.0 ± 3.8	0.8 ± 3.3	.73
Collegiate	1.3 ± 4.1	0.3 ± 1.6	.33
KJOC score[d]			
Overall	86.5 ± 17.0	86.5 ± 15.7	.97
HS	87.1 ± 14.5	89.4 ± 12.8	.31
Collegiate	85.6 ± 20.2	85.8 ± 15.8	.93
AC score[e]			
Overall	91.9 ± 11.1	93.4 ± 9.9	.22
HS	91.7 ± 11.4	94.4 ± 9.5	.13
Collegiate	91.9 ± 10.9	92.8 ± 9.9	.56
Proportion of athletes able to return to preinjury level of sport who attempted to return after surgery, % (n)	96.6 (199/206)[f]	98.5 (128/130)[g]	.65

[a]Data are presented as mean ± SD unless otherwise indicated. In the repair group, there were 109 high school athletes and 94 collegiate athletes. In the reconstruction group, there were 54 high school athletes and 76 collegiate athletes. AC, Andrews-Carson; ASES-E, American Shoulder and Elbow Surgeons Elbow assessment form; HS, high school; KJOC, Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow.
[b]Out of 36; 36 = best elbow-related function.
[c]Out of 100; 0 = best/lowest elbow-related pain.
[d]Out of 100; 100 = best elbow-related function.
[e]Out of 100; 100 = best elbow-related function.
[f]Ten baseball athletes in the repair group did not attempt to return to sport.
[g]Seven baseball athletes in the reconstruction group did not attempt to return to sport.

comparisons of clinical outcomes between UCL repair with internal brace and more traditional UCL reconstructions are sparse. In this study, we demonstrated that UCL repair with internal brace performed equivalently to UCL reconstruction in competitive athletes, with both procedures offering excellent functional outcomes, including similar changes in baseline to postoperative PRO scores, success in RTS, and similarly low proportions of revisions and reoperations. Furthermore, we demonstrated that UCL repair with internal brace offers a faster RTS timeline for athletes whose injury is amenable to repair. In light of the increasing rate of UCL injuries in overhead athletes, this emphasizes the urgency for optimized surgical interventions tailored to an athlete's unique needs and underscores the significance of our findings.

For athletes in our cohort undergoing primary UCL reconstruction, we found the mean ASES-E function score to be 35.6 out of a maximum (best) score of 36, the mean ASES-pain score to be 1.8 out of 100 (with 0 indicating no pain), the mean KJOC score to be 86.1 (best/maximum score: 100), and the mean Andrews-Carson score to be 92.5 (best/maximum score: 100). These scores are similar to or higher than PRO scores reported by cohorts of competitive athletes throughout the literature after UCL reconstruction.[5,20,17,32,44] Taken together, athletes can expect to regain a high level of elbow-related function after primary UCL reconstruction. In athletes who underwent primary UCL repair with internal brace augmentation in our cohort, the mean ASES-E function scores was 35.3, the mean ASES-pain score was 3.4, the mean KJOC score was 84.4, and the mean Andrews-Carson score was 90.3. Similar to our findings, a smaller previous study enrolled 111 athletes to evaluate outcomes after repair with internal brace and reported mean KJOC scores of 86.2 at 1 year postoperatively and 91.1 at 2 years postoperatively.[18] Another similar study reported a mean KJOC score of 92.6 in their UCL repair cohort, with a mean follow-up time of 23.8 months.[37] In the current study, no significant differences in ASES-E, KJOC, or Andrews-Carson scores were found between athletes who underwent UCL reconstruction versus UCL repair with internal brace. This is consistent with previous studies comparing UCL reconstruction and UCL repair finding no difference in ASES score or RTS rates between the 2 procedures.[44] Additionally, when examining outcomes within baseball athletes only, as well as stratified by level of competition (high school or collegiate), we similarly found no differences in outcomes between UCL procedures. While there are less data available regarding outcomes of UCL repair than more traditional UCL reconstruction, the data presented herein show that outcomes after UCL repair are comparable to those of UCL reconstruction when performed in a patient whose injury is amenable to repair. Importantly, these outcomes may not be replicated in athletes whose injury is better suited to surgical reconstruction, and we believe correct identification of athletes indicated for UCL repair is critical.

TABLE 4
Baseline to Follow-Up Patient-Reported Outcome Data Between Groups[a]

Variable	Repair Group (n = 221)	Reconstruction Group (n = 69)	*P* Value[f]
ASES-E function score[b]			.56
Baseline	28.4 ± 5.3	28.9 ± 3.9	
Follow-up	35.4 ± 2.1	35.7 ± 1.0	
Effect size (*d*)	1.3	1.6	
ASES-E pain score[c]			.39
Baseline	35.8 ± 19.7	34.0 ± 16.9	
Follow-up	2.9 ± 10.2	1.1 ± 7.0	
Effect size (*d*)	1.6	1.6	
KJOC score[d]			.27
Baseline	45.6 ± 15.8	49.9 ± 16.5	
Follow-up	85.1 ± 17.4	89.9 ± 12.9	
Effect size (*d*)	1.9	2.1	
AC score[e]			.48
Baseline	69.4 ± 16.6	64.4 ± 19.9	
Follow-up	91.3 ± 11.8	93.4 ± 11.4	
Effect size (*d*)	1.2	1.4	

[a]Data are presented as mean ± SD unless otherwise indicated. Baseline data were collected before ulnar collateral ligament procedures in a subset of athletes.
[b]Out of 36; 36 = best elbow-related function.
[c]Out of 100; 0 = best/lowest elbow-related pain.
[d]Out of 100; 100 = best elbow-related function.
[e]Out of 100; 100 = best elbow-related function.
[f]The *P* values were calculated using linear regression modeling with presurgery scores and follow-up time as the covariates, follow-up scores as the dependent variable, and group as the independent variable.

Upon analysis of our patient population of athletes with UCL surgeries, we found significant heterogeneity in those who underwent UCL repair with internal brace versus UCL reconstruction. The repair cohort contained significantly more partial UCL tears, due to the necessity of superior tissue integrity for repair procedures, as previously described in the literature.[18] The reconstruction group, conversely, encompassed a wider range of injury severity, including a greater number of complete UCL tears, reaffirming the tendency to reserve reconstruction for cases in which UCL tissue is substantially compromised. We posit that tissue quality is a primary indicator for the appropriateness of repair, rather than the injury's location or the extent of the tear as observed through imaging or during surgery, which is supported by findings from Dugas and colleagues.[18] In cases in which MRI suggests tissue deficiency or intraoperative assessment reveals poor tissue quality, reconstruction remains the preferred option given its established success and low complication rates in long-term follow-up.[9,44] Given the challenges in preoperative assessment of tissue quality via MRI alone, we deem it necessary to preoperatively prepare athletes for both UCL reconstruction and repair, making the final decision based on intraoperative evaluation.[18,43] This practice necessitates a thorough discussion regarding the potential for either procedure, ensuring their informed consent and willingness for the associated postoperative rehabilitation and relevant RTS process. Furthermore, athlete preferences and the seasonality of their sport play crucial roles in the surgical decision-making process. For athletes with more extended periods available for recovery, reconstruction might be more suitable, given its well-documented long-term success. Conversely, athletes under time constraints to RTS, such as those progressing to higher competitive levels or facing injuries late in the season, may favor the potential shorter rehabilitation timeline associated with UCL repair, provided they meet other criteria, like possessing good tissue quality. However, the comparable outcomes between cohorts demonstrate that despite differences in injury characteristics, similar satisfactory outcomes can be reasonably expected, regardless of tear type and UCL procedure. Indeed, our subgroup findings in those with only partial UCL tears or only complete UCL tears showed no differences in PRO measures between those who underwent UCL repair and those who underwent UCL reconstruction.

In our study, the vast majority of athletes (98%) who attempted to RTS were able to return at their same level of play or higher after UCL repair, with only 2% reporting limitations from surgery hindering their return. Similarly, 99% of athletes who attempted return were successful after UCL reconstruction, with 1% reporting limitations from surgery. When considering all reasons for the inability to return to preinjury sport (including lack of talent to move to the next level and decreased interest as examples), 90% of those who underwent UCL repair returned and 94% of those who underwent UCL reconstruction returned. A large proportion of athletes who underwent UCL repair competed at the high school level, which limited the number of opportunities for players to continue competing at the same level or higher due to graduation. In comparison, nonoperative treatment of UCL insufficiency allows less than half of athletes to return to their previous level of competition, with meta-analysis of nonoperative treatments demonstrating an overall return-to-play rate of 79.7%; indicating that operative treatment is likely ideal for high-level athletes returning to competition.[24,42] After UCL reconstruction, previous meta-analyses found that between 86% and 89% of athletes are able to RTS at a mean of 12.2 months postoperatively.[12,20] However, in baseball athletes, the proportion who return to play at the same level of competition is lower than total proportion who returned to play at any level.[40] In the largest cohort described in a single study, Cain and colleagues[9] previously reported that 83% of athletes competing in a variety of sports returned to their preinjury sport after primary UCL reconstruction, including a large proportion of baseball players. Our study further demonstrated that when the appropriate surgical treatment was selected, there were no significant differences in an athlete's ability to return to preinjury sport between UCL repair with internal brace and UCL reconstruction. Related to the timing of RTS, previous work by Cain and colleagues[9] reported a mean RTS time of 11.6 months after UCL reconstruction, compared with Dugas and colleagues[18] reporting a mean RTS time of 6.7 months after repair. In our current comparative study, we observed a mean RTS time of 10.2 ± 11.7 months for UCL reconstruction, with a significantly shorter RTS time of 6.7 ± 3.5 months for UCL repairs with internal brace. Other studies evaluating UCL repair with internal brace report similarly accelerated RTS, with a mean time to return of approximately 7 to 7.5 months.[37,44] The notably accelerated time to successful RTS after UCL repair with internal brace offers a competitive advantage for athletes whose UCL injury is amenable to repair. Adolescent pitchers are more commonly evaluated with high-grade partial UCL tears, making implementation of UCL repair in this demographic group of clinical interest.[23,41]

In the current study, we observed an overall reoperation rate of 8% after UCL reconstruction, with further surgical treatment most commonly needed for subsequent UCL revision (6/13 procedures) and UNT (5/13). Similarly, we found a comparable rate of reoperations after UCL repair, with 9% of patients requiring reoperation, and the most common procedures being ulnar nerve decompressions (4/25 procedures) and UNT (15/25 procedures). Previous studies, including meta-analyses, have reported complication rates after primary UCL reconstruction ranging from approximately 10% to 20%, with self-resolving ulnar neurapraxia described as the most common, and osteophyte excision the most common reason for reoperation.[9,20,33] Previous studies evaluating UCL repair with internal brace report a complication rate ranging from approximately 5% to 12%, with approximately 3% requiring reoperation.[18,43] In these cases, the most common reoperation was for ulnar nerve exploration or decompression.[18,43] In both groups, procedures to address the ulnar nerve represented a large proportion of reoperations, but a small proportion of total patients. Previous meta-analyses have found that between 6% and 12% of patients will experience some form of postoperative ulnar nerve complication after reconstruction, with higher rates of involvement after procedures incorporating UNT.[13,49] Indeed, ulnar nerve paresthesia resolving with time occurred in approximately 8% of patients and medial elbow pain occurred in approximately 3% of patients.[43] Notably, our low PRUNE scores, a measure of ulnar nerve–related pain and function, in both the repair and reconstruction groups suggest that both procedures have low rates of chronic ulnar nerve symptoms, and that the majority of athletes do not have lasting ulnar nerve symptoms or require subsequent operation.[34]

Limitations

Our study is subject to several limitations that warrant consideration. First, athletes in the included cohort may be subject to selection bias. The athletes who successfully completed follow-up may not represent the broader population of patients who underwent these procedures. However, we did not find differences in key demographic measures between athletes for whom we completed follow-up data collection and those for whom we did not. Second, the lack of in-clinic evaluations limits our ability to make objective assessments of clinical outcomes. Instead, our data only include PRO measures, which can be affected by recall bias, especially concerning RTS, RTS timing, and the perceived quality of their return, and are a key limitation of the present study. We acknowledge this limitation, and future studies examining outcomes among UCL procedures should strive to incorporate objective measures, such as postoperative MRI studies or clinical physical evaluations (including elbow stability, range of motion, and strength measurements), to further validate and complement the findings of our study. Third, the overrepresentation of male athletes in our study compared with female athletes may limit the generalizability of our findings. However, UCL injuries are significantly more common in males than females, likely because of the predominance of male athletes playing baseball.[51] The quality of rehabilitation, which is a crucial component of successful postoperative recovery, was not uniformly controlled or reported in our study. This variable, essential for a successful return to play, could significantly affect the outcomes we reported and could have differed between the UCL repair with internal brace and UCL reconstruction groups. These factors, along with other limitations in comparing RTS metrics among existing literature, as noted by van der List and colleagues[50] and Anderson and colleagues,[2] underscore the need for increased validation and consistency in reporting outcomes in this domain. Lastly, the outcomes described here are the product of 1 institution, with similarly trained surgeons performing both UCL repair and reconstruction with identical techniques. Additionally, our cohort includes a vast majority of baseball athletes as well as athletes participating at the high school and collegiate level, with few professional athletes. These results may not be generalizable to patients whose surgeon performed the procedure with variations in operative technique or to athletes in other sports or at higher levels of competition (eg, professional). Of particular interest is the potential for overtightening of the UCL repair, for which in vitro studies have suggested that overtightening changes kinematics and biomechanics at time zero.[47] Future research should aim to address these limitations by including more objective outcome clinical measures and, if possible, improving the balance representation of sexes, to enhance the generalizability of the results. Additionally, given the observational and retrospective nature of the current study, future research should evaluate randomized surgical intervention of UCL injuries, as well as outcomes of these procedures by surgeons trained outside our institution.

CONCLUSION

UCL repair with internal brace augmentation shows significant promise, yielding results comparable to the established UCL reconstruction in terms of RTS success, PROs, and complication/reoperation rates. While long-term studies on UCL repair are pending given its relative novelty, our findings support its efficacy in the short to midterm. However, these outcomes are reliant on individualized surgical selection for each athlete, to optimize their treatment success.

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