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The anterolateral ligament of the human knee: an anatomic and histologic study

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Abstract
Purpose The functional anatomy of the knee is frequently studied but remains incompletely understood. Numerous authors have described a structure in the lateral knee connecting the lateral femoral condyle with the lateral meniscus and tibial plateau. The goal of this study is to define the incidence, anatomy, and histology of this structure, the anterolateral ligament.
Methods The incidence of the ligament was determined in 30 consecutive patients undergoing total knee arthroplasty (TKA) for medial compartment osteoarthritis. The anatomy and histology were evaluated using 10 cadaveric knees.
Results The anterolateral ligament was noted to be present in all 40 knees. In all cases, it was noted to take origin near or on the popliteus tendon insertion and insert into the lateral meniscus and tibial plateau 5 mm distal to the articular surface and posterior to Gerdy's Tubercle. The average width of the relatively flat structure was 8.2 ± 1.5 mm, and the average length was 34.1 ± 3.4 mm. Histologic analysis revealed a discreet structure with a fibrous core surrounded by synovium. Fibers blended with the popliteus at its origin and with the lateral meniscus as it passed distally.
Conclusions The anterolateral ligament may play a role in preventing anterior tibial translation. The role, if any, of this structure in meniscal stability and the pathology of meniscal tears remain unclear.
Level of evidence Not applicable—Descriptive Anatomic Study.

Keywords Knee · Anatomy · Anterolateral ligament · Stability

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Introduction

The tibiofemoral articulation of the human knee joint is stabilized by a complex system of static and dynamic stabilizers. Although significant effort has been spent investigating the anatomy of the lateral knee, the relationships between these structures and their respective functions are not completely understood, especially during active motion of the knee [9, 10].

During the performance of total knee arthroplasty (TKA), one observes a relatively consistent structure in the lateral knee linking the lateral femoral condyle, the lateral meniscus, and the lateral tibial plateau. The earliest description of this structure was likely by Segond in 1879 when he described reinforcement of the lateral joint capsule by fibers of the iliotibial band [11]. In 1948, last termed this structure the "short lateral ligament" [8]. Terry et al. [12–14] have referred to this structure as the "capsulo-osseous layers" of the iliotibial band, LaPrade et al. [7] have used the term "midthird lateral capsular ligament", and Campos et al. [2] coined the term "lateral capsular ligament". Although the descriptions are somewhat variable, we believe all of these authors are describing the same structure, which we will refer to as the "anterolateral ligament" and suggested by Vieira et al. [15].

It has been suggested by Terry et al. [14] that the presence or absence of concurrent injury to this structure may partially explain the variability in physical examination findings after

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ACL injury. In spite of the potentially important role of this structure in knee stability, relatively little work investigating it has been published. The goals of this study are (1) to define the incidence of the structure, (2) define its anatomical attachment sites on the femur, tibia, and lateral meniscus, and (3) evaluate histologically the composition of the structure and the nature of its interface with the lateral meniscus.

Materials and methods

Investigation of the incidence of the anterolateral ligament

In order to determine the incidence of this structure in the population, we evaluated a consecutive series of 30 patients undergoing TKA at our center. We included only patients undergoing TKA for primarily medial compartment osteoarthritis via a medial parapatellar approach. Any patient with a history of prior knee surgery was excluded.

For each patient, demographic data were recorded. During the course of the TKA, the lateral side of the knee was examined to identify the anterolateral ligament. In all 30 cases, it was identified and dissected free from the lateral joint capsule. A vessel loop was then placed around the structure to identify it and photographs were taken from anterior, anteromedial, and anterolateral.

Cadaveric anatomic investigation

Anatomic investigations were performed on ten fresh cadaveric knees, two male and eight female. The mean age was 85.3 ± 5.1 years. Six left and four right knees were included. Each knee was dissected according to the same protocol, beginning with removal of the skin and subcutaneous tissues. A medial parapatellar arthrotomy was performed, the patellar tendon was dissected free of the tibial tuberosity, and the extensor mechanism was removed. The cruciate ligaments were then removed along with the medial collateral ligament and medial joint capsule. The insertions of the iliotibial band onto Gerdy's Tubercle and the fibular head were sectioned. A Hohmann retractor was then placed in the notch and used to dislocate the tibia anteriorly.

At this point, the anterolateral ligament was clearly visualized inside the lateral joint capsule running obliquely from the lateral femoral condyle to the lateral meniscus and tibial plateau. The locations of its origin and insertions as well as its size and relationship to neighboring structures were documented.

The anterolateral ligament was excised from the knee *en bloc*. This resection was accomplished by first performing a vertical osteotomy of the lateral condyle of the femur, which included the origins of the lateral collateral ligament (LCL) and popliteus tendon as well as the anterolateral ligament. The LCL was then sectioned distally at its fibular insertion, and the popliteus tendon was sectioned near its myotendinous junction. The anterior and posterior horns of the lateral meniscus were then divided at their tibial attachments. A vertical osteotomy of the lateral tibial plateau allowed removal of a specimen including the entire anterolateral ligament and the bone at its origin and insertions, the LCL, the popliteus tendon, and the lateral meniscus from the knee. This specimen was then utilized for histologic analysis.

Histologic analysis

The entire harvested specimen was fixed in a mixture of formaldehyde and methanol and subsequently decalcified. The specimens were embedded in paraffin, and 4 μm sections though areas of interest were obtained and stained with hematoxylin and eosin. Slices obtained for analysis included transverse and longitudinal sections of the structure of interest proximal and distal to the lateral meniscus, transverse sections of the structure as it passed the lateral meniscus, and sections from the origin of the structure on the femur and its insertion on the tibia.

Results

The anterolateral ligament was identified as a clearly defined structure in each of the 30 patients examined during the performance of TKA. In each case, it was noted to take origin on the lateral femoral condyle and extend anteroinferiorly toward the lateral meniscus and tibial plateau (Fig. 1).

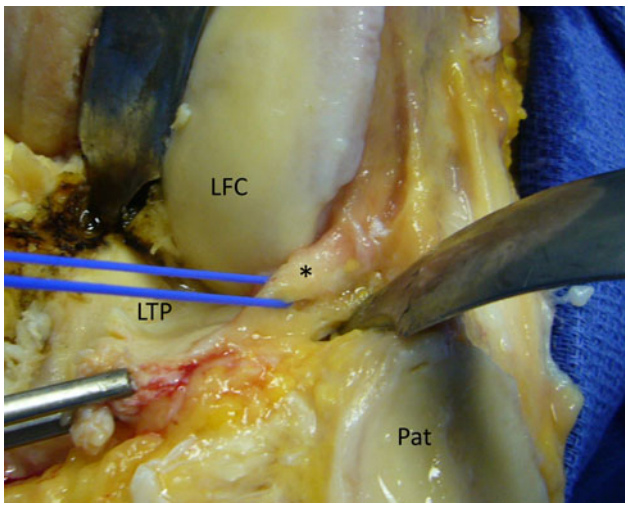

Fig. 1 An intra-operative view of a left knee during the performance of a total knee arthroplasty demonstrating the anterolateral ligament (*asterisk*) taking origin from the lateral femur. The lateral femoral condyle (*LFC*) femoral condyle, lateral meniscus (*LM*), and everted patella (*Pat*) are labeled

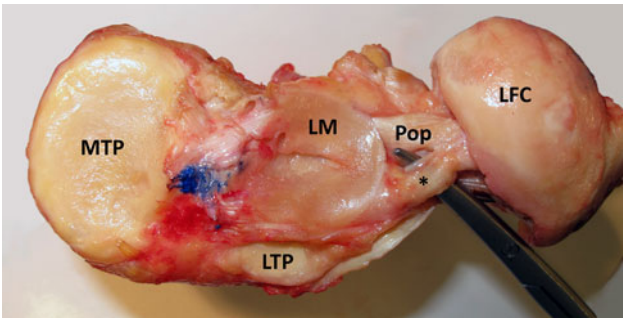

Fig. 2 A superior view of the tibial plateau of a left knee of a cadaveric specimen. The femur has been rotated laterally to provide visualization. The anterolateral ligament (*asterisk*) can be seen taking origin on the lateral femoral condyle (*LFC*) just anterior to the popliteus tendon (*Pop*) and inserting onto the lateral meniscus (*LM*) and lateral tibial plateau (*LTP*). The medial tibial plateau (*MTP*) is also labeled

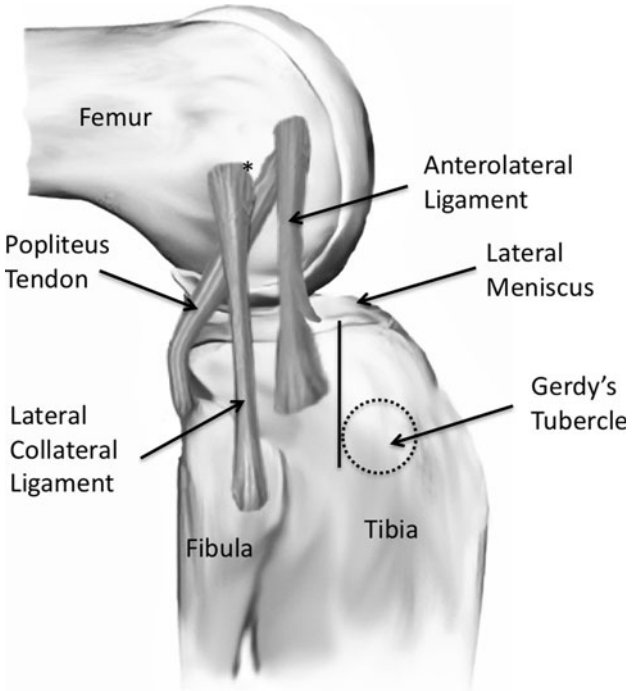

Fig. 3 A diagram of an anterolateral view of the knee demonstrating the lateral knee structures with the knee in 90° of flexion. The lateral collateral ligament takes origin on the posterosuperior portion of the lateral epicondyle (*asterisk*). The popliteus tendon inserts approximately 1 cm distal and anterior. The anterolateral ligament originates just anterior to the popliteus tendon, blending with its fibers. Distally, the anterolateral ligament inserts into the lateral meniscus and into the tibia 5 mm below the joint line, just posterior to a line drawn perpendicular to the joint line on the posterior border of Gerdy's Tubercle

Cadaveric anatomic investigation

The anterolateral ligament was clearly identified in all 10 cadaveric specimens. The origin was noted to be on the lateral femoral condyle, closely associated with the popliteus tendon. In nine of ten cases, the ligaments origin was just anterior to the popliteus tendon insertion, blending with its fibers (Fig. 2). In the remaining case, the structure arose from the popliteus tendon itself 5 mm from its insertion. As the structure passed distally, it was noted in each case to be closely associated with the lateral meniscus near the junction of its anterior and middle thirds. Macroscopically, it was impossible to assess whether some fibers of the structure actually inserted onto the meniscus. In each case, the structure inserted on the proximal anterolateral tibia approximately 5 mm from the articular cartilage. The insertion was always posterior to a line drawn vertically from the posterior border of Gerdy's Tubercle to the joint line (Fig. 3). The structure passed nearly directly distally under little tension with the knee joint reduced in extension (Fig. 4a). Anterior tibial dislocation resulted in a more oblique course and significant tightening of the ligament (Fig. 4b). Flexion of the knee to 90 degrees also resulted in tightening of the structure. The structure was relatively flat, with an average width of 8.2 ± 1.5 mm, thickness of 2–3 mm, and an average length of 34.1 ± 3.4 mm.

Histologic analysis

Transverse sections through the anterolateral ligament revealed it to be a strip of connective tissue surrounded by loose synovial tissue (Fig. 5). The dense fibrous tissue in the core of the structure accounted for approximately 20% of its cross-sectional area and was noted to be more abundant in sections obtained superior to the lateral meniscus. Just adjacent to the fibrous core, neurovascular and adipose tissue were visualized. Longitudinal sections demonstrated wavy collagenous fibers of the dense central core with a parallel orientation, suggestive of ligamentous or tendinous tissue (Fig. 6).

Sections from the proximal origin of the structure on the lateral femoral epicondyle showed a common origin with the insertion of femoral popliteus tendon with blending of collagen fibers from each structure. Sections obtained at the interface between the structure and the lateral meniscus confirmed the adherence of the strip to the meniscus without a cleavage plane and insertion of some collagen fibers into the meniscus itself (Fig. 7). The majority of fibers came close to the meniscal tissue, but continued without interruption toward the tibial plateau.

Discussion

The most significant findings of this study are that the anterolateral ligament is a distinct structure containing dense collagenous tissue and that the structure is quite consistently present. All forty specimens (30 patients

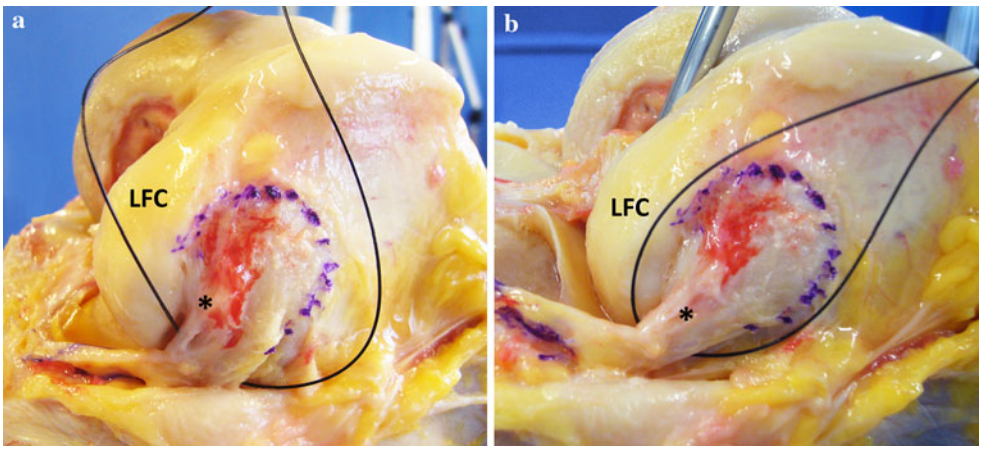

Fig. 4 A lateral view of a cadaveric specimen showing the anterolateral ligament originating the lateral femoral condyle (*LFC*). **a** With the knee joint reduced, the anterolateral ligament (*asterisk*) is nearly vertical and without tension. **b** When the tibia is translated anteriorly, the anterolateral ligament becomes taut and takes a more oblique path anteroinferiorly toward the tibia

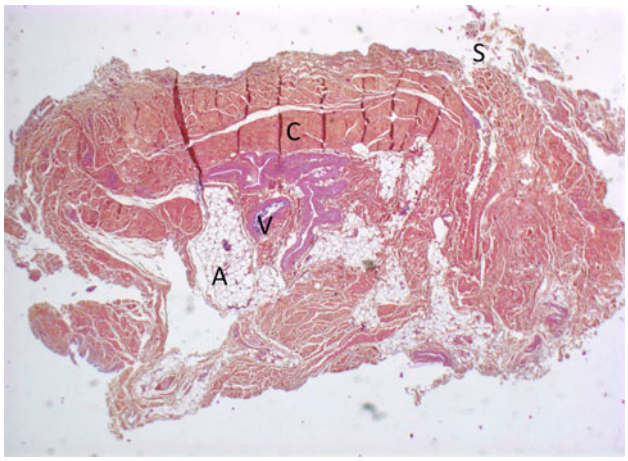

Fig. 5 A transverse section of the anterolateral ligament stained with hematoxylin and eosin and viewed at ×20 magnification demonstrates dense connective tissue (*C*) along with adipose (*A*) and vascular (*V*) tissue. Synovial tissue is noted at the periphery (*S*)

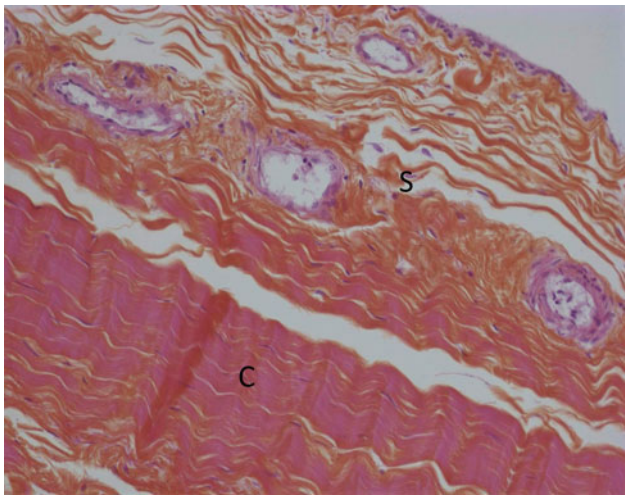

Fig. 6 A longitudinal section of the anterolateral ligament stained with hematoxylin and eosin and viewed at ×200 magnification demonstrates dense, well-organized connective tissue (*C*) bordered by synovial tissue (*S*)

undergoing TKA and 10 cadavers) demonstrated the presence of the ligament.

Previous descriptions of this structure in the literature are inconsistent. Some authors have described the ligament as an independent structure, [13] while others see it as a part of the iliotibial band [9, 15]. Vieira et al. described five distal insertions of the iliotibial tract: the linea aspera, the lateral epicondyle, the patella (also described by Amis et al. [1] as the lateral patellofemoral ligament), Gerdy's tubercle, and the capsular-osseous insertion, which they also refer to as the anterolateral ligament as described in the current study [15]. Similarly, Fairclough described two portions iliotibial tract: proximal "tendon" and distal "ligament" separated by an insertion onto the lateral femoral epicondyle anchored by "fibrous ropes" [4].

Hughston et al. [5] separated the lateral capsuloligamentous tissues into three portions: anterior, middle, and posterior. The middle segment included the "midthird capsular ligament", which was described as a structure that played a major role in the stability of the knee at about 30° of flexion. A lesion of this structure was described as being necessary for the occurrence of anterolateral rotatory instability (in addition to rupture of anterior cruciate ligament). Johnson demonstrated this tibial attachment to be a firm structure able to significantly contribute to knee stability [6]. In an imaging study, LaPrade et al. [7] described a structure on MRI attaching the lateral condyle to the lateral meniscus and tibia, but felt it to be a capsular thickening rather than an independent structure.

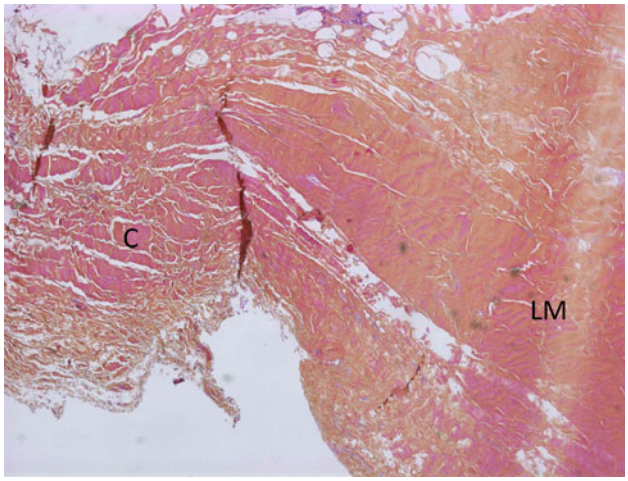

Fig. 7 A transverse section of the anterolateral ligament at the level of the lateral meniscus stained with hematoxylin and eosin and viewed at ×50 magnification demonstrates the insertion of some dense connective tissue (*C*) into the lateral meniscus (*LM*)

Terry et al. [14] advanced a hypothesis that the integrity of the capsulo-osseous insertion of the iliotibial band predicts the wide variety of clinical expression of a ruptured anterior cruciate ligament. We believe this structure to be what we have referred to as the anterolateral ligament. They noted that lesions of this structure correlated with increasingly abnormal Lachman test, pivot-shift test, and anterior drawer at 90° of flexion on physical examination.

As this structure may play a role in the prevention of anterior tibial translation, its preservation may be important to avoid excessive anterior tibial translation following total knee arthroplasty. This structure may be at risk when exposing the lateral tibial plateau and removing the meniscus. Care should be taken to preserve this structure during this portion of the case. Performing "pie crusting" of lateral knee structures to obtain ligament balance has been recommended by some authors [3]. When utilizing this technique for ligament balancing, we do not recommend completely sectioning this structure.

Our histologic findings demonstrate the anterolateral ligament to be a distinct fibrous structure in contact with the synovium. This finding is consistent with our gross anatomic finding that the structure is distinct from the lateral capsule. The collagen orientation is consistent with that found in tendons and ligaments.

Terry et al. [14] documented a clear association of rupture of this structure with ACL injury. The gross and histologic findings that the anterolateral ligament attaches distally to both the lateral meniscus as well and the proximal lateral tibia may contribute to the association of lateral meniscal tear with ACL injury. It is conceivable that following avulsion of the anterolateral ligament from the proximal tibia, further anterior tibial translation could result in tension on the meniscus from the anterolateral ligament's remaining femoral attachment. This force may contribute to tearing of the lateral meniscus, still anchored at its roots.

Finally, this structure, which is closely connected with the lateral meniscus, may play a role in lateral meniscus stability even in the absence of ACL pathology, including limiting anteroposterior translation during flexion and preventing meniscal extrusion. This effect should be considered when performing meniscal repair and perhaps more importantly during meniscal allograft transplantation, where secure lateral fixation may be as important the anchoring of the meniscus at is roots.

There are several weaknesses of this study. First, we have not performed a biomechanical analysis of the anterolateral ligament. This information would be useful in assessing the ability of this ligament to contribute to knee stability. Second, our assessment of the incidence of the ligament was performed in knees undergoing TKA via a medial approach for medial compartment osteoarthritis. While this population allowed us to assess a relatively normal lateral compartment, the presence of the everted patella did impede visualization. Finally, because the patients utilized in this study had not suffered an acute ACL injury, we were unable to determine whether this structure plays a role in the pathogenesis of the Segond Fracture.

Conclusions

The anterolateral ligament is consistently present. It is a distinct fibrous structure that takes origin just anterior to and blending with the popliteus tendon insertion on the femur. It inserts distally into the lateral meniscus and lateral tibial plateau 5 mm distal to the joint line and posterior to Gerdy's Tubercle.

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