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Anatomical Reconsideration of the Lateral Collateral Ligament in the Human Knee: Anatomical Observation and Literature Review

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ABSTRACT

In the published literature as well as in the most commonly used textbooks, the lateral collateral ligament (LCL) is described as having 1 attachment at the lateral epicondyle of the femur and another at the head of the fibula. In this article, we reconsider the attachments, the length of the LCL, and the tissues surrounding the LCL by presenting our anatomical observations and by reviewing the literature. Our results have shown that the LCL is not only attached to the lower part of the lateral epicondyle of the femur, but also extends to the upper part of the lateral epicondyle. The attachment of the LCL on the fibula is enclosed by 2 insertion points of the biceps femoris tendon. The average length of the LCL in 71 knees was 51.4 mm. There is an "incomplete gap" on the LCL that is interrupted under the tendon of the biceps femoris.

Keywords: Knee Joint; Lateral Collateral Ligament; Morphological Feature; Incomplete Gap; Human

1. Introduction

Recently, varus instability has been reported as causing injuries of the lateral collateral ligament (LCL) [1-5]; reconstruction of the injured LCL by semitendinosus grafting has also been reported [6,7]. Since the development of clinical imaging modalities such as computed tomography and magnetic resonance imaging, more detailed morphological data relating to the LCL have been acquired. However, the textbooks and published literature remain unclear as to where the LCL attaches to the femur and the fibula. We believe that for clinical examination and reconstruction of the LCL to be successful, it is very necessary to reconsider the attachment of the LCL on the femur and fibula, to determine the average length of the LCL, and to describe the surrounding tissues.

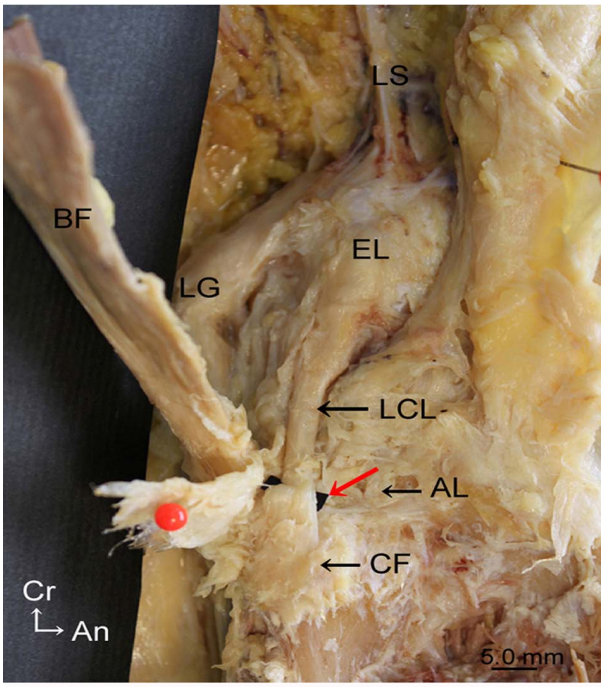
This new data will be useful for further clinical examinations. The objectives of the present observational study were as follows: 1) to reconsider differences in attachments on the femur and fibula; 2) to explain differences in the length of the LCL based on our present observations and unpublished data; and 3) to describe the surrounding tissue and nerve innervation of the LCL.

2. Materials and Methods

Eight cadavers (5 male, 3 female; 16 knees) were examined to observe the LCL and surrounding structures. The specimens were obtained from cadavers during the 2010 and 2011 courses of dissection at Iwate Medical University School of Medicine (fixed with 10% formalin through the radial artery and preserved in 50% alcohol for 6 months). The superficial tissues of the lower limbs were removed, and the LCL and structures surrounding the LCL were dissected out carefully. Attachments on the femur and fibula were carefully identified. As shown in **Figures 1** and **2**, the length of the LCL was measured as the distance between the central point of attachment on the lateral epicondyle of the femur and the apex of the head of fibula. The LCL and the surrounding structures were photographed and sketched.

3. Results

We previously investigated the LCL in 55 knees [8]. Here, we report our unpublished data from that study as well as our observations from the present investigation (total 71 knees). As shown in **Figure 2**, an attachment on the lateral epicondyle of the femur was observed on the lower part of the LCL; however, a fiber bundle of the LCL also extended to the upper part of the lateral epicondyle of the femur. The attachment on the fibula was observed on the anterolateral apex of the head of fibula, and was overlapped by the tendon of the biceps femoris. The tendon of the biceps femoris also extended



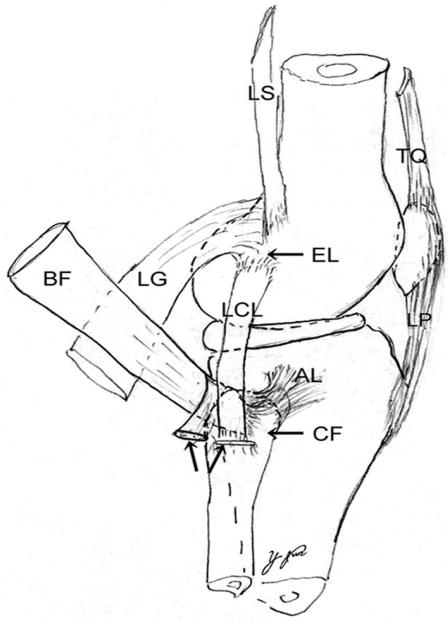


Figure 1. The photo and sketch show the attachments of the LCL and other structures surrounding the LCL. Note that the insertion of the tendon of biceps femoris includes two parts, the superficial (red small ball in photo and black arrow in sketch) and deep parts. The "incomplete gap" on the surface of the LCL also extends to the deep portions of the LCL (red arrow in photo). The deep part of the tendon of biceps femoris attaches to the apex under the LCL and blends with the anterior ligament of the fibular head. AL: anterior capitis fibular ligament; An: anterior; BF: biceps femoris; Cr: cranial; CF: caput fibulae; EL: epicondylus lateralis; LG; lateral caput of gastrocnemius; LP: patella ligament; LS: lateral intermuscular septum; TQ: tendon of quadriceps femoris.

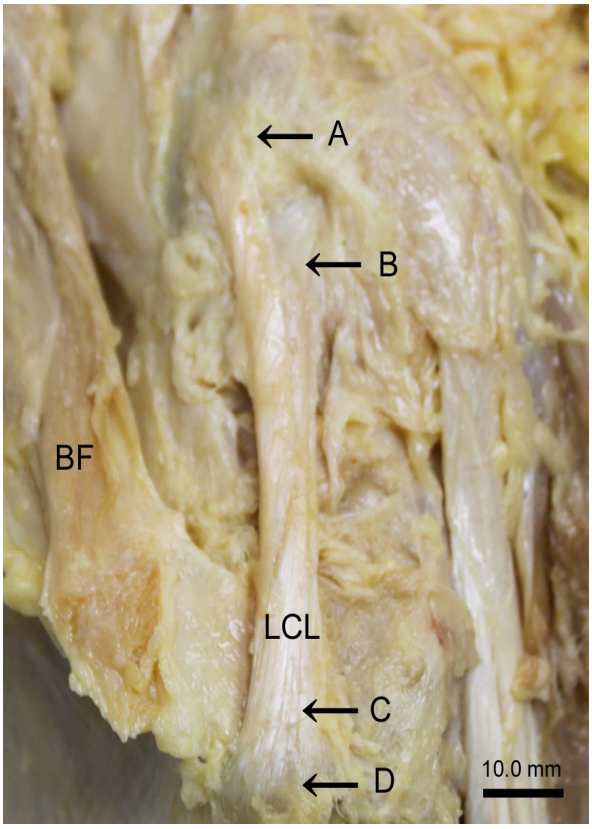


Figure 2. The photo shows the attachments on the lateral epicondyle of femur and the head of fibula. The attachment on femur is not at lower part of lateral epicondyle only, but also extended to the upper part of the lateral epicondyle. A: The end of the attachment of the LCL on femur; B and C: show the upper and lower central points of the attachments of the LCL; D: the end of the attachment on fibula of the LCL; BF: biceps femoris.

deep into the LCL, forming a "sandwich" structure (**Figures 1** and **2**). As shown in **Figure 2**, consideration of the length of the LCL was possible using 2 criteria. One was the distance between AD (the ends of the LCL on the femur and fibula attachments) and the other that between BC (the central points of attachment on the femur and the fibula). In this study, AD ranged from 65.1 - 71.2 mm (the average value for 16 knees was 69.8 mm) and BC ranged from 45.2 - 55.3 mm (the average value for 71 knees was 51.4 mm).

In our previous study, an "incomplete gap" [8] between the surface of the LCL and the deep portion of the tendon of the biceps femoris was observed (**Figure 3**). In the present study, the gap was found to possibly extend into the deep portion of the LCL, especially to the lower part of the LCL (**Figure 3**).

4. Discussion

The lateral structures of the knee have been well reported. The lateral patellofemoral ligament, popliteus tendon,

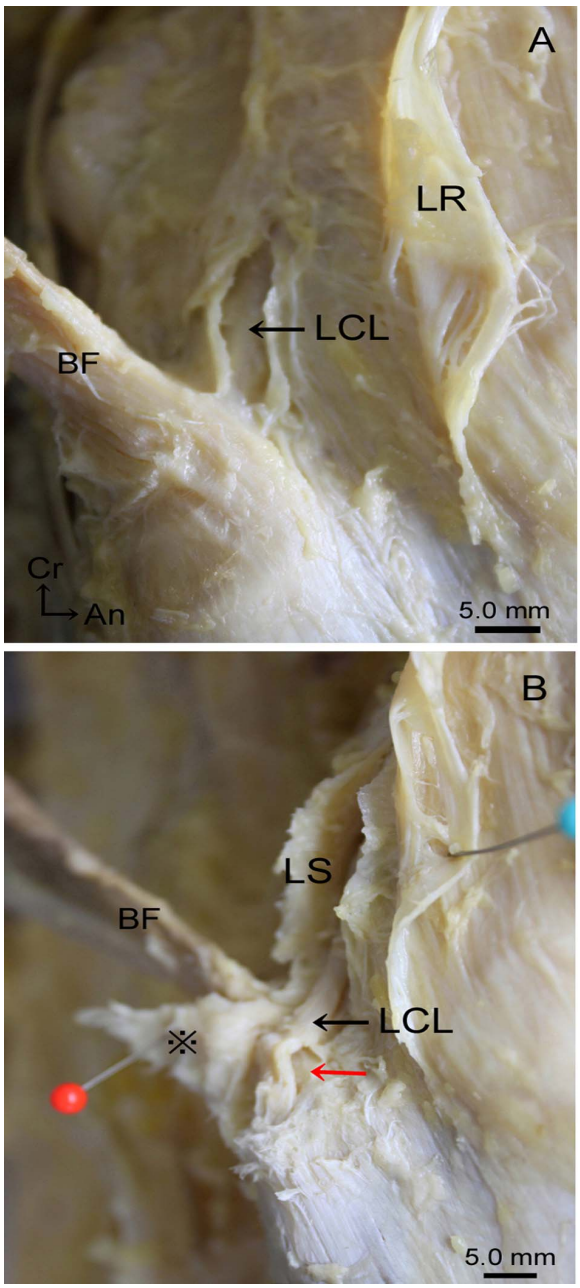


Figure 3. The photos show the "incomplete gap" on the surface of the LCL. Upon removal of the tendon of biceps femoris, a soft tissue membrane superficial to the LCL was clear (A). The "incomplete gap" also extended deep to the lower edge of the LCL (red arrow in B). Asterisk: superficial part of the tendon of biceps femoris. An: anterior; BF: biceps femoris; Cr: cranial; LR: lateral retinaculum; LS: lateral intermuscular septum.

popliteofibular ligament, and fabellofibular ligament have all been described in detail [3,9-13], but to date descriptions of the attachments of the LCL remain incomplete in the published literature.

In textbooks, the LCL is described as a strong cord (or a cord-like structure) attached to the lateral epicondyle of the femur, proximal to the popliteal groove, and extending anteriorly to the apex of the head of fibula. It is largely overlapped by the tendon of the biceps femoris, which surrounds and partly blends with it [14-18]. In the newest version of Gray's Anatomy (40th), the LCL is reported as being attached to the lower part of the lateral epicondyle of the femur [19]. Our findings show that the LCL is not only attached to the lower part of the lateral epicondyle of the femur, but also extends to the upper part of the lateral epicondyle. We believe that this may be the reason for the different reports of the length of the LCL in the literature. The point of attachment on the fibula is not consistent in current textbooks and in the published literature. Gardner *et al*. [20], Hollinshead [21], and Sugita [22] reported that the LCL is attached to the head of the fibula. Clemente [23] and Eswpregueira and Silva [24] stated that the attachment is on the anterolateral side of the apex of the head of fibula. Meister *et al*. [25] described the fibular attachment as being on the lateral surface with a V-shaped plateau. In our study, we found the fibular attachment of the LCL to be on the anterolateral head of the fibula at its apex, similar to the reports of Clemente [23] and Eswpregueira and Silva [24]. On the other hand, our findings indicate that the attachment fibers of the biceps femoris could be divided into 2 layers, the superficial and profound layers. An insertion of the LCL was enclosed between these layers to form a "sandwich," and this point has not been noted in the literature. This finding also highlights the close connection between the LCL and the tendon of the biceps femoris.

The length of the LCL has been well reported. Meister *et al*. reported that the length of the LCL ranges from 59 to 72 mm [25]. Gil *et al*. reported a length of 51.99 mm [26], and Ishigooka *et al*. a length of 56.3 - 65.7 mm [27]. Otake *et al*. reported that the anterior length of the LCL is 45.6 - 60.2 mm and the posterior length is 47.4 - 61.8 mm [28]. Jung *et al*. reported a mean length of 53.0 mm [29], and LaPrade *et al*. indicated that the average length of the LCL is 35.3 mm [30]. Kozanek *et al*. reported a range of 45.5 to 57.7 mm [31], and in a review of the literature, Lai *et al*. reported an LCL length of 59.0 - 72.0 mm [32]. We believe that 2 standards are used for the measurement of the LCL: one is the distance from the end of the attachments on the femur and fibula; the other is the distance between the central points of attachment on the 2 bones. As shown in **Figure 2**, when the measurement point was between the central points of attachment on the femur and fibula, the average length of the LCL was 51.4 mm. This value is lower than that reported by Lai *et al*., but the AD average value of the present observation is 69.8 mm, which is similar to the results of Lai *et al*. [32].

The lateral soft tissues of the knee are arranged in 3

layers, and the LCL belongs to the second layer [33]. The surface of the LCL is overlapped by the fabellofibular ligament and the tendon of the biceps femoris [25,34]. However, Yan *et al*. reported that there is an "incomplete gap" between the tendon of the biceps femoris and the surface of the LCL [8]. Based on the present results, this "gap" is not on the surface of LCL alone, but also extends to the deep portions of the LCL near its fibular attachment.

In textbooks, innervation of the LCL is not clearly delineated [14,35,36]. The articular branches of the knee joint in humans and cats may be supplied by branches of the sciatic nerve, but no detailed routes and distribution patterns of the nerve branches are described [37-39]. Yan *et al*. [8] demonstrated that the nerves distributed to the LCL could be classified into 3 types with 6 patterns. The nerve innervating the LCL could be a single nerve branch or multiple branches stemming from a common fibular nerve. The main branching patterns are branch(es) stemming from the innervating nerve of the breve caput of the biceps femoris and/or branch(es) stemming directly from the common fibular nerve. In about 25% of 55 cases, the nerve fibers coming from the tibial nerve entered the branch(es) innervating the LCL.

5. Conclusion

The LCL is attached to the lower part of the lateral epicondyle of the femur, but it also extends to the upper part of the lateral condyle. The attachment of the LCL on the fibula is overlapped by the tendon of the biceps femoris both superficially and deeply. Different reports of LCL length may be related to different considerations of the points of attachment on the femur and fibula. There is also an "incomplete gap" between the surface of the LCL and the deep part of the tendon of the biceps femoris.

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