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Insertional anatomy of the anterior medial collateral ligament on the sublime tubercle of the elbow

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Background: Acute injuries to the anterior medial collateral ligament (AMCL) can occur due to valgus trauma or during other dislocating events to the elbow. AMCL lesions are often associated with bony lesions, such as radial head fractures or fractures of the coronoid process. We analyzed the insertion of the AMCL on the sublime tubercle in relation to surrounding osseous structures. We aimed to increase the understanding of the involvement of the AMCL in bony lesions to the sublime tubercle.
Methods: We investigated 86 elbows from 43 embalmed human specimens. We measured the most ventral extensions of the AMCL at the sublime tubercle in relation to a clearly defined and reproducible landmark. We used as our landmark a horizontal line (baseline) originating on the lesser sigmoid notch in a right angle to the ulnar ridge.
Results: The mean distance of the coronoid process tip to the baseline was 4.0 mm (standard deviation [SD], 1.3 mm; range, 1.4-6.7 mm). The mean distance of the ventral extension of the AMCL to the horizontal line was 3.7 mm (SD, 2.6 mm; range: 9.4-2.2 mm). The mean horizontal distance between the ventral aspect of the AMCL and the coronoid tip was 13.7 mm (SD, 2.5 mm; range, 7.7-20.5 mm).
Conclusions: We present a detailed description of the insertional anatomy of the AMCL at the sublime tubercle. These values could be helpful for classifications of coronoid fractures and to estimate the involvement of the AMCL in fractures of the sublime tubercle.
Level of evidence: Anatomy Study; Cadaver Dissection

Keywords: Elbow surgery; coronoid fracture; sublime tubercle; collateral ligament; elbow anatomy; anterior medial collateral ligament

The elbow joint is stabilized by its highly congruent bony anatomy, muscles crossing the joint, and the collateral ligaments.[11] The collateral ligaments comprise the medial collateral ligament complex (MCL) and the lateral collateral

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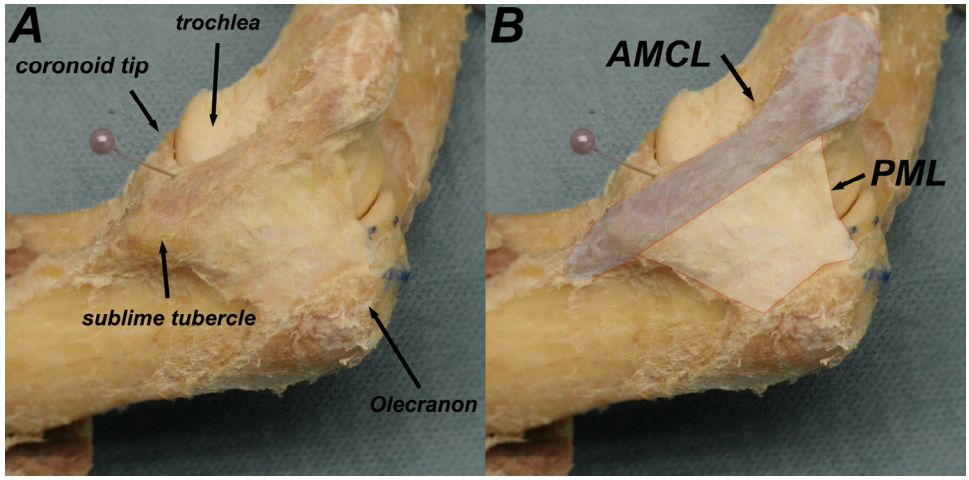

Figure 1 Preparation of the medial collateral ligament complex. The most ventral extension of the anterior medial collateral ligament (*AMCL*) is marked with a needle. (**A**) Osseous structures are labeled. (**B**) The AMCL is marked in *blue*, and the posterior medial collateral ligament (*PML*) is marked in *light white*.

ligament complex (LCL), both stabilizing the joint throughout its range of motion.[18] The MCL is usually divided into an anterior part (AMCL), a posterior part, and a transverse part that is only present irregularly (Fig. 1).[5] The AMCL originates at the central 65% of the anterior surface of the medial epicondyle, inserts medially to the coronoid process at the sublime tubercle, and is the most stable part of the MCL. It has also been described as the most important structure for valgus stability of the elbow[5,11,12] Previous work on the anatomy of the MCL studied its function, length, width, and failure load.[5,16,18] Detailed morphometric data on the insertional anatomy of the AMCL relative to other osseous structures is not yet available, however.

Injuries to the MCL can occur in several settings. They are very well described as a result of chronic overuse in overhead athletes, such as baseball pitchers, where they are attributed to repetitive high-force valgus stress to the ligament. The chronic pain in these patients can be treated with a reconstruction of the ligament.[3,16] Injuries to the ligament as a result of an acute trauma are also possible, either in simple or complex elbow injuries. However, the stabilizing effect of the AMCL can also be compromised by fractures involving the bony insertion of the AMCL at the sublime tubercle of the ulna.[13,21]

Aim of the study was to present the anatomic relation between the insertional anatomy of the AMCL and surrounding osseous structures with the idea that this may help to diagnose coronoid fractures that include a bony avulsion of that ligament. Reference values for this region could therefore help to estimate whether a fracture at the sublime tubercle comprises a bony avulsion of the AMCL. We hypothesized that the insertion of the AMCL varies between individuals but that reference values can be determined.

Materials and methods

The study used 86 elbows from 43 formalin-embalmed specimens (20 men, 23 women). The median age of the donors was 83.6 ± 8.9 years (range, 62-101 years).

We used the same approach to the MCL in every specimen, including the careful removal of the surrounding soft tissue. The flexor muscles were removed from their insertion at the medial epicondyle, and the brachial muscle was removed from the ventral capsule. The most ventral and dorsal extensions of the MCL were carefully identified, marked, and dissected from the joint capsule and the surrounding tissue (Fig. 1). The most ventral extension of the MCL was marked and the ligament dissected.

A calibrated image was acquired perpendicular to the coronoid with the coronoid in the center of the image and a scale next to the sample. We used a 50-mm prime lens for image acquisition to further prevent image distortion. Preparation and photography were repeated in all specimens in a standardized fashion. Images were measured with ImageJ digital image analysis software (http://imagej.net).[22] Every picture was individually scaled to measure distances on the digital images. To determine the position of the coronoid tip and the anterior aspect of the MCL, we digitally constructed a sagittal line along the greater sigmoid notch. A second line (baseline) was drawn at a right angle to the first line starting at the ventral border of the lesser sigmoid notch (Fig. 2). Distances to the most ventral aspect of the coronoid (distance *a*) and the most ventral aspect of the MCL (distance *b*) were measured at a right angle to the baseline. Then, the distances between these points to the baseline were measured (distance *c*).

To account for differences in the specimens' height, we measured the length of the radius (styloid process to the articular surface of the radial head) with an analog measuring device and the smallest and largest diameter of the radial head with a digital caliper.

The excellent inter-rater correlation of such measurements was confirmed in previous studies.[26] For each of the parameters, the mean, minimum and maximum, the standard deviation (SD), and the 95% confidence interval were calculated.

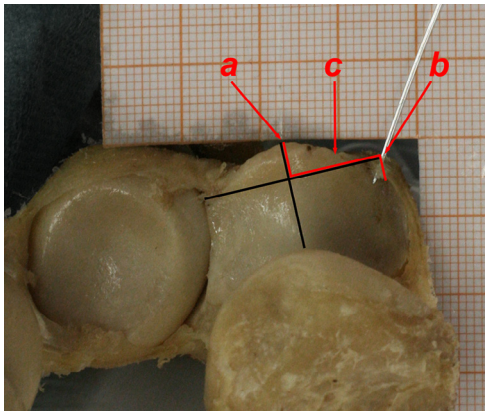

Figure 2 Measurement of the coronoid and the ventral extension of the medial collateral ligament complex (MCL). First, a line was drawn along the ridge of the coronoid. Then, a second line (baseline) was drawn from the ventral extension of the lesser sigmoid notch crossing the first line at a right angle. Distances of the most ventral extension of the coronoid (*distance a*), the most ventral extension of the MCL (*distance b*) to the baseline, and distance between the crossing along the baseline (*distance c*) were measured.

After validating the normal distribution of the data using the Kolmogorov-Smirnov test, we calculated the Pearson correlation coefficient to analyze the linear correlation between the 2 variables.

Results

The mean distance of the most ventral aspect of the coronoid process to the baseline (Fig. 3, *A*, *distance a*) was 4.0 mm

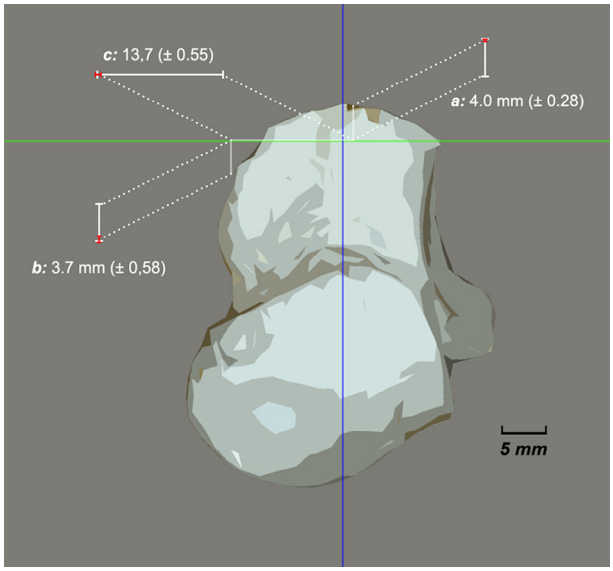

Figure 3 Schematic en face view of a right coronoid (with baseline in *green* and sagittal line in *blue*). The mean distances (*white lines*) and their 95% confidence interval (*red lines*) are depicted: ventral aspect of the coronoid to the baseline (*distance a*), ventral aspect of the anterior medial collateral ligament (AMCL) to the baseline (*distance b*), and the horizontal distance along the base-line between the ventral aspect of the coronoid and AMCL (*distance c*).

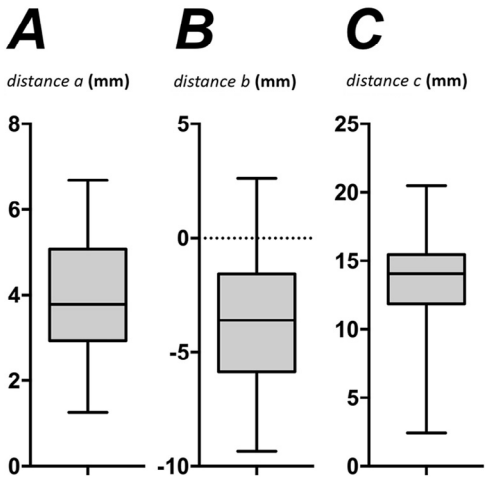

Figure 4 Box-and-whisker plots of (**A**) *distance a* (**B**), *distance b*, and (**C**) *distance c* at the coronoid. The *top* and *bottom borders* of the box show the standard deviation, the *center line* shows the mean, and the *whiskers* show the minimum to maximum values.

(SD, 1.3 mm; range, 1.4-6.7 mm). The mean distance from the ventral aspect of the AMCL to the baseline (Fig. 3, *B*, *distance b*) was 3.7 mm (SD, 2.6 mm; range, 9.4-2.2 mm). The mean distance between the ventral aspect of the AMCL (ie, the insertion of the AMCL) and the coronoid tip on the sagittal line was 7.8 mm (SD, 2.6 mm; range, 1.4-13.9 mm). The mean distance along the baseline between the most ventral aspect of the coronoid and the ventral aspect of the AMCL (Fig. 3, *C*, *distance c*) was 13.7 mm (SD, 2.5 mm; range, 7.7-20.5 mm; Fig. 4).

The mean largest diameter of the radial head was 24.2 mm (SD, 2.2 mm; range, 19.9-30.3 mm; Table I), and the mean smallest diameter was 22.5 mm (SD, 2.0 mm; range, 18.9-27.5 mm). The interobserver reliability for these measurements was $r = 0.98$ and $r = 0.97$, respectively. The correlation between the radial head diameters and distances of the coronoid and the AMCL are reported in Table II. The largest diameter of the radial head was moderately correlated with the horizontal distance along the baseline (Fig. 5).

Table I Radial head diameter

Statistic	Smallest diameter radial head (mm)	Largest diameter radial head (mm)
Mean	22.5	24.2
Maximum	27.5	30.3
Minimum	18.9	19.9
Standard deviation	2.0	2.2
Inter-rater reliability (Pearson *r*)	0.97	0.98
95% confidence interval	0.96-0.98	0.98-0.99

Table II Measured distances of the anterior medial collateral ligament complex and the coronoid process in relation to radial head size

Measurement	Smallest diameter radial head	Largest diameter radial head
Ventral coronoid process to horizontal line *(distance a)*		
Pearson *r*	0.2	0.23
95% confidence interval	−0.022 to 0.41	0.0088 to 0.43
r^2	0.041	0.054
Ventral AMCL to horizontal line *(distance b)*		
Pearson *r*	−0.034	−0.043
95% confidence interval	−0.26 to 0.19	−0.26 to 0.18
r^2	0.0012	0.0018
Distance from ventral AMCL to ventral coronoid *(distance c)*		
Pearson *r*	0.47	0.51
95% confidence interval	0.28 to 0.63	0.32 to 0.66
r^2	0.22	0.26

AMCL, anterior medial collateral ligament complex.

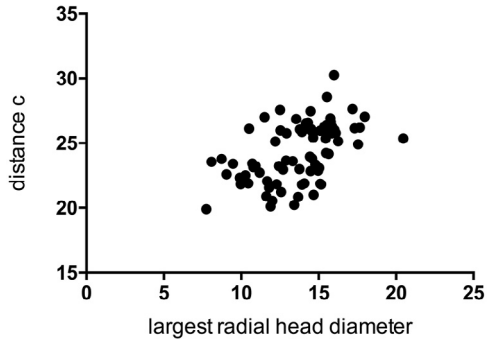

Figure 5 Correlation between the largest radial head diameter and the horizontal distance along the baseline between the ventral anterior medial collateral ligament complex and the ventral coronoid (*distance c*).

Discussion

We measured the extension of the AMCL and its insertion on the sublime tubercle of the ulna relative to other osseous anatomical landmarks of the proximal ulna. Our data suggest a high variance for the insertion of the AMCL relative to the tip of the coronoid in the investigated human specimens. Such interindividual variance has also been shown for other ligamentous structures on the elbow joint.[9]

Quantitative measurement of the AMCL was previously described by Cage et al.[2] They used a digital caliper to measure the distance between the tip of the coronoid and the AMCL along the medial edge of the coronoid in 20 fresh frozen specimens. The AMCL inserted at a mean distance of 18.4 mm proximal to the coronoid tip along the medial edge of the coronoid and 1.5 mm medial to the articular surface of the coronoid. Using our method, we found that the AMCL inserted at a mean of 3.7 mm posterior to a horizontal line to the ventral extension of the lesser sigmoid notch and a mean of 7.7 mm medial to the coronoid tip along this line (Fig. 3).

Due to the different measurement techniques used in this study and by Cage et al,[2] the measured distances cannot be directly compared. However, in contrast to the technique used by Cage et al, the present measurements enable the evaluation of the possible involvement of the ligament in fractures using 3-dimensional (3D) computed tomography (CT) reconstructions of the elbow joint. Because our method uses a baseline in relation to the lesser sigmoid notch, the measurement is possible even if a fracture of the coronoid process is present. In contrast to our anatomical measurements, when radiographic imaging techniques are used to measure these distances, differences due to the missing cartilage on radiographic images must be considered.

As the primary and most important stabilizer against valgus force on the elbow, the AMCL is crucial for elbow stability. Chronic overuse or trauma to the elbow can result in an injury of the ligament. Isolated injuries of the AMCL are rare; combined injuries in dislocations of the elbow or in fracture-dislocations are more common.[5-7,20]

Fractures of the coronoid have historically been classified with use of the Regan-Morrey classification.[17] This classification is based on the height of the involved coronoid fragment and can be divided into type I: tip fracture; type II: <50% involved; and type III: with >50% of the coronoid involved.[17] Using our method, coronoid fractures presumably involve the AMCL if the fracture exceeds a tip fragment with a mean of 7.7 mm. Ablove et al[1] showed the average coronoid height is 17.0 mm. Our study therefore suggests that most coronoid fractures of Regan-Morrey type III and some fractures of type II involve the insertion of the AMCL. However, the highly individual anatomy of the elbow, which is shown by the differences in minimal and maximal distances between these structures (range, 1.4-13.9 mm) should be considered in this presumption.

The first to recognize fractures of the coronoid involving the anteromedial facet were O'Driscoll et al.[13,23] Besides the percentage of involvement, they hypothesized that involvement of the anteromedial facet could lead to a higher degree

of instability in these fractures because the anteromedial facet stabilizes the elbow against a varus force. The authors concluded that patients with an anteromedial facet fracture should be treated with buttress plating to prevent early post-traumatic arthrosis.[13] Moreover, injuries to the lateral collateral ligament, which are common in these patients, need to be addressed because these injuries can further destabilize the elbow against a varus force.

Pollock et al[14] investigated the fragment size of anteromedial facet fractures and their effect on the stability of the elbow joint. They showed that instability under a combination of passive varus load and flexion of the LCL-deficient elbow was significantly higher when a larger part (>2.5 mm) of the anteromedial facet was involved.[14] In a combined passive valgus load and flexion of LCL-deficient cadaveric elbow joints, significant differences in the stability were found when fragments of simulated O'Driscoll anteromedial subtype 2 and subtype 3 fractures involved a larger fragment (size >5 mm).[14]

Coronoid fractures can be associated with injuries to the collateral ligaments. Using magnetic resonance images of injured elbows, Rhyou et al[20] found in their study that isolated coronoid fractures are mostly associated with injuries to the LCL (94% in their study). In 18% of the cases, however, isolated coronoid fractures also showed an injury to the MCL.[20] All fractures with injuries to the MCL were classified as O'Driscoll anteromedial fractures.[20] In another study, Rhyou et al[19] found that only 2 of 18 patients with an anteromedial facet fracture showed no strain or rupture to the MCL.

The limited clinical data on coronoid fractures treated nonoperatively suggest an early post-traumatic arthritis if a posteromedial rotatory instability results from this fracture.[5,13,24] However, published series (on a total of 16 patients) of anteromedial fractures treated nonoperatively also showed satisfactory results.[4,10,25] The authors of these reports concluded that nonoperative treatment of anteromedial facet fractures can be considered if subluxation or dislocation is excluded and the fracture is not or only minimally displaced.

In summary, the existing literature suggests that with smaller anteromedial facet fractures that are inherently hard to fix, nonoperative treatment might be the alternative to reconstruction of the anteromedial facet. However, these patients should be thoroughly evaluated for injuries to the MCL and LCL. Because CT images are typically obtained as part of the assessment of these injuries, our reference values could be used to estimate the osseous AMCL insertion using CT images of the elbow. Extension of the fracture line to the MCL could be included as a possible prognostic factor when deciding on a treatment method.

In addition, the involvement of the AMCL could be suitable as a landmark to differentiate between subtypes of coronoid fractures. Because differentiation between subtypes of O'Driscoll anteromedial fractures can be challenging in clinical routine, we suggest differentiating according to the involvement of the AMCL.

The present study has several limitations. We used formalin-embalmed specimens to measure the osseous insertion of the AMCL relative to the coronoid tip. Shrinkage of the tissue due to the fixation technique is a limitation, because it potentially altered the anatomic measurements. These effects on sample size due to the fixation with formalin has especially been shown for soft tissue. In calcified bone, however, no shrinkage effects due to formalin fixation were shown.[8] We therefore believe that the osseous insertion of the AMCL was not affected by shrinkage. Moreover, in embalmed specimens, distinction of the capsule and the collateral ligament can be difficult. In all of our specimens, however, the AMCL could be differentiated as a thickening of the capsular tissue.

Our results were measured on anatomic specimens with intact elbow joints. Therefore, reference values included cartilage on the joint surface. Anatomic studies of the cartilage thickness on the coronoid have shown a mean thickness of 3.0 mm (range, 1.7-4.6 mm) on the coronoid tip.[15] When these values are directly compared with CT images, the variance due to the missing cartilage has to be considered. Also, we evaluated the 3D dimensions of the AMCL in relation to the height of the coronoid tip. However, when analyzing fractures for the involvement of a ligamentous structure, fracture lines could extend into the height of the AMCL insertion but do not need to involve the insertion on a sagittal plane if the fracture line is close to the articular surface. This needs to be considered when using our data for estimation of AMCL involvement.

Measurements of the distances of the AMCL were acquired at 90° flexion of the elbow. More posterior parts of the medial collateral ligament complex are taut in this position, whereas more ventral parts are loose. The area of the MCL is likely affected by the position; however, equivalent alterations are likely to be present in any other position of the elbow affecting various regions. Moreover, we used scaled photographs for the measurement. Alterations of the angle to the camera may have led to minor variations in the measurements. More accurate techniques, such as 3D measurements, could overcome these issues.

Conclusion

Our data may help clinicians treating bony lesions on the anteromedial facet of the coronoid to estimate whether the AMCL insertion is affected by the injury. Individual indications of nonoperative treatment in this region should therefore be decided in conjunction with physical examination and use of tools such as CT and magnetic resonance imaging.

Disclaimer

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