1 Clinically Relevant Elbow Anatomy and Surgical Approaches

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Pertinent Anatomy of the Thrower's Elbow

Osseous Anatomy

The elbow is primarily a ginglymus or hinge joint, but in reality consists of three bony articulations including ulnohumeral, radiocapitellar and radioulnar joint. The primary arc of motion during throwing motions is flexion and extension through the ulnohumeral articulation; however, some pronation-supination does occur through the ulnohumeral and radioulnar joints. In full extension, the elbow has a normal valgus-carrying angle of 11–16°. Morrey and An determined the osseous anatomy's contribution to resistance to valgus stress remains fairly constant throughout elbow motion [1].In full extension, roughly one third of valgus force was resisted by the ulnar collateral ligament (UCL); 31 %), one third by the anterior capsule (38 %), and one third by the bony architecture (31 %). At 90° of flexion, the UCL increased its relative contribution to 54 %, whereas the anterior capsule provided only 10 % to valgus stability, and the bony anatomy contribution remained relatively unchanged at 36 %.

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Muscular Anatomy

Flexor-Pronator Mass

The flexor-pronator mass is a collection of muscles that form a common origin from the medial epicondyle. These muscles can be viewed and organized into superficial and deep layers or groups. Pronator teres, flexor carpi radilais, flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), and palmaris longus (PL) muscle are found in the superficial layer. In the deep layer, three muscles are found and composed of flexor digitorum profundus, flexor pollicus longus, and pronator quadratus muscles (Fig. 1.1). The combined function is to perform wrist flexion and forearm pronation. An analysis of the primary muscles of the flexor-pronator group (pronator teres, FDS, FCU, and flexor carpi radialis) indicates that their dynamic action applies a varus moment and therefore resisting valgus force across the elbow [2]. In relation to throwing mechanics; however, electromyogram (EMG) studies indicate that the flexor muscles do not reflect a compensatory increase in activity in throwers with valgus instability. Furthermore, both flexor carpi radialis and pronator teres show a paradoxical decrease in activity in throwers with valgus instability after medial ulnar collateral ligament (MUCL) rupture [2, 3]. It is unclear

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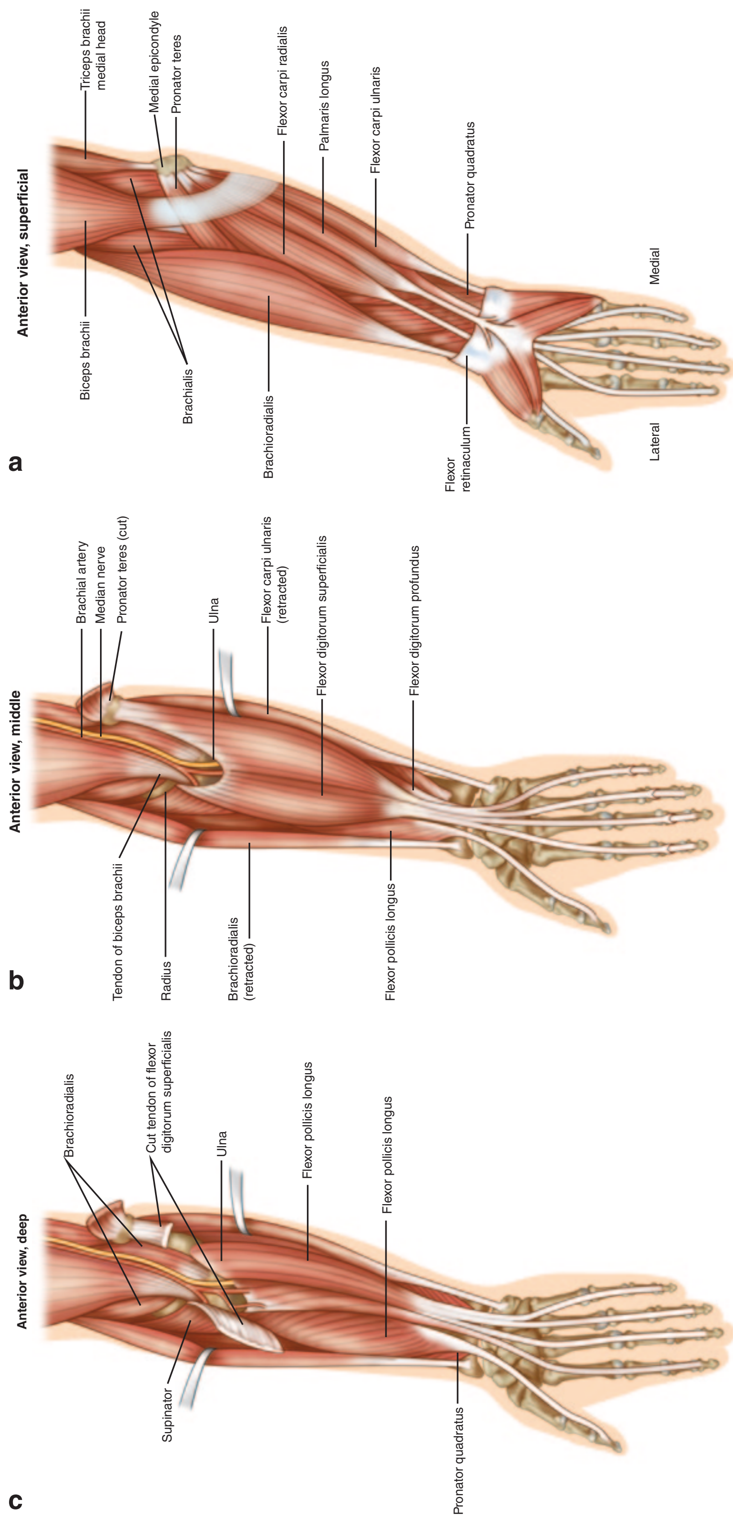

Fig. 1.1 Anterior view of the superficial and deep components of the elbow flexor-pronator mass

whether the decrease in EMG activity is a cause or effect of MUCL injuries. Despite these EMG findings, ruptures of the flexor-pronator mass and medial epicondylitis can occur in the clinical setting of MUCL injuries of throwers indicating some level of contribution of the muscles to function and likely stability [4, 5]. An anatomic analysis revealed that the FCU muscle is the predominant musculotendinous unit overlying the UCL essentially independent of elbow flexion and forearm rotation [6]. The only other muscle with less frequent contribution to coverage was the FDS. Several authors have reported FCU as the biggest contributor to valgus stability in MUCL deficient elbows [7, 8]. In contrast, despite suboptimal muscle coverage, Udall et al. [9] showed FDS as the greatest contributor to valgus stability of the elbow due to its bulk (increased cross-sectional area).

Palmaris Longus Tendon

The PL tendon is an ideal source of graft for MUCL reconstruction; however, it is clinically absent in 15 % of the population with incidences varying widely depending on ethnicity [2]. Clinically, the presence of the PL can be verified by opposing the thumb and small finger together, which creates a characteristic appearance over the volar surface of the wrist (Fig. 1.2). The PL tendon is located between the flexor carpi radialis tendon and the FDS tendons at the level of the wrist.

Fig. 1.2 The presence of the palmaris longus can be verified preoperatively by opposing the thumb and small finger together, which creates a characteristic appearance over the volar surface of the wrist

Nerve Anatomy

Medial Antebrachial Cutaneous Nerve

The medial antebrachial cutaneous nerve arises from the medial cord of the brachial plexus. In the distal brachium, the nerve travels medial to the brachial artery. The nerve then courses down the ulnar aspect of the forearm and enters the deep fascia with the basilica vein. It is responsible for sensation over the medial aspect of the elbow. Branches pass 3–60 mm distal to the medial epicondyle and are at risk with the typical longitudinal incision used in UCL reconstructive surgery [10]. Identification and protection of these nerve branches protect from iatrogenic injury and prevents the development of painful, symptomatic neuromas or superficial sensory derangement. The nerves are encountered immediately after skin incision (Fig. 1.3) and are variable in their size, appearance, and distribution [11].

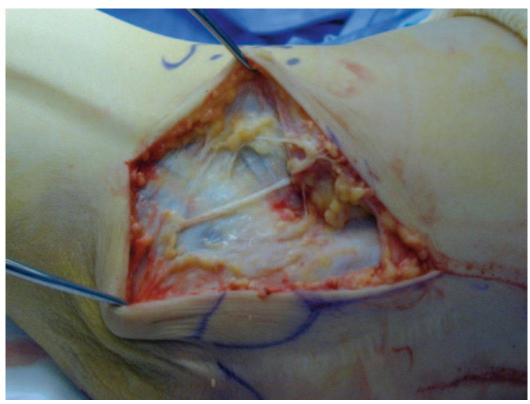

Fig. 1.3 The medial antebrachial sensory nerve is encountered immediately after the skin incision during the approach for the UCL reconstruction. Care is taken to identify and protect this nerve throughout the procedure to prevent injury

Ulnar Nerve

The surgical approach to the UCL demands a clear understanding of the location of the neurovascular structures. The ulnar nerve is the most thought of neurologic structure in regard to UCL reconstructive surgery. The ulnar nerve descends along the posteromedial aspect of the humerus and then enters the cubital tunnel posterior to the medial epicondyle (Fig. 1.4). After exiting the cubital tunnel, the ulnar nerve gives off an articular sensory innervation branch and then enters the flexor compartment of the forearm. It is positioned under the FCU adjacent to the ulna. The nerve innervates the FCU and the medial half of flexor digitorum profundus.

The ulnar nerve courses with the ulnar artery and distally in the hand it is responsible for sensory innervation of the ulnar 1.5 digits, and intrinsic hand motor function as well. A muscle-splitting approach for UCL reconstruction can be performed without detachment of the flexor-pronator mass of the forearm [10, 12]. Exposure for this technique is performed either through a naturally occurring raphe that delineates the separation between the FCU and the remaining flexor muscle mass or simply in-line between the medial epicondyle and sublime tubercle (Fig. 1.5). This region is a natural watershed area between motor innervation of the ulnar nerve and median nerve as verified through cadaveric analysis. This approach, therefore, avoids iatrogenic denervation to these muscles [10, 12].

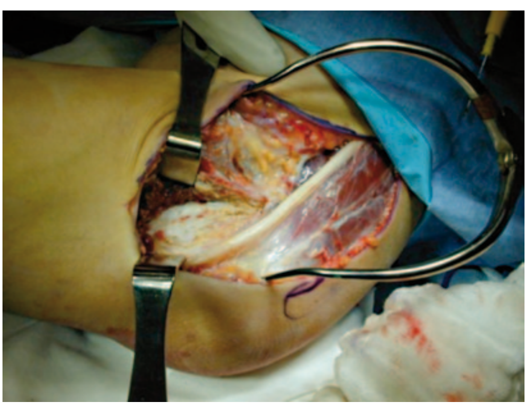

Fig. 1.4 The ulnar nerve descends along the posteromedial aspect of the humerus and then enters the cubital tunnel posterior to the medial epicondyle

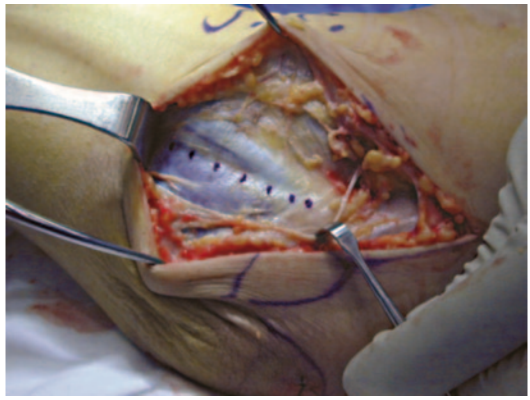

Fig. 1.5 Exposure for the muscle-splitting approach is performed through a naturally occurring raphe that delineates the separation between the flexor carpi ulnaris and the remaining flexor muscle mass (*blue dots*) or simply in-line between the medial epicondyle and sublime tubercle

Ligamentous Anatomy

Ulnar Collateral Ligament

The medial collateral ligament of the elbow is composed of three bundles, including the anterior, posterior, and transverse bundles [1, 13]. The transverse bundle has also been described as the oblique bundle [12]. The anterior bundle is composed of two different histological layers and two different functional bands. The deep layer is confluent with the joint capsule, while the superficial layer is a more distinct structure above the capsule with thick parallel fibers with a mean width of 4–5 mm [14]. An anatomic and biomechanical evaluation of the UCL revealed that the anterior bundle can be further delineated into two distinct functional sub-units, the anterior and posterior bands 15]. The anterior and posterior bands of the anterior bundle of the UCL perform reciprocal functions with the anterior band functioning as the primary restraint to valgus rotation at 30, 60, and 90° of flexion. The anterior and posterior bands are equal functioning restraints at 120° of flexion while the posterior band acts as a secondary restraint at 30 and 90° of flexion (Fig. 1.6) [15].

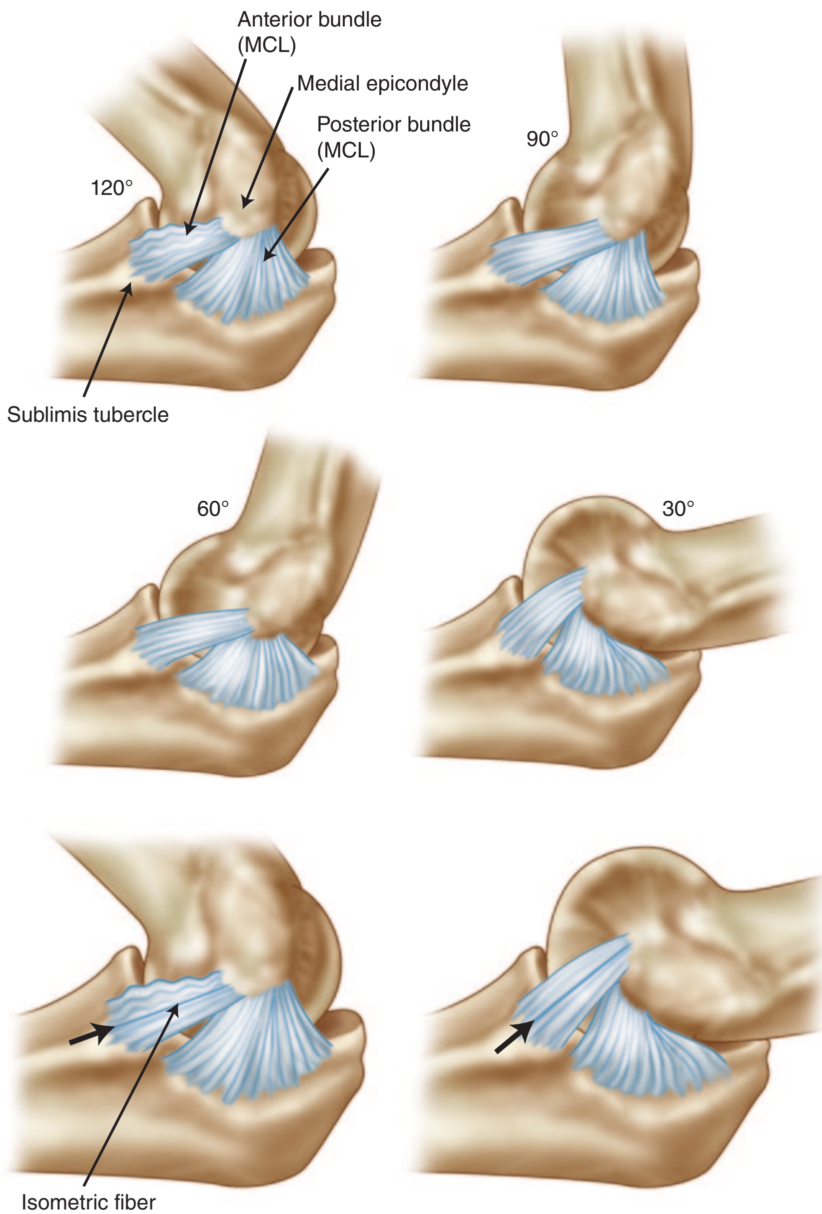

Fig. 1.6 Illustrations of the anatomy of the medial collateral ligament (*MCL*) of the elbow at 30, 60, 90, and 120° of flexion. The anterior bundle arises from the inferior aspect of the medial epicondyle (ME) and inserts immediately adjacent to the joint surface on the ulna near the sublimis tubercle. The anterior bundle widens slightly from proximal to distal and can be subdivided into anterior and posterior bands of equal width. The bands tighten in reciprocal fashion as the elbow is flexed and extended (*bottom frame*), and they are separated by easily identifiable isometric fibers (*arrows*). The posterior bundle arises from the ME slightly posterior to its most inferior portion. It inserts broadly on the olecranon process. The posterior bundle appears to be thickened joint capsule when the elbow is extended. As the elbow is flexed, the ligament tightens and fans out to form a sharp edge that is perpendicular to the long axis of the ulna

The anterior bundle arises from the inferior aspect of the medial epicondyle [16] and inserts immediately adjacent to the joint surface on the ulna near the sublimis tubercle. The anterior bundle widens slightly from proximal to distal and can be subdivided into anterior and posterior bands of equal width. The bands tighten in reciprocal fashion as the elbow is flexed and extended (bottom frame), and they are separated by easily identifiable isometric fibers (arrows). The posterior bundle arises from the medial epicondyle slightly posterior to its most inferior portion. It inserts broadly on the olecranon process. The posterior bundle appears to be thickened joint capsule when the elbow is extended. As the elbow is flexed, the ligament tightens and fans out to form a sharp edge that is perpendicular to the long axis of the ulna. Furthermore, the anterior bundle originates from the anteroinferior edge of the medial humeral epicondyle with an origin measuring 45.5 ± 9.3 mm^2 in diameter and inserts onto the sublime tubercle on the ulna in an area measuring 127 ± 35.7 mm^2 in diameter [17].

The anterior bundle is the primary restraint to valgus stress from 20 to 120° of flexion and is the critical structure requiring reconstruction after injury in throwers. Because its origin is slightly posterior to the axis of the elbow, there is a cam effect created so that the ligament tension increases with increasing flexion. The anterior bundle of the UCL is the strongest of the different components with a mean load to failure of 260 N [18]. The posterior bundle is not a significant contributor to valgus stability unless the remaining structures of the UCL are sectioned. The posterior bundle of the UCL is thinner and weaker than the anterior bundle, originates from the medial epicondyle and inserts onto the medial margin of the semilunar notch and acts only as a secondary stabilizer of the elbow beyond 90° of flexion [19]. Lastly, the oblique bundle or transverse ligament does not span the ulnohumeral joint but instead acts to increase the greater sigmoid notch as a thickening of the joint capsule [20].

Relevant Surgical Approaches

Positioning

UCL reconstruction is performed with the patient under either regional block or general anesthesia in the supine position with the extremity outstretched onto an arm board. A pneumatic tourniquet is placed on the upper arm and inflated to 200–250 mmHG during the graft harvest and critical portions of the procedure. Routine sterile prep and drape of the extremity is done under sterile conditions. Diagnostic elbow arthroscopy is performed before graft harvest and UCL reconstruction.

Elbow Arthroscopy

Arthroscopic evaluation is performed with the operative extremity in an arm holder and positioned across the patient's chest utilizing the Spider Limb Positioner (Smith & Nephew, Tenet Medical Engineering, Memphis, TN) (Fig. 1.7). An 18-gauge spinal needle is used to enter the joint via the "soft spot" or "direct lateral portal" that is located in the middle of a triangle formed by the lateral epicondyle, Radial Head, and olecranon. Forty to 50 ml of normal saline is injected to distend the Elbow Joint before trocar insertion

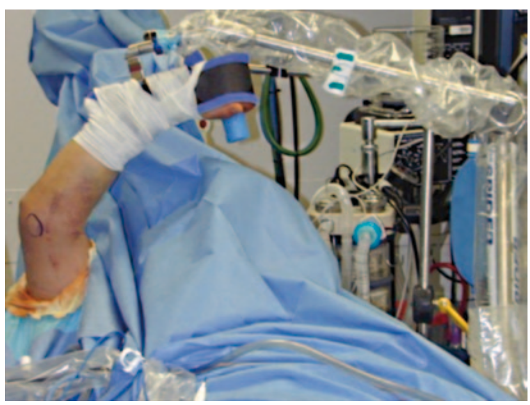

Fig. 1.7 Arthroscopic elbow evaluation is performed with the operative extremity in an arm holder and positioned across the patient's chest utilizing the Spider Limb Positioner. (Smith & Nephew, Tenet Medical Engineering, Memphis, TN)

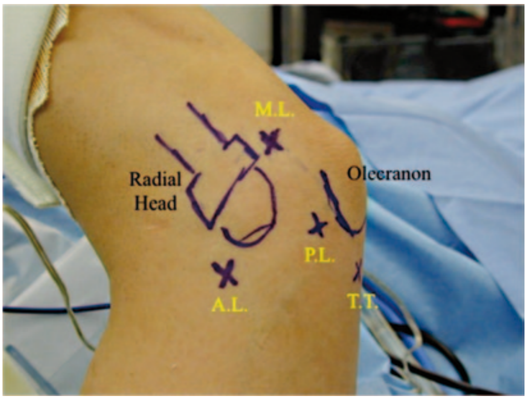

Fig. 1.8 Commonly utilized elbow arthroscopy portals for evaluation prior to the UCL reconstruction procedure. Midlateral (*M.L.*), Anterolateral (*A.L.*), Posterolateral (*P.L.*), and Trans-triceps (*T.T.*) portal sites

to prevent articular cartilage damage. Distension of the joint will move the soft tissue along with the neurovascular structures away from the capsule, thus minimizing the risk of injury. The direct or mid lateral (ML) portal (Fig. 1.8) is excellent for viewing and evaluations of the posterior compartment, specifically, the radioulnar joint, inferior surfaces of the capitellum, and radial head. It is relatively safe, passes between the plane between the anconeus and triceps muscle and within 7 mm of the lateral antebrachial cutaneous nerve [21, 22].

An anterolateral (AL) portal (Fig. 1.8) is the first portal established in the elbow arthroscopy sequence before the UCL reconstruction to examine the anterior and medial elbow compartment. More importantly, we perform an arthroscopic stress test on every patient to confirm valgus instability. This is done (viewing from the AL portal) with the forearm in full pronation and the elbow in 70° of flexion, an opening of 2 mm between the humerus and ulna with valgus stress is considered a positive sign. The AL portal is preferred for examination and viewing of the anterior and medial side of the elbow joint. Andrews and Carson [23] originally described this portal position as 3 cm distal and 1 cm anterior to the lateral epicondyle. Recent anatomic cadaver studies have shown that the 3 cm distal location places the trochar in very close proximity to the radio nerve, which significantly increases the risk of injury [16, 24]. Thus, several authors have moved this portal more anterior and less distal. Plancher et al. [22] advocate an AL portal placed in the sulcus, which is located between the radio head and the capitellum (1 cm distal and 1 cm anterior to the lateral epicondyle). Even with the newer proposed locations, the average distance of the radial nerve to the trochar in the AL portal position is between 3–7 mm in nondistended joints [16, 22–24], which increases to 11 mm with joint distension [16].

In order to examine the posteromedial olecranon and humeral fossa for impingement, loose bodies and spurs, we will establish a second portal posterior and lateral to the triceps tendon (posterolateral portal). The posterolateral (PL) portal location has the largest area of safety provides excellent visualization of the posterior and posterolateral compartments. It is established approximately 3 cm proximal to the tip of the olecranon and at the lateral border of the triceps tendon. Allowing the elbow to flex (20–30°) will relax the posterior capsule and facilitate successful trochar insertion [22]. Structures at risk include the posterior antebrachial cutaneous and the lateral brachial cutaneous nerves. The scope is then advanced distally to the radiocapitellar joint to further evaluate for pathology. If debridement or removal of spurs or loose body is needed in the posteromedial gutter, then another accessory trans-triceps (TT) tendon portal (Fig. 1.8) can be created above the olecranon tip as a working portal for instrumentation. This portal is established above the tip of the olecranon through the musculotendinous junction of the triceps muscle with the elbow in a partially extended position. It is excellent for spur debridement and removing loose bodies from the posteromedial compartment. Structures at risk include the posterior antebrachial cutaneous nerve (23 mm away) and the ulnar nerve (25 mm away) when the elbow is distended [16, 22]. Once the elbow arthroscopy is finished and the graft (palmaris vs. gracillis autograft or allograft) is prepared, the medial approach to the elbow is performed to start the UCL reconstruction.

Medial Approach—Muscle Splitting

All portal sites from the elbow arthroscopy were closed with monocryl before the start of the medial exposure. The arm was then exsanguinated to the level of the tourniquet with an Esmarch bandage. An 9–10 cm incision was made with a #15 blade starting 2 cm proximal to the medial epicondyle and extending along the intermuscular septum to approximately 2 cm beyond the sublime tubercle (Figs. 1.3 and 1.5). Meticulous dissection is performed and the medial antebrachial cutaneous nerve is commonly encountered at this time (Fig. 1.3). We typically tag this nerve with vessel loop and care is taken to avoid injury or damage. At this time, the common flexor-pronator mass is seen inserting on the medial epicondyle along with the anterior fibers of the FCU muscle. A muscle-splitting approach is performed between the raphe of the FCU and the anterior portion of the flexor-pronator mass (Fig. 1.5) which comprises of the flexor carpi radialis, PL, and the flexor digitorm superficialis. This approach is performed through a true internervous plane between the median nerve (anterior portion of the flexor-pronator mass) and the ulnar nerve (FCU muscle). It is also done within the anatomic safe zone that is defined as the region between the medial humeral epicondyle to the area that is 1 cm distal to the attachment of the MUCL on the sublime tubercle [10]. A blunt self-retainer retractor maybe used to help with the exposure of the MUCL during this step of the operation. The MUCL is inspected and a longitudinal incision in line with the MUCL is made with a deep knife to expose the joint. Subsequently, the sublime tubercle is exposed with a periosteal elevator. Two small homans are placed superiorly and inferiorly to the sublime tubercle to help with the exposure. A small burr (3.0 mm) is used to create two tunnels anterior and posterior to the sublime tubercle perpendicular to each other. A small curette is used to complete the tunnels; care is taken to make sure that a 2-cm bone bridge is left between the two tunnels. At this time, the medial humeral epicondyle is exposed with periosteal elevator and a longitudinal tunnel (along the axis of the epicondyle) is created on the anterior half of the medial epicondyle/MUCL footprint with a 4 mm burr (Fig. 1.9). Care is taken not to violate the posterior cortex of the proximal epicondyle, which would place the ulna nerve at risk and compromise graft fixation. See the pertinent chapter for more details on the tunnel position, graft shuttling, and tensioning techniques.

Fig. 1.9 Surgical approach to the ulnar collateral ligament (UCL) reconstruction. Medial antebrachial cutaneous nerve is identified (*blue stars*) and protected while a single bone tunnel is drilled with a burr in the medial epicondyle (*M.E.*). Passage of palmaris longus graft through the sublime tubercle and bone tunnel in the medial epicondyle

Medial Approach—Flexor-Pronator Mass Elevation

Alternative to the muscle-splitting technique is the flexor-pronator mass elevation or take down described by Jobe et al. [25] as the original medial elbow approach to the UCL reconstruction procedure. A similar medial incision is made centered over the medial epicondyle and extending down past the sublime tubercle. Care is taken to protect both the medial antebrachial cutaneous nerve and the ulna nerve. First, a longitudinal split was made in the fascia and in line with the flexor muscles. At this time, the damaged MUCL is exposed and examined. Additional exposure to the UCL reconstruction procedure is provided with elevation and transection of the common flexor mass along with most of the pronator teres one centimeter distal to the medial epicondyle origin leaving a small stump of tissue for reattachment

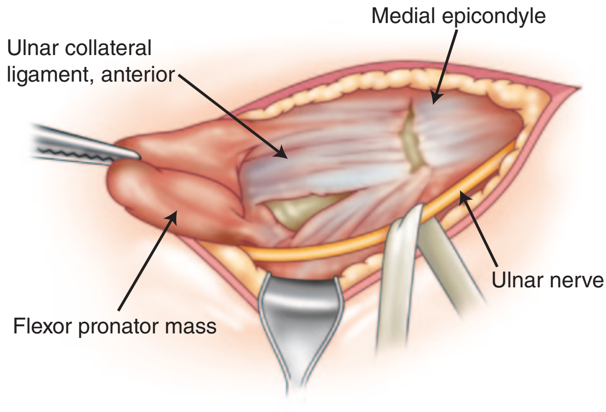

Fig. 1.10 Flexor-pronator mass is transected approximately one centimeter distal to the medial epicondyle origin and retracted to expose the damaged ulnar collateral ligament for reconstruction

(Fig. 1.10). This approach has been shown to provide a safe and reliable method for the exposure of the UCL and surrounding anatomy. However, detachment and reattachment of the flexor-pronator mass may create unnecessary morbidity to the patient; thus, several authors have advocated the muscle-splitting technique as a less traumatic approach to the UCL reconstruction procedure without increased risks [10, 26, 27].

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