[ Orthopaedic Surgery ]

# Ulnar Collateral Ligament Reconstruction: Anatomy, Indications, Techniques, and Outcomes

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**Context:** Ulnar collateral ligament (UCL) injuries lead to pain and loss of performance in the thrower's elbow. Ulnar collateral ligament reconstruction (UCLR) is a reliable treatment option for the symptomatic, deficient UCL. Injury to the UCL usually occurs because of chronic accumulation of microtrauma, although acute ruptures occur and an acute-on-chronic presentation is also common.

**Evidence Acquisition:** Computerized databases, references from pertinent articles, and research institutions were searched for all studies using the search terms *ulnar collateral ligament* from 1970 until 2015.

**Study Design:** Clinical review.

**Level of Evidence:** Level 5.

**Results:** All studies reporting outcomes for UCLR are level 4. Most modern fixation methodologies appear to be biomechanically and clinically equivalent. Viable graft choices include ipsilateral palmaris longus tendon autograft, gracilis or semitendinosus autograft, and allograft. Clinical studies report excellent outcomes of UCLR for both recreational and elite level athletes with regard to return to sport and postoperative performance. Complications, although rare, include graft rerupture or attenuation, ulnar nerve symptoms, stiffness, pain, and/or weakness leading to decreased performance.

**Conclusion:** Injuries to the UCL have become commonplace among pitchers. Nonoperative treatment should be attempted, but the limited studies have not shown promising results. Operative treatment can be performed with several techniques, with retrospective studies showing promising results. Complications include ulnar neuropathy as well as failure to return to sport. Detailed preoperative planning, meticulous surgical technique, and a comprehensive rehabilitation program are essential components to achieving a satisfactory result.

**Keywords:** ulnar collateral ligament reconstruction; Tommy John; elbow; surgical management; biomechanics; instability; throwing athlete; pitcher

## EPIDEMIOLOGY OF MEDIAL ELBOW PAIN AND ULNAR COLLATERAL LIGAMENT RECONSTRUCTION

Medial elbow pain is common among baseball pitchers and can also be seen in gymnasts, javelin throwers, wrestlers, quarterbacks, and offensive linemen.[18,20,33,34,64] In collegiate pitchers, elbow injuries are the most common cause of time loss (over 10 days).[14] Among National Collegiate Athletic Association (NCAA) baseball players, the upper extremity accounts for 45% of all injuries, with the elbow accounting for 7% to 8% of injuries.[14] More than 97% of elbow pain in pitchers is located medially.[10]

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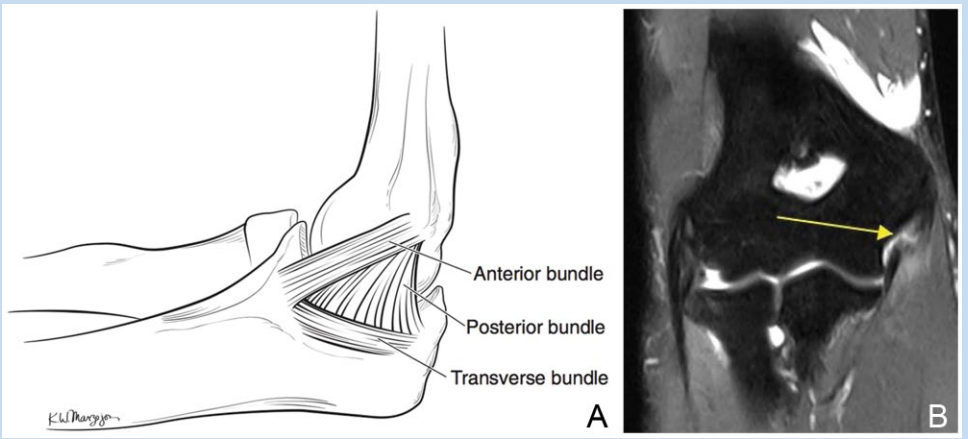


Figure 1. (A) Anatomy of the ulnar collateral ligament (UCL). (B) Magnetic resonance image demonstrating a tear of the UCL at the tip of the arrow.

Ulnar collateral ligament (UCL) deficiency is rapidly increasing in incidence. The number of Major League Baseball (MLB) pitchers who have undergone ulnar collateral ligament reconstruction (UCLR) significantly increased between 1986 and 2012.[22] Revision surgery, although rare, is also beginning to occur in MLB pitchers and other athletes.[19,32] Unfortunately, the results of revision UCLR are not as predictable as primary UCLR, with lower return-to-sport rates seen in MLB pitchers.[42] However, more concerning is the evolution to high school pitchers. For instance, in a single surgeon's series there was an 11-fold increase in UCLR performed in high school pitchers between 1988 and 2003.[53]

## HISTORICAL PERSPECTIVE

The initial technique by Jobe et al[31] for UCLR involved an elevation of the flexor muscles off the medial epicondyle and submuscular transposition of the ulnar nerve. Drill holes (3.2 mm) were created in the ulna (2 holes) and medial epicondyle (3 holes) to mimic the attachment points of the native UCL, and a donor tendon (palmaris longus) was passed in a figure-of-8 configuration and sutured to itself.[12] With the initial Jobe technique, >60% of elite throwing athletes were able to return to their preinjury level of sport (RTS). Although 21% of these patients developed postoperative ulnar neuropathy, these all resolved within 7 years.[12] Since the initial technique described by Jobe et al,[31] the technique has undergone several modifications of the approach to the flexor-pronator mass and ulnar nerve, fixation, graft type, and configuration (Table 1 in Appendix 1, available at http://sph.sagepub.com/content/by/supplemental-data).[3,12,16,25,27-29,36,43,45,56,61]

## APPLIED SURGICAL ANATOMY/ BIOMECHANICS

### Soft Tissue Restraints

Soft tissue restraints afford 50% of elbow stability and can be broken down into dynamic muscular restraints and static ligamentous restraints.[37,52] For valgus instability, the main dynamic stabilizer is the flexor-pronator mass and the main static stabilizers are the UCL and the medial joint capsule.[37,52] Cadaveric studies demonstrate that within the flexor-pronator mass, the flexor carpi ulnaris provides the most significant contribution to resisting valgus stress, followed by the flexor digitorum superficialis, with the pronator teres contributing the least dynamic valgus restraint.[37,52] The UCL is a dynamic structure that undergoes hypertrophy with training; the mean thickness of the UCL was 6.2 ± 1.6 mm in the throwing arm compared with 4.8 ± 1.3 mm on the nonthrowing arm ($P < 0.001$).[11]

The UCL is composed of 3 separate bundles: anterior (the primary restraint to valgus restraint and the most commonly injured bundle), posterior, and transverse, with a mean length of 4.7 to 5.4 cm (Figure 1, A and B).[23,59,62] The anterior bundle is composed of 2 distinct bands: the anterior band, which is taut and serves as the primary valgus stabilizer from 30° to 90° of flexion, and the posterior band, which is taut and serves as the primary stabilizer from 90° to 120° of flexion.[9,46,59] It is fan-shaped and originates on the medial epicondyle of the humerus and inserts onto the medial aspect of the semilunar notch of the ulna. Finally, the transverse bundle is variably present, originates from the medial olecranon, and inserts onto the inferomedial aspect of the coronoid process. It does not cross the elbow joint and affords no support to valgus stress.[10]

### Elbow Throwing Biomechanics

During the late cocking and early acceleration phases, the medial elbow experiences significant force—approximately 64 N•m—and the UCL is most vulnerable to injury.[24] Because the elbow is usually at 90° to 100° of flexion, the posterior band of the anterior bundle of the UCL is the most critical stabilizer. Eccentric contraction within the flexor pronator mass also serves to resist this valgus force, but >50% of the valgus load is transmitted through the UCL, correlating with stresses greater

than 32 N•m.[15,46] The mean ultimate load to failure for a native UCL is 34.29 N•m and for a reconstructed UCL is 30.55 N•m; thus, the stress placed on the UCL during the late cocking phase of every pitch is nearly sufficient to cause a UCL tear.[2,46]

Many of the overall biomechanical concepts are the same for the overhead throwing motions of football, javelin, and other sports, although some differences exist. In football, quarterbacks tend to flex their elbow more in the cocking phase and undergo an abbreviated follow-through phase to avoid contact between their hand and arm and another player. This abbreviated deceleration phase in quarterbacks reduces the torque on the elbow, thereby protecting the UCL from injury.[38] Javelin throwers have a similar overall motion but with a prolongation of the acceleration phase, which occurs between foot strike and javelin release and is termed the "thrust" phase, to produce increased distance throws.[18,47] The tennis serve is also akin to a baseball throw, making the elbow vulnerable during this phase of tennis.

## CLINICAL EVALUATION

### History

It is imperative to determine how long the patient has had pain, the point in the pitch cycle that causes pain, whether there has been a change in pitching velocity or accuracy, and whether the patient has any mechanical symptoms. The athlete may also complain of changes in stamina and strength of their throws.[8,12] Pitchers often complain of pain during the acceleration phase (85%), while some also complain of pain during the follow-through phase (25%).[12] Ulnar nerve symptoms must be closely evaluated since chronic UCL injuries are associated with ulnar neuropathy.[71]

### Physical Examination

A thorough examination of the medial elbow structures is imperative. The examiner should check to see whether the patient has a palmaris longus on either arm by having the patient flex his or her wrist and oppose the thumb and small finger. Evaluation of bilateral shoulder rotational range of motion for glenohumeral internal rotation deficit (GIRD) is a critical part of the examination.[17,26] Elbow flexion contractures and pain at terminal extension are common among pitchers secondary to posterior osteophytes (seen in up to 65% of pitchers who undergo elbow surgery),[3] likely caused by valgus extension overload syndrome (VEOS). A variety of specialized tests for the UCL have been developed (Figures 2-4), with accompanying videos available online (see video supplements, available at http://sph.sagepub.com/content/by/supplemental-data). Other provocative tests include the Tinel test at the cubital tunnel for ulnar nerve irritability and resisted forearm pronation for medial epicondylitis.[31,71]

### Imaging Studies

Stress views have been described in which a progressive valgus stress is applied and the degree of joint widening measured, with a difference of 1 to 3 mm from the contralateral side suggestive of UCL injury.[59,71] However, interpretation of these views is unclear, as normal, asymptomatic pitchers can have increased gapping of the medial joint of their dominant elbow.[11,21]

The UCL is best visualized on more advanced imaging such as magnetic resonance imaging (MRI), magnetic resonance arthrography (MRA), and ultrasound.[5,41] Sensitivity and specificity for diagnosis of UCL injuries of computed tomography arthrography (CTA) is 86% and 91%, and of MRI is 57% and 100%, respectively.[63] MRA has a sensitivity of 92% and specificity of 100% and has the best interobserver reliability.[9,60] While a healthy UCL has a low signal intensity on T1,[48] an injured UCL will show a fluid-like, bright, high signal intensity


Figure 2. Valgus stress test. The anterior bundle of the ulnar collateral ligament (UCL) is the primary restraint to valgus stress about the elbow. The valgus stress test is used to evaluate the anterior bundle of the UCL and is performed with the patient sitting or supine and the forearm held between the examiner's trunk and forearm. This is similar to a varus/valgus stress test of the knee. The patient is placed in a (A) standing or (B) supine position. The elbow is flexed to 20° to 30°, which removes the osseous constraint of the ulnohumeral joint, and a valgus stress is applied. During this maneuver, the examiner palpates along the course of the UCL, with tenderness or laxity without a firm endpoint indicating a UCL injury. A small side-to-side difference in laxity can be normal in pitchers[11,21] (see Video 1, available at http://sph.sagepub.com/content/by/supplemental-data).

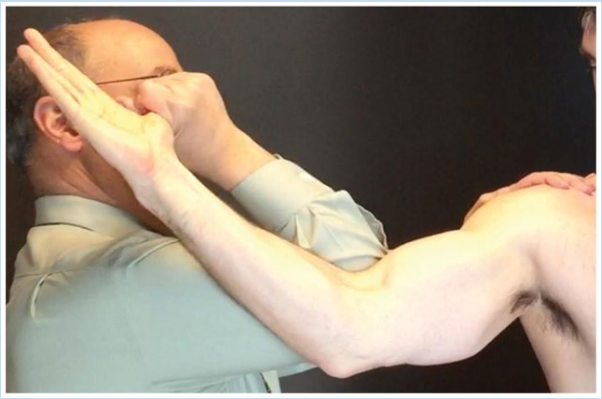

Figure 3. Milking maneuver. This test evaluates the posterior band of the anterior bundle of the ulnar collateral ligament (UCL) and is performed with the forearm supinated, shoulder extended and externally rotated, and elbow flexed at 90°. The examiner pulls the patient's thumb, thereby generating a valgus stress at the elbow. Pain and apprehension with the maneuver is indicative of a UCL injury.[71] Video supplement available online (Video 2, available at http://sph.sagepub.com/content/by/supplemental-data).

Figure 4. Moving valgus stress test. This test is performed with the shoulder abducted to 75°. The examiner maximally flexes the elbow and externally rotates the shoulder and exerts a constant valgus load to the elbow as the elbow is extended quickly to 30°. The test, reported to be 100% sensitive and 75% specific, is positive when the pain generated during the examination mimics the medial elbow pain on throwing and when the pain is most significant between 120° and 70° (referred to as the shear range) as the elbow is extended. This correlates with the late cocking/early accelerations phases[50] (Video 3, available at http://sph.sagepub.com/content/by/supplemental-data).

on fat-suppressed T2-weighted images (see Figure 1). MRI studies have demonstrated that the UCL is injured more frequently at its origin on the medial epicondyle.[35,54] MRI may also be prognostic: Retrospective studies suggest that a UCL with a higher T2 signal intensity is less likely to respond to conservative treatment.[35] A reconstructed UCL may have a variable appearance on MRI.[67]

## TREATMENT

### Nonoperative

Although widely used, few studies have been published regarding nonoperative treatment. In a retrospective review of 20 pitchers, 9 infielders, and 2 javelin throwers, a 42% rate of return to sport was found with nonoperative treatment at a mean 24.5 weeks from the date of diagnosis.[55] Their treatment regimen consisted of 2 phases: Phase 1 involved rest from pitching for 2 to 3 months, daily icing of the elbow, anti-inflammatory medications, a splint or brace at night, and therapy with range of motion of the flexors and pronators. Once a pain-free elbow is achieved, phase 2 begins, which consists of strengthening, progressive return to throwing over 3 months, and a hyperextension brace, if needed.

### Surgical Indications

The primary surgical indication is failure of an exhaustive attempt at nonoperative treatment, with significant dysfunction and persistent medial elbow pain coupled with a desire to return to competition at the same or higher level. Patients with MRI-documented complete UCL ruptures secondary to an acute event can be offered surgery earlier on. Contraindications include inability or unwillingness to complete the rigorous postoperative rehabilitation program and significant ulnotrochlear or radiocapitellar arthritis. Recent evidence has shown that, in the college and adolescent athlete with a normal quality UCL and a UCL injury isolated to the proximal and/or distal end, UCL repair is an option, with an RTS rate of 97% and a failure rate of 6.7%.[58] UCLR should never be offered as a performance enhancer to improve velocity, accuracy, or stamina as the procedure has risks and is unpredictable with regard to these outcomes.

### Surgical Techniques

Many variations on the original Jobe technique for UCLR have been proposed and are outlined in the Appendix (see Table 1 [Appendix 1] and Appendix 2).[3,12,16,27-29,31,43,45,56,61] Each of these techniques is performed in the supine position on an arm board with a tourniquet (Figure 5A and B). The main differences between techniques involve treatment of the ulnar nerve, graft configuration, and how the graft is attached to the ulna and medial epicondyle. No studies have shown a clear benefit of one technique over another, although studies directly comparing various surgical techniques are lacking.[65]

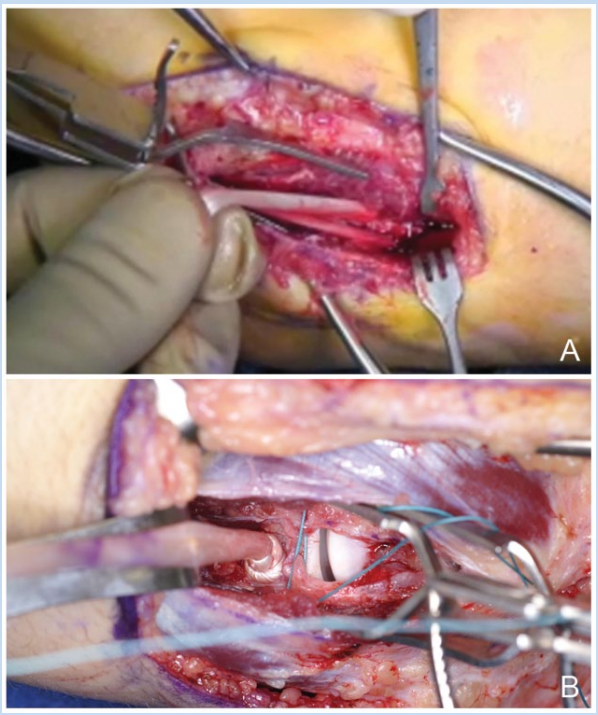


Figure 5. (A) Intraoperative photograph demonstrating the standard docking technique. The graft has been passed through a tunnel created in the ulna and is being prepared to be docked into the medial epicondyle. Notice the 2 strands of the palmaris longus autograft that are available to be docked into the medial epicondyle. A cricket is used to maintain exposure. (B) Intraoperative photograph demonstrating the double-docking technique. The hamstring autograft has been docked into the ulna and is being prepared to be docked into the medial epicondyle. Notice the gapping present at the ulnohumeral joint, indicating an incompetent ulnar collateral ligament.

### Graft Choices

While studies have shown that palmaris longus autograft is the most common graft used in UCLR (50%-74%), there have been no studies to date that have clearly shown 1 graft is superior to another.[7,16,57,65] Graft choices for UCLR include either gracilis or semitendinosus autograft, toe extensor autograft, plantaris autograft, patellar tendon autograft, Achilles autograft, or allograft.[7,27,57] Recent biomechanical evidence has shown that an increase in graft diameter does not effect valgus stability of the elbow.[13]

### Postoperative Rehabilitation

Phase 1 (weeks 0-3) aims to promote healing while preventing stiffness. The elbow is immobilized for the first week and then gentle range of motion (ROM) is started in a hinged elbow brace from 30° to 100° for week 2 and 15° to 110° for week 3 postoperatively. Generally, ROM goals are increased by 5° of extension and 10° of flexion each week until full ROM is achieved. The brace is generally discontinued at 6 weeks postoperatively.

Phase 2 (weeks 4-8) aims to restore strength. While ROM continues to progress and to focus on achieving full elbow extension, the athlete begins exercises with 1-pound weights, increasing by 1 pound per week. Exercises focus on the elbow, shoulder, and scapular stabilizers.[68-70]

Phase 3 (weeks 9-13) aims to restore more comprehensive upper extremity neuromuscular function. The main focus is on flexibility. Isotonic and manual resistance exercises are begun, along with proprioception and dynamic stabilization drills. At 12 weeks, athletes begin a sport-specific plyometric program. Proper throwing mechanics are emphasized during this phase.

Phase 4, the final stage from weeks 14 to 26, aims to restore throwing specifically. Athletes begin a throwing progression with short toss (throws of 45 feet) and gradually progresses to lofted long toss (throws of 120 feet), followed by long toss throws on a line. The athlete then throws from their knees to isolate the arm. The final progression is to throw from the mound, game-simulation throwing, and finally, return to competition.

The entire rehabilitation process can take a variable amount of time based on the player and any concomitant pathology. Generally, players can begin competitive throwing at 7 to 9 months. For most athletes, it takes significantly longer before they are game ready, with many taking between 10 and 18 months.[22]

## SURGICAL OUTCOMES

Surgical outcomes from the literature are listed in Table 2 (see Appendix 1).[6,7,16,18,33,44,49,51,57] Despite the public opinion that pitchers who undergo UCLR throw harder after surgery, evidence has shown that pitchers either maintain the same or lose a very small amount of velocity.[1,30] Unfortunately, no studies to date have shown a benefit to routine ulnar nerve transposition versus transposition in symptomatic patients. Similarly, the ideal time to return to sport has yet to be identified.

On the whole, no technique or graft choice appears to be consistently biomechanically superior.[29,39,40,45] A recent systematic review of 21 biomechanical and clinical studies including 1368 patients concluded that the docking technique resulted in a higher rate of return to play and lower complication rate compared with both the Jobe and modified Jobe techniques.[66] Comparative clinical studies regarding graft choice are not available.

Unfortunately, there is no standard to determine whether a pitcher has successfully returned to baseball after UCLR. Most studies to date have evaluated various statistical and sabermetric parameters and have shown mixed results.[22] Studies have shown that 83% of MLB pitchers are able to RTS after UCLR.[22] MLB pitchers tend to pitch fewer innings, throw fewer complete

games, and have fewer wins per season. However, MLB pitchers also have a less walks plus hits per inning pitched (WHIP), fewer home runs given up, fewer walks given up, and a lower earned run average (ERA).[22] Hence, while a UCL tear is no longer a career-ending injury, pitchers should understand their ability to RTS is not 100%.

## COMPLICATIONS/PEARLS TO PREVENT COMPLICATIONS

Complication rates range from 8.8% to 40% based on patient selection and previous surgeries.[4,19] Complications include graft harvest site pain or paresthesias (4%),[4,53] synovitis (7%),[19] elbow stiffness (13%),[19] ulnar neuropathy (26%),[12] medial epicondyle avulsion fracture (0.5%),[7] and reoperation (2%).[4] A meticulous graft harvest, careful dissection and protection of the ulnar nerve, early postoperative ROM, and proper rehabilitation can help reduce complication rates.

## CONCLUSION

Injuries to the ulnar collateral ligament have become commonplace among pitchers. Nonoperative treatment should be attempted, but limited studies have not shown promising results. Operative treatment can be performed in a variety of manners, with retrospective studies showing promising results. Complications include ulnar neuropathy as well as failure to return to sport. Detailed preoperative planning, meticulous surgical technique, and a comprehensive rehabilitation program are essential components to achieving a satisfactory result.

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