Intermediate Outcomes of Medial Ulnar Collateral Ligament Reconstruction Using Gracilis Allograft in Adolescent Patients

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Background: Autograft palmaris has been the primary choice for the reconstruction of the medial ulnar collateral ligament (UCL) in the elbow. Agenesis of the palmaris tendon is not rare, and outcomes of allograft reconstruction in the breadth of athlete types found in the adolescent population are lacking.

Hypothesis: Allograft tendon reconstruction of the medial UCL in the young elbow would have low failure rates and satisfactory outcome scores.

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

Methods: The records of patients who underwent allograft medial UCL reconstruction (UCLR) by a single surgeon between 2009 and 2019 were reviewed. Patient-reported outcome scores in adolescent patients obtained at a minimum 4-year follow-up (for intermediate assessment) were recorded, with no exclusion according to sex or sport type. Outcomes included the Timmerman-Andrews score, the Single Assessment Numeric Evaluation (SANE), and the Conway-Jobe score.

Results: Of 29 patients who underwent allograft UCLR, 10 adolescents (40% women; mean age at surgery, 15.8 years [age range, 15-17 years]) met the inclusion criteria and were included in the study. The mean follow-up was 8 years (range, 4.3-11.9 years). There were 4 overhead athletes (baseball, water polo) and 6 impact sports athletes (motocross, gymnastics, wrestling, and soccer). The mean SANE score was 86.3, and the mean subjective Timmerman-Andrews score was 92.5. The Conway-Jobe score was ''excellent'' in 7 of 10 participants; nonetheless, 3 elected not to return to sport (2 for reasons unrelated to the elbow). No patients experienced loss of range of motion, contracture, or ulnar nerve neuropathy. There was 1 patient with early failure (10%) who required revision reconstruction .

Conclusion: Allograft reconstruction for medial UCL instability in adolescent patients from sport and trauma mechanisms demonstrated excellent patient-reported functional scores in this study. If the patient and surgeon desire to avoid autograft morbidity or agenesis of the palmaris longus, allograft tendon UCLR appears viable for both the throwing and the high-impact adolescent athlete, regardless of sex.

Keywords: adolescent; allograft; athlete; reconstruction; ulnar collateral ligament

Early specialization in sports resulting in increasing incidences of medial ulnar collateral ligament (UCL) injuries in overhead throwing athletes and other sports—including wrestling, soccer, and gymnastics—has increased remarkably over the past 2 decades.[3,7,13,15] Young athletes aim to reach higher echelons of competition while skeletally immature. Youth also participate in various high-risk activities such as riding in all-terrain vehicles and participating extreme sports, resulting in accidental trauma that may involve the elbow. As an increase in high-impact injuries and sports overuse injuries continues, surgeons and patients may benefit from new techniques to reduce procedure morbidity.

Savoie et al[16] examined hamstring allograft reconstruction of the medial UCL in male baseball players—whose mean/median ages were unclear, but most of them were college and professional athletes—and found similar outcomes to autograft reconstruction. Kennon et al[11] examined 3 different allografts for the medial UCL in nonelite athletes ranging from 12 to 65 years (median age, 25 years) and found similar outcomes to autograft reconstruction. Kennon et al[11] excluded adolescent athletes participating at the Junior Olympic level or equivalent, as they were considered elite-level athletes. Neither study focused on adolescent patients or quantified the age distribution of the included patients.

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The option to use allografts is a welcome addition to the arsenal of techniques available to the treating surgeon, given the possibility of palmaris longus agenesis and certain athlete types being less interested in harvesting hamstring tendon autografts. In pediatric/adolescent patients, the use of allografts might be particularly desirable for certain patients and has been successful in a more recent study on adolescent anterior cruciate ligament reconstruction.[18] A young patient population would benefit from avoiding additional morbidity at the harvest site as well as the reduction of potential long-term repercussions of autografts, such as loss of function.[8,12,20] For those without an ipsilateral palmaris longus, avoiding morbidity at an additional donor site reduces the risk of complications. Moreover, in the trauma patient population, reducing additional associated procedures—such as autograft harvest—is desirable to reduce the overall surgical burden, perhaps making an allograft a desirable alternative.

This study aimed to evaluate the efficacy of allograft reconstruction in adolescent patients who failed nonoperative management of medial UCL injuries. This study included athletes and trauma patients to assess the efficacy of medial UCL allograft reconstruction for all adolescents regardless of sex. We hypothesized that allograft tendon reconstruction of the medial UCL in the young elbow would have low failure rates and satisfactory outcome scores.

METHODS

The study protocol received institutional review board approval, which included a partial Health Insurance Portability and Accountability Act waiver of authorization and a waiver of written documentation of consent. Data were collected from a single pediatric, multicenter institution database with a large geographic catchment area. Current Procedural Terminology (CPT) code 24346 was used to search the database, which includes repair, reconstruction, and revision surgery of the humerus and elbow. The inclusion criteria were as follows: age <19 years; trial of nonoperative management; medial UCL reconstruction (UCLR) surgery with a gracilis allograft; and a minimum 4-year follow-up between 2009 and 2019. Patients were not excluded based on sex, race, ethnicity, or primary language spoken. All causes of injury were trauma and persistent instability. The exclusion criteria were autograft reconstruction, other allograft sources, and inability/unwillingness to complete patient-reported outcome scores.

Preoperative Evaluation

All patients were evaluated by the same group of pediatric orthopaedic surgeons and referred to a single surgeon (E.W.E.) for operative management when indicated. The initial work-up included a physical examination and radiographs of the affected elbow. Physical examination included range of motion (ROM) in flexion, extension, pronation, and supination. Each elbow was tested for varus and valgus instability at 0° and 30° compared with the contralateral elbow. Moreover, the milking maneuver was utilized, which consisted of a valgus stress across the medial collateral ligament created by placing the forearm in supination with the elbow flexed at 60° and pulling the thumb laterally. Nonoperative management consisted of a period of relative rest, physical therapy focused on the medial UCL and surrounding structures, and nonsteroidal anti-inflammatory medications, either ibuprofen or naproxen. Patients were not offered platelet-rich plasma or bracing. A noncontrast magnetic resonance imaging of the elbow was obtained to evaluate the medial UCL. When a patient was deemed a surgical candidate, a referral was made to a fellowship-trained, pediatric orthopaedic sports surgeon in the group for definitive management.

Surgical Procedure and Postoperative Rehabilitation

Patients were brought to the operating room and underwent an examination under anesthesia of the affected elbow, evaluating ROM and instability versus the contralateral elbow. Patients then underwent a diagnostic arthroscopy of the ulnohumeral joint with valgus stress testing verifying displacement >2 mm. Concurrently, the ulnohumeral joint was evaluated for any additional pathology.

After the examination and arthroscopy were complete, the ligament reconstruction was completed as an open procedure. Patients elected to have gracilis allografts when they did not have an available ipsilateral palmaris longus to harvest. An incision was made from the medial epicondyle to the sublime tubercle. The raphe of the flexor mass and the flexor carpi ulnaris muscle were identified and split. Next, dissection down to the medial epicondyle to determine the origin of the native UCL was followed by dissection to the sublime tubercle, sharply splitting the native remnant from epicondyle to tubercle. The graft was first secured at the medial epicondyle at the native origin using a socket and interference screw fixation. Next, the opposing end of the graft was secured to the ulna at the sublime tubercle at the insertion of the native UCL

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Ethical approval for this study was obtained from the University of California, San Diego (ref No. 171732).

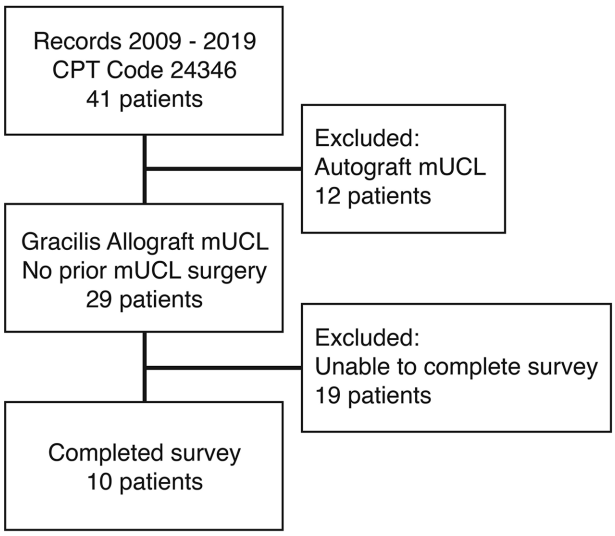

Figure 1. CONSORT Diagram. Application of the inclusion and exclusion criteria resulted in the final 10-patient cohort. CONSORT, Consolidated Standards of Reporting Trials; CPT, Current Procedural Terminology; mUCL, medial ulnar collateral ligament.

using a socket with interference screw fixation. Before fixation, the elbow was brought to 60° of flexion with a varus load while the ulnar end of the graft was pulled through via sutures and placed on tension through an exit drill hole on the opposite side of the proximal humerus. ROM was then assessed to confirm appropriate tension of the graft. The wound was then irrigated and closed, and the native UCL tissue longitudinal split was repaired. The patient was placed in an elbow ROM brace, which was locked at 60° of flexion.

The postoperative protocol remained the same for all patients, with postoperative follow-ups occurring at 1 week, 6 weeks, and 3 months intervals. Patients were placed in a ROM elbow brace starting locked at 60° of flexion and extension for the first week. They then advanced 10° to 15° per week in both directions until fully unlocked by 6 weeks. At the 6-week follow-up, patients began formal physical therapy with an approved rehabilitation protocol provided to the treating physical therapist but remained in the ROM elbow brace fully unlocked for an additional 6 weeks while at school. Initial therapy focused on ROM and then progressed to strength training with an emphasis on periscapular and medial stabilization. The ROM brace was discontinued at 3 months postoperatively. At 4.5 months, physical therapy advanced to proprioceptive and functional exercises. Return-to-sports-specific training occurred at 6 months, with the goal of sports-specific rehabilitation being completed around 10 months. Finally, a full unrestricted return to sports (RTS) occurred 1 year postoperatively.

Outcome Measures and Analysis

All patients were contacted to complete a phone survey of the following patient-reported outcome measures: Single Assessment Numeric Evaluation (SANE), Conway-Jobe score, and subjective Timmerman-Andrews score. The SANE is a single question that rates the level of function of the operative extremity from 0 to 100. It has previously been validated in the pediatric population.[3,18] The subjective Timmerman-Andrews scale evaluates pain, swelling, locking/catching, and ability to participate in activities. The categories are scored in 5-point increments from 0 to 25, and these subscores are then totaled to determine the total subjective score[19] up to 100. The Conway-Jobe score was utilized for RTS and postoperative RTS level .[2,17] It categorizes RTS as "excellent—at or higher preinjury level within 12 months," "good," "fair," and "poor—unable to RTS."

Descriptive statistics were calculated for this cohort. Interval data were reported as means with associated ranges, and categorical variables were reported as percentages. Raw data were also tabulated and reported.

RESULTS

Cohort Characteristics

Between 2009 and 2019, a total of 41 records were identified using CPT code 24346. After screening for gracilis allograft reconstruction, 29 patients remained eligible, and 10 patients met all inclusion and exclusion criteria, including successful completion of the phone survey, and were included in the study (Figure 1). Cohort characteristics are summarized in Table 1. The patients' age ranged from 15 to 17 years at the time of surgery (mean, 15.8 years), and 4 of the 10 patients were women. Mechanisms of injury included overhead throwing sports (water polo, baseball), impact sports (soccer, wrestling, and gymnastics), and trauma (motocross). The patients participated

TABLE 1
Cohort characteristics (N = 10)[a]

Characteristic	Value
Age at surgery, y	15.8 ± 0.9
Sex	
Male	6 (60)
Female	4 (40)
Mechanism of injury	
Overhead sport	4 (40)
Impact sport	4 (40)
Trauma	2 (20)
Clinical follow-up, y	4.9 ± 3.4
Survey completion, y	8 ± 3

[a]Values are represented as mean ± SD or n (%).

in nonoperative treatment including physical therapy for 1.8 to 58.6 months (mean, 16.72; median, 10.95) from when they were initially evaluated at the institution's orthopaedic department. Survey completion occurred 4.3 to 11.9 years postoperatively (mean, 8 years). Of the patients who underwent allograft UCLR and were included in this study, only 30% had a primary sport of baseball.

In this study, 2 patients reported medial UCL injury via acute trauma. One patient experienced a medial epicondyle fracture with >5 mm of displacement, which was treated with open reduction internal fixation at the time of injury. She presented with persistent pain 4 years later, was found to have medial UCL instability, and was indicated for medial UCLR. The second trauma patient had no reported concomitant injury to her affected elbow and was a high school softball player who went on to play at the collegiate level .

Outcome Scores and Complications

The mean SANE score was 86.3 (range, 50-100) for our cohort. The mean Timmerman-Andrews subscores were as follows: pain = 20.5 (range, 20-25); swelling = 24 (range, 20-25); locking/catching = 25; and activities = 23 (range, 20-25); and the mean total Timmerman-Andrews score was 92.5 (range, 80-100) (Table 2). All patients reported full ROM in flexion/extension and pronation/supination at the follow-up. A Conway-Jobe score of "excellent" was reported by 7 patients (70%), indicating RTS at or above the level of injury. No patients reported RTS at a lower level of play. The remaining 3 patients (30%) reported no RTS; 1 did not return because of persistent pain (Table 3). This patient incurred her injury via a motocross trauma with associated elbow injuries, including a fracture. The fractures were operatively managed at the time of initial trauma presentation. The remaining 2 patients who did not RTS had reasons unrelated to their elbow function.

All patients were satisfied with their surgery, except 1 patient who reported he would not undergo the surgery again because of the rehabilitation time. He subsequently injured the contralateral elbow participating in his sport (wrestling) when he self-discharged from physical therapy at 6 months postoperatively. He elected not to proceed with surgery on the contralateral elbow, leading to no return to wrestling.

No patients experienced complications such as infection or neuropathy. Three patients reported sequelae. Two reported persistent pain. The first was the motocross athlete who did not RTS. The second returned to sport, baseball, and progressed to the collegiate level. The third patient was a gymnast who initially returned to the sport before being released by the surgeon and developed recurrent instability. Subsequently, she underwent a second allograft reconstruction to restore elbow stability but chose to retire from gymnastics after that second surgery.

DISCUSSION

Allograft reconstruction for medial UCL instability in adolescent patients from sport and trauma mechanisms demonstrated excellent patient-reported functional scores in the present study, with a mean SANE score of 86.3, a mean Timmerman-Andrews score of 92.5, and an "excellent" Conway-Jobe score in 70% of patients. We experienced a complication rate of 10% (1 failure), while Kennon et al[11] and Savoie et al[16] experienced a 20% and 6% complication rate, respectively, in their studies of allograft UCLR. Autograft UCLR has been reported to have a complication rate[20] of 3% to 25%. Thus, if a patient and a surgeon desire to avoid autograft morbidity or agenesis of the palmaris longus, allograft tendon UCLR appears viable for both the throwing athlete and the high-impact adolescent athlete, regardless of sex.

The literature regarding an injury to the medial UCL primarily involves overhead-throwing athletes, almost exclusively male baseball players.[1,2,4,6,10,14-16,20] The preponderance of research studies focus on skeletally mature athletes playing at a high level of competition. The adolescent elbow is in the process of fusing the 6 ossification centers, with the medial epicondyle being the last to fuse.[5] Over the past few decades, numerous studies have focused on autograft types and surgical techniques.[4,6] However, this injury pattern occurs across a diverse range of sports and trauma, from weekend warriors to laborers to high school athletes. Since the original reconstruction described by Jobe et al,[10] surgical reconstructions of the medial UCL continue to be the mainstay for those who fail nonoperative management. The present study demonstrated that the utilization of allograft reconstruction can provide functional midterm outcomes in this youthful cohort in both sexes and within a diversity of activity types.

Traditionally, UCLR is performed with autografts from the ipsilateral palmaris longus.[4,10,15] If the ipsilateral palmaris longus is unavailable because of agenesis or another factor, several other autograft sites exist—including contralateral palmaris longus, gracilis, plantaris, Achilles, and toe extensors.[4,6] This group of techniques has proven reliable in reconstructing the medial UCL using autografts.[4,6,14,20] However, complications from autograft

TABLE 2
Timmerman-Andrews Subjective Scores

		Subscores				
Age at Surgery, y	Sex	Pain	Swelling	Lock/Catch	Activities	Total
16	Male	25	25	25	20	95
15	Male	20	25	25	25	95
17	Female	20	25	25	20	90
16	Male	20	25	25	25	95
15	Female	25	25	25	25	100
15	Male	25	25	25	25	100
15	Female	20	20	25	25	90
17	Male	20	20	25	25	90
17	Female	20	25	25	20	90
15	Male	10	25	25	20	80

TABLE 3
Return to Play Data[a]

Age at Surgery, y	Sex	Sport	Time to RTS	Postop Level of Play[b]	Reason for No RTS
16	Male	Baseball	6 mo	Above preinjury[b]	—
15	Male	Soccer	6 mo	Above preinjury[b]	—
17	Female	Motocross	No return	No return	Pain
16	Male	Baseball	12 mo	Above preinjury[b]	—
15	Female	Water polo	12 mo	At preinjury[b]	—
15	Male	Wrestling	6 mo	At preinjury[b]	—
15	Female	Motocross	12 mo	Above preinjury[b]	—
17	Male	Wrestling	No return	No return	Unrelated to injury
17	Female	Gymnastics	6 mo	At preinjury,[b] no return[c]	Unrelated to injury
15	Male	Baseball	No Return	No return	Unrelated to injury

[a]The preinjury level of play was high school for all patients. Dashes indicate areas not applicable. Postop, postoperative; RTS, return to sport.
[b]Considered "excellent" according to the Conway-Jobe score.
[c]The second outcome is related to this patient's second surgery.

harvest sites do occur—including infection, loss of function, scarring, and rare nerve injuries. Vitale and Ahmad[20] found an overall complication rate of 10% in their review of autograft reconstructions. Avoidance of additional morbidity of graft harvesting is desirable for many patients. Reasons to avoid other morbidity include prevention of added surgical risk, graft site morbidity, trauma patients, and potential loss of function at the harvest site. For our adolescent patients, minimizing risk while obtaining the same outcomes by using allografts instead of autografts is potentially a desirable alternative. Allografts may particularly be necessary in such sports as gymnastics and soccer that require a higher dependence on the hamstring tendon and other lower extremity autograft types .

Savoie et al[16] focused on overhead throwing athletes with a mean age of 20.4 years, used hamstring allografts, observed patients for a mean of 39 months, and used a single surgical technique in all patients. They reported a complication rate of 6%. Kennon et al[11] reported a 20% complication rate in a 25-patient cohort of laborers and recreational athletes, with a mean age of 25. They utilized 3 allograft types and used a variety of surgical methods. The variation in reported complication rate for these allograft studies is between 6% and 20%, consistent with the reported[20] range of complication rate in autograft reconstruction (6%-46.3%). Specific to autograft reconstruction in adolescents, Petty et al[15] reported a 7% complication rate—all being transient nerve injuries secondary to autograft harvest. Neither the allograft study nor the present study reports any failed index medial UCLR due to allograft failure. All 3 studies benefited from a lack of harvest site complications by using allografts.

The Conway-Jobe scores in this study cohort were comparable with reports in the literature of autograft utilization in the same age group. Petty et al[15] reported an "excellent" RTS in 74% (20/27) of adolescents who underwent autograft UCLR, which is similar to the 70% (7/10) in our study. A systematic review of adolescent autograft UCL conducted by Hadley et al[7] demonstrated an "excellent" Conway-Jobe score in 84% of patients (215/256

patients). This same review found a mean Timmerman-Andrews score of 94.7, comparable to the score of 92.5 found in the present study for adolescent allograft UCLR. The Conway-Jobe scores in the present study are difficult to compare to existing larger data sets, predominately because no patients who pursued continued athletic participation returned at a lower level of sports participation—they just elected not to participate. Either way, the findings of this initial study indicate that allograft reconstruction is a comparable alternative to autograft reconstruction for returning to sport at or above the preinjury level of play in this youthful cohort.

The longevity of allograft for UCLR is unknown. This midterm study and the study published by Savoie et al[16] with a 2-year follow-up provide early evidence that allograft in UCLR has promising survivability. No graft failures occurred in our study until the 11.9-year follow-up.

The inclusion of all athlete types in our series—including trauma patients—created some heterogeneity in our study and some challenges to interpreting the data. The 2 patients who were injured via motocross accidents also sustained a fracture or fracture/dislocation of the elbow at the time of index injury. These patients presented to an orthopaedic surgeon with persistent pain and instability after their traumatic injuries had healed resulting in a work-up, which demonstrated chronic UCL instability. One of the trauma patients played softball competitively before her traumatic all-terrain vehicle injury and went on to play collegiate softball after her UCL allograft reconstruction. Her ability to RTS after a traumatic rupture of her UCL is an encouraging indicator of the efficacy of gracilis allograft in adolescents.

Our 1 patient with complications experienced recurrent instability because she returned to gymnastics within weeks of her index surgery and continued to train and compete until persistent and recurrent instability resulted in her returning in <12 months from the index surgery. She was found to have persistent instability and required a repeat allograft UCLR. During the examination under anesthesia and diagnostic arthroscopy, her allograft appeared intact but gapped >2 mm when the UCL was stressed. After her second reconstruction, because of her high school graduation and the lack of a gymnastics team at the college of her choice, she did not RTS. She did go on to coach gymnastics and had no residual instability when participating at the recreational level. In the short term, allografts used in anterior cruciate ligament reconstruction have slower incorporation into host tissue than autografts[9]; nonetheless, it is not known whether this same biology holds true for extra-articular ligamentization processes such as the UCL.

Limitations

There are limitations to this study that include the inherit issues with retrospective study design, small sample size, heterogenicity in activity, and inability to confirm physical examinations at the final follow-up. Regarding our limited success (only 10 of 29 patients) in achieving intermediate duration follow-up scores, we must recognize that longer-term follow-ups can be difficult in pediatric studies, as patients become adults and move from home. Of the 2 other studies utilizing gracilis allografts for UCLR, only Kennon et al[11] had 8 years of follow-up; nevertheless, their cohort was not limited to adolescent patients and was in "non-elite" athletes. However, they also reported good outcomes with retained allografts in all their patients. Another limitation is that the technique used is specific to the surgeon and not previously described in the literature. This is the same technique used for either autograft or allograft reconstruction of the medial UCL in our practice. Finally, our heterogenic cohort included a variety of mechanisms of injury ranging from overhead athletes, impact athletes, and trauma. We acknowledge that this detracts from the ability to generalize allograft reconstruction of the medial UCL to a specific adolescent patient population, such as overhead athletes. Still, it does allow us to consider the application of allografts across a wider demographic spread.

CONCLUSION

The study hypothesis was upheld in that excellent patient-reported functional scores were reported at the midterm duration follow-up after allograft reconstruction of the medial UCL in adolescent patients, regardless of the mechanism of injury. For adolescent patients who desire to avoid the additional morbidity of autograft harvest, have palmaris agenesis, or have other reasons to select allografts over autografts, then an allograft tendon reconstruction is a viable option for both the throwing and the high-impact athlete, regardless of sex.

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