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ELBOW INJURIES TO THE THROWING ATHLETE

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The diagnosis and treatment of throwing injuries of the elbow rely on a thorough understanding of the complex anatomy of the elbow, including both osseous and soft-tissue attachments. This article discusses the anatomy, the biomechanics of throwing relating to the elbow joint, and the diagnosis and treatment of medial- and lateral-sided injuries to the elbow.

ANATOMY

The elbow consists of three articulations that contribute to stability: the ulnohumeral, the radiocapitellar, and the proximal radioulnar joints. The osseous articulations of the elbow provide stability at less than 20 and more than 120 deg of flexion.[32] Morrey and An[18] showed that the joint articulations account for approximately 30% of the resistance to valgus stress and 70% of the resistance to varus stress with the elbow at 90 deg of flexion. The remaining stability of the elbow joint is provided by its soft-tissue constraints.

The elbow joint is contained within a capsule whose medial and lateral thickenings comprise the collateral ligaments. The medial ligament, or ulnar collateral ligament (UCL) complex, consists of three parts: an anterior (oblique) bundle, a posterior bundle, and a transverse

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segment (Fig. 1*A*). The transverse segment is not well defined and probably does not contribute to stability. The anterior bundle is the most discrete and well-defined part that takes its origin from the inferior surface of the medial epicondyle and inserts on the medial aspect of the coronoid process. The posterior bundle is a fan-shaped thickening of the capsule, which is poorly defined unless the elbow is flexed to about 90 deg. It originates just posterior to the anterior bundle on the medial

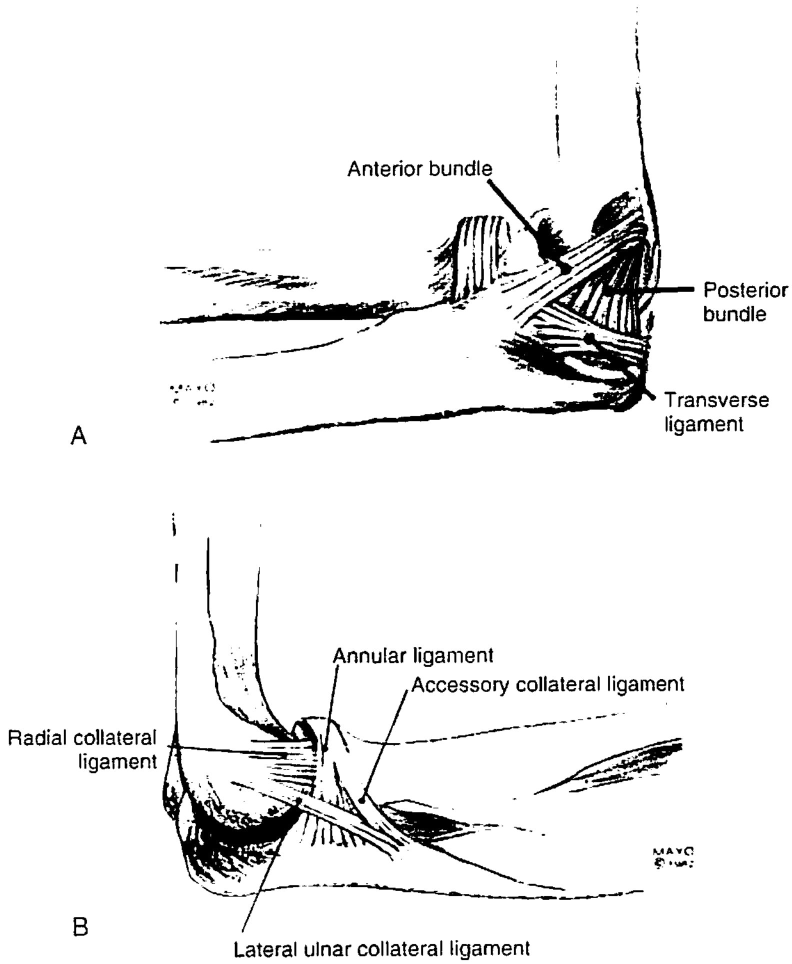

Figure 1. *A*, Medial side of the elbow. The UCL complex is pictured, including the anterior bundle, the posterior bundle, and the transverse ligament. *B*, Lateral side of the elbow. The lateral collateral ligament (LCL) complex, consisting of the radial collateral ligament, lateral ulnar collateral ligament, the annular ligament, and the accessory collateral ligament, is illustrated. (By permission of Mayo Foundation as published in Clin Orthop 271:172, 1991.)

epicondyle and inserts along the posteromedial aspect of the olecranon. Both of these bundles originate posterior to the axis of elbow rotation.[19] The anterior bundle is functionally divided further into anterior and posterior portions.[26] With a valgus load, the anterior portion is tense with elbow flexion from 0 deg to 85 deg, whereas the posterior portion of the anterior bundle is taut from 55 deg through full flexion. The posterior bundle of the UCL also tightens similarly when under valgus stress beginning at 65 deg of flexion. The sequential tightening of the anterior oblique bundle of the UCL ensures that a portion of the bundle is taut during the entire arc of flexion. It is easy to understand, then, how this structure is the primary stabilizer of the elbow against valgus stress.[18]

The lateral collateral ligament (LCL) complex is not as well defined. Most authors believe there are four structures that compose the LCL complex, though this is controversial[27] (Fig. 1*B*). The radial collateral ligament is fan-shaped and takes its origin from the lateral epicondyle and inserts into the annular ligament. A portion of its fibers remain taut throughout the full arc of flexion with varus or valgus stress, confirming that the axis of rotation passes through its humeral origin. The second component, termed by Morrey and An[19] as the *lateral ulnar collateral ligament*, originates from the lateral epicondyle inserting distally on the crista supinatoris of the ulna. This ligament becomes taut at 120 deg of flexion, but when a varus load is applied, it is taut throughout the entire arc of flexion. This is homologous with the anterior band of the UCL and is the primary constraint to both varus and posterolateral rotatory instability of the elbow.[8] The other two components of the LCL complex are the annular ligament and the accessory collateral ligament, neither of which plays a significant role in varus stability.

BIOMECHANICS OF THROWING

The motion of throwing is common to many sports. There are five stages of the pitching motion: wind-up, early cocking, late cocking, acceleration, and follow-through[8] (Fig. 2). The greatest tensile stresses across the elbow develop during the late cocking and acceleration phases, during which most injuries occur.

A large force is generated by the muscles of the shoulder and arm while acting against the weight of the arm and the object being thrown. The elbow's supporting structures must resist these forces during late cocking and acceleration. The hand, forearm, and object being thrown initially lag behind the upper arm resulting in tremendous tensile valgus stress placed across the medial aspect of the elbow.[5] The anterior oblique bundle of the UCL as the primary resistance to this stress[18] is most prone to injury. Repetitive compressive forces felt on the lateral side of the elbow, primarily resisted by the articular surface of the radiocapitellar joint, cause injury to these structures. Over time, this stress will lead to radiohumeral loose bodies. Osteochondritis dissecans of the capitellum

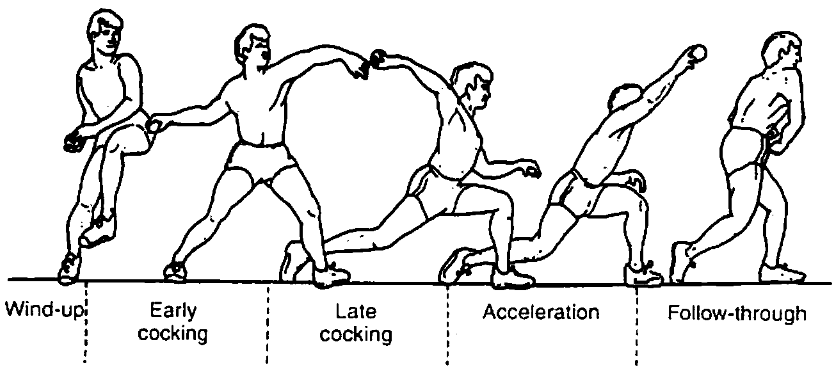

Figure 2. The five phases of pitching. (*From* Glousman RE, Barron J, Jobe FW, et al: An electromyographic analysis of the elbow in normal and injured pitchers with medial collateral ligament insufficiency. Am J Sports Med 20:311–317, 1992; with permission.)

is thought to occur in the pediatric age group by this same mechanism.[31] Valgus extension overload is thought to be caused by a wedging effect of the olecranon into the olecranon fossa also during the late cocking and acceleration phases of throwing.[33]

During follow-through, the triceps muscle forcefully achieves elbow extension. This explosive elbow extension is stopped primarily by the anterior capsule and the contraction of both the biceps and brachialis muscles.[5] Injury to these structures most often occurs during this phase of throwing.

MEDIAL-SIDED INJURIES

Slocum[28] originally classified throwing injuries of the elbow. Medial-sided elbow injuries include overuse syndromes, fascial compression syndrome, medial epicondylitis, ulnar nerve injuries, the presence of posteromedial osteophytes, and UCL tears.

An overuse syndrome seen in the throwing athlete is caused by microtears of the flexor pronator muscle group leading to contractures. These tears occur secondary to the muscle group's role as a dynamic stabilizer against valgus stress, as well as from fatigue incurred during the forceful contractions needed for throwing. Symptoms are characterized by pain and swelling medially over the muscle group with loss of elbow extension. Treatment includes rest, ice, anti-inflammatory medication, and range-of-motion exercises.

Bennett's fascial compression syndrome,[3] which is rarely seen, is caused by hypertrophy of this same flexor pronator muscle group within the fascial compartment. With repeated throwing, this hypertrophy causes medial-sided elbow pain, forcing pitchers to stop throwing after only a few innings. Treatment consists of rest, adequate time for warmup exercises, and 3 to 5 days between pitching starts. Fasciotomies, although rarely done, may be necessary if conservative treatment fails.

Medial epicondylitis is characterized by pain and tenderness at the tendinous origin of the flexor pronator mass, the medial epicondyle. Symptoms often can be reproduced by resisted wrist flexion and pronation. Conservative treatment consists of rest, activity modification, and anti-inflammatory medication, followed by resistance exercises. Those who fail conservative treatment undergo open excision of the pathologic tissue at the epicondyle, with reapproximation and abrading of the medial epicondyle to promote soft-tissue healing.

Symptoms attributable to ulnar nerve injury can occur in isolation but often present in association with other medial-sided elbow pathologic conditions.[6] Nirschl[22] found that 60% of patients undergoing surgery for medial epicondylitis had symptoms of ulnar nerve neuritis. Conway et al[4] showed that more than 40% of patients undergoing reconstruction of the UCL had ulnar nerve symptoms preoperatively.

Injury to the ulnar nerve may result from direct trauma, traction, compression, or friction.[7] Traction injuries are caused by stretching of the ulnar nerve secondary to valgus instability. Friction injuries often are due to subluxation of the nerve from within its groove and abrasions by osteophytes. Compression injuries result from hypertrophy of the flexor pronator muscle group or adhesions within the soft tissues. Paresthesias in an ulnar nerve distribution along with tenderness and a positive Tinel's sign at the elbow suggest the diagnosis. Conservative measures of rest, splinting, and ice usually fail in long-standing cases, and surgery consisting of either decompression or a transposition is carried out depending on the association of other medial-sided elbow pathologic conditions.

Valgus Extension Overload

Valgus extension overload syndrome also may cause medial-sided elbow symptoms secondary to impingement, as well as pain posteriorly over the olecranon. King et al[14] feel that medial elbow stress with cubitus valgus and a narrowed bony fossa secondary to hypertrophy is the cause of the impingement of the olecranon process onto the medial wall of the olecranon fossa. Wilson et al[33] believe this impingement is caused by a wedging effect during the early acceleration phase of pitching when the excessive valgus stress is applied to the elbow. This impingement in turn leads to osteophyte formation on the posterior and posteromedial aspects of the olecranon tip (Fig. 3). It is this posteromedial osteophyte impinging against the medial articular surface of the olecranon fossa, that causes pain and a subsequent kissing lesion of chondromalacia.

These patients have pain with valgus stressing and extension. Most also will have pain posteriorly over the olecranon process. Baseball pitchers typically will present with a history of pain upon throwing that increases early in a game. They will notice also a loss of control, which

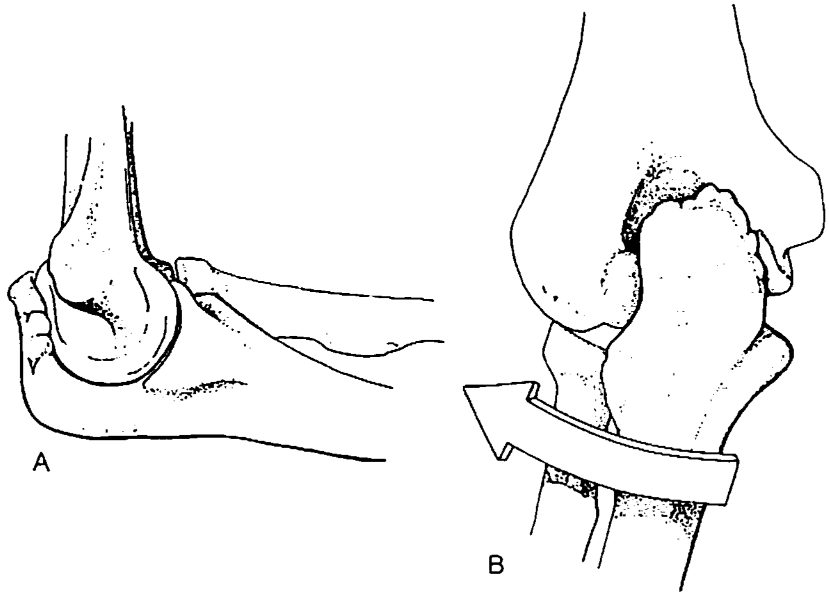

Figure 3. *A*, Lateral view of the elbow demonstrating olecranon osteophytes. *B*, Posterior view of the elbow demonstrating the posterior and posteromedial osteophytes impinging under valgus stress (*arrow*). (*From* Wilson FD, Andrews JR, Blackburn TA, et al: Valgus extension overload in the pitching elbow. Am J Sports Med 11:83–88, 1983; with permission.)

causes an early release and highly thrown pitches. Tennis players have the same painful symptoms as pitchers while performing overhead serving as they attempt full extension.

Conservative treatment is composed of moist heat and ultrasonography, along with a stretching and isotonic strengthening program. If this is unsuccessful, surgery is recommended.

Surgical Treatment

The surgical approach described by Wilson et al[33] involves a straight posterolateral incision beginning at the lateral epicondylar ridge and extending 6 cm. The triceps tendon is identified and sharply elevated off the epicondylar ridge of the humerus, exposing the posterior compartment of the elbow. The anconeus fibers are elevated off the humerus, allowing visualization. Flexing and extending with varus stress allows good visualization of the entire olecranon process and any pathologic conditions present. A one-quarter–inch osteotome is used to cut 1 cm of the olecranon process (Fig. 4, line A), erring on the side of more rather than less. This will allow for exposure of the posteromedial aspect of the olecranon. A one-eighth– or one-quarter–inch curved osteotome is used to make a curved cut into the posteromedial osteophyte (Fig. 4, line B). With this second cut, the medial wall of the olecranon fossa now can be visualized, and any further osteophytes can be rongeured off. The triceps and anconeus are reapproximated with heavy synthetic absorbable sutures, as nonabsorbable sutures have been shown to cause postoperative irritation.

Postoperatively, range-of-motion exercises are begun at 7 to 10 days, and the patient progressively works into a resistance exercise program. After pain is relieved and motion is complete (approximately 4 to 6 weeks), a long-ball-toss program is begun.[4]

The results for a group with an average follow-up of 1 year showed that all athletes who underwent this procedure returned to their preoperative sport at full strength for at least one full season. The average return to sport was 11 weeks (the range was 6 to 20 weeks). One patient underwent reoperation for recurrent symptoms and was found to have recurrence of exostosis medially and severe chondromalacia of the olecranon articular surface. All patients had improvement or resolution of their flexion contracture, which is seen currently with this entity.

Arthroscopy is also a viable alternative for debridement of these osteophytes and decompression of the olecranon fossa. The use of posterior and posterolateral portals is necessary.[17] This technique will afford the athlete an earlier return to competition. The authors use this technique in lieu of an open method, as technology now allows for the successful completion of this operation.

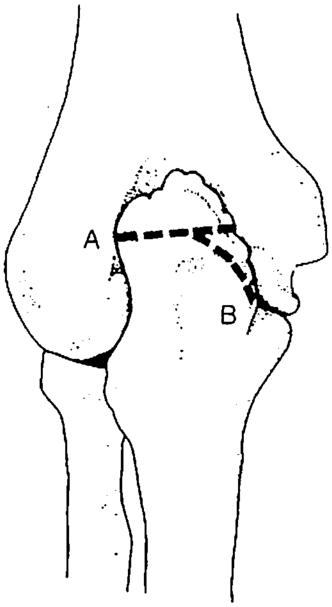

Figure 4. Posterior view of the elbow. Line marked A indicates first cut made with straight osteotome. Line marked B indicates second cut made with curved osteotome. (*From* Wilson FD, Andrews JR, Blackburn TA, et al: Valgus extension overload in the pitching elbow. Am J Sports Med 11:83–88, 1983; with permission.)

Ulnar Collateral Ligament Injuries

UCL injuries usually occur as a result of repetitive valgus overload leading to recurrent microtrauma, attenuation, and eventual rupture. As described earlier, the anterior oblique bundle is the primary stabilizer of the elbow against valgus stress. Acute ruptures of the UCL complex can occur. Jobe et al[11] found that 50% of the throwing athletes ruptured their UCL in a sudden catastrophic event. Almost all, however, had pain and tenderness for months or years about the medial elbow associated with throwing. These injuries, then, were most likely an acute rupture of a chronically attenuated ligament.

Diagnosis

A history of pain localized to the medial side of the elbow during the late cocking and acceleration phases of throwing is common. The history and physical examination are crucial for diagnosing UCL insufficiency. On examination, the amount of tenderness medially over the UCL varies with the amount of inflammation.[4] Patients also may have ulnar nerve neuritis secondary to a traction-type injury to the nerve with an incompetent UCL. Usually a positive Tinel's sign is present over the cubital tunnel.

The valgus stress test may demonstrate instability.[4] To perform the valgus stress test, the arm of the standing patient is positioned in the coronal plane of the body with the shoulder abducted and externally rotated and the forearm supinated. The elbow is flexed 30 deg to reduce bony constraint. The patient's hand is held between the examiner's arm and chest wall. One of the examiner's hands is used to apply valgus stress to the elbow, and the other hand palpates the medial joint line

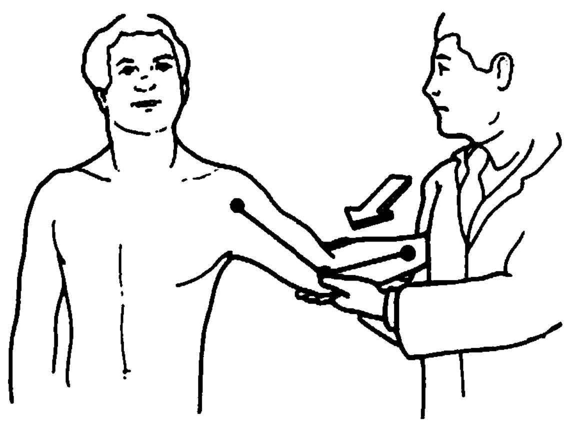

Figure 5. Illustration demonstrating the valgus stress test. Valgus stress *(arrow)* is applied with the right hand of the examiner. (*From* Conway JE, Jobe FW, Glousman RE, et al: Medial instability of the elbow in throwing athletes. J Bone Joint Surg Am 74:69, 1992; with permission.)

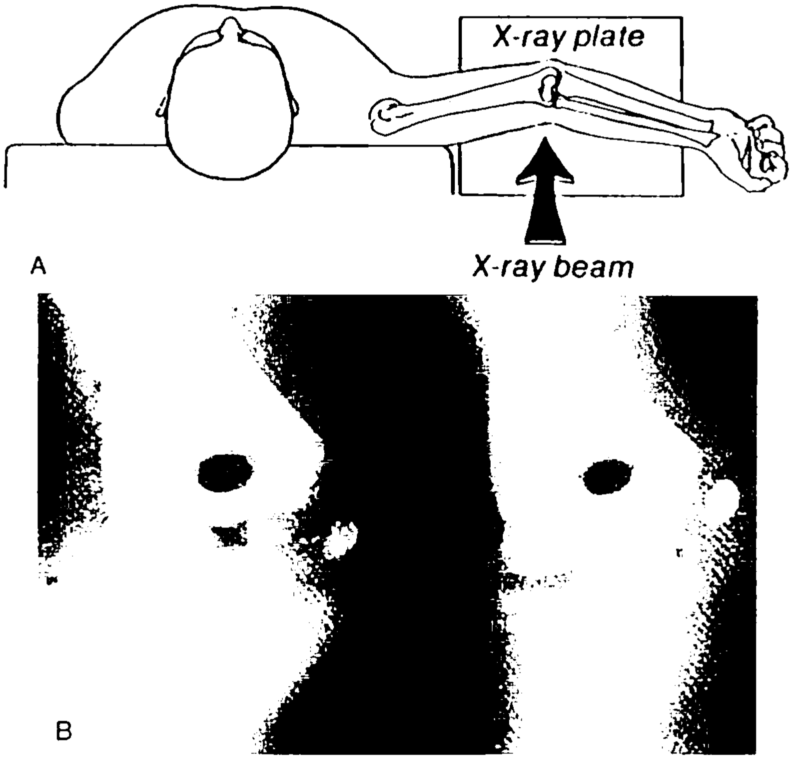

Figure 6. *A*, The taking of a gravity stress radiograph with the patient positioned on the table. The arm is abducted and externally rotated, the forearm is supinated, and the elbow is flexed at 20 to 30 deg. *B*, *Right*, plain view of the elbow. *Left*, stress radiograph, in this case, demonstrating medial widening secondary to a fractured medial epicondyle. (*From* Schwab GH, Bennett JB, Woods GW, et al: Biomechanics of elbow instability: The role of the medial collateral ligament. Clin Orthop 146:42–52, 1980; with permission.)

beneath the UCL (Fig. 5). The joint line may display opening not present on the opposite side.

Routine radiographs may demonstrate calcification within the UCL, chronic traction spurs on the ulna, or loose bodies. A gravity valgus stress radiograph (Fig. 6), including the comparison side, also can be useful in assessing medial joint line opening, although a negative radiograph should not rule out the diagnosis of UCL insufficiency. Others have found it difficult sometimes to evaluate valgus instability by clinical examination and suggest other methods to aid in the diagnosis.[29]

In a recent study, CT arthrograms and MR imaging scans were compared to see which had a higher accuracy in diagnosing suspected UCL injuries in baseball players.[30] With surgical confirmation, it was shown that both CT arthrography and MR imaging had 100% sensitivity in detecting complete tears, but only CT arthrography was helpful in detecting partial undersurface tears (71% sensitivity versus 14% for MR imaging), in which a thin superficial layer of the anterior bundle is still intact. Both methods showed high specificity in detecting tears (CT arthrogram: 91%; MR imaging: 100%). The authors believe that with contrast-enhanced MR images, the shortcomings of detecting partial tears may be eliminated.

Conservative Treatment

Nonoperative management, if begun soon after the onset of symptoms of a UCL injury, may stop the progression leading to elbow instability and allow an athlete to return to competition.[1] Conservative treatment consists of rest, ice, and anti-inflammatory medication. A stretching and strengthening program is begun once the acute inflammatory phase has been treated. Repetitive stretching of the forearm flexors and extensors is carried out. Morrey et al[20] have shown that the role of strengthening of the flexor pronator group may decrease symptoms of instability. These authors believe eccentric strengthening is best. In UCL-deficient elbows of pitchers, there is decreased activity of the pronator teres and flexor carpi radialis muscles during the late cocking and acceleration phases of throwing.[8] If these muscles are to act as dynamic stabilizers of the elbow, a specific strengthening program should be undertaken. After the patient has achieved normal strength, plyometric exercises and interval throwing are used to progress the patient to normal sports activity.[17]

If joint stability and pain relief are the main goals, nonoperative treatment usually suffices. If the patient desires to return to highly competitive overhead or throwing sports, however, rest periods with rehabilitation of up to 3 months should be attempted and repeated at least once, especially in those patients who have not experienced an acute rupture. If the athlete fails to improve, surgical intervention is indicated. Pitchers with a complete UCL tear often have difficulty returning to professional pitching at their preinjury level.

Surgical Treatment

Surgical management of symptomatic valgus instability due to UCL injury consists of two methods: repair and reconstruction. The indications for direct repair of the UCL are rare. A repair can be considered in a patient who has an acute injury with no associated ulnar nerve symptoms.[9] In the majority of patients, a reconstruction using free autologous tendon graft is performed to restore medial stability to the elbow.

As described by Jobe et al,[4,9,11] the patient is positioned supine with a well-padded tourniquet placed on the upper arm. A 10-cm incision centered over the medial epicondyle is used, with care taken to protect the medial antebrachial cutaneous nerves as they pass through the medial aspect of the forearm. If there has been a previous anterior transposition of the ulnar nerve, the nerve should be identified and protected prior to exposure of the UCL. A longitudinal split is made in the flexor pronator aponeurosis and muscle mass at its more anterior origin from the medial epicondyle. Retraction of the flexor mass to both sides provides access and exposure to the anterior portion of the UCL. A longitudinal incision is made into the ligament itself to inspect the medial aspect of the elbow joint. For confirmation of the diagnosis, the elbow may be flexed 20 to 30 deg and a valgus stress applied. With UCL insufficiency, the medial joint line should open several millimeters.

An avulsion of the ligament from its attachment to the medial epicondyle, although not commonly found, can be repaired by placing a Bunnell-type stitch through the body of the ligament and then passing the two free ends of suture through drill holes in the medial epicondyle. The reattachment sites should be roughened with a rongeur or curette to provide a good base for healing. Then the sutures are tied securely on the posterior aspect of the medial epicondyle, with care taken to protect the ulnar nerve (Fig. 7). An alternative may be the use of a miniature anchor system. In patients for whom there is no ulnar nerve symptom or finding, the nerve is not transposed.

In patients with associated preoperative ulnar neuropathy or evidence suggesting posterior compartment osteophytes or loose bodies, preparation is made to transpose the ulnar nerve anteriorly. The tendinous origin of the flexor pronator muscle bundle is transected 1 cm distal to the attachment of the aponeurosis on the medial epicondyle, leaving a stump of tendon for reattachment. The tendon and muscle are then reflected distally, leaving the thin layer of muscle fibers attached to their bed of origin on the UCL itself. This provides excellent exposure

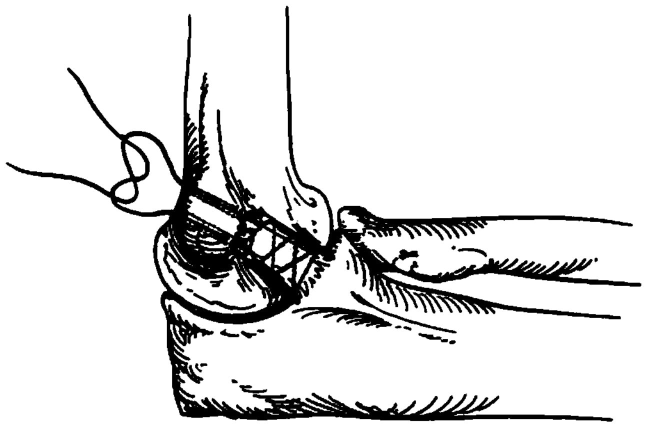

Figure 7. In rare cases, the UCL may be repaired using a Bunnell-type stitch through drill holes. (*From* Tullos HS, Bennett J: Acute injuries to the elbow. *In* Nicholas JA, Hershman GB (eds): The Upper Extremity in Sports Medicine, ed 2. St. Louis, MO, CV Mosby, 1995, p 308; with permission.)

of the entire UCL and its attachment to the tubercle on the medial aspect of the coronoid process.

The ulnar nerve is located proximally and released from the cubital tunnel. The fascial arcade of Struthers, passing over the ulnar nerve from the medial head of the triceps muscle to the medial intermuscular septum, is identified and released. The nerve is dissected free and carefully mobilized proximally from the level of the arcade of Struthers and distally to the interval between the two heads of the flexor carpi ulnaris muscles. All points of compression are released with care taken to preserve any blood vessels that course with the nerve to minimize segmental devascularization.

The posterior compartment of the elbow is easily accessible through a thin veil of capsular tissue with the nerve anteriorly transposed, and any posterior loose bodies or osteophytes on the posteromedial margin of the olecranon can be removed.

Next, divergent 3.2-mm drill holes are made in the medial epicondyle, creating bone tunnels through which the graft will be passed. A single-entry hole is made anteriorly near the base of the epicondyle. The drill holes diverge and exit separately in the cubital tunnel posteriorly.

Convergent 3.2-mm drill holes are made in the ulna located at the level of the tubercle on the medial aspect of the coronoid process. These holes are separated approximately 1 cm (Fig. 8).

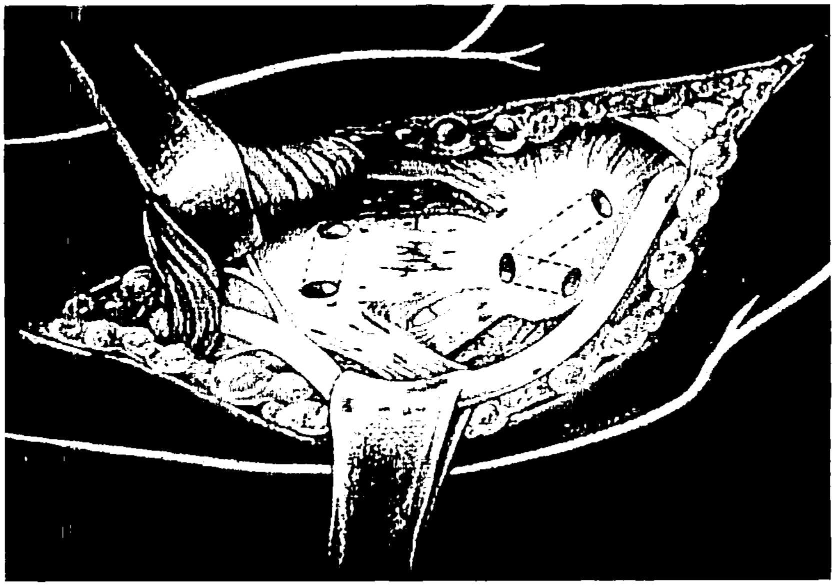

Figure 8. The appropriate placement of drill holes in the ulna for repair of the UCL. The underlying bone tunnels are depicted by the dotted lines. (*From* Jobe FW, El Attrache NS: Treatment of ulnar collateral ligament injuries in athletes. *In* Morrey BF (ed): Master Techniques in Orthopaedic Surgery: The Elbow. New York, Raven, 1994, p 159; with permission.)

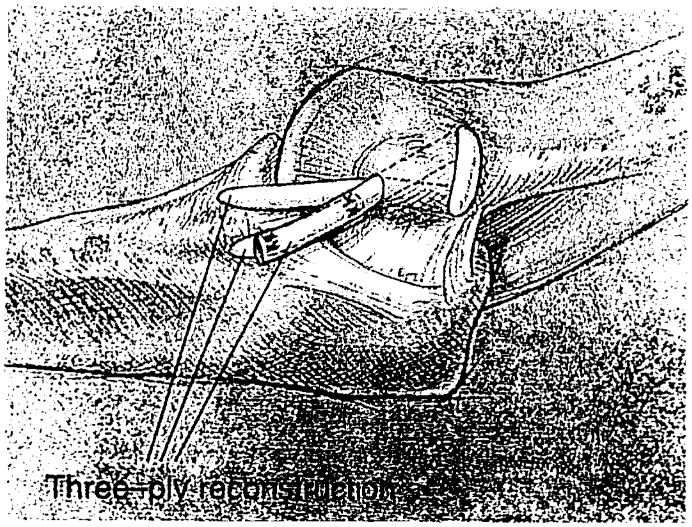

Figure 9. Final appearance of UCL reconstruction with tendon graft in place and sutured to itself. (By permission of Mayo Foundation as published in Morrey BF (ed): Master Techniques in Orthopaedic Surgery: The Elbow. New York, Raven, 1994, p 159.)

An ipsilateral palmaris longus tendon of 15 cm then is harvested as a suitable tendon donor. If this is not present, however, alternatives include the contralateral palmaris longus, the plantaris tendon, a 3- to 5-mm medial strip of Achilles tendon, or tendon from the lesser toe extensors.

A No. 1 nonabsorbable braided suture is placed in one end of the graft, and a flexible suture passer is used to thread the tendon through the bone tunnels in a figure-eight fashion. With the elbow held in 45 deg of flexion and neutral rotation, the graft is pulled taut and sutured to itself (Fig. 9). The graft also is sutured to the soft tissue in the cubital tunnel and to any remnant of the UCL.

Then the elbow is brought through a full range of motion to verify isometricity and to check for abrasion of the graft on the joint line. A gentle valgus stress is applied with the elbow in 30 deg of flexion to test stability. A stable reconstruction will prevent medial joint line opening.

The flexor pronator muscle is reattached to the medial epicondyle, superficial to the anteriorly transposed ulnar nerve. A surgical drain also is placed beneath the flexor pronator mass. The submuscular transposition of the ulnar nerve is now complete.

Postoperatively, the same program is used for both repair and reconstruction patients. The elbow is placed at 90 deg of flexion in a posterior splint, with the forearm in a neutral position and the wrist left free for 10 days. Hand grip exercises are begun as soon as the patient feels only minimal discomfort. Active range-of-motion exercises for the elbow and shoulder are started at 10 days. Strengthening exercises of the wrist and forearm are started at 4 to 6 weeks. After 6 weeks, elbow strengthening exercises are begun, avoiding valgus stress for 4 months.

At 4 months, the sport-specific rehabilitation program is begun. Baseball pitchers are allowed to toss a ball up to 30 to 40 feet, without a wind-up, two to three times a week for 10 to 15 minutes. After 5 months, the distance is increased to 60 feet, and the pitcher continues progressive strengthening exercises. At 6 months, the athlete starts lobbing the ball 60 feet using an easy wind-up, and thereafter does exercises and ball-lobbing on alternate days. At 7 months, the individual is allowed to throw from the mound (60 feet) at half full speed; duration of a throwing session is increased slowly only to 25 minutes. During the eighth and ninth months, depending on the athlete's progress, pitching at 75% of the athlete's maximum speed is commenced. From months 10 to 12, duration of sessions and velocity of each pitch gradually is increased until the patient can pitch a simulated game.

Pitching in competition is permitted at 12 months if there is no pain while throwing, the strength of the forearm muscles have returned to normal, and both the elbow and shoulder have normal range of motion and strength. Only three innings are allowed with at least 6 days rest between outings. Pitchers are encouraged not to return to the regular rotation until 18 months.

Results and Complications

Results of 70 operations reported by Conway et al,[4] in which 14 were direct repairs and 56 were reconstructions, showed that 50% of the repair group and 68% of the reconstruction group returned to their previous level of competition. The mean time to return was 9 months for the repair group and 12.5 months for the reconstruction group.

The complications were as follows: one patient had a postoperative hematoma; two patients had cutaneous nerve paresthesias, of which one required excision of a neuroma for resolution of the symptoms; and the remaining complications were related to the ulnar nerve. Fifteen patients (21%) developed ulnar nerve symptoms postoperatively despite transposition. Six had transient paresthesias, which resolved after a mean of 4 months. The other nine patients required a repeat operation (eight ulnar nerve revisions, one primary anterior transposition). Symptoms in four of these nine patients initially presented after 5 months postoperatively.

This high complication rate has convinced the authors to recommend dissection and anterior transposition of the nerve only when symptoms of ulnar neuropathy are present preoperatively or when a pathologic condition in the posterior compartment requires exposure through the cubital tunnel.[9]

The indication for surgery in this series was an athlete who had a torn or incompetent UCL, had failed to improve after nonoperative treatment, and wanted to return to competitive sports. It is not clear whether this operation is appropriate for those patients not wishing to return to a highly competitive level, although Bennett et al[2] reported good results after UCL repair or reconstruction in patients with symptoms of instability who had moderate or heavy elbow demands at work.

LATERAL-SIDED INJURIES

The effects of valgus strain are not limited to the medial side of the elbow. The lateral joint line experiences compressive forces during the act of throwing. These forces cross the articular surfaces of the radius and capitellum and can lead to capitellar osteochondral fractures, osteochondritis dissecans, and radiohumeral loose bodies. These findings are especially true in the presence of an incompetent UCL.[5] Posterolateral rotatory instability of the elbow, although not associated with the valgus strain of throwing, also may occur in athletes.

Osteochondritis dissecans of the capitellum in the adolescent is thought to occur from focal arterial injury and subsequent bone necrosis resulting from radiocapitellar compression forces.[6] This is one of the clinical entities that falls under the term "Little League elbow." Most commonly, "Little League elbow" is associated with medial elbow pain. This pain is secondary to medial epicondylar apophysitis or avulsion. Less often, though, the adolescent will present with lateral elbow pain and tenderness. The diagnosis of osteochondritis dissecans can be made most often from plain radiographs of the elbow.[15] Treatment of these lesions is dictated by radiographic and clinical findings. Intact lesions can be treated with restriction of activity and occasionally splinting.[10] Symptomatic loose bodies and persistent pain in the older child require surgical intervention consisting of arthroscopy or arthrotomy with loose body removal, excision of capitellar lesions, and curettage to bleeding bone to provide pain relief and improve joint motion.[10, 15]

As osteochondritis dissecans is a disease of immature articular cartilage still capable of undergoing endochondral ossification, there is no evidence that this process can occur in a skeletally mature individual.[15] In adults, however, it is not uncommon to see loose bodies within the radiohumeral joint space.[14] These loose bodies are thought to be caused by medial elbow stress applied across an attenuated medial joint support leading to compression of the radial head against the capitellum (Fig. 10). Patients usually present with pain, stiffness, locking, and decreased range of motion. Stretching, strengthening, and removal of loose bodies via either arthroscopy or arthrotomy is the usual treatment. If degenerative changes are present, however, a return to a presymptomatic level of competition is sometimes difficult.

Posterolateral Rotatory Instability

Posterolateral rotatory instability (PLRI) of the elbow follows injury to the lateral ulnar collateral ligament (LUCL). In young patients PLRI is usually secondary to an elbow dislocation. In adults, it is more

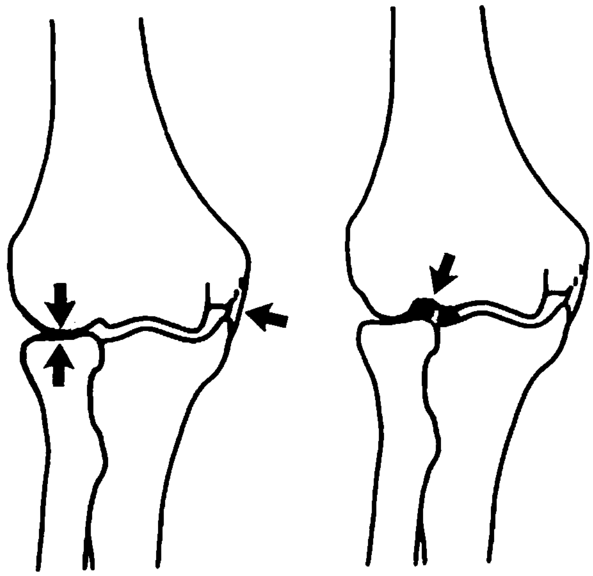

Figure 10. Depiction of valgus stress causing radiocapitellar compression and secondary loose bodies *(arrows)*. (*From* King JW, Brelsford HJ, Tullos HS: Analysis of the pitching arm of the professional baseball pitcher. Clin Orthop 67:116–123, 1969; with permission.)

commonly caused by a varus extension stress without dislocation,[21] which initially may be diagnosed as a sprain. This condition may also be iatrogenic, caused by violation of the ulnar part of the LCL during a lateral release for lateral epicondylitis or a radial head excision.[21] The subsequent ligamentous laxity allows transient rotatory subluxation of the ulnohumeral joint and secondary subluxation or dislocation of the radiohumeral joint.[9, 21, 24] The annular ligament remains intact and therefore the proximal radius and ulna move together as a unit.

Diagnosis

Patients present complaining of recurrent painful locking, snapping, and episodes of instability, which can be mistaken for dislocations. When this occurs in athletes, not only can their level of competition be limited but also their activities of daily living may be restricted. The episodes of instability occur only when the elbow is extended and the forearm is supinated.

The physical examination is usually unremarkable except for the posterolateral rotatory instability test. This test as described by O'Driscoll et al[24] is performed with the patient supine and the extremity over the patient's head with the shoulder fully externally rotated (Fig. 11). When the patient's forearm is fully supinated, the examiner grasps the wrist or forearm and, starting from full extension, slowly flexes the elbow while applying valgus and supination moments and an axial compression force. This procedure produces a rotatory subluxation of the ulnohumeral joint; the semilunar notch of the ulna is displaced from the trochlea of the humerus. This rotation dislocates the radiohumeral joint posterolaterally by a coupled motion. As the elbow is flexed to approximately 40 deg, the posterolateral rotatory displacement reaches a maximum, creating a posterior prominence (the dislocated radiohumeral joint) associated with a skin dimple proximal to the radial head. Additional flexion causes a sudden reduction of the radiohumeral and ulnohumeral joints. The dimple disappears and the radius and ulna palpably and visibly snap into place. This result can be confirmed under fluoroscopy, which reveals posterolateral dislocation of the radial head with widening of the ulnohumeral articulation due to the rotation (supination) of the ulna away from the trochlea.

The displacement is best demonstrated under general anesthesia and rarely can occur with the patient awake. The test is highly sensitive, however, as an apprehension test with the patient awake.[23]

Surgery is indicated in patients with symptomatic instability. The only known nonoperative treatment is permanent use of an elbow brace with the forearm held in pronation.[23]

Surgical Treatment

Surgical correction of PLRI is performed by either reattaching the avulsed LUCL or reconstructing it with a tendon graft. Children with open epiphyseal plates should not undergo reconstruction until their growth plates have closed.

The procedure as performed by Morrey et al[21, 23] is approached

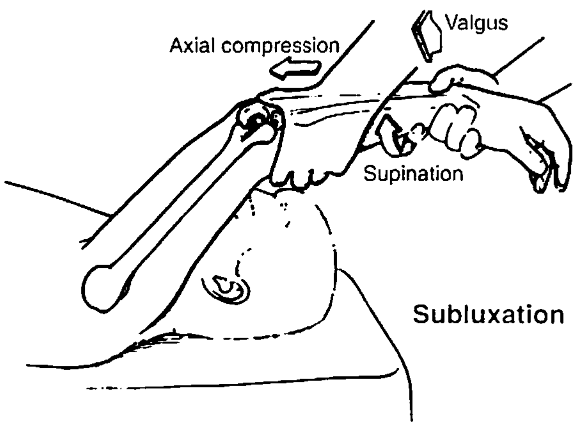

Figure 11. Posterolateral rotatory instability test. (*From* O'Driscoll SW, Bell DF, Morrey BF: Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am 73:441, 1991; with permission.)

through a modified Kocher incision. The deep fascia is incised along the supracondylar ridge and distally between the anconeus and extensor carpi ulnaris muscles. The common extensor origin is elevated carefully by sharp dissection to reveal the origin of the radial collateral ligament complex at the lateral epicondyle. The anconeus muscle is reflected posteriorly and the extensor carpi ulnaris muscle anteriorly. The extension of the origin of the anconeus to the lateral aspect of the triceps fascia also is reflected. The supinator crest of the ulna is identified. Typically, a lax ulnar band of the radial collateral ligament is observed, and the abnormal portion of the ligament is proximal to the annular ligament.

The pivot-shift maneuver reveals laxity of the anterior part of the capsule over the radial head and of the posterior part of the capsule at the posterior aspect of the radiohumeral joint. The subluxation of the joint confirms the diagnosis of a stretched LUCL.

The capsule is incised along the capitellum in an arc to permit inspection of the joint for loose bodies and abrasions of the articular surfaces. The anterior and posterior aspects of the capsule are tightened with plication sutures, but these sutures are not yet tied. If the LUCL appears intact but stretched or detached from its origin, it is imbricated and advanced with a Bunnell's suture technique similar to that described by Osborne and Cotterill.[25] Care is taken to suture and plicate both the ulnar and the radial parts of the radial collateral ligament complex. The sutures are advanced through holes placed through the bone at the humeral anatomic origin of the ligament (Fig. 12).

If the tissue of the collateral ligament is of poor quality, the LUCL is reconstructed with an autogenous graft consisting of the palmaris longus tendon or semitendinosus.

With at least 20 cm of length required, the insertion site for the tendon graft is prepared then by making two drill holes in the ulna, one near the tubercle of the supinator crest (which is felt by stressing the elbow in varus or supination) and the other 1.25 cm proximally at the base of the annular ligament. The underlying bone is channeled with a curved awl from the Bankart shoulder instruments. A No. 1 suture is passed through these holes and tied to itself. It is pulled then toward the lateral epicondyle with a hemostat placed at the center of rotation (Fig. 13). The isometric ligament origin is then determined by flexing and extending the elbow to see if the suture moves. No movement will occur if the hemostat and suture are held at the isometric point. The entry site for the graft then is burred into the humerus at that point. The hole is made slightly posterior and proximal to this point, as the hole is bigger than the tip of the hemostat. An exit hole is made with the bur just posterior to the supracondylar ridge approximately 1.5 cm proximal to the entry hole. A tunnel is created between the two holes using an awl. A third hole is then burred distally, leaving 1.25 cm of bridging bone between the two holes. A tunnel is made then from this hole to the original entry hole.

The tendon graft is taken then through the two holes in the ulna

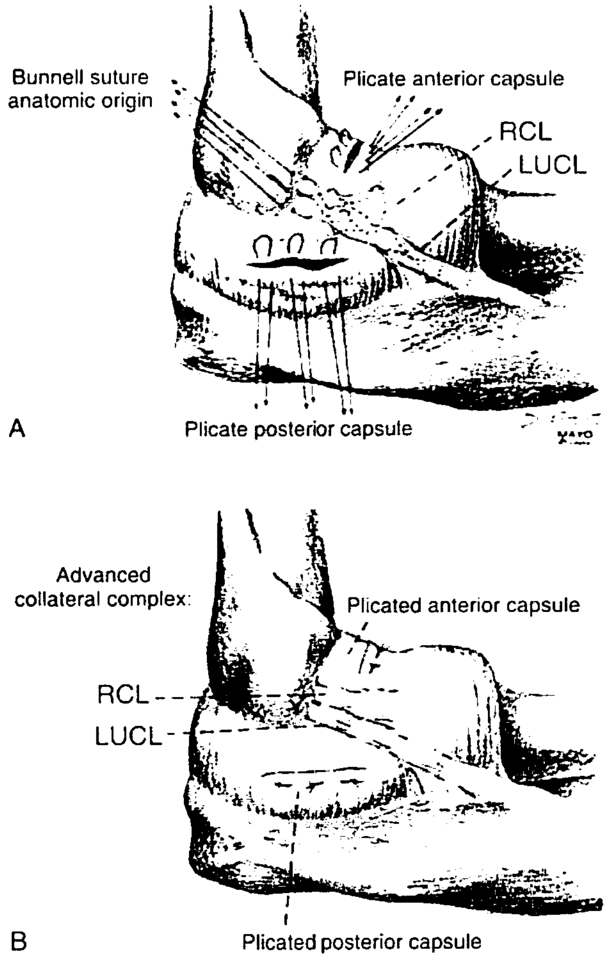

Figure 12. Repair technique for PLRI. *A*, The anterior and posterior capsules are incised. Imbrication and advancement of both the LUCL and the radial collateral ligament (RCL) using a Bunnell-type stitch, which is taken through the drill holes in the humerus, are performed. *B*, Final result after advancement and plication are completed. (By permission of Mayo Foundation as published in J Bone Joint Surg Am 74:1238, 1992.)

and sutured to itself. Next, it is passed into the isometric entry hole in the humerus, out through the proximal hole, back in through the third (distal) hole, and back out of the isometric hole (Fig. 14).

The graft is tensioned with the elbow in 30 deg of flexion and forced pronation and then sutured back down to itself (Fig. 15). The capsule is closed and plicated, and the original arch made by the LCL is restored by pulling the graft anterior and suturing it to the capsule. This also

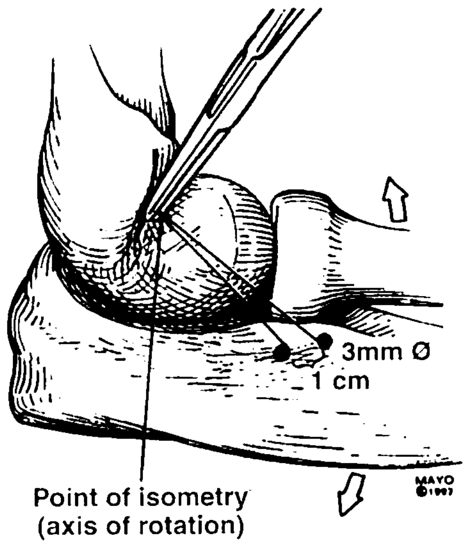

Figure 13. The LUCL's anatomic site of attachment to the humerus is also the isometric point, as demonstrated in this illustration. Hemostat will not move with flexion and extension of the elbow *(arrows)* if placed at isometric point. (By permission of Mayo Foundation as published in J Bone Joint Surg Am 74:1238, 1992.)

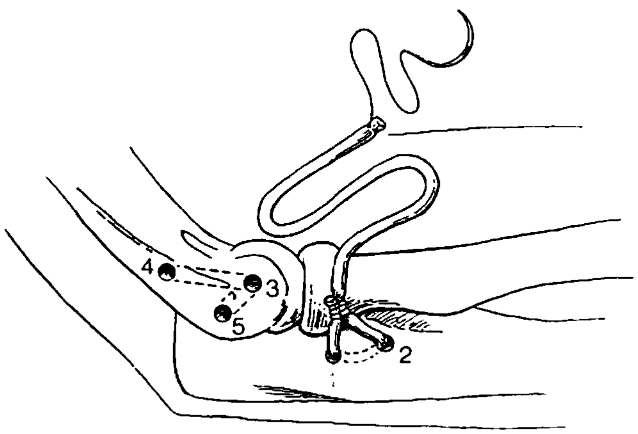

Figure 14. In PLRI reconstruction, the graft is passed into the isometric hole in the lateral epicondyle, out through hole 4, back in through hole 5, and re-emerges out of the isometric hole (3). (*From* Morrey BF (ed): Master Techniques in Orthopaedic Surgery: The Elbow. New York, Raven, 1994, p 177; with permission.)

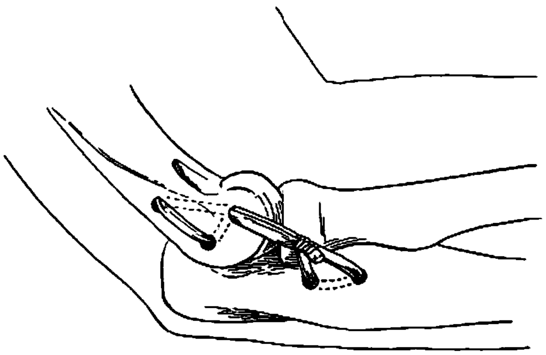

Figure 15. In PLRI reconstruction, the graft is tensioned with the elbow at 30 to 40 deg of flexion and full pronation. The graft is then sutured to itself. (*From* Morrey BF (ed): Master Techniques in Orthopaedic Surgery: The Elbow. New York, Raven, 1994, p 178; with permission.)

prevents the graft from slipping posteriorly. The capsule must be closed under the graft to prevent rubbing. If more tension is needed, a suture can be used to close the triangular gap distally between the two limbs of the graft. After completion, the elbow is tested for posterolateral rotatory instability prior to skin closure.

Postoperatively, the extremity is immobilized in a cast for 4 weeks with the elbow flexed 90 deg and the forearm fully pronated. Then a cast brace with a 30-deg extension block is used for 6 weeks, followed by removal of the extension block for up to another 6 weeks. Normal activity is allowed at 6 months after the operation.

Results and Complications

Osborne and Cotterill[25] reported on eight patients who underwent imbrication and reattachment of the LCL, none of whom had recurrences. Of the 11 cases performed by Morrey[21] (three repairs, eight reconstructions), posterolateral rotatory instability was eliminated in all but one. The average follow-up was 42 months, ranging from 24 to 68 months. The one failure, which was reconstructed using palmaris longus muscle along with a synthetic ligament augmentation device, had a positive pivot–shift test at 3 months postoperatively and was revised.

The majority of young patients in this study developed posterolateral rotatory instability secondary to a traumatic elbow dislocation. It is known that in all simple dislocations of the elbow, there are complete tears of both the medial and lateral collateral ligaments.[12, 13] The standard treatment for an elbow dislocation is closed reduction and immobilization. Josefsson et al[12] found no benefit to exploring and repairing the collateral ligaments over conservative treatment. Prolonged immobilization after injury, however, has been shown in adults to cause flexion contractures and chronic pain.[16]

Because the potential for recurrent instability is now well recognized in children and because this age group does not lose substantial range of motion postinjury, these and other authors[21] now recommend immobilizing patients less than 16 years of age for 3 to 4 weeks following the reduction of a simple elbow dislocation.

SUMMARY

Elbow injuries in the throwing athlete are common. Because of the tremendous medial tensile forces and lateral compressive forces borne by the elbow, there is a wide array of injuries that occur. A detailed history and physical examination are necessary for an accurate diagnosis. Many of the injuries discussed can be treated successfully with conservative measures followed by aggressive physical therapy. Prompt recognition and early treatment is mandatory. In those conditions in which conservative treatment tends to fail, the detailed surgical options have been discussed. It is important to select highly motivated patients for those procedures that require extensive rehabilitation postoperatively. The keys to success in elbow surgery are a compliant patient and a well-regimented rehabilitation program.

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