Ulnar collateral ligament injury in the elbow: current trends for treatment

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Abstract: The last two decades have seen a drastic rise in the incidence of ulnar collateral ligament (UCL) injuries and their surgical treatment. There continues to be a better understanding of the related anatomy and biomechanics, as research continues to be active on the topic of the UCL of the elbow. The growing body of knowledge regarding UCL anatomy and biomechanics continue to inform surgeons on approaches for treatment, which continue to evolve.

Keywords: Ulnar collateral ligament (UCL); elbow; baseball

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Introduction

The last two decades have seen a drastic rise in the prevalence of ulnar collateral ligament (UCL) reconstructions amongst baseball players in the United States (1-4). From 2002 to 2011, the rate of UCL reconstructions within the entire state of New York tripled, especially amongst younger patients aged 17–20, theoretically due to increasing pitch counts at the Little League and amateur pitching levels (3). According to one large questionnaire study that included 2,706 active major and minor league pitchers, the prevalence of UCL reconstruction in professional pitchers is 16% (5).

UCL injuries occur frequently in pitchers since the throwing motion results in a strong valgus moment across the elbow that applies tensile forces with magnitudes that near the ultimate strength of the UCL. This can cause microtrauma that can lead to chronic, attritional tearing of the ligament (6). Repetitive micro-trauma may result in laxity of the ligament without gross disruption of the collagen fibers. UCL injuries can also occur with traumatic injuries when an acute valgus stress is applied to the elbow, which can happen in sports like gymnastics and wrestling. An acute traumatic injury may overload the ligament resulting in complete disruption of the fibers. With emerging treatment options for UCL injuries, the mechanism of injury can have implications on the choice of treatment, with acute, traumatic injuries potentially treated differently than chronic, attritional injury. The aim of this review is to describe the anatomy and biomechanics of the UCL as well as trends in treatment for UCL injuries.

Anatomy of the UCL

The anatomy of the UCL has been well characterized, with the ligamentous complex being described as triangular-shaped ligamentous complex providing stability to valgus stress. The anterior band of the anterior bundle (AB) of the UCL serves as the primary restraint against a valgus load from 20–120 degrees of flexion (7-10). The origin and insertion of the anterior band of the AB of the UCL have been well described with a humeral attachment along the anterior inferior medial epicondyle and an insertion along the length of the sublime tubercle (11,12). The posterior bundle (PB) of the UCL is a broader and thinner part of the UCL complex originating from the humeral epicondyle and broadly inserting on the medial ulna. The PB provides valgus stability at flexion angles greater than 120 degrees (13). A recent study has reported on quantitative anatomy of the UCL, describing its humeral insertion as 8.5 mm distal and 7.8 mm lateral to the medial epicondyle while the ulnar attachment was located 1.5 mm distal to the sublime tubercle and 7.3 mm distal to the joint line along the ulnar ridge (14).

Histologic analysis has shown the anterior band of the UCL to be a single-layered ligament with parallel collagen fibers running longitudinally between the medial epicondyle and the sublime tubercle (15), although a prior study did describe a second layer to the anterior band which consisted of collagen bundles deep within the medial capsule (16). A recent anatomic study of the vascular supply to the UCL has demonstrated a dense blood supply to the proximal humeral UCL attachment with hypovascularity at the ulnar attachment distally (17). This information helps to inform clinicians on which types of UCL tears may have a higher likelihood to heal with conservative treatment or surgical repair based on tear location.

Biomechanics of the UCL

There has been previous investigation into the macro and microscopic behavior of the anterior band of AB of the UCL (8,13,18,19). Regan *et al.* showed that the AB of the UCL had an average load to failure of 260 N (13). In 1985, Morrey *et al.* investigated the 3-dimensional length of the anterior band and determined it to be isometric after 60 degrees of flexion, noting slight increase in length of the ligament from extension to 60 degrees of flexion (8). More recent cadaveric and 3-D modeling studies had shown that the AB of UCL is not isometric (20). The fibers at the lateral most fibers at the anteroinferior aspect of the medial epicondyle were nearly isometric (20,21). Understanding the isometry of the ligament is critical when optimizing surgical management, particularly with emerging surgical techniques, specifically augmentation with an internal brace, that require greater precision in identifying the most isometric location of the UCL fibers (22).

To understand the biomechanics of the UCL, it is important to understand its microstructural organization and how the alignment of the collagen network changes during loading conditions. Determining the collagen alignment of a tissue offers a valuable means to assess its function and predict its mechanical response to load. Quantitative polarization light imaging (QPLI), a technique using transmission of polarized light through tissues, allows for real-time microstructural evaluation collagen fiber alignment in tissue by leveraging an optical property in collagen called birefringence (23-25). Smith *et al.* recently evaluated the real-time microstructural changes in the AB and the PB of the UCL under load using QPLI (26). Both the AB and PB of the UCL exhibited highly aligned collagen that demonstrated only small changes in collagen fiber alignment with load. This data suggests that the UCL is a static restraint to valgus stress that does not experience much change in its microstructural organization in response to loading. This may explain why the UCL is vulnerable to injury with supra-physiological loads that may be seen during throwing. This could help to explain the US findings in pitchers that show thickening, joint space gapping with valgus stress, and increased prevalence of hypoechoic foci and calcifications in the UCL fibers observed clinically on ultrasound (27-29).

On a macroscopic level, the ultimate load of failure of the UCL has varied widely in anatomic cadaveric studies from 17.1 to 22.7 Nm (30-32) in studies with elderly cadavers. In one study with younger cadavers, a mean age of 43, the load to failure was 34 Nm (33). The amount of varus torque applied to the elbow during pitching has been kinematically estimated to be 64–82 Nm. Morrey's study found that the UCL was responsible for generating 54% of the varus torque needed to resist a valgus force at 90 degrees of flexion, thus it is estimated that, the UCL would need to resist 34.6 Nm of torque (8). This amount of torque is beyond the ultimate load to failure of the UCL. These biomechanical studies do not account for the force dissipation of the musculature around the elbow. Udall *et al.* showed that the flexor digitorum superficialis, flexor carpi ulnaris and pronator teres are the most important muscles for dynamic stability of the medial elbow (34).

Non-surgical treatment for UCL injuries

Physical therapy can be effective in treating UCL injuries, particularly with partial tears. In general, "active" rest with no throwing and no activities that place valgus stress on the elbow is recommended 2–3 months. Physical therapy focused on strengthening the flexor pronator muscles to provide dynamic stability to the elbow is critical (34). Additionally, it is important to strengthen the legs, trunk and shoulder during rehabilitation to optimize function in the entire kinetic chain involved in generating velocity during throwing for overhead athletes (35,36). When there is no longer pain with provocative exam maneuvers that stress the UCL, a throwing program can be started in throwing athletes. Non-throwers can resume normal activities when they are pain free. A brace can be helpful to protect the elbow during return to sport in non-throwing athletes.

In the setting of partial UCL tear, PRP injections have been shown to be effective in helping patients successfully return to sport without the need for surgery (37,38). While there is data that demonstrates good outcomes with use of PRP injection for partial UCL tears, it should be noted that this is based on level 4 evidence only. There have been no randomized controlled trials have tested the efficacy of PRP injections in the treatment of UCL tears. Podesta *et al.* utilized leukocyte-rich PRP for injections in a case series of 34 patients with partial thickness UCL tears, of which 30 (88%) were able to successfully return to sport at an average of 12 weeks after injection (38). Dines *et al.* similarly presented a case series of 44 patients who underwent PRP injection for partial UCL tear and showed 73% good to excellent results with mean return to sport also at 12 weeks (37). This study provided additional sub-analysis based upon the location of tear and showed all 7 patients with distal UCL tears to have poor results compared to only 3/22 patients with proximal tears (37). This finding correlates with the recently published anatomic report regarding a richer vascular supply for the proximal UCL attachment (17) and has implications for which patients should be considered ideal candidates for conservative treatment.

Due to the small number of available studies on this topic and the considerable heterogeneity that exists in PRP preparations, there is much that remains unknown about ideal PRP preparation and overall efficacy for this condition.

When considering optimal treatment for UCL injuries, it is important to keep in mind the expectations of the athlete, the timing of the season in which the injury occurs, and the desire of the athlete to continue throwing. UCL injuries in athletes who do not intend to continue their sport beyond the recovery time from UCL reconstruction and who have no symptoms with everyday activities may be best treated without surgery. For in-season athletes or those planning to play beyond the recovery time for treatment of the injury, the timing of the injury is critical in determining a reasonable treatment plan. Complete UCL tears and UCL injuries at the distal insertion at the sublime tubercle are more likely to fail nonsurgical treatment (39). If a complete tear or distal tear occur early in a baseball season, a prolonged rehabilitation program that fails will compromise the current season and potential compromise part or all the following season due to the lone recovery time after UCL reconstruction. When discussing treatment options with athletes, it is important to be aware of some perceptions of UCL surgery that exist outside of the medical community, as these ideas may influence an athlete's desire for or against nonsurgical treatment. Many pitchers falsely believe that UCL reconstruction will add additional velocity to their throws. Performance metrics have been studied in Major League Baseball (MLB) after UCL surgery (40). While most MLB pitchers returned to play, their performance in earned run average, walks and hits per inning, and total innings pitched declined from prior to surgery (40). Baseball players need to be appropriately counseled on the risks of surgery, timing or recovery, and expectations regarding performance after surgery.

Surgical treatment for UCL injuries

UCL reconstruction techniques

A variety of different techniques for UCL reconstruction have been described since the early description of the figure of 8 reconstruction technique described by Jobe (41) (*Table 1*). The original reconstruction technique described by Jobe involved detachment of the flexor pronator mass from the medial epicondyle to expose the UCL. In his original report, 10 of 16 (63%) athletes returned to their previous level of sport (41). Several years later, Conway reported excellent results in less than 70% of patients undergoing this reconstruction technique (42). Azar *et al.* reported excellent results in 81% of patients using a modified technique that involved elevating the flexor pronator muscle off of the UCL rather than detaching the flexor pronator muscle from the epicondyle (Modified Jobe technique) (43). Cain *et al.* reported that 83% of 734 athletes returned to their previous level of sports with this technique (1). Thompson at el described yet another modification to the UCL exposure that involved a muscle-splitting approach through the flexor pronator muscle (44). Using this technique, 93% of athletes returned to their previous level of sports (44).

There have been several modifications to reconstruction techniques. The docking technique brings both limbs of the

Table 1 Evolution of UCL surgical treatment

Surgical technique	Outcomes
UCL repair	Conway—50% returned to previous level of play
	Argo—94% all female athletes returned to previous level of play (58% throwing athletes)
	Savioe—93% good to excellent results in non-professional athletes (85% throwing athletes)
UCL repair with internal brace	Dugas—92% returned to the same level or higher
UCL reconstruction	
Jobe	
Flexor pronator detached	Jobe—63% returned to previous level of play
	Conway—68% returned to previous level of play
Modified Jobe	
Elevate flexor pronator muscle	Azar—79% returned to previous level of play
	Cain—83% returned to previous level of play
Split flexor pronator muscle	Thompson—93% returned to previous level of play
Docking technique	
Split flexor pronator muscle	Rohrbough—92% returned to previous level of play
	Paletta—92% returned to previous level of play

UCL, ulnar collateral ligament.

graft passed through the sublime tubercle into a single tunnel on the humeral epicondyle (45) (*Figure 1*). Both limbs of the graft are docked in the humeral tunnel and secured by tying sutures in the graft over a bone bridge over the posterior medial epicondyle. The docking technique has been shown to have a higher load to failure than the modified Jobe technique (46) with 92% returning to their previous level of sports (45,46). Other modifications to the UCL reconstruction techniques that had been described (47). Regardless of technique used, the outcomes of UCL reconstruction are generally favorable with 80–93% athletes able to return to their sport at or above pre-injury level (1,45,46,48). The standard UCL reconstruction surgery requires a lengthy recovery and rehabilitation period with average time until return amongst major league pitchers reported from 15–18.5 months (49-51). Furthermore, upon return pitchers tended to see worsening of performance metrics although not statistically significant compared to age-matched peers who did not undergo surgery (51).

UCL repair and UCL repair with internal brace

Early reports by Conway *et al.* indicated that only 50% of patients undergoing UCL repair returned to their previous level of play (42). More predictable results were seen with UCL reconstruction leading to UCL reconstruction as the standard of care treatment for complete tear or insufficiency of the UCL (41,42). There has been renewed interest in UCL repair with reports of >90% return to play after repair in properly selected non-professional athletes (52,53). The new attention toward UCL repair has been brought about by the emergence of the concept of the internal brace. Internal brace refers to a surgical construct in which a ligamentous repair or reconstruction is offloaded by an additional structure separate from the graft, typically a high-strength, synthetic, tape-style suture. An internal brace can be placed in addition to a collagen-based ligament and fixed with slightly less tension than the ligament in order to offload but not stress shield the ligament. Theoretically, ligaments that do not change collagen alignment with stress are good candidates for internal brace supplementation. This concept has been applied to various ligaments within the body, and provides enhanced time zero biomechanical stability for various ligaments (54-59). Given the recent biomechanical evidence showing that UCL collagen is well-aligned and does not become much more aligned with

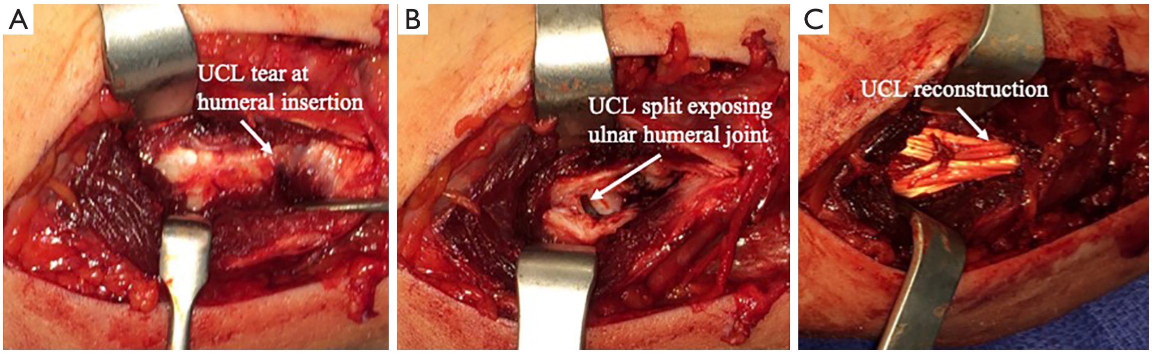

Figure 1 Intra-operative picture showing a tear in the UCL at the humeral insertion on the medial epicondyle (A), a split in the UCL created to identify the ulnar humeral joint with demonstration of ulnar humeral gapping (B) and a ulnar collateral ligament reconstruction with palmaris longus autograft using a standard docking technique (C). UCL, ulnar collateral ligament.

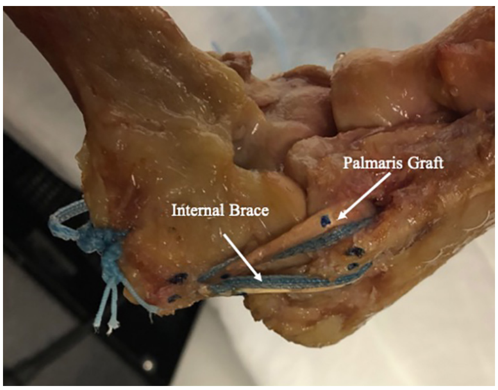

Figure 2 Cadaveric specimen showing a standard docking technique UCL reconstruction with incorporation of a strong braided suture passed through the standard tunnels to serve as an internal brace. UCL, ulnar collateral ligament.

stress (26), an internal brace in the setting of UCL repair or reconstruction can provide an important additional check rein against valgus stress across the elbow.

In a cadaveric study, Dugas *et al.* showed a repair technique with internal brace showed favorable biomechanical performance compared to a figure of 8 UCL reconstruction with equivalent load to failure and showed greater resistance to gapping after cycling (60). Bodendorfer *et al.* also reported the biomechanical performance of a standard docking technique with an internal brace repair construct. They also showed that internal brace repair performs similarly to the docking reconstruction technique (61). Recently, Dugas *et al.* reported 92% success some returning overhead athletes to the same a high level of competition is an average of 6.7 months with UCL repair and internal brace (62). The athletes that were treated with UCL repair and internal brace had tares either from the sublime tubercle or medial epicondyle with good tissue quality. In the athlete with a quality ligament torn from the attachment to the ulna or humeral epicondyle, the UCL repair with internal brace can drastically shortened than the average time to return after UCL reconstruction.

UCL reconstruction with internal brace

Many chronic attritional tears of the UCL are not amenable to repair with internal brace because of poor tissue quality. In a biomechanical study, Armstrong *et al.* demonstrated that none of the standard UCL reconstruction techniques restored normal resistance to ulnar humeral gapping compared to an intact native ligament (30). The stiffness of the reconstruction constructs or the inherent differences in the microstructural organization of the grafts used to reconstruct the UCL compared to the native UCL tissue may explain the failure to adequately resist ulnar humeral gapping. With the success of UCL repair using internal brace, there is a growing interest in finding the use of internal brace with UCL reconstruction to reduce the ulnar humeral gapping closer to that seen with the intact native ligament. Bernholt *et al.* showed that the addition of an internal brace using a strong braided suture with a standard docking reconstruction technique restored the total stiffness and resistance to ulnar humeral gapping nearly to the level of the native intact ligament (63) (*Figure 2*). Leasure *et al.* showed that UCL reconstruction with internal brace demonstrated better resistance to gap formation than a standard docking technique without an internal brace (64). Although only biomechanical data is currently available regarding this treatment construct, the increased biomechanical strength with the presence of an internal brace may allow for earlier rehabilitation in patients undergoing UCL reconstruction as has been the case with UCL repair with internal brace.

Future considerations of UCL treatment

Future studies further treatment of UCL injuries starts with prevention. Better clinical surveillance identifying potential at risk athletes could help mitigate the rising numbers of UCL injuries. Better biomechanical data evaluating the real-time microstructural behavior of the ligament can provide insight into the changes in the ligament with rate loading and fatigue loading. Additionally the real-time micro structural data is needed to show how elbow flexion angle affect the microstructural organization of the UCL during loading. The static may lead to a better understanding of the effective arm position and pitching mechanics on the risk of UCL injury, thereby elucidating conditions that may lead to damage and failure.

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Footnote

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