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The lateral ulnar collateral ligament: Anatomical and structural study for clinical application in the diagnosis and treatment of elbow lateral ligament injuries

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Abstract

The lateral ulnar collateral ligament (LUCL) is considered one of the main stabilizers of the elbow. However, its anatomical description is not well established. Imaging techniques do not always have agreed upon parameters for the study of this ligament. Therefore, herein, we studied the macro and microanatomy of the LUCL to establish its morphological and morphometric characteristics more precisely. Fifty-five fresh-frozen human elbows underwent dissection of the lateral collateral ligament. Morphological characteristics were studied in detail. Ultrasound (US) and magnetic resonance (MR) were done before dissection. Two specimens were selected for PGP 9.5 S immunohistochemistry. Ten additional elbows were analyzed by E12 sheet plastination. LUCL was identified in all specimens and clearly defined by E12 semi-thin sections. It fused with the common extensor tendon and the radial ligament. The total length of the LUCL was 48.50 mm at 90°, 46.76 mm at maximum flexion and 44.10 mm at complete extension. Three morphological insertion variants were identified. Both US and MR identified the LUCL in all cases. It was hypoechoic in the middle and distal third in 85%. The LUCL was hypointense on MR in 95%. Free nerve endings were present on histology. The LUCL is closely related to the anular ligament. It is stretched during flexion and supination. US and MR can reliably identify its fibers. Anatomical data are relevant to the surgeon who repairs the ligaments of the elbow. Also, to the radiologist and pain physician who interpret imaging and treat patients with pain syndromes of the elbow.

KEYWORDS

elbow instability, lateral ulnar collateral ligament, semi-thin plastination

1 | INTRODUCTION

The lateral collateral ligament or lateral ligament complex of the elbow (LCL) is recognized as the main stabilizer against varus and posterolateral forces for this joint (Cohen & Hastings, 1997; Dargel et al., 2015; Dunning et al., 2001; O'Driscoll et al., 1991; Olsen et al., 1996). However, there is no current consensus about which fascicles can be distinguished in the LCL (Cohen & Hastings, 1997; Hackl et al., 2016; Imatani et al., 1999; Llusá et al., 2009). Indeed, some authors describe only a single anatomical structure called the radial collateral ligament (Cunningham, 1972; Gardner & O'Rahilly, 1986; Williams, 1995). The most controversial fascicle corresponds to those fibers of the LCL that inserts at the supinator crest of the ulna, which Morrey and An (1985) called the lateral ulnar collateral ligament (LUCL). There are many discrepancies about its anatomical description and some authors do not even recognize these fibers as being part of the LCL (Cohen & Hastings, 1997; Seki et al., 2002).

The functional role of the LUCL in the biomechanics of the elbow has been emphasized. Isolated injury to this ligament has been stated as the main cause of posterolateral instability of the elbow (O'Driscoll et al., 1991), and its surgical repair has led to successful outcomes in treating this kind of instability (Rhyou & Park, 2011). However, the lack of a precise anatomical description of the ligament, coupled with poor references for image diagnosis, means that a LUCL injury is not always considered and repaired when necessary. The consequence of not addressing this structure can be instability of the elbow.

Therefore, in this study we describe the anatomy, microanatomy and ultrasound (US) and magnetic resonance (MR) images of the LUCL in detail, to clarify its normal anatomy and also to define morphological characteristics that aid in the diagnosis of ligament injuries.

2 | MATERIALS AND METHODS

Fifty-five fresh frozen (−20°C) human adult upper limbs (33 right/22 left) were studied by macro and microdissection under a stereomicroscope (KARL KAPPS® SOM 62 G-Nr 18406, Germany). The age at death of the specimens ranged from 58 to 92 years (mean 74.6 years). No specimen had a known history of surgery or trauma/pathology in the elbow region.

With the elbow in 90° of flexion, the skin and superficial fascia of its lateral aspect were removed. The deep fascia was sectioned and retracted between the anconeus and extensor carpi ulnaris muscles. The latter was sectioned and retracted proximally. The extensor digiti minimi and extensor digitorum muscles were removed to expose the deeper lying supinator muscle, which was carefully separated from the joint capsule in a proximal-distal direction starting at the neck of the radius. Next, the anconeus muscle was removed from its ulnar insertion to the lateral epicondyle. Thus, the capsule and the LCL of the elbow were exposed. The components of the LCL were microdissected and morphological data of the LUCL were collected (Figure 1).

With the elbow in 90° of flexion, we measured the length, maximum width and thickness of the LUCL using a digital microcaliper (TURATA® A-123, 0.01 mm resolution). The length of the LUCL was also recorded with the elbow at both maximum flexion (130°) and complete extension (0°). Each measurement was obtained twice (in different sessions) by the main author (D.N.). Quantitative variables were analyzed by central tendency parameters (mean, median) and dispersion (SD). For qualitative variables we used absolute and relative frequencies. Continuous variables were verified as normally distributed using the Shapiro–Wilk test.

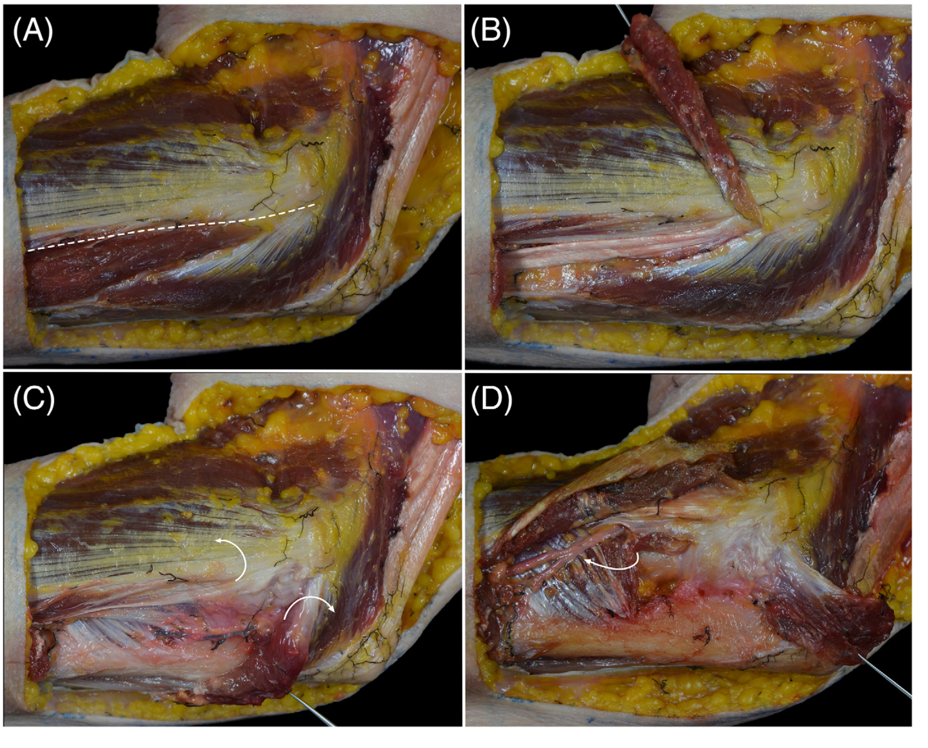

FIGURE 1 Images corresponding to the lateral ligament complex of the elbow (LCL) dissection protocol. (A) Sectioning the interval between extensor digitorum-extensor digiti minimi and extensor carpi ulnaris muscles. (B) Section and retraction of the extensor carpi ulnaris.
(C) Retraction of the anconeus and extensor digitorum-extensor digiti minimi muscles to expose the LCL. (D) Retraction of the proximal fibers of the supinator muscle to expose the distal insertion of the lateral ulnar collateral ligament (LUCL)

In 20 randomly selected specimens, (11 right side/nine left side), US and MR images of the elbow joint were studied prior to dissection. A radiologist with expertise in musculoskeletal imaging (J.G.) analyzed the images.

For US, a lineal transducer was used (13–5 MHz, Aloka Arietta V60, Hitachi, Japan). The elbow was at 90° of flexion, neutral position. The transducer was positioned parallel to a line joining the lateral epicondyle to the supinator crest of the ulna, with an incidence angle of 10° anteriorly.

For MR, we used a Signa™ 1.5 T scanner (General Electric, United States). The elbow was positioned at maximum extension and supination (Cotten et al., 2014). Transcondylar T2-weighted coronal sections (2 mm) were obtained.

After dissection, two LUCL specimens were used for examining nerve fibers in the ligament (Navarro et al., 1995). The ligament was divided into three parts (proximal third, from the epicondyle to the anular ligament; middle third, around the anular ligament; distal third, beyond the anular ligament) (Figure 2). Using a cryostat, we obtained 60 μm sections, which were incubated for 24 h with the primary antibody Protein Gene Product 9.5 S (1:200 PGP, Bio-Rad®) (PGP). After rinsing with PBS, the samples were incubated overnight with Cyanine Secondary Antibody Cy3 (1:200, Jackson Immunoresearch, United States). Finally, they were examined under an epifluorescence microscope (Leica DMR-XA, Leica Microsystems, Switzerland).

Ten additional fresh-frozen (−80°C) adult upper limbs (five right/five left) were processed to obtain semi-thin Biodur®E12 plastinated slices. Specimens were frozen with the elbow at 20° of flexion and the forearm in a neutral position. Transepicondylar coronal serial slices of 1.5 mm thickness were obtained using a bandsaw. These sections were dehydrated in acetone, degreased with dichloromethane and posteriorly impregnated under vacuum using a bath of Biodur® E12/E1. They were finally cured at 45°C for 72 h (Ottone et al., 2018) and used for descriptive and morphometric analysis of the LUCL.

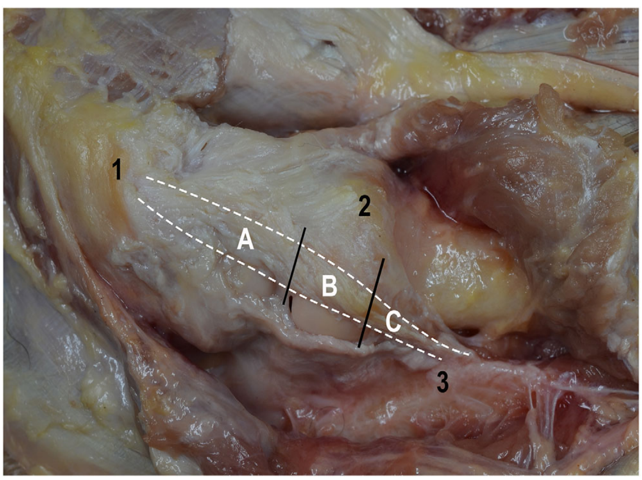

FIGURE 2 Image showing the three parts in which we divided the lateral ulnar collateral ligament (LUCL). (A) Proximal to the anular ligament. (B) Beside the anular ligament. (C) Distal to the anular ligament) for studying the presence of nerve fibers

The protocols of study were approved by the Ethics Research Board (CEI Girona, University Hospital Dr. Trueta, ref. 2017.042). The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research (Iwanaga et al., 2022).

3 | RESULTS

3.1 | Macro–micro anatomy of the LUCL

The LUCL was identified in all specimens except for one, which showed rheumatoid degeneration of the elbow with extensive anatomical disruption of its articular surfaces, ligaments and joint capsule. The LUCL was recognized as a group of fibers in the LCL between the radial collateral ligament and the posterior fibers of the lateral joint capsule, superficial to the posterior fibers of the anular ligament. Its origin was from the lateral epicondyle, where it was firmly meshed with the posterior fibers of the radial collateral ligament and tightly joined on its superficial surface with the common extensor muscle tendon.

From its origin, the fibers ran obliquely distal and posterior. The LUCL separated progressively from the radial collateral ligament, passing superficial to the posterior third of the anular ligament. The more supinated the elbow, the closer the relationship between the LUCL and the anular ligament.

The distal insertion of the LUCL was in the supinator crest of the ulna, deep to the insertion of this muscle and closely related to the anular ligament. The mean width of the LUCL at this point was 14.77 mm (SD 7.15) (Figure 3).

The mean lengths of the LUCL at 0°, 90°, and 130° of flexion were 44.10 mm (SD 7.20), 48.50 mm (SD 6.82), and 46.76 mm (SD 6.46), respectively. The mean thickness of the LUCL at 90° of elbow flexion was 1.26 mm (SD 0.36). Supination increased the tension in the ligament and pronation decreased it (Figure 3).

We distinguished three morphological variants of the LUCL in relation to the anular ligament. Type 1 (36.4%) had an isolated insertion, clearly independent of the anular ligament; Type 2 (40%) had a joint insertion with the anular ligament, which made it difficult to separate the two; finally, Type 3 (23.6%) had membranous tissue between the two ligaments, which allowed them to be distinguished (Figure 4).

3.2 | Image diagnosis applied to the LUCL

The LCL and LUCL were identified in all specimens by either US or MR. However, there was no clear differentiation from the common extensor tendon at the lateral epicondyle.

US was superior to MR in image definition of the LUCL. The US image was hypoechoic at the anular ligament level (middle third) in all cases, and at the supinator crest of the ulna (distal third) in 85%. However, the US image of the LUCL at the lateral epicondyle was

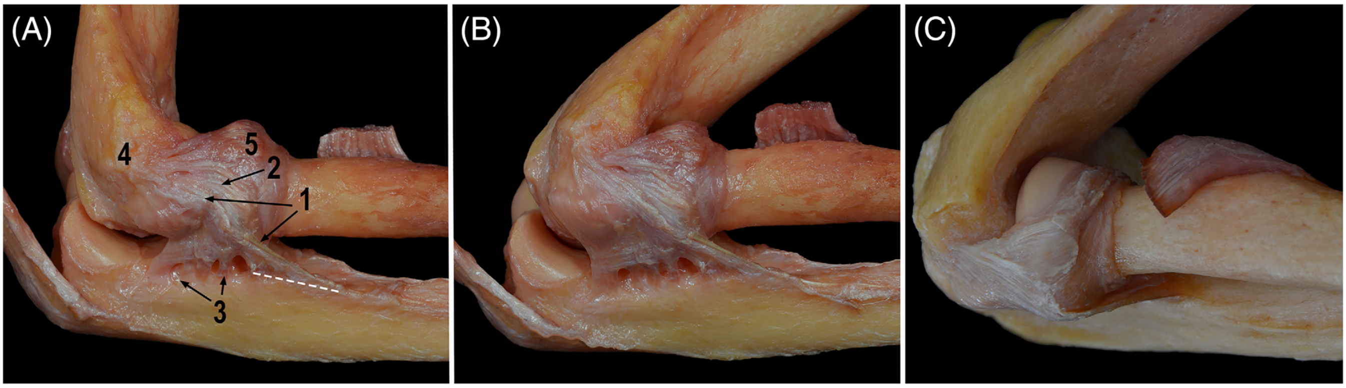

FIGURE 3 (A) Image corresponding to the macroanatomy of the lateral ulnar collateral ligament (LUCL) (1). Its fibers were observed between the radial collateral ligament (2) and the posterior part of the lateral capsule (3). Note the distal insertion of the LUCL on the supinator crest of the ulna (white dash line). (4) Lateral epicondyle. (5) Anular ligament. (B) Specimen in flexion and pronation. (C) Specimen in flexion and supination

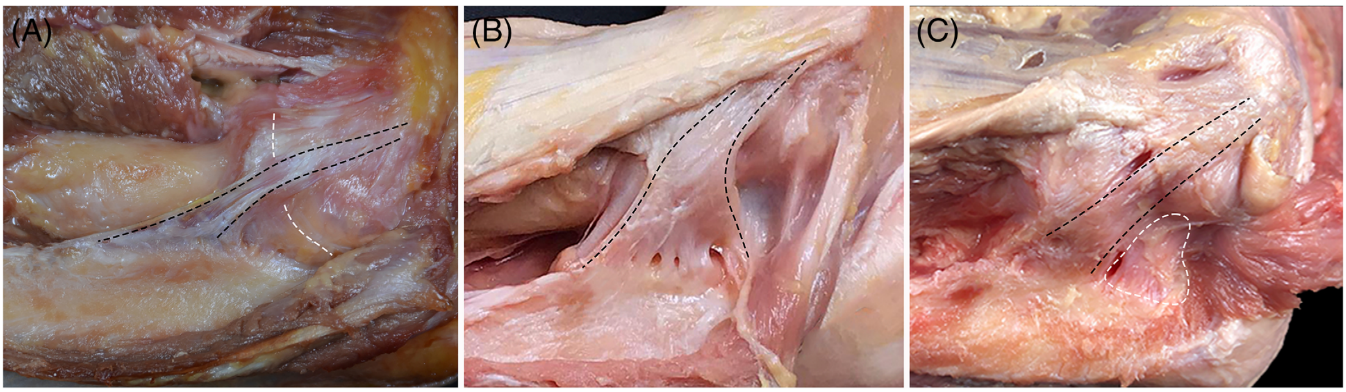

FIGURE 4 Morphological variants of the lateral ulnar collateral ligament (LUCL) in relation to the anular ligament. (A) Type 1: Isolated and independent insertion of the LUCL (black dash lines) from the anular ligament (white dash line). (B) Type 2: Joint insertion of the LUCL and the anular ligament (dotted area). (C) Type 3: Membranous tissue (white dotted area) between the LUCL (black dash lines) and the anular ligament

completely different, being hyperechoic in 85%. The mean thickness of the LUCL measured by US at the neck of the radius level was 1.3 mm (SD 0.47) (Figure 5).

The LUCL was also identified in all specimens using MR, but the degree and clarity of definition was lower than with US. As with US, MR could not distinguish the LUCL clearly from the other structures of the LCL or from the common extensor muscle tendon at the lateral epicondyle. The LCL-MR signal was hypointense at the lateral epicondyle in 95% of cases. The distal insertion of the LUCL was also hypointense, but only in 70% of specimens was it clearly identified. The mean thickness of the LUCL measured by MR at level of the neck of the radius was 2.21 mm (SD 0.94) (Figure 5).

3.3 | LUCL PGP immunohistochemistry

PGP immunostaining revealed nerve fibers along the thickness of the LUCL. Confocal images were consistent with free nerve endings. No encapsulated nerve endings were observed.

The regions where the LUCL showed the highest PGP signal were the common origin with the LCL and the terminal insertion into the supinator crest. The nerve fibers in the proximal third of the ligament were arranged perpendicular to the tissue fibers; in the middle third, they were characteristically arranged parallel to the fibers of the ligament. The distal third of the ligament contained numerous nerve fibers, which were disposed either parallel or oblique to the ligament (Figure 6).

3.4 | Sectional anatomy of the LUCL

The LUCL was identified in transepicondylar-coronal semi-thin Biodur® E12 plastinated sections. Its fibers arose from the lateral epicondyle deep to the common extensor muscles tendon. At the lateral epicondyle, these fibers were fused with the rest of the LCL, forming a homogeneous layer of dense connective tissue (thickness 3.05 mm, SD 1.10). The joint capsule was identified as areolar tissue deep to the LCL. It formed a humeroradial meniscoid that protruded into the joint cavity (Figure 7).

The tendinous fibers of the common extensor muscles were tightly joined to the surface of the LCL. They separated progressively from the inferior border of the head of the radius, where some muscle fibers appeared.

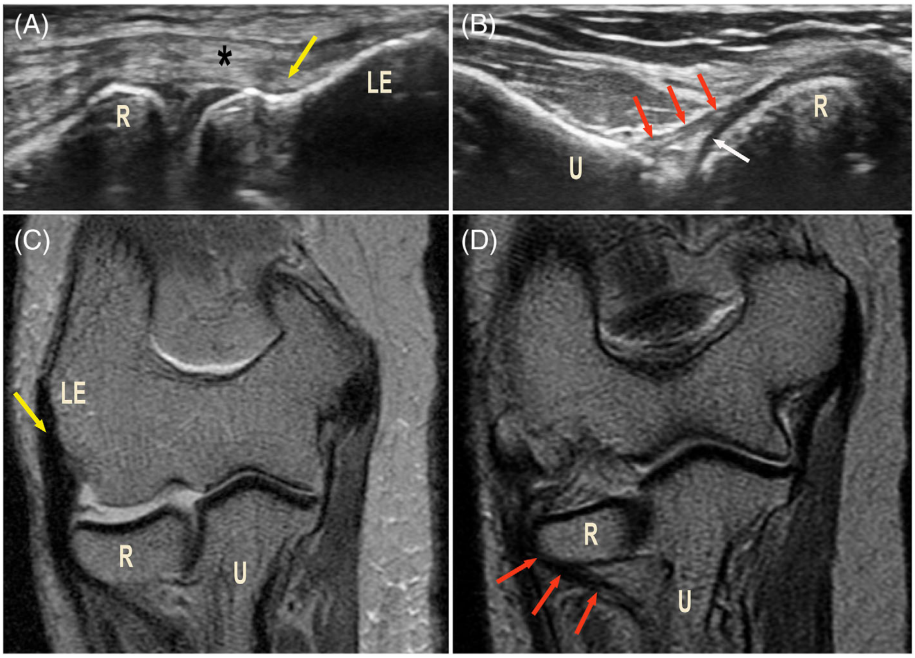

FIGURE 5 (A, B) Ultrasound (US) images of the lateral collateral ligament of the elbow. Yellow arrow: Common origin of the lateral ligament complex of the elbow (LCL) from the lateral epicondyle (LE). *Common tendon origin of the extensor muscles from the LE; red arrows: Lateral ulnar collateral ligament (LUCL) distal third inserting in the ulna (U); white arrow: Anular ligament. (C, D) Transcondylar coronal sections T2-weighted MR of the elbow. Yellow arrow: Common origin of the LCL and extensor muscles from the LE; red arrows: LUCL distal third inserting on the ulna (U); R: Head of the radius

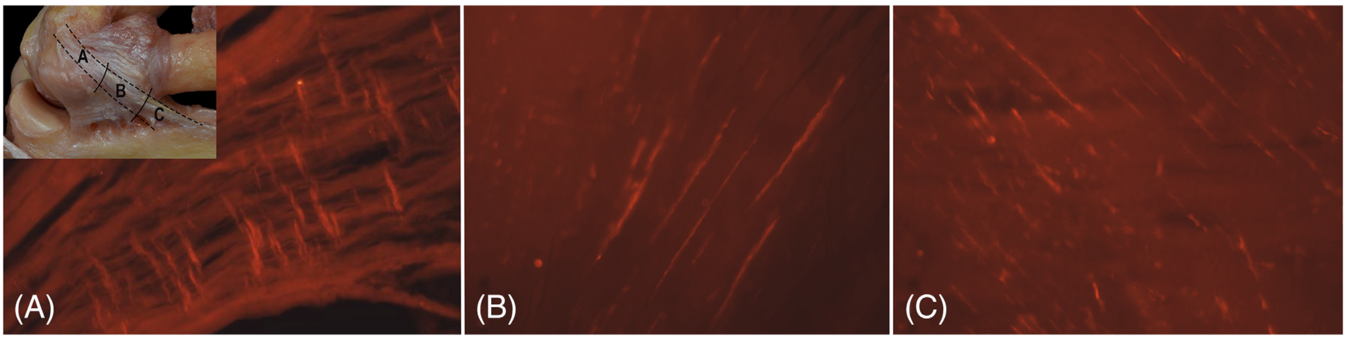

FIGURE 6 PGP 9.5 S immunostaining of the lateral ulnar collateral ligament (LUCL). Non-encapsulated nerve fibers were observed. (A) Proximal third with fibers arranged perpendicularly to the ligament. (B) Middle third: Fewer number of fibers, parallel to the ligament. (C) Distal third: Abundant nerve fibers, which were arranged either parallel or oblique to the ligament

From the inferior border of the head of the radius the fibers of the LUCL were clearly identified as a dense fibrous tissue band deep to the supinator muscle. The LUCL ran obliquely medially and dorsally, and finally ended in the supinator crest of the ulna (Figure 7). The mean thickness of the distal insertion of the LUCL was 1.82 mm (SD 0.75).

4 | DISCUSSION

Currently, the precise anatomy and biomechanics of the LCL remain uncertain, especially in relation to one of its components, the LUCL. Classical anatomy books do not name this ligament. They state that the lateral ligament of the elbow comprises three fascicles, anterior, medial and posterior. The medial one is longer and inserts into the posterior margin of the radial notch of the ulna (Paturet, 1951; Rouvière & Delmas, 2005; Testut & Latarjet, 1979). More recently, and inconsistently with those referenced above, Llusá et al. (2009) described the posterior fascicle of the LCL as fibers originating in the anteroinferior lateral epicondyle and ending in the supinator crest. Other authors consider the lateral ligament of the elbow to be a unique structure without fascicles (radial collateral ligament), but they describe some fibers in the lateral compartment that take origin from the anular ligament and insert into the coronoid process and into the lateral border of the ulna (Cunningham, 1972; Gardner & O'Rahilly, 1986; Williams, 1995). Seki et al. (2002) described the LCL as a three-dimensional structure with three arms, but they did not consider the LUCL as having the consistency of a ligament. Previously, Martin (1958) termed these fibers that originate from the radial collateral ligament and insert into the supinator crest the posterior accessory anular ligament.

The LUCL was first defined as a consistent ligament of the elbow by Morrey and An (1985). They described it as a group of fibers that split from the radial collateral ligament and inserted into the supinator

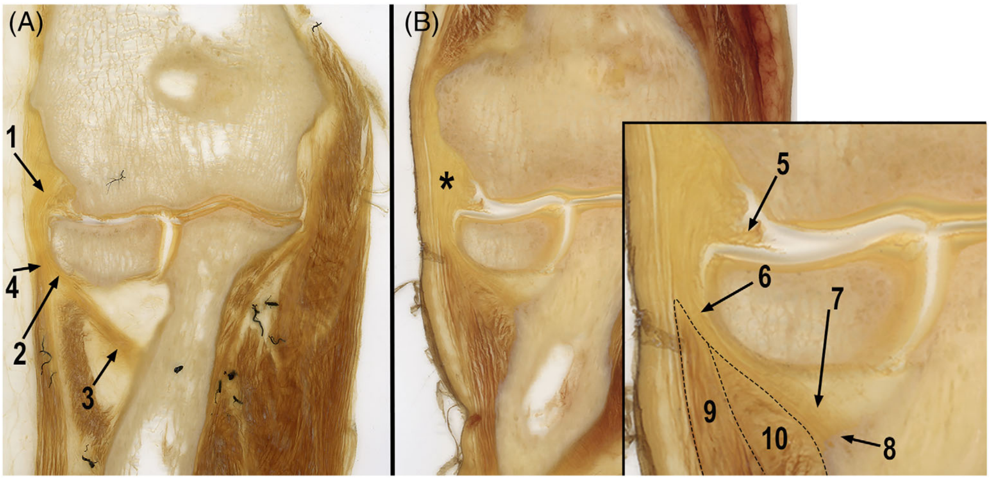

FIGURE 7 Transepicondylar-coronal semi-thin Biodur® E12 plastinated sections of two elbow specimens (A, B). 1: Dense connective tissue corresponding to the common tendon origin of the epicondylar muscles and the lateral collateral ligament of the elbow. *Loose connective tissue corresponding to the capsule of the elbow. 5: Meniscoid humeroradial. 2, 6: Lateral ulnar collateral ligament (LUCL) detached from the deep layer of the lateral ligament complex of the elbow (LCL), beyond the anular ligament. 3, 7: Distal third of the LUCL inserting into the supinator crest of the ulna (8). 4: Origin of the common extensor muscle fibers; 9: Extensor digitorum muscle; 10: Supinator muscle

crest of the ulna. However, other authors consider this fascicle to have insufficient consistency and to be almost absent in most subjects (Beckett et al., 2000; Cohen & Hastings, 1997; Hackl et al., 2016; Imatani et al., 1999; Lühmann et al., 2022). On the other hand, some anatomical series identified the LUCL in a wide range (between 50% and 100%) of cases (Beckett et al., 2000; Cohen & Hastings, 1997; Dunning et al., 2001; Imatani et al., 1999; Morrey & An, 1985; O'Driscoll et al., 1991; Olsen et al., 1996).

Our study found fibers of the LCL of the elbow that were inserted into the supinator crest of the ulna in all specimens. At the lateral epicondyle, the fibers were dorsal to the radial collateral ligament but meshed with it. According to Moritomo et al. (2007) and Hackl et al. (2016), who stated that the LCL cannot be separated from the epicondylar muscles, the semi-thin plastinated sections showed that the LCL and the common tendon of extensor muscles formed a single connective tissue layer, structurally homogeneous, without muscle fibers. Recent studies have shown that the deep aponeurosis of the superficial extensor and supinator muscles cannot be distinguished from the portion of the joint capsule of the elbow defined as the LUCL (Fukai et al., 2022). Our results have shown that the LUCL can be identified. However, we could specifically distinguish the fibers of the LUCL only from the distal third of the head of the radius, as they progressively separated from the anular ligament in the deep layer of the LCL.

The accurate dissection procedure allowed us to establish that the fusion between the anular ligament and the LUCL at its distal insertion was clear in only 40% of the specimens (insertion Type 2). Although most authors consider that the LUCL and the anular ligament are inseparable in almost all cases (Hackl et al., 2016; Hannouche & Bégue, 1999; Imatani et al., 1999; Llusá et al., 2009; Takigawa et al., 2005), we could differentiate the LUCL from the ulnar ligament (insertion Type 1) in 36.4% of our specimens, and membranous tissue between the two ligaments enabled us to distinguish them (insertion Type 3) in another 23.6%. Our results show that the LUCL has enough consistency to be identified by macro-microscopical dissection in 60% of subjects. Takigawa et al. (2005) considered the frequencies of the three types of insertion to be very similar, which is not consistent with our results. In addition, the plastinated semi-thin sections (not previously used for studying the LCL in the human elbow) made it possible for us to clarify the distinction between the anular ligament and the LUCL. In all specimens, the LUCL was clearly identified in transepicondylar coronal sections. Its fibers detached from the deep layer of the LCL and inserted beyond the anular ligament into the supinator crest of the ulna. The LUCL could only be distinguished from the anular ligament after the middle third of the head of the radius.

From a functional point of view, different authors have highlighted the role of the LUCL as a stabilizer of the elbow joint against varus and posterolateral forces (Cohen & Hastings, 1997; Dargel et al., 2015; Dunning et al., 2001; Morrey, 1996; O'Driscoll, 2000; O'Driscoll et al., 1991; Olsen et al., 1996). Its functional role seems to be closely related to the function of the supinator, extensor digitorum and extensor carpi ulnaris muscles, acting as a static-dynamic stabilizer (Fukai et al., 2022). Our results showed that LUCL tension rose with supination of the elbow. In agreement with Regan et al. (1991), we observed that tension in the LUCL was maintained during all flexion movements of the elbow under varus forces. It was maximal at 90° and minimal at complete extension, as other authors have stated (Hackl et al., 2016; Takigawa et al., 2005). In accordance with results of Camp et al. (2019), the LUCL shortened from 90° of flexion to extension (mean shortening 4.4 mm), indicating reduction of the passive tension in it. We found that the tension in the LUCL also decreased when we increased the flexion of the elbow from 90° to 130°, but this decrease was less than in complete elbow extension.

Isolated injuries to this ligament have been proposed as the main cause of posterolateral instability of the elbow (O'Driscoll et al., 1991). More recent studies consider that two or more components of the LCL must be injured to provoke the development of such instability (Dunning et al., 2001; Olsen et al., 1996; Seki et al., 2002). In this sense, some authors argue for the reconstruction of a triangular area of the joint capsule between the lateral epicondyle, the lateral part of the coronoid process and the posterior part of the radial notch of the ulna (Fukai et al., 2022). However, surgical repair of the LUCL and techniques for LUCL reconstruction have given positive results in treating posterolateral instability (Dargel et al., 2015; Jung et al., 2019; Lee & Teo, 2003; Rhyou & Park, 2011). This makes an accurate anatomical description of LUCL dissection crucial for assisting the surgical approach and also for improving image diagnosis of LCL injuries, together with the possibility of specific surgical repair of the LUCL.

There is no consensus about the surgical approach to the LUCL (Beckett et al., 2000; Hackl et al., 2016; Hannouche & Bégue, 1999; Seki et al., 2002; Takigawa et al., 2005). Our results showed the best approach to be incision of the deep fascia between the common belly of the extensor digitorum-extensor digiti minimi muscles and the extensor carpi ulnaris. After that, the supinator muscle was identified. This muscle was detached from the ulna in a ventral and distal direction in order to expose the ulnar insertion of the LUCL and the anular ligament at the neck of the radius. Finally, the anconeus muscle was removed from its ulnar insertion, allowing the posterior part of the capsule to be exposed.

Our morphometrical data of the mean lengths of the LUCL are consistent with those published in 1999 by Hannouche and Bégue (48.50 vs. 44.60 mm). Other authors have reported significant differences from our measurements (Takigawa et al., 2005), but specified neither the position of the elbow nor the reference points for measurement. In relation to the mean width of the LUCL at its ulnar insertion, our data are consistent with those of Morrey and An (1985), Takigawa et al. (2005), and Camp et al. (2019). However, the morphology of the ulnar insertion differed from other authors' descriptions. Cohen and Hastings (1997) only described two types. We distinguished three morphological types of LUCL distal insertion, as did Takigawa et al. (2005) and Hackl et al. (2016), though our results differ from theirs in terms of frequency. Takigawa et al. (2005) found that all three types had similar frequencies. Hackl et al. (2016) found Type 3 to be the most frequent (50%); Types 1 and 2 showed similar frequencies (27.3% and 22.7%, respectively). Our series showed that the most usual insertion pattern was Type 2 (40%), fusion between LUCL and anular ligament, followed by Type 1 (36.4%), isolated insertion of the LUCL, and Type 3 (23.6%), membranous tissue between the anular ligament and the LUCL. According to Hackl et al. (2016), Types 2 and 3 showed a significantly higher mean width of insertion than Type 1.

The use of US for diagnosing musculoskeletal injuries is widely accepted, but for the LCL of the elbow there is no consensus about the best method for studying the LUCL (Camp et al., 2017; Gondim et al., 2011; Jacobson et al., 2014; Stewart et al., 2009; Villamonte-Chevalier et al., 2015). Moreover, the correlation between US images and anatomy is uncertain (Döring et al., 2018; Kichouh et al., 2009; Lonchena et al., 2016). Optimal visualization of the LUCL was achieved in coronal section with the transducer positioned parallel to a line joining the lateral epicondyle to the supinator crest of the ulna. The image improved when the incidence angle of the transducer was 10° anteriorly. Stewart et al. (2009) and Gondim et al. (2011) presented US images of the LUCL in the coronal plane but did not specify the incidence angle of the transducer.

Our results showed that the LUCL was hypoechoic, but it could not be identified along its entire length. The LCL and the common extensor tendon gave similar US signals in the lateral epicondyle, but in some cases a thin hypoechoic line was observed between them. In the lateral epicondyle, the LUCL was not clearly differentiated from the radial collateral ligament, as other authors have mentioned (Gondim et al., 2011). The LUCL was clearly observed from the middle third of the head of the radius, consistent with the images from semi-thin plastinated sections. The mean thickness of the LUCL from US (1.3 mm) was very similar to our macroscopical dissection results (1.26 mm) and in line with data reported by other authors (Stewart et al., 2009).

Anatomical studies of the LUCL by MR are scarce (Kichouh et al., 2009; Potter et al., 2005). We identified the LUCL on T2-weighted MR in all cases. Mostly, it was a hypointense structure, but the ligament was correctly defined in only 70% of subjects. Although it is accepted that MR gives better soft tissue definition, our MR results were not superior to our US images. The difficulty of orienting the specimen to find the best plane of study probably explains the superior US results. Moreover, the characteristics of US as a dynamic technique make it superior to MR for defining the LUCL. On the other hand, most MR studies of the elbow have been performed on patients. The use of human specimens from a body donation program could also explain the loss of MR image definition in our study. Morphometrical data of the LUCL obtained by MR were similar to those obtained by other authors (Cotten et al., 2014). However, they did not correlate with our dissection data.

The presence of mechanoreceptors in the human elbow joint has not been fully studied. Petrie et al. (1998) searched for mechanoreceptors in the radial and anular ligaments, but not in the LUCL. They noted a high density of mechanoreceptors in both extremes of the radial collateral ligament, especially at the distal end. These authors hypothesized that if tension in the extremes of the radial collateral ligament is high, the ligament-muscle reflex is activated and protects the joint. Mechanoreceptors are homogeneously distributed in the anular ligament, so they probably act along the complete range of movement. Our results showed free nerve endings along the total length of the LUCL. No encapsulated receptors were found and this is a major difference from the results of Petrie et al. (1998). However, like those authors, we found a qualitatively greater density of free nerve endings in both extremes of the LUCL. Our findings could explain why the LUCL in the elbow has a similar protective role. However, more studies are needed to corroborate this.

4.1 | Limitations

Although more specimens were used in this study than in other previous works studying the LUCL, the mean age of the subjects could have affected the definition of the LUCL both in dissection and in image diagnosis. We found no statistical concordance (Intraclass Correlation Coefficient ICC <0.4) between the morphometrical data of the LUCL obtained by macro-microdissection and the data obtained by US or MR.

Although the nerve fibers in the LUCL showed positive immunostaining, more studies are needed to clarify which mechanoreceptors are present in the human elbow and their functional role in the pathogenesis of instability.

4.2 | Clinical implications

The LUCL can be visualized by US and MR if the radiologist uses the correct orientation of the transducer and if the coronal plane of exploration is accurate. The normal image of the anatomy of this ligament that we observed by semi-thin plastination can help in the diagnosis of traumatic injuries. The optimal surgical approach to the LUCL is through the interface between the extensor digitorum-extensor digiti minimi muscles and the extensor carpi ulnaris muscle.

5 | CONCLUSIONS

Such anatomical data is important to the surgeon who operates and repairs the ligaments of the elbow as well as the radiologist and pain physician who interpret imaging and treat patients with pathology, for example, pain syndromes of the elbow.

AUTHOR CONTRIBUTIONS

Design, conduct, and reporting of the results: Diana Noriego, Anna Carrera, Richard Shane Tubbs, Joe Iwanaga, Jose Sañudo, Francisco Reina. *Data collection*: Diana Noriego, Anna Carrera, Jorge Guibernau, Marta San Millán, Aïda Cateura, Francisco Reina.

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ETHICS STATEMENT

Ethics Research Board (CEI Girona, University Hospital Dr. Trueta, ref. 2017.042).

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