Ulnar Collateral Ligament Reconstruction

The Rush Experience

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Background: Ulnar collateral ligament reconstruction (UCLR) is a common surgery performed in professional, collegiate, and high school athletes.

Purpose: To report patient demographics, surgical techniques, and outcomes of all UCLRs performed at a single institution from 2004 to 2014.

Study Design: Case series; Level of evidence, 4.

Methods: All patients who underwent UCLR from January 1, 2004, through December 31, 2014, at a single institution were identified. Charts were reviewed to determine patient age, sex, date of surgery, sport played, athletic level, surgical technique, graft type, and complications. Data were collected prospectively, and patients were contacted via phone calls to obtain the return-to-sport rate, Conway-Jobe score, Andrews-Timmerman score, and Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow score. Continuous variable data were reported as weighted means, and categorical variable data were reported as frequencies with percentages.

Results: A total of 187 patients (188 elbows) underwent UCLR during the study period (92% male; mean age, 19.6 ± 4.7 years; 78.2% right elbows). There were 165 baseball players (87.8% of all patients), 155 of whom were pitchers (82.5% of all patients). Ninety-seven (51.6%) were college athletes, 68 (36.2%) high school athletes, and 7 (3.7%) professional athletes at the time of surgery. The docking technique was used in 110 (58.5%) patients while the double-docking technique was used in 78 (41.5%). An ipsilateral palmaris longus graft was used in 110 (58.5%) patients while a hamstring autograft was used in 48 (25.5%) patients. The ulnar nerve was subcutaneously transposed in 79 (42%) patients. Clinical follow-up data were available on 85 patients. Mean follow-up was 60 ± 30.8 months. Overall, 94.1% of patients were able to return to sport and had a Conway-Jobe score of good/excellent while 4.3% had a score of fair. The mean KJOC score was 90.4 ± 6.7 and mean Andrews-Timmerman score was 92.5 ± 7.1. Subsequent surgeries were performed in 5.3% of patients.

Conclusion: UCLR was performed most commonly on collegiate athletes using an ipsilateral palmaris longus graft. Overall, 94.1% of patients who underwent UCLR were able to return to sport with a mean KJOC score of 90.4 and Andrews-Timmerman Score of 92.5.

Keywords: ulnar collateral ligament reconstruction (UCLR); Tommy John; elbow; pitcher; baseball; injury; surgical treatment

Ulnar collateral ligament reconstruction (UCLR), commonly known as Tommy John surgery, was first described by Dr Frank Jobe in the 1980s.[18] The goal of the surgery is to restore the function of a damaged ulnar collateral ligament (UCL) in a patient with a symptomatic, deficient UCL.[4] Since Dr Jobe's initial description of the procedure, several modifications have been made to the surgical technique, including different ways to expose the UCL, different graft types, and different fixation methods of the graft to the medial epicondyle and sublime tubercle of the ulna.[1-3,5,14-16,20,25] Clinical outcome data are not available for every technique modification, although the results of several techniques have been encouraging.[3,5] Dines et al[5] reported on 22 patients who underwent UCLR using the DANE-TJ technique and found that 19 of 22 patients had excellent results using the Modified Conway Scale. Similarly, Cain et al,[3] in the largest outcome study to date, reported on 743 patients who underwent UCLR with the American Sports Medicine Institute (ASMI) modification of the Jobe technique and found that 83% returned to their previous level of activity.[3]

The UCL is an essential structure of the pitcher's elbow. When a player throws a pitch, tremendous force is placed through the UCL, specifically during the late cocking and

acceleration phases.[12] The UCL is made up of 3 bundles: anterior, posterior, and transverse.[21] Of these 3, the anterior bundle, more specifically the posterior band of the anterior bundle, is the most important bundle at higher degrees of flexion, and therefore, the most important part of the UCL in overhead athletes.[22] The goal of UCLR is to reestablish a functional anterior bundle of the UCL to allow these athletes to return to their preinjury level of competition. The technique described by Dr Jobe, as well as the published modifications, have succeeded in this aim.[3,17-19]

The purpose of this study was to review all of the UCLRs performed at a single institution between January 2004 and July 2014 and report the patient demographics, clinical outcomes, return to sport rate, and complications.

METHODS

After institutional review board approval (IRB approval number, 14051905-IRB01), the surgical database of a single group practice was reviewed from January 1, 2004 through December 31, 2014 to determine how many patients underwent UCLR by 1 of 8 sports, shoulder/elbow, or hand fellowship–trained surgeons. A start date of January 1, 2004, was chosen as this was when our practice moved to an electronic medical record. Surgical data were prospectively collected, although no subjective data were obtained prior to surgery. All patients underwent a standard series of elbow radiographs (anteroposterior, lateral, oblique) as well as either magnetic resonance imaging (MRI) or magnetic resonance arthrogram (MRA) examinations to confirm the diagnosis of a UCL tear. The accepted current procedural terminology (CPT) for UCLR (24346) was used to search the database. CPT code 24346 is defined as: "Reconstruction medial collateral ligament, elbow, with tendon graft (includes harvesting of graft)." A total of 187 patients (188 elbows) were identified. The electronic charts of patients who underwent UCLR were reviewed to determine patient age both at surgery and current age, sex, hand dominance, presence or absence of preoperative ulnar nerve symptoms, presence or absence of a preoperative milking maneuver or moving valgus stress test, prior elbow surgeries, date of surgery, elbow injured (right vs left), traumatic or atraumatic injury, whether the surgery was performed on the dominant or nondominant arm, sport played (if any), level of sport played (high school, collegiate, professional, recreational), surgical technique, whether an

TABLE 1
Preoperative History and Physical Examination Findings on All Patients Who Underwent UCLR From 2004 to 2014[a]

	n (%)
Traumatic injury	92 (48.90)
Nontraumatic injury	96 (51.10)
Preoperative ulnar nerve symptoms	70 (37.20)
Preoperative Tinel sign at the elbow	44 (23.40)
Preoperative numbness/paresthesia in hand	43 (22.90)
Preoperative ulnar nerve subluxation	8 (4.30)
Preoperative milking maneuver	104 (55.30)
Preoperative valgus stress test	29 (15.40)
Preoperative moving valgus stress test	117 (62.20)
Preoperative valgus extension overload test	1 (0.50)
Prior elbow surgeries	5 (2.70)

[a]UCLR, ulnar collateral ligament reconstruction.

arthroscopy and/or ulnar nerve transposition was performed concomitant with the UCLR, graft type, and complications.

Patient charts and operative notes were reviewed to obtain the surgical technique and graft used, as well as any reports of intraoperative or postoperative complications. Physical examination findings and history of injury were identified in preoperative office notes and are shown in Table 1. Postoperative physical examination was not performed, nor was imaging obtained at final follow-up. Patients with working phone numbers on file who were more than 18 months out from surgery were then contacted via phone calls. Patients were asked about their ability to return to sport, their function on return to sport (the same, better, or worse than prior to surgery), and any complications experienced. The following scores were obtained through questioning: Conway-Jobe score, Andrews-Timmerman score, and Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow score. The KJOC score is typically administered in person where the respondent places an "x" on a line that is 10 cm long. The examiner then measures the distance from the far left of the scale (which is 0) to the mark and records this distance to the nearest millimeter. This is then translated to centimeters (75 mm would be a score of 7.5) and the scores from all questions are added up. As patients were contacted via phone calls and not brought back for these surveys, the patients were asked to quantify their answers from 0 to 100, and the answer was

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divided by 10 to get the score for each question (an answer of 85 would be a score of 8.5). The lead author (B.J.E.) personally made each phone call and administered the questionnaire to each patient, so there was no variability in the way the questions were asked from patient to patient.

Surgical Technique

All patients in this cohort underwent UCLR using either the standard docking (111 elbows) or double-docking (77 elbows) technique. Although some techniques call for routine elbow arthroscopy, we do not routinely perform an arthroscopic examination unless concomitant pathology that is clinically relevant exists and is amenable to arthroscopic treatment. Similarly, we do not routinely transpose the ulnar nerve unless the patient is having preoperative ulnar nerve symptoms. To begin, the graft is harvested, or, if an allograft is used, prepared. The most common graft for the authors is the ipsilateral palmaris longus, which is harvested through an apex radial chevron incision or straight transverse incision just proximal to the wrist flexion crease. Tension can be placed on the exposed palmaris tendon, then a second small, 1-cm transverse incision can be made 8 to 10 cm proximal to the first to clearly identify and confirm the identity of the palmaris tendon. The distal tendon is whipstitched with No. 2 nonabsorbable sutures and amputated as distal as possible to maximize graft length. After the tendon is released from any fibrous connections, a small, closed-ended tendon stripper aimed toward the medial epicondyle (muscular origin) is used to finalize the harvest of the tendon. The graft is checked, freed of any strands of muscular tissue, and then placed in a moist sponge, followed by placement in a sealed sterile container.

Exposure for both the standard docking and double-docking techniques is the same; both use a muscle-splitting approach to reduce the risk of postoperative ulnar neurapraxia and displacement of the flexor-pronator attachment from the epicondyle.[25,27] A curvilinear incision posterior to the medial epicondyle is made, and the medial antebrachial cutaneous branches are protected. The ulnar nerve, which is identified running between the 2 heads of the flexor carpi ulnaris (FCU), is also carefully protected. A formal subcutaneous transposition was performed if the patient was experiencing preoperative ulnar nerve symptoms. The FCU is split in line with its fibers over the sublime tubercle to expose the native UCL. A valgus stress placed on the elbow may visually confirm UCL deficiency in high-grade partial-thickness and complete UCL tears.

Standard Docking. The docking technique has been described previously.[23] Briefly, a 3.5-mm V-shaped drill guide is used to drill 2 blind end tunnels on the ulna (on either side of the sublime tubercle) that converge while ensuring a bone bridge of at least 1 cm between the 2 tunnel entry points. The drill guide (typically set at 55°) is placed parallel to the articular surface on either side of the sublime tubercle, and once the tunnels are drilled, a curette and chamfer are used to enlarge the mouth of each tunnel, as well as passed into each tunnel to ensure the tunnels are connected without any bone in the way. This facilitates

graft passage. A suture passing wire is then threaded through the tunnels, and the sutures from the graft are passed. Sterile mineral oil rubbed on the graft also helps with graft passage. A 3.5-mm humeral socket is then drilled to a depth of 15 mm, ensuring the starting point is at the central position on the anteroinferior aspect of the medial epicondyle. Identifying the correct position of the tunnel is facilitated by the remaining humeral attachment of the UCL. Again, a chamfer is used to smooth the socket edges. A variable angle humeral drilling guide is then used to drill two 2.0-mm holes on the posterior aspect of the medial epicondyle, leaving at least 5 to 10 mm of bone in between holes, that enter into the previously drilled humeral socket. These tunnels will allow the graft to be docked in the humerus. A suture-passing device is used to pass the suture from the free end of the graft out the holes. To properly dock the graft within the humerus, the graft limb coming out the anterior ulnar tunnel is passed into the socket until it bottoms out after its sutures are passed out the anterior humeral tunnel. The posterior limb is then measured and cut at a point where 5 to 10 mm of graft will enter the humeral socket and the graft can be properly tensioned (a 15-mm tunnel was drilled to ensure the surgeon maintains the ability to tension the graft). This posterior limb is prepped in the same manner as the anterior limb. The sutures are passed out the posterior humeral tunnel, and the graft is docked into the humeral socket. The sutures are tied with maximal force over the bone bridge with a varus stress placed on the elbow and the forearm in supination. More recently, some surgeons will tie the sutures over a small metallic button to avoid having the sutures cut through the bone of the medial epicondyle. Graft isometry and stability are then checked, and the native UCL is incorporated into the graft with multiple side-to-side nonabsorbable sutures that serve to provide additional tension to the graft and secure apposition to the native UCL.

Double Docking. The double-docking technique has been described previously, although the authors perform it with several modifications.[13] A single isometric drill hole is created in both the ulna and humerus to allow docking of the graft on both ends. The ulna is addressed first. A unicortical socket is drilled to the far ulnar cortex at the center of the sublime tubercle with a 4.5-mm drill bit. A 0.0625 Kirschner wire is then used to create 2 divergent holes with at least a 1-cm bone bridge through the ulnar socket exiting the ulna posterolaterally. Prior to drilling with the Kirschner wires, the posterior aspect of the ulna should be exposed through the same incision and a retractor placed posterolaterally to protect the ulnar nerve. A suture-passing device is then used to pass the free ends of the sutures from the prepared graft out the posterolateral holes. The sutures are then tied down under maximal tension (Figure 1A). The 4.5-mm humeral socket is created similar to the docking technique, although 1 author (M.S.C.) prefers to use a guidewire to set the starting point of the humeral socket at the UCL footprint followed by a cannulated drill bit to overdrill this wire. If the surgeon wished to fix the graft with a 10-mm titanium cortical fixation button that has not been preloaded with sutures, a tunnel is created such that all sutures can be passed and
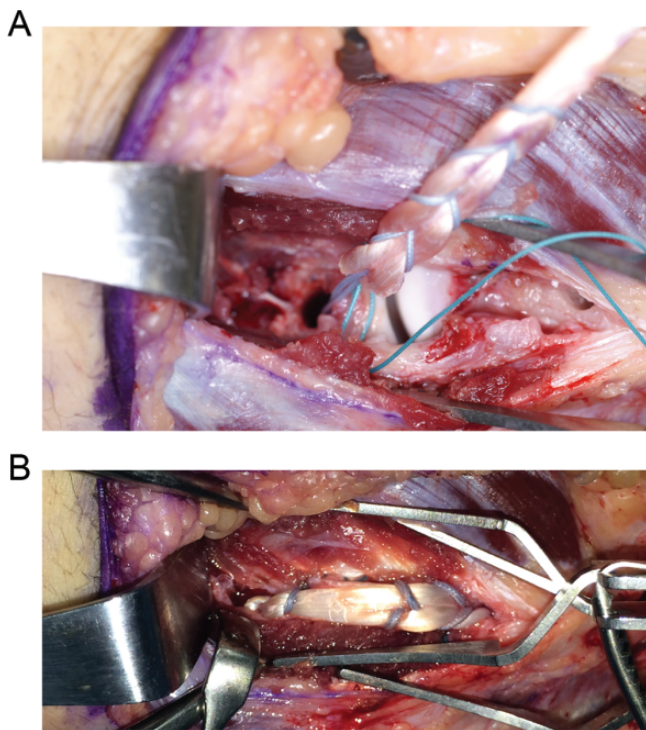
Figure 1. (A) Intraoperative photograph of the double-docking technique demonstrating gapping of the medial elbow indicating an insufficient ulnar collateral ligament (UCL). The graft has been stitched on one end and the sutures have been passed through the drill holes in the ulna. The graft is being docked into the ulna. (B) Intraoperative photograph demonstrating the final graft construct in the double-docking technique for UCL reconstruction. One end of the graft has been docked into the ulna and the other end has been docked into the medial epicondyle.

tied over the cortical fixation button after the graft is prepped. Alternatively, 2 posterior humeral holes can be drilled, the graft measured and cut to the proper length such that it can be placed into the humeral socket with enough space to properly tension the graft, and the end of the graft is prepped with No. 2 nonabsorbable sutures. The graft is docked into the socket and the sutures are passed out the tunnels and tied over the bone bridge with the forearm in supination and a varus stress placed on the elbow (Figure 1B). The native UCL is then incorporated into the graft with transverse side-to-side sutures, followed by evaluation of range of motion as well as graft isometry. It should be noted that the double-docking technique allows for a single strand of graft while the standard docking technique calls for a graft that has been doubled back on itself.

Postoperative Care and Return to Sport. The elbow is immobilized in a splint or hinged elbow brace for 1 week. Rehabilitation begins after the initial postoperative evaluation confirms appropriate wound healing and reduced swelling. The initial goal of therapy is to minimize inflammation and swelling while regaining the patient's

range of motion. This plan continues for 3 to 4 weeks. Strengthening begins after the majority of the elbow motion is regained, usually by 4 weeks. Sport-specific training and advanced strength training begins at weeks 9 to 13. In addition to a continued focus on the operated elbow and ipsilateral shoulder, a greater emphasis is now placed on core mechanics, as studies have shown an increase in elbow and shoulder torques as the core weakens.[9]

Plyometric exercises can begin at week 12, and a throwing progression program beginning on flat ground is typically initiated at 16 weeks if the sports-specific training is progressing without the athlete experiencing any significant pain at the surgical reconstruction site. A typical throwing progression program includes short toss (45 feet), followed by lofted long toss (120 feet), long toss on a line, throwing from the knees, throwing from the mound beginning at 6 months after surgery (if patient is a pitcher), game simulation, and finally, competitive play. It typically takes 7 to 9 months before a player can engage in competitive play. Furthermore, although controversial, pitchers, their family members, trainers, and coaches should be informed preoperatively that return to competition does not imply return to preinjury level of function, as recent analysis of Major League Baseball pitchers suggested that return to preinjury level of play based on objectively measured outcomes may take up to 15 months after UCLR.[6]

Statistical Analysis

Continuous variable data were reported as weighted means ± weighted standard deviations. Categorical variable data were reported as frequencies with percentages. For all statistical analysis either measured and calculated from study data extraction or directly reported from the individual studies, $P < .05$ was considered statistically significant. The overall number of UCLRs and the ages of patients undergoing UCLR were reported using a linear regression model.

RESULTS

A total of 187 patients (188 elbows) underwent UCLR between January 1, 2004 and December 31, 2014 (92% male; mean age, 19.6 ± 4.7 years; 78.2% right elbows). From 2004 to 2014, the number of UCLRs significantly increased ($P = .0017$ $R^2 = 0.729$) (Figure 2). There was no significant difference in patient age at the time of UCLR from 2004 to 2014 ($P = .83$, $R^2 = 0.0062$) (Figure 3). The yearly quarter in which the UCLRs were performed was not statistically significant ($P > .05$) and is shown in Figure 4. In all, there were 165 baseball players (87.8% of all patients), 155 of whom were pitchers (82.5% of all patients). The majority of patients (51.6%) were collegiate athletes at the time of surgery (Tables 2 and 3). The only surgical techniques used in this patient cohort were the standard docking (111 elbows, 58.7%) and double-docking (77 elbows, 41.3%) techniques. An ipsilateral palmaris longus graft was used in 111 (58.7%) patients, while a hamstring autograft was used in 48 (25.4%) patients (Table 4). Autograft was used in 86.2%
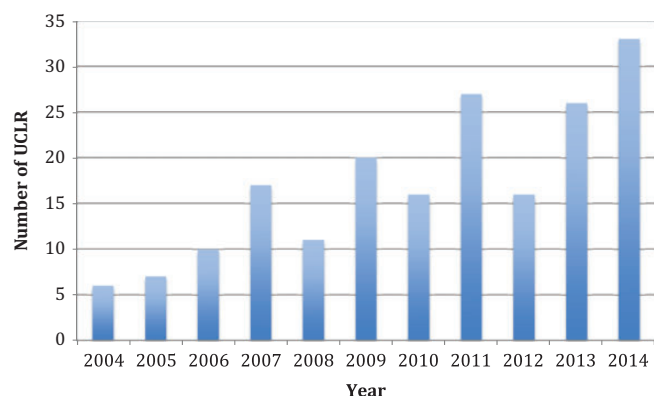
Figure 2. Number of ulnar collateral ligament reconstructions (UCLR) performed per year from January 2004 to July 2014.
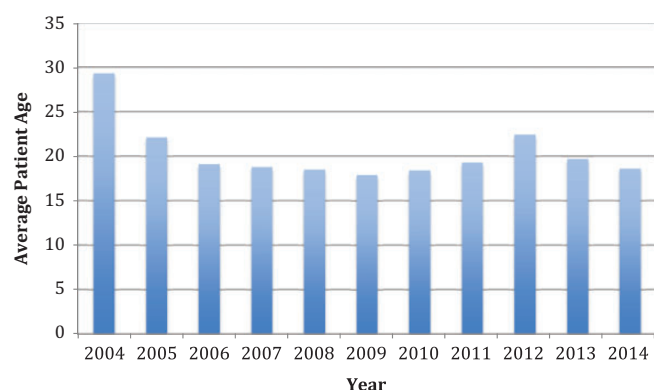

Figure 3. Mean patient age per year for patients undergoing ulnar collateral ligament reconstructions.
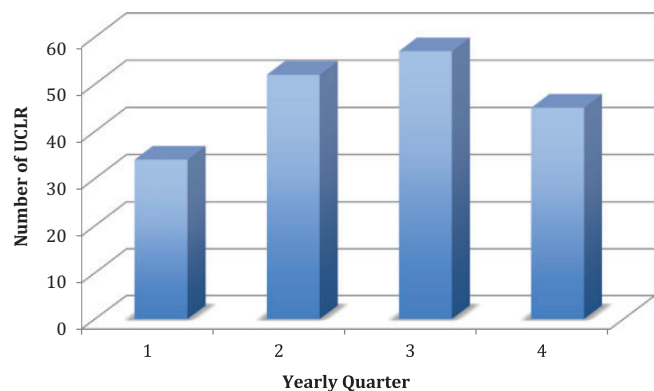

Figure 4. Number of ulnar collateral ligament reconstructions (UCLRs) stratified by yearly quarter. Quarter 1, January to March; quarter 2, April to June; quarter 3, July to September; quarter 4, October to December.

of patients in this study, while allograft was used in 13.8%. The ulnar nerve was transposed subcutaneously in 79 (41.8%) patients. All of these patients had some form of preoperative ulnar nerve symptoms (positive Tinel sign at the elbow, positive paresthesia in the hand, etc). Only 4

patients underwent concomitant elbow arthroscopy for additional pathology.

As 67 patients had less than 18 months of follow-up and were excluded from the outcomes data, there were 120 patients with prospectively collected surgical data available for clinical outcomes. Eighty-five (71%) were contacted via phone interview at a mean follow up of 60 ± 30.8 months. There were 42 collegiate (49.4%), 35 high school (41.1%), 5 recreational (5.9%), and 1 middle school (1.2%) athlete. Seventy-six (89.4%) were baseball players (74 pitchers, 1 catcher, and 1 infielder). There were 2 softball players, 2 gymnasts, 1 football player, and 1 cheerleader. The remaining 38 patients could not be reached despite a minimum of 3 call attempts to primary numbers as well as calls to emergency contacts. Patient demographics of those available for follow-up were similar to the overall cohort.

Overall, 80 athletes (94.1%) were able to return to the same or higher level of competition and had a Conway-Jobe rating of good/excellent; 92.1% of baseball pitchers returned to the same or higher level of competition at an average of 55.0 ± 30.8 months of follow-up. Forty-one (91.1%) collegiate, 31 (88.6%) high school, and 1 middle school (100%) athlete were able to return to the same or higher activity level after surgery. The mean KJOC score for all patients was 90.4 ± 6.7, and mean Andrews-Timmerman score was 92.5 ± 7.1. Scores were then separated out by level of competition (Table 5) and sport (Table 6). Only 1 patient had a concomitant surgery (excision of a posteromedial osteophyte). We noted no differences in return-to-sport rate in our early clinical experience versus later clinical experience or in patients with attritional versus traumatic injury mechanisms (*P* = .164 and .162, respectively). Subjective data were not collected prior to surgery.

All 187 patients were seen in follow-up clinic visits after surgery. As such, all charts were reviewed to determine subsequent surgeries and complications. Subsequent surgeries were performed in 5.3% (10/187) of patients. These reoperations included removal of the cortical fixation button (1 patient) and subsequent ulnar nerve transposition for persistent postoperative ulnar nerve symptoms (7 patients). One patient had a subsequent elbow arthroscopy for loss of motion and 1 patient required a revision UCLR 4 months after his index UCLR. The index UCLR was performed with a hamstring autograft, and the revision UCLR was performed with a palmaris longus allograft. Finally, 1 patient retore his UCL 4 years after surgery (which was performed with a hamstring autograft) but elected not to have it reconstructed again as he was retiring from competitive baseball.

DISCUSSION

UCLR has become a common procedure in elite and high-level overhead-throwing athletes, with the incidence increasing dramatically over the past decade.[3,6,8] The goals of this study were to report the patent demographics, clinical outcomes, return-to-sport rate, and complications for

TABLE 2
Level of Sport at the Time of UCLR[a]

	Level of Sport at Time of Surgery				
	Middle School	High School	Collegiate	Professional	Recreational
No. of patients	1	68	97	7	15

[a]UCLR, ulnar collateral ligament reconstruction.

TABLE 3
Sport Played at the Time of UCLR[a]

	Baseball Player (Former or Current)	Pitcher	Nonpitcher	Softball Player	MLB Player	Volleyball Player	Football Player	Gymnast
No. of patients	165	155	10	4	7	2	6	4

[a]MLB, Major League Baseball; UCLR, ulnar collateral ligament reconstruction.

TABLE 4
Graft Choice in Patients Who Underwent UCLR, January 2004 to July 2014[a]

	Ipsilateral Palmaris Autograft	Contralateral Palmaris Autograft	Hamstring Autograft	Triceps Autograft	Palmaris Allograft	Hamstring Allograft
No. of patients	111	2	48	2	2	24

[a]UCLR, ulnar collateral ligament reconstruction.

TABLE 5
Andrews-Timmerman and KJOC Scores by Preoperative Level of Competition for Patients Who Underwent UCLR, January 2004 to July 2014[a]

	Andrews-Timmerman Score	KJOC Score
Middle school	100 ± 0.0	91.6 ± 0.0
High school	92.7 ± 6.1	89.3 ± 9.1
Collegiate	86.22 ± 7.4	85.21 ± 3.9
Recreational	96 ± 5.5	93 ± 1.7

[a]Data are presented as mean ± SD. KJOC, Kerlin-Jobe Orthopaedic Clinic; UCLR, ulnar collateral ligament reconstruction.

TABLE 6
Andrews-Timmerman and KJOC Scores by Sport for Patients Who Underwent UCLR, January 2004 to July 2014[a]

Sport	No. of Athletes	Return to Previous Level, %	Andrews-Timmerman Score	KJOC Score
Baseball	76	94.70	92.8 ± 6.8	90.8 ± 5.8
Baseball pitcher	74	92.1	92.8 ± 6.8	90.5 ± 5.8
Baseball nonpitcher	2	100	95 ± 7.1	94.5 ± 2.1
Softball	2	100	95 ± 7.1	90.7 ± 0.9
Gymnastics	2	50	87.5 ± 3.5	76.3 ± 24.5
Football	1	100	100	92
Cheerleader	1	100	85	94.7

[a]Data presented as mean ± SD except for football and cheerleader, which both represented only 1 patient. KJOC, Kerlin-Jobe Orthopaedic Clinic; UCLR, ulnar collateral ligament reconstruction.

all UCLRs performed at a single institution from January 2004 to December 2014. The most common graft choice in this study was an ipsilateral palmaris longus autograft, used in 59.3% of patients, followed by a hamstring autograft, used in 25.4% of patients (Table 4). This finding is similar to the study by Cain et al,[3] which evaluated 1281 athletes treated between 1988 and 2006 and found that 74.4% of patients were treated with a palmaris longus autograft while 23.4% were treated with a hamstring autograft. However, one difference is the use of allograft in the current study compared with the aforementioned patient population. While the study by Cain et al[3] did not report on any patients treated with allograft, 13% of patients in our study were treated with allograft (either palmaris longus or hamstring).

The return-to-sport rate from this study is similar to others seen in the literature in that 92.1% of baseball pitchers returned to the same or higher level of function.[3,5] An interesting finding of this study was the breakdown in athletic level of patients who underwent UCLR. The majority of patients in this study were collegiate (51.6%) and high school (36.2%) athletes. Although this procedure has been common in collegiate athletes for some time, the number of high school athletes undergoing UCLR is somewhat

concerning. There has been a trend in the literature toward younger patients undergoing UCLR, with a recent increase in the percentage of high school athletes compared with other levels.[3,8] A recent study on national trends in UCLR between 2007 and 2011 using the Pearl Diver database showed that UCLR was most commonly performed in 15- to 19-year-old patients; 57% of all patients undergoing UCLR fell into this age group.[8] Although injury prevention programs have been instituted over the past decade to protect adolescent athletes from injury, these programs have yet to yield a significant decline in injury rates.[10,11] Interestingly, this study did not show a significant difference in the yearly timing of UCLR. One could postulate that pitchers are at greater risk for injuries during the beginning of the season, as they have not yet returned to game shape, but this does not appear to be accurate based on this study. The implications of this finding are that preventative programs aimed at reducing injuries at the beginning of the season may not be effective given the relatively even distribution of yearly UCLR timing seen in this study. Further research into injury prevention is crucial to slow the increase in UCLR, specifically in the high school athlete population.

There is a relative paucity of literature regarding the use of allograft in UCLR. Savoie et al[24] reported the largest series of allograft UCLR in which 116 patients (a mixture of high school, college, and professional athletes involved in baseball, softball, and javelin) underwent UCLR with hamstring allograft and found that 94.8% of players had returned to play, 88% of whom returned to play at an equal or higher level. Allograft alleviates the issue of donor site morbidity but introduces foreign human tissue into the young athlete's elbow, and there may be substantial variability in the quality of the allograft tissue. Allografts are expensive, but the overall cost related to the procedure may be offset by avoiding autograft harvest and wound closure. The results of our study are consistent with the prior study and suggest that allograft UCLR is a reasonable option for surgeons after appropriate patient and family consent.[24]

While graft choice is an important aspect of UCLR, treatment of the ulnar nerve is also important and has become controversial. Some authors recommend routine anterior subcutaneous transposition while others do not transpose the nerve at all.[3,18,24] All the authors in this study treated the ulnar nerve with the same philosophy of management. If the patient had preoperative ulnar nerve symptoms such as paresthesia in the small and ring fingers, wasting of the interossi muscles of the hand, a positive Tinel sign at the elbow, or subluxation of the nerve, an anterior subcutaneous ulnar nerve transposition was performed as part of the index procedure. However, if the patient did not have any of the above preoperative symptoms, the ulnar nerve was not formally transposed but rather simply identified for protection and decompressed in situ. Of the 188 elbows in this study, 7 (3.7%) underwent subsequent ulnar nerve transposition for persistent ulnar nerve symptoms during the routine follow-up period. Vitale and Ahmad[26] reviewed the literature on UCLR and found postoperative ulnar neuropathy in 3% to 8% of patients depending on the technique used (excluding the Jobe technique, which had a 20% rate

of postoperative ulnar neuropathy after submuscular transposition). Hence, to date, there is no literature to strongly support any 1 practice over another, and as such, recommendations on how best to treat the ulnar nerve cannot be made at this time. In our study, the ulnar nerve was transposed subcutaneously in 79 (41.8%) patients, with an additional 7 (3.7%) requiring subsequent ulnar nerve transposition. Theoretically, if all patients underwent systematic ulnar nerve transposition, more than 50% of our patients would have been unnecessarily exposed to the potential added complications and adverse events associated with the subcutaneous ulnar nerve transposition.

The 1 patient in this series who required a revision UCLR was initially treated as a high school pitcher via the standard docking technique with a hamstring autograft and subcutaneous ulnar nerve transposition. He retore his UCL 4 months after surgery while in college and underwent a subsequent revision UCLR via the standard docking technique utilizing a palmaris longus allograft. As this was the only patient in this series to require a revision UCLR, it is difficult to determine whether there are any risk factors for retearing a UCL after UCLR. Other studies have shown that risk factors for sustaining an initial UCL tear include growing up in warm weather climates and pitching while fatigued (including pitching for multiple teams at a time, pitching more than 100 innings per season, pitching more than 9 months of the year, etc).[7,10] Interestingly, throwing breaking pitches at early ages has not been shown to correlate with UCL injuries, which is a common misconception among athletes, parents, and coaches.[10]

The patients in this study did not routinely undergo elbow arthroscopy at the time of UCLR unless there was documented or suspected intra-articular pathology. This is in contrast to some studies in which patients routinely undergo elbow arthroscopy at the time of UCLR to confirm instability at the medial elbow and address any intra-articular pathology.[3,24] The authors believe that, while some patients necessitate an arthroscopic evaluation and treatment for various intra-articular pathologies including osteochondritis dissecans and/or posteromedial osteophytes, the vast majority of patients do not need an arthroscopic evaluation. Using the combination of history (overhead athletes with medial elbow pain), physical examination (positive moving valgus stress test or milking maneuver), and diagnostic imaging (MRI or MRA), the authors feel comfortable diagnosing and treating UCL tears and associated pathology through a direct open approach without arthroscopy in the vast majority of patients.

Limitations

Although this study was the largest cohort of double-docking UCLR and second largest overall cohort of UCLR patients reported in the literature to date for the patient demographics, there are several limitations. First, the patients did not have preoperative clinical scores to compare with postoperative scores. The surgical data were extracted from the electronic medical record, which may have been incomplete. There were patients who were

unable to be contacted, and this could have affected the results, specifically falsely lowering the rate of postoperative ulnar neuropathy or falsely elevating the rate of return to sport. Furthermore, the study is subject to recording and recall bias as patients may not have recalled their complications or their complications may not be recorded in the electronic medical record. Similarly, they may have reported better results to the lead author (B.J.E.) on the phone in comparison with them completing a questionnaire. Patient physical examinations were not performed, so range of motion, strength, and valgus stress of the elbow were unable to be assessed, and performance measures were not evaluated. The KJOC questionnaire was administered over the phone, and it is possible that this introduced some recording or recall bias as this was administered by one of the study personnel. Furthermore, this questionnaire has not been validated for over-the-phone use, and although the patients seemed comfortable when answering the questions, this could have affected the results. Finally, although the patients in the standard docking group all had the graft fixed in the same manner, there were 7 surgeons who performed these surgeries. While all the surgeons were fellowship-trained sports, shoulder/elbow, or hand surgeons, there may have been some subtle differences in their techniques. However, in comparing the patients of each surgeon with the others, we were unable to find any statistically significant differences in outcomes or complications.

CONCLUSION

UCLR was performed most commonly on collegiate athletes using an ipsilateral palmaris longus graft. Overall, 94.1% of patients who underwent UCLR were able to return to sport, with a mean KJOC score of 90.4 and a mean Andrews-Timmerman score of 92.5.

REFERENCES

1. Andrews JR, Timmerman LA. Outcome of elbow surgery in professional baseball players. *Am J Sports Med*. 1995;23:407-413.
2. Azar FM, Andrews JR, Wilk KE, Groh D. Operative treatment of ulnar collateral ligament injuries of the elbow in athletes. *Am J Sports Med*. 2000;28:16-23.
3. Cain EL Jr, Andrews JR, Dugas JR, et al. 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*. 2010;38: 2426-2434.
4. Conway JE, Jobe FW, Glousman RE, Pink M. Medial instability of the elbow in throwing athletes. Treatment by repair or reconstruction of the ulnar collateral ligament. *J Bone Joint Surg Am*. 1992;74:67-83.
5. Dines JS, ElAttrache NS, Conway JE, Smith W, Ahmad CS. Clinical outcomes of the DANE TJ technique to treat ulnar collateral ligament insufficiency of the elbow. *Am J Sports Med*. 2007;35:2039-2044.
6. Erickson BJ, Gupta AK, Harris JD, et al. Rate of return to pitching and performance after Tommy John surgery in Major League Baseball pitchers. *Am J Sports Med*. 2014;42:536-543.
7. Erickson BJ, Harris JD, Tetreault M, Bush-Joseph C, Cohen M, Romeo AA. Is Tommy John surgery performed more frequently in Major League Baseball pitchers from warm weather areas? *Orthop J Sports Med*. 2014;2:2325967114553916.

8. Erickson BJ, Nwachukwu BU, Rosas S, et al. 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*. 2015;43:1770-1774.
9. Escamilla RF, Barrentine SW, Fleisig GS, et al. Pitching biomechanics as a pitcher approaches muscular fatigue during a simulated baseball game. *Am J Sports Med*. 2007;35:23-33.
10. Fleisig GS, Andrews JR. Prevention of elbow injuries in youth baseball pitchers. *Sports Health*. 2012;4:419-424.
11. Fleisig GS, Andrews JR, Cutter GR, et al. Risk of serious injury for young baseball pitchers: a 10-year prospective study. *Am J Sports Med*. 2011;39:253-257.
12. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med*. 1995;23:233-239.
13. Furukawa K, Pichora J, Steinmann S, Faber KJ, Johnson JA, King GJ. Efficacy of interference screw and double-docking methods using palmaris longus and GraftJacket for medial collateral ligament reconstruction of the elbow. *J Shoulder Elbow Surg*. 2007;16:449-453.
14. Hechtman KS, Zvijac JE, Wells ME, Botto-van Bemden A. Long-term results of ulnar collateral ligament reconstruction in throwing athletes based on a hybrid technique. *Am J Sports Med*. 2011;39: 342-347.
15. Jackson A, Maerz T, Koueiter DM, Andrecovich CJ, Baker KC, Anderson K. Strength of ulnar fixation in ulnar collateral ligament reconstruction: a biomechanical comparison of traditional bone tunnels to the tension-slide technique. *J Shoulder Elbow Surg*. 2012;21:1674-1679.
16. Jackson TJ, Adamson GJ, Peterson A, Patton J, McGarry MH, Lee TQ. Ulnar collateral ligament reconstruction using bisuspensory fixation: a biomechanical comparison with the docking technique. *Am J Sports Med*. 2013;41:1158-1164.
17. Jiang JJ, Leland JM. Analysis of pitching velocity in Major League Baseball players before and after ulnar collateral ligament reconstruction. *Am J Sports Med*. 2014;42:880-885.
18. Jobe FW, Stark H, Lombardo SJ. Reconstruction of the ulnar collateral ligament in athletes. *J Bone Joint Surg Am*. 1986;68:1158-1163.
19. Makhni EC, Lee RW, Morrow ZS, Gualtieri AP, Gorroochurn P, Ahmad CS. Performance, return to competition, and reinjury after Tommy John surgery in Major League Baseball pitchers: a review of 147 cases. *Am J Sports Med*. 2014;42:1323-1332.
20. Morgan RJ, Starman JS, Habet NA, et al. A biomechanical evaluation of ulnar collateral ligament reconstruction using a novel technique for ulnar-sided fixation. *Am J Sports Med*. 2010;38:1448-1455.
21. Morrey BF. Applied anatomy and biomechanics of the elbow joint. *Instr Course Lect*. 1986;35:59-68.
22. Morrey BF, An KN. Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med*. 1983;11:315-319.
23. Rohrbough JT, Altchek DW, Hyman J, Williams RJ 3rd, Botts JD. Medial collateral ligament reconstruction of the elbow using the docking technique. *Am J Sports Med*. 2002;30:541-548.
24. Savoie FH 3rd, Morgan C, Yaste J, Hurt J, Field L. Medial ulnar collateral ligament reconstruction using hamstring allograft in overhead throwing athletes. *J Bone Joint Surg Am*. 2013;95:1062-1066.
25. Thompson WH, Jobe FW, Yocum LA, Pink MM. Ulnar collateral ligament reconstruction in athletes: muscle-splitting approach without transposition of the ulnar nerve. *J Shoulder Elbow Surg*. 2001;10: 152-157.
26. Vitale MA, Ahmad CS. The outcome of elbow ulnar collateral ligament reconstruction in overhead athletes: a systematic review. *Am J Sports Med*. 2008;36:1193-1205.
27. Watson JN, McQueen P, Hutchinson MR. A systematic review of ulnar collateral ligament reconstruction techniques. *Am J Sports Med*. 2014;42:2510-2516.