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Functional outcomes of ulnar collateral ligament reconstruction with a novel double suspensory fixation

Raffy Mirzayan, MD[a,*], Neilen Benvegnu, MD[b], Margo Sidell, ScD, MSPH[c], Daniel C. Acevedo, MD[d], David O. DeWitt, PA-C[a], Nikko Lowe, BS[a], Anshuman Singh, MD[e]

[a]*Department of Orthopaedics, Kaiser Permanente Southern California, Baldwin Park, CA, USA*
[b]*Department of Orthopaedics, USC Keck School of Medicine, Los Angeles, CA, USA*
[c]*Department of Research & Evaluation, Kaiser Permanente Southern California, Pasadena, CA, USA*
[d]*Department of Orthopaedics, Kaiser Permanente Southern California, Panorama City, CA, USA*
[e]*Department of Orthopaedics, Kaiser Permanente Southern California, San Diego, CA, USA*

Background: Ulnar collateral ligament reconstruction (UCLR) has allowed the return of overhead athletes to throwing sports. We describe a new double suspensory (DS) technique using a single tunnel in the ulna and humerus, achieving fixation with adjustable loop buttons.

Methods: Inclusion criteria included skeletally mature baseball players with clinical and magnetic resonance imaging diagnosis of UCL insufficiency who failed a trial of structured nonoperative treatment. A total of 36 baseball players underwent DS UCLR, between 2011 and 2017, by 1 surgeon with minimum 2-year follow-up. The graft was fixated with an adjustable button loop on the humeral side and a tension slide technique with a button on the ulnar side. Pre- and postoperative Kerlan-Jobe Orthopaedic Clinic and Single Assessment Numerical Evaluation and postoperative Conway scores were obtained.

Results: The mean age was 19.8 ± 4.6 years (range, 14-35 years). All were male. Mean years played before surgery was 14.3 ± 4.6 years (range, 8-28 years). There were 32 (89%) pitchers and 4 (11%) position players. There were 13 (36%) high school, 20 (55%) college, 2 (6%) minor league, and 1 (3%) adult league athletes. The mean follow-up was 55.3 ± 23.7 months (range, 26-97 months). There was significant improvement in Kerlan-Jobe Orthopaedic Clinic (33.2 ± 19.9 to 89.7 ± 15.1, $P < .0001$) and Single Assessment Numerical Evaluation (20.7 ± 16.7 to 93.6 ± 11.9, $P < .0001$) scores. Using Conway scoring, 25 (69%) had excellent, 5 (14%) good, 3 (8%) fair, and 3 (8%) poor scores. Mean return to play was 9 ± 1.5 months (range, 6-16 months). Only 1 (3%) athlete required a revision surgery and ultimately returned to play and 1 (3%) hardware removal. None developed ulnar nerve symptoms.

Conclusion: DS fixation for UCLR in baseball players can lead to excellent clinical results and early return to play.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Ulnar collateral ligament; tommy john; baseball; pitching; elbow; reconstruction

The ulnar collateral ligament (UCL) is an important static medial stabilizer of the elbow, providing restraint to valgus stress to the elbow. Overhead athletes, especially baseball players, are at increased risk of injury to the UCL

This study was approved by the Kaiser Permanente Southern California Institutional Review Board (study# 11763).

*Reprint requests: Raffy Mirzayan, MD, Department of Orthoapedic Surgery, Kaiser Permanente Medical Center, 1011 Baldwin Park Blvd., Baldwin Park, CA 91706, USA.

E-mail address: Raffy.mirzayan@kp.org (R. Mirzayan).

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due to repetitive extreme valgus stress during overhead throwing motion.[20,29] The typical mechanism of injury for UCL insufficiency is a gradual degradation of functional performance with increasing medial elbow pain over time due to stretching, degeneration, and partial or complete tearing of the UCL on magnetic resonance imaging from years of repetitive forces across the medial elbow.[39]

The original technique described by Dr. Frank Jobe in 1974 used a palmaris longus autograft that was weaved through bone tunnels in the ulna and medial epicondyle in a figure-of-eight fashion, achieving fixation by suturing the graft to itself.[24] This technique allowed 62.5% of throwers to return to the preinjury level. Because of the technical difficulty of drilling small tunnels close to one another with risk of tunnel convergence, collapse, or fracture, as well as a high complication rate (mostly due to ulnar neurapraxia), modifications have been made to improve the strength and reproducibility of reconstruction. These modifications include the docking technique,[35] interference screw technique,[2] the DANE or hybrid technique combining an interference screw with the docking technique,[13] and EndoButton fixation.[4] These techniques often present difficulty in proper graft tensioning, with laboratory studies demonstrating 50% of biomechanical failures due to suture failure.[36]

Myeroff et al[31] introduced a double suspensory fixation technique where a button is tunneled laterally across the trochlea from the medial aspect and flipped on the lateral epicondyle as well as the ulna, with a 69.6% return to sport at the same or better level. With this technique, the graft exits the humeral tunnel and makes a killer turn toward the ulnar tunnel. Our previously described double suspensory fixation technique places the button on the anterior surface of the medial epicondyle that more anatomically reproduces the UCL origin.[1] In addition, the use of a single humeral and ulnar tunnel eliminates the risk of tunnel collapse and uses a more robust fixation than suturing graft to itself or tying sutures over a bone bridge. We report on the clinical outcomes, with minimum 2-year follow-up, on the use of double suspensory fixation for UCL reconstruction in baseball players.

Methods and materials

After obtaining Institutional Review Board approval, a retrospective analysis of prospectively collected data of a case series of UCL reconstructions performed by the senior author (RM) was performed. All consecutive UCL reconstructions with double suspensory humeral and ulnar-sided button fixation performed between January 12, 2011, and January 10, 2017, which met the inclusion criteria, were included in our analysis. Double suspensory fixation is the author's technique of choice for the primary UCL reconstruction cases. Data were collected from the electronic medical record and patient telephone calls according to a scripted protocol.

Inclusion criteria included skeletally mature baseball players who were diagnosed with UCL insufficiency and failed the structured nonoperative rehabilitation protocol. The diagnosis of UCL insufficiency was made by a single fellowship-trained surgeon (RM) based on the history of presentation, tenderness to palpation at the sublime tubercle, and positive moving valgus test. An elbow magnetic resonance imaging arthrogram was also obtained and used to aid in the diagnosis. None were acute ruptures. All patients had undergone 1-2 cycles of nonoperative management, each cycle consisting of 6 weeks of shutting down from throwing, but continuation of all other core and extremity-strengthening exercises, followed by a 6-week throwing program. If the patient's symptoms persisted, surgical intervention was recommended. Exclusion criteria were athletes with a mode of failure that was not throwing a baseball, less than 2-year follow-up, patients who opted to undergo traditional UCL reconstruction (Kerlan-Jobe Orthopaedic Clinic [KJOC] technique), revision UCL reconstructions, UCL for chronic medial epicondyle avulsion, and UCL for traumatic dislocation/instability.

Collected data included demographic information, pre- and postoperative KJOC scores, Single Assessment Numerical Evaluation (SANE), postoperative Conway scores, and patient satisfaction. The KJOC score was obtained in-person or over the phone. The KJOC score is a functional assessment tool for the upper extremity in the overhead athlete and has been shown to be valid and responsive[3] and has been validated when administered over the telephone.[18] Additional data collected were handedness, position, years played, level of play before and after injury, prior and concomitant procedures, graft type, tourniquet time, graft and tunnel diameter, return to and level of play, as well as complications.

Operative technique

The operative technique has been previously described in detail.[1] Briefly, the ipsilateral palmaris longus tendon is harvested using 3 percutaneous incisions without use of a tendon stripper. If absent or insufficient, an allograft is used. The preferred graft is 4.5 mm in diameter and approximately 65 mm in length.

The graft is folded over and through the suture loop of an ACL TightRope RT (Arthrex, Naples, FL, USA). The 2-tail ends of the graft are sewn with #2 FiberWire (Arthrex) sutured in a Krakow fashion, 15-20 mm up the graft. The TightRope sutures are toggled, shortening the loop and reducing the button down to the folded end of the graft. The toggle sutures are tied together ensuring that the button is staying in contact with the graft and the graft is left under tension on the back table and kept moist (Fig. 1).

A muscle-splitting approach to the elbow, as described by Thompson et al,[38] is used. The ulnar nerve is not routinely transposed or decompressed. The native UCL is incised in line with the muscle fibers and the fascial incision. Anterior and posterior leaflets are created via sharp dissection off the ulna, exposing the sublime tubercle. A 3.2-mm spade-tipped guide pin is drilled bicortically, angled 30° distally and caudally to exit out of the posterior/

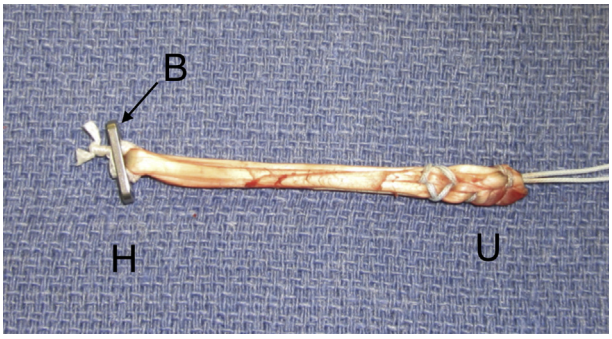

Figure 1 Doubled-over (2-ply) graft over the adjustable loop button (B) on the humeral side (H) for humeral fixation with the ulnar end (U) of the graft sutured with a high strength suture.

dorsal ulnar cortex, as described by Lee et al.[27] Using the calibration marks on the guide pin, the tunnel length can be measured. The tunnel should be approximately 30 mm in length or as long as possible without violating the dorsal cortex. A 5.5-mm cannulated reamer is then used to ream the ulnar tunnel unicortically over the guide wire.

Through a separate fascial incision proximal to the medial epicondyle, the anterior surface of the medial epicondyle is exposed. A 2.4-mm guide pin is drilled from the origin of the UCL at the distal aspect of the medial epicondyle to the proximal, anterior aspect of the medial epicondyle. A 4.5-mm cannulated reamer is used over the guide wire to ream the proximal tunnel, bicortically, penetrating the anterior cortex, with a depth of 12-15 mm. The guide pin is aimed slightly lateral to avoid overhang of the button on the medial cortex.

Once the 2 tunnels have been prepared, the free ends of the graft are passed from proximal to distal, through the humeral tunnel until the TightRope button lays flat and rests on the anterior surface of the medial epicondyle (Fig. 2). The sutures from the free ends of the graft are passed through a BicepsButton (Arthrex), which is then passed through the ulnar tunnel and flipped on the far cortex. Once the button is flipped, the suture limbs are pulled and the graft is reduced into the ulnar tunnel in a tension slide manner and tensioned at 90° of elbow flexion. An arthroscopic knot pusher is used to tie knots and advance them to the bottom of the ulnar tunnel. A 4.75 biocomposite interference screw is inserted into the ulnar tunnel to provide aperture compression and keep the suture at the bottom of the tunnel. The native ligament is repaired over the graft with an absorbable suture. Postoperative radiographs are taken to ensure proper tunnel and button placement (Fig. 3).

The patient is placed in a long-arm, posteriorly molded splint in neutral forearm rotation until the first postoperative visit. The splint is discontinued at the first postoperative visit and a standard progressive rehabilitation program is followed, with the goal of return to play at approximately 10 months postoperatively. A

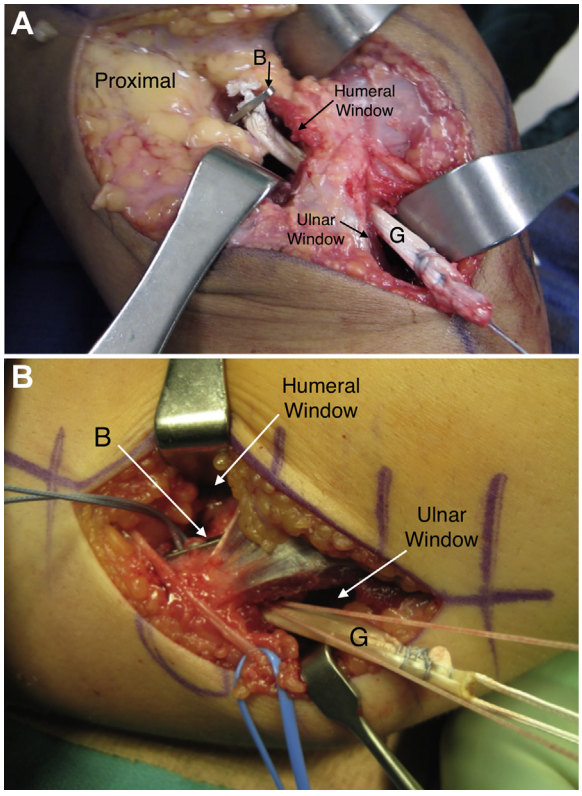

Figure 2 (**A**) Graft (G) being passed through a single humeral tunnel through a fascial split in the pronator mass (humeral window) and exiting through a fascial split in the flexor carpi ulnaris (ulnar window). (**B**) Button (B) resting on the anterior surface of the medial epicondyle.

postoperative brace was not used after the first postoperative visit given the biomechanical security of this construct.

Statistical analysis

Continuous demographic and surgery variables were described with means and standard deviations. The mean difference and 95% confidence interval for pre- and post-SANE and KJOC scores were calculated and assessed with paired *t*-tests, to account for the within patient correlation between pre- and post-measures. Statistical analysis was performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA).

Results

Patient demographics

During the study period, 79 patients underwent a UCL reconstruction by a single surgeon. Thirty-five patients were excluded because of (1) traditional KJOC reconstruction (6 patients), (2) chronic medial epicondyle

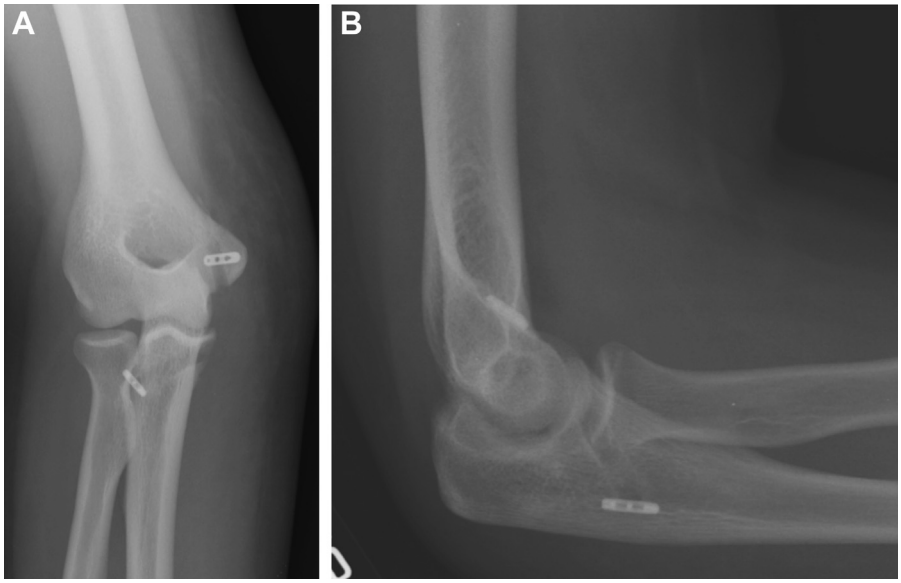

Figure 3 (**A**) Anteroposterior and (**B**) lateral postoperative radiographs demonstrating button and tunnel placement.

avulsions (6 patients), (3) traumatic dislocation/instability (3 patients), and (4) sports other than baseball (20 patients), leaving 44 patients who met the inclusion criteria. Eight patients chose not to participate in the study, leaving 36 (82%) patients available for analysis. The mean age was 19.8 ± 4.6 years (range, 14-35 years). All were male. The mean number of years played before surgery was 14.3 ± 4.6 years (range, 8-28 years). The dominant arm was involved in all cases. There were 32 (89%) pitchers and 4 (11%) position players. There were 13 (36%) high school, 20 (55%) college, 2 (6%) minor league, 1 (3%) adult league, but no Major League athletes. The mean postoperative follow-up time was 55.3 ± 23.7 months (range, 26-97 months). An in-person examination and questionnaire were performed in 5 (14%) patients and a phone interview in 31 (86%) patients.

Surgical information

Palmaris longus autograft was used in 29 (81%) patients, allograft in 6 (16%), and hybrid in 1 (3%). The mean graft length was 63.7 ± 3.4 mm (range, 50-65 mm). The mean graft diameter on the humeral side was 4.3 ± 0.5 mm (range, 3.5-5 mm) and on the ulnar side 4.5 ± 0.4 mm (range, 3.5-5.5 mm). The humeral tunnels were line to line with the graft diameter and the ulnar tunnel was over-reamed by 1 mm to allow the arthroscopic knot pusher to reach the bottom of the tunnel. The graft was folded once (2 ply) in 14 (39%) patients and folded twice (3 ply) in 22 (61%). Mean tourniquet time was 75.5 ± 20.6 minutes (range, 50-120 minutes). Two patients had prior surgery of the ipsilateral elbow, including 1 ulnar nerve transposition and 1 arthroscopy for valgus extension overload (VEO). Twelve patients (33%) had a concomitant procedure including 5 elbow arthroscopies for VEO, 3 ulnar nerve transposition, 2 treatment of osteochondritis dissecans of the capitellum, 1 arthroscopy with capsular release, and 1 simultaneous elbow arthroscopy for VEO and ulnar nerve transposition. Only patients with preoperative ulnar nerve symptoms underwent transposition.

Clinical outcomes

The mean follow-up was 55.3 ± 23.7 months (range, 26-97 months). There was a significant improvement in KJOC (33.2 ± 19.9 to 89.7 ± 15.1, $P < .0001$) and SANE (20.7 ± 16.7 to 93.6 ± 11.9, $P < .0001$) scores. Regarding Conway scores, 25 (69%) had excellent, 5 (14%) good, 3 (8%) fair, and 3 (8%) poor. The mean return to play was 9 ± 1.5 months (range, 6-16 months) with 24 (67%) returning to the same level or better, 6 (17%) returning to a lower level, and 6 (17%) did not return to play. Of these 6 patients who did not return, 1 was directly because of his elbow, whereas the other 5 were due to loss of interest or graduating high school and not seeking to play at a higher level. Overall, 28 (77%) were extremely satisfied and 6 (17%) were satisfied and would undergo the same procedure, whereas 2 (6%) were unsatisfied with the procedure and would not undergo again.

Complications

We did not have functional outcomes on 8 excluded patients who chose not to participate in this study. We accessed these patients' charts in the integrated medical record, and found no reoperations or complications captured for those 8 excluded patients. It is possible that individuals presented with complications to providers

outside of the system; however, these visits are not reimbursed without approval by the chief of orthopedics and are generally captured in the billing records.

A secondary procedure was performed in 3 of 44 (6.8%) patients. One patient required an arthroscopy with débridement, 1 patient required hardware removal of the button on the humeral side, and 1 patient underwent revision UCL reconstruction but ultimately returned to play. None of the patients who underwent a secondary procedure had subsequent issues with their elbow, and 2 of 3 were able to return to the same level of play or better. There were no new cases of postoperative ulnar neurapraxia. There were no cases of medial epicondyle or ulnar fracture.

Discussion

Double suspensory fixation for UCL reconstruction in baseball players leads to a significant improvement in patient satisfaction, KJOC, SANE, and Conway scores, with a return to sport rate comparable with current methods of UCL reconstruction.[33] The use of a single tunnel theoretically reduces risk of fracture and tunnel collapse, although we did not have a comparison group. This technique has low complication rate with high patient satisfaction and return to throwing. A total of 83% (67% at the same or a higher level, 17% at a lower level) of athletes returned to pitching at an average of 9 months after surgery. Patients had excellent outcomes regardless of whether or not they returned to sport. Patients had an average KJOC score of 89.7 and SANE of 93.6, with 25 (69%) having an excellent Conway score, with an additional 5 noting a good outcome. A more anatomic orientation of the humeral tunnel allowed proper humeral button placement and without a killer turn in the graft. In addition, the use of a single tunnel on both sides through 2 separate intramuscular windows allows less retraction and a less technically demanding approach. As a result, only 3 patients required reoperation, including 1 for hardware removal, another for arthroscopic débridement, and 1 revision that was able to return to sport. In addition, 0% of cases had new-onset ulnar nerve neurapraxia. This is an improvement on rates reported in the literature ranging from 2% to 20.8%.[8,16,17,26,35]

Elbow injuries represent between 16% and 22% of all Major League Baseball (MLB) injuries.[28] An online questionnaire distributed amongst the MLB found an overall prevalence of 10% of players undergoing at least 1 UCL reconstruction, with pitchers (16%) reporting a significantly higher prevalence of UCL reconstruction compared with nonpitchers (3%). In addition, studies have shown that the annual incidence of UCL reconstructions in professional baseball players has increased.[9-11,19,21] These injuries can be devastating to an overhead athlete's career. Before the original description of UCL reconstruction in 1974 by Dr. Frank Jobe, a ruptured UCL was career ending. A recent systematic review and meta-analysis showed the return to sport at the previous level to be 79% for MLB players but only 67% for Minor League Baseball players.[33] In addition, it was shown that after UCL injury, pitchers had an increased earned run average, walks, and hits per inning pitched, with a decrease in innings pitched and decreased fastball velocity.[23] Several techniques have been developed in order to effectively address the UCL injury and return athletes to sport at the same or a higher level.[14]

Nonoperative treatment includes rest from throwing along with anti-inflammatories and range of motion exercises of flexor and pronator muscles, followed by progressive strengthening and throwing exercises that take place over a 3- to 6-month period. Studies showed a 42% return to sport at the preinjury level at an average of 24.5 weeks.[34] When nonoperative treatment fails, surgical options may be indicated. For young patients with acute avulsion injuries, 93% showed good to excellent outcomes with 97% returning to sports at 6 months.[37] Less than favorable results have been found with older overhead throwing athletes, with only 50% returning to sport in 1 study,[12] and 70% in another due to experienced surgeons and an enhanced postoperative rehabilitation program.[5]

Since the original technique used for UCL reconstruction, various modifications in technique and graft fixation have been described due to concerns in strength of suture fixation, adequate tensioning of the graft, and potential complications resulting from tunnel collapse from converging tunnels. Despite many patients returning to sport, Jobe et al[24] found a greater than 50% complication rate. These included 4 subsequent reoperations secondary to ulnar nerve issues, flexor mass reattachment, and osteophyte excision. Conway et al[12] subsequently reported on 56 athletes and found a similar rate of return to play (68%) but with a complication rate of 25%, with 12 reoperations due to ulnar nerve issues. As a result, Thompson et al[38] developed a muscle-splitting approach and reported on 83 patients. Their complication rate reduced to 8.4% and 82% had excellent results. In the largest series to date, Cain et al[8] examined 1281 UCL reconstructions with ulnar nerve transposition and found 83% of patients returned to their previous level of competition or higher, and 16.3% rate of postoperative ulnar nerve neurapraxia.

The docking technique was developed by Rohrbough et al,[35] in which a single humeral and 2 ulnar tunnels are created. The graft is secured with sutures over a humeral bone bridge. They reported on 36 patients who underwent the procedure and had a 92% rate of return to play. They used a similar muscle splitting approach; only 2.8% of patients suffered from postoperative ulnar nerve neurapraxia, and 1 patient had a fracture of the ulnar tunnel requiring revision reconstruction. Subsequent studies using the docking technique showed return to play rates of 85%-90% and a 2%-5% rate of ulnar neurapraxia.[16,26] A modification to this technique was later introduced in which 4 strands of the palmaris tendon graft were used.[32] Results using this modified technique achieved excellent results as well, with a return to play of 76%-92% and 0%-4% incidence of ulnar nerve neurapraxia.[7,15,32]

Modern techniques using interference screw fixation attempt to improve the fixation strength of the graft have been described.[2,13,14,25] Ahmad et al[2] first studied the biomechanical properties of interference screws. Kodde et al[25] later clinically evaluated patients undergoing UCL reconstructions with triceps fascia autografts and interference screw fixation. In their series of 20 athletes, 90% had an excellent Conway score, with a 5% incidence of ulnar neurapraxia. A hybrid technique (DANE) was developed in 2006 by Conway,[13] in which ulnar fixation was achieved via an interference screw, and humeral-sided fixation was achieved via the docking technique. Dines et al[14] performed a case series evaluating 22 athletes using the DANE technique. Excellent results were achieved by 86% of their patients. A high complication rate of 17% was found, with a 9% incidence of ulnar neurapraxia and elbow stiffness, with 3 patients requiring reoperation.

The goal of any reconstruction is to achieve immediate, secure fixation to allow early rehabilitation. With original techniques, fixation was tenuous and rehabilitation was limited to avoid early failure. With modern techniques, including the current one described, immediate fixation is achieved to allow for early rehabilitation. A biomechanical study performed by Armstrong et al[4] compared 4 methods of fixation: the Jobe, docking, interference screw, and button techniques. Although peak load to failure for each technique was significantly lower than the native ligament, the docking and EndoButton reconstruction showed similar values that were superior to the interference screw and Jobe reconstructions. The number of cycles sustained before failure was significantly higher in the docking and EndoButton reconstruction as compared with the Jobe technique. Interference screws failed due to tendon pulling out of the tendon-screw interface, whereas the remaining techniques failed at the suture-ligament interface. Jackson et al[22] evaluated 6 cadaveric elbows comparing the docking technique with a single bundle bisuspensory technique. Both techniques were able to restore valgus laxity to the intact state, and there was no significant difference with regard to stiffness, ultimate torque, ultimate torque angle, energy absorbed, and applied moment to reach 10° of valgus. Lynch et al[30] compared ulnar tunnel cortical button fixation with TightRope vs. traditional docking reconstruction. Seven cadaveric elbows showed no significant difference between the native state and reconstructed state in either group. Although the TightRope group did have higher angular displacement and lower stiffness than the native ligaments, there were no significant differences found between the TightRope and docking groups. In addition, the authors observed that less dissection was necessary for the TightRope group, as a result requiring only 1 drill hole for the ulna.

Secure fixation is key to a patient's functional outcome, but whether or not a patient is able to return to the sport in which they performed at a high level is of significant importance to many patients. In our study, 83.3% of patients were able to return to sport. A systematic review of UCL reconstruction showed a rate of return to play ranging from 62.5% to 92%.[5,7,8,13,15-17,24-26,32,35,38,39] Another systematic review and meta-analysis reported a return to sport proportion of 92%, ranging from 86% to 97%.[33]

Myeroff et al[31] published the first report of clinical outcomes using a dual-sided, far cortical button suspension technique. In their series of 23 amateur athletes, 82.6% returned to play with excellent postoperative range of motion and significant improvements in visual analogue scale (VAS) and disabilities of the arm, shoulder, and hand (DASH) score. The authors noted limitations to their technique, which include the superficial nature of the lateral humeral button, which led to symptomatic hardware in 13% of their patients that required removal and intra-articular hardware migration in 1 patient. In addition, the use of a lateral humerus cortical button causes the graft to make an acute "killer turn" as it enters the medial trochlea toward the lateral epicondyle where the button is flipped. In our technique, the graft exits the medial epicondyle in a more anatomic orientation, similar to the Jobe and docking techniques, avoiding a killer turn of the graft. In our series, 1 patient complained of irritation at the humeral button requiring removal of the hardware. This was early on in the series, and we modified the tunnel placement by drilling it more laterally to avoid the button from overhanging from the medial epicondyle.

We believe that the technique described in this article has several advantages. This reconstruction technique uses single humeral and ulnar tunnels and provides immediate secure fixation. By using the TightRope button for humeral-sided fixation, we minimize the number of tunnels to a single tunnel as opposed to 2 tunnels, thus reducing the risk of tunnel convergence and fracture. In addition, the BicepsButton is low profile and rests securely on the dorsal surface of the ulna allowing the graft to be inserted into the tunnel using a tension slide technique. The use of the interference screw on the ulnar side of the graft offers additional compression and fixation of this portion of the graft, and allows us to incorporate an internal brace to the reconstruction.[6] The use of 1 tunnel on the ulna allows the surgeon to place the graft at the exact insertion point of the anterior bundle of the UCL on the sublime tubercle and avoids the risk of fracturing the bone bridge between 2 tunnels.

Our study is not without limitations. We did not have a control group with randomization. Most of the athletes were high school and college players, and not professionals. The cost of implants is also a factor to consider in some practice settings.

Conclusion

We described a double suspensory technique of UCL reconstruction and reported our functional outcomes with a minimum 2-year follow-up. Our technique used a single tunnel in the ulna and medial epicondyle and button fixation on both sides and led to significant improvements in KJOC and SANE scores, and a high rate of return to play, with low complication rates.

Disclaimer

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