The Lateral Collateral Ligament Complex and Related Muscles
Act as a Dynamic Stabilizer as well as a Static Supporting Structure at the Elbow Joint: An Anatomical and Experimental Study

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Summary: Among 71 osteoligamentous elbow joint specimens from Japanese subjects, 66% of the lateral ulnar collateral ligaments (LUCls) were in an incomplete form, such as a fibrous intermuscular septum lying between the anconeus, supinator and extensors, and terminated on the annular ligament. The ‘typical’ complete ligament, extending from the lateral epicondyle and over the radial collateral ligament (RCL) to the crista spinatoris, appeared in only 20% of the elbows examined. This observation suggests that, in Japanese subjects, the LUCl is not usually a simple ligamentous static stabilizer, but acts as a dynamic stabilizer, together with its related muscles. In addition, when the elbow was flexed by more than 90°, the distance between the lateral epicondyle and the radial head became almost 1.5 mm larger than the distance from the epicondyle to the annular ligament. We therefore consider that, in the overflexed position, the radial head moves slightly distal while the length of the RCL remains almost constant. This morphometrical observation suggests that the annular ligament needs to be supported by the LUCI-muscle complex from the distal side, as well as by the RCL from the proximal side. This extended definition of the lateral collateral ligament complex and its associated muscular function is discussed.

Since Morrey and An (1985) first proposed the existence of a ‘lateral collateral ligament complex’, posterolateral rotatory instability of the elbow due to a dysfunction of this complex has been noted as a major pathological factor leading to symptoms of varying severity in the lateral area of the elbow, such as pain and/or subluxation. Morrey’s colleagues, O’DriscolI et al. (1991, 1992), reported that the lateral ulnar collateral ligament (LUCL) plays a major role in the stabilizing activity of the ligament complex. Later, however, several researchers questioned this role because of the great interindividual variations seen in the LUCL, especially the frequent absence of this structure (73.5–80%) reported in Japanese subjects (Aoki et al., 1995; Ta-kahashi et al., 1997). Similar findings were reported from France: of 20 elbows studied, all had weak, capsule-like LUCLs (Hannouché and Bégué, 1999). Although these studies included a relatively limited number of specimens, their results led us to believe that there may well be significant morphological differences in the LUCL between ethnic populations.

Another criticism of the proposed action of the LUCL arose from the opinion that the radial collateral ligament (RCL) plays a more critical role as a stabilizer than other ligaments, including the LUCL (Seki, 1999; Imatani et al., 1999; Hannouché and Bégué, 1999). However, according to Cohen and Hastings (1997), the contribution of the RCL...
seems to be limited. Systematic sectioning experiments performed by these investigators demonstrated that stability of the annular ligament is critically important in maintaining the rotatory as well as the flexion-extension stability of the elbow, and that the muscles covering and attaching to the lateral ligament complex cooperate with the RCL in stabilizing the annular ligament. Histological observations by Imatani et al. (1999) supported the latter finding, i.e., dynamic stabilization of the elbow with the aid of muscles such as the anconeus, supinator and extensor carpi ulnaris. Nevertheless, these researchers also regarded the LUCL as a thickening of the septum or fascia of the supporting muscles.

During recent research into rotatory instability, little attention has been paid to the kinetics of the radial head, despite the fact that rotation occurs around this part of the joint. Based on a previous study of the contact points of the radiohumeral joint using resin casts, we proposed that, as aging occurs, the articular contact pattern of the radiohumeral joint during supination-pronation alters to a paradoxical pattern, such as peripheral or pin-point contact, to maintain sufficient flexion-extension movement (Niño et al., 2001). We have also shown that the morphology of the adult synovial fold in the radiohumeral joint, as opposed to that of the embryonic fold, indicates the specific compression stress pattern on the lateral portion of the annular ligament, and that this site corresponds almost exactly to the insertion point of the RCL (Isogai et al., 2001). The fact that the fold itself is usually present and, moreover, is often well developed in elderly subjects, is consistent with slight but increasing primary displacement of the radiohumeral articulation. Based on our previous results, we are of the opinion that the lateral ligament complex permits and absorbs additional, paradoxical movement of the radial head, such as proximal-distal movement during flexion-extension of the elbow. Although the length of the RCL changes only slightly during flexion-extension (Morrey and An, 1985), we speculate that there is a discrepancy in length between the RCL and the radiohumeral articular distance.

To test these theories, we undertook the present study 1) to re-examine the morphology of the LUCL using an adequate number of specimens and paying attention to the adjacent muscles; and 2) to perform morphometric evaluations of the length of the RCL during flexion-extension, in combination with observations of the position of the radial head inside the annular ligament-RCL complex.

Materials and Methods

Seventy-one elbows (46 from men and 25 from women), obtained from 42 Japanese cadavers (aged 55–94 years at death; mean 78 years), were used. The cadavers had all been donated to Sapporo Medical University for educational purposes and research into anatomy. The cadavers were perfused with 10% v/v formalin solution in water before dissection of the elbows. All the extensors of the forearm were dissected step-by-step to identify the RCL, LUCL and annular ligament. Although the border between the RCL and the origins of the extensors was not clear, the collagen fiber bundles were dissected so as to identify those with a longitudinal fiber direction (i.e., those of the RCL) under a surgical microscope. The superficial surfaces of the anconeus and supinator muscles became visible after removing the covering fascia. The LUCL was consistently located between these two muscles. After the morphologies of these ligaments had been recorded using a digimatic micrometer caliper (Mitsutoyo Co., Kawasaki, Japan), we measured the distance from the lateral epicondyle to the an-
nular ligament, as well as the distance between the radial head and the lateral epicondyle, for flexion positions 15° apart (i.e., 0, 15, 30, 60, 75, 90, 105, 120 and 135°). The position of the radial head inside the annular ligament was identified by piercing the ligament with a fine sewing needle. All measurements of the ligament and the bone position were performed three times at each point by the first author.
Results

Morphology of the LUCL

After the superficial dissection, the anconeus and extensor carpi ulnaris muscles were the first to appear. Several tendinous bands, forming the origins of the extensors, issued from the lateral epicondyle and RCL. Part of the anconeus also originated from the RCL. The most posterior of these tendinous bands formed the origin of the extensor carpi ulnaris, ran along the anterior margin of the anconeus (Fig. 1) and maintained a thickened appearance as far as the ulnar origin of the supinator (i.e., the crista supinatoris). The consistent morphology of this tendinous band corresponded to that described by Hannouche and Bégué (1999) (see also the last paragraph of the Discussion). After complete removal of the extensor carpi ulnaris, including the tendinous band, the LUCL (if it was present) appeared between the supinator and the anconeus. However, there was always a small amount of loose connective tissue between the anconeus and the LUCL. The LUCL was located immediately below or posterior to, and ran alongside, the tendinous band forming the origin of the extensor carpi ulnaris. The superficial portion of the supinator originated from both the LUCL and the tendinous band of the extensor carpi ulnaris. Thus, the LUCL can be regarded as one of the common tendinous structures (i.e., bands) forming the origins of the extensors and supinator.

We identified three types of LUCL: ‘typical’, vestigial and absent. The typical type (20% of specimens) contained obvious continuations of the RCL fibers. These fibers were located not on the superficial surface of the RCL but relatively deep inside it. The LUCL inserted distally onto the ulna at the crista musculi supinatoris (Fig. 2). The typical LUCL was a thickened structure forming part of the origin of the supinator. Despite its anatomical definition, the vestigial type (66% of specimens) looked more like a limited form, i.e., comprising only the distal portion from the ulna to the posterior aspect of the distal margin of the annular ligament. Moreover, the vestigial-type ligament changed, along its distal course, into a fibrous intermuscular septum located between the supinator and anconeus muscles (Fig. 3). The supinator inserted into this septum. Thus, the distal insertion on the crista supinatoris was also identifiable in the incomplete type. No LUCL could be found in 14% of specimens; instead, a thin intermuscular septum between the two muscles was present (Fig. 1).

In the typical type at the 90° flexion position,

![Typical-type LUCL](image)

**Fig. 2.** Typical-type LUCL.
Posterolateral view of the right elbow. The typical LUCL continues into the RCL. The supinator and anconeus have been removed. ANL: annular ligament; CH: capitulum humeri; LE: lateral epicondyle; O: olecranon; R: radius; U: ulna.
the mean length of the LUCL was measured as 63.5 ± 8.5 mm and its mean width at its midpoint was 3.3 ± 1.2 mm. In contrast, the vestigial type, which ended on the annular ligament, was shorter (41.7 ± 4.8 mm) and narrower (2.7 ± 0.6 mm). We found no change in the length of the LUCL during flexion-extension movement.

Morphometrical and experimental study of the RCL and radial head

The RCL was consistently observed in all specimens. The RCL originated from the lateral epicondyle of the humerus and inserted onto the superficial, lateral portion of the annular ligament. It was narrowest at its origin, but formed a wide, fan shape at its insertion point on the annular ligament. The mean length of the RCL was 16.9 ± 2.9 mm at the 90° flexion position, while its mean width at its midpoint along its proximodistal course was 5.8 ± 1.3 mm.

The distance from the lateral epicondyle to the annular ligament changed, depending on the flexion-extension position (Fig. 4). Briefly, the distance increased from 15.6 ± 2.2 mm at 0° to 16.8 ± 3.1 mm at 90° during flexion, then decreased slightly to 16.3 ± 3.1 mm during overflexion of the elbow to 135°. In other words, 90° flexion seemed to increase the tension in the RCL, whereas in the extension position (0°), the RCL was relaxed. Likewise, during flexion, the distance from the lateral epicondyle to the radial head increased from 15.1 ± 3.2 mm at 0° to 18.1 ± 3.5 mm at 90°. However, it remained almost constant during overflexion. During the experiment, the fluctuation in the distance from the lateral epicondyle to the ra-

Fig. 3. Incomplete-type LUCL.
The LUCL ends on the distal margin of the annular ligament (ANL). Other abbreviations are same as for Fig. 2.

Fig. 4. Fluctuations in distances from the lateral epicondyle to the annular ligament and the radial head for every 15° increase in flexion.
dial head was larger than that in the distance to the annular ligament, and the difference was statistically significant (maximum, 2.5 times larger; p < 0.01 by Student’s t-test). Notably, due to the difference in the fluctuation in the distances, especially in the overflexed position, there was a significant discrepancy in the relative positions of these structures (Fig. 4). In other words, the radial head moved distally along the inside of the ligament during overflexion. Conversely, the radial head appeared to slide proximally along the annular ligament (also along the RCL) during extension.

Discussion

The present observations revealed that the UCL can usually be regarded as a ligamentous septum between the anconeus and supinator muscles. As to whether the UCL really acts in cooperation with these muscles, according to Basmajian and De Luca (1985), moderate activity of the anconeus muscle can be detected by electromyography during both pronation and supination, no matter whether these movements are resisted or unresisted; however, activity is most apparent when there is resistance. The supinator muscle exhibits similar moderate activity during flexion as well as extension, in contrast to the pronator teres muscle, which is inactive during extension. These authors concluded that the function of the anconeus is joint stabilization, and speculated that this stabilizing function might be shared by the medial head of the triceps and perhaps the supinator. In addition, Ohuchi (1982) also hypothesized that the anconeus might stabilize the elbow at a certain position against the long antebraclial flexors acting on the wrist and finger. These classical physiological explanations are consistent with recent suggestions based on morphological investigations by Cohen and Hastings (1997) and Imatani et al. (1999) (see Introduction).

We agree with these hypotheses and consider that the anconeus, the supinator and, perhaps, the extensor carpi ulnaris stabilize the humeroulnar joint in combination with the UCL (irrespective of any individual variations in its strength) or the intermuscular ligamentous septum. Indeed, based on our present findings, the UCL can be regarded as one of the common tendinous bands forming the origins of the extensors and supinator, as also suggested by Imatani et al. (1999). Moreover, our morphometrical comparison of the distances from the lateral epicondyle to the annular ligament and the radial head suggest that the radial head, surrounded by the annular ligament, not only rotates but also moves reciprocally in a proximodistal direction, like a piston, during flexion-extension of the elbow. The slight fluctuation in the distance from the lateral epicondyle to the annular ligament observed during the present study is almost the same as the change in the length of the RCL during flexion reported by Morrey and An (1985), although they did not describe any change in the proximodistal position of the radial head. Because our measurements were made using formalin-treated specimens, and because of the different reductions in size that may have been caused by this fixation, our absolute data may not correspond exactly with the physiological state during life. However, we believe that the difference in fluctuation between the distance from the lateral epicondyle to the annular ligament and to the radial head is not an artifact but a real effect. The suggested proximodistal movement of the radial head would result in a biphasic mechanical effect, i.e., cycles of relaxation and tension, on the annular ligament. During flexion, the RCL probably resists the extension stress (i.e., loading toward the distal side) on the annular ligament. This hypothesis is supported by the consistent finding of strong bundles of collagen fibers in its structure. In contrast, during extension, the radial head would push the annular ligament to the proximal side. However, the UCL, if it is typical and complete, would resist this movement to keep the annular ligament in the same position. However, if the UCL is incomplete, as seems to be the usual pattern in Japanese subjects, withstanding such stress during flexion-extension would require dynamic stabilization of the annular ligament by the supinator and the distal half of the anconeus. We speculate that the UCL (or the intermuscular ligamentous septum) transmits the actions of these muscles to the annular ligament. Therefore, the lateral collateral ligament ‘complex’ should include not only the ligaments themselves but also their closely-related muscles, to allow for the dynamic stabilizing action. The UCL itself, even if it is well developed, does not seem to play a major role in dynamic stabilization, but appears to conduct the transmission of muscle activity from the distal side rather than the ulnar side of the annular ligament. The RCL, rather than the UCL, seems to play a great role as a static stabilizer. Recently, we hypothesized that compression-extension stress on the annular ligament would lead to the development of a specific morphology in the synovial fold of the radiohumeral joint in elderly subjects, i.e., a lateral fold (Isogai et al., 2001). This stress is consistent with the biphasic mechanical effect on the annular ligament discussed above. Conversely, the lateral fold could be considered to be
an adaptation to posterolateral instability due to a dysfunction of the LUCL-muscle complex.

According to this extended concept of the lateral collateral ligament complex, to preserve the activity of the lateral collateral ligament complex against posterolateral rotatory instability, muscle damage during surgery should be minimized. Because the LUCL is generally incomplete in Japanese subjects, specific reconstruction of the LUCL itself, such as a palmaris tendon graft passing through an osseous tunnel (Nestor et al., 1992), may not be suitable. Moreover, simple bone-to-bone connection using a grafted tendon is unlikely to restore the ability to transmit muscle actions (especially that of the supinator) to the annular ligament. Recently, Hannouche and Bégué (1999) proposed a reconstruction technique using the tendinous band forming the origin of the extensor carpi ulnaris. This thick, tendinous band was often observed during the present study, and ran superficial to and alongside the LUCL if the latter was of the typical type (Fig. 1). This method seems feasible, partly because of the natural arrangement of the complex, as expected for a dynamic stabilizer, and partly because it would allow a simple approach to the graft. However, we propose that additional ligation of the origins of the anconeus and supinator muscles to the tendinous band forming the origins of the extensors would also be effective in reconstructing the hypothetical LUCL-muscle functional complex.

References