A Layered Anatomic Description of the Anterolateral Complex of the Knee

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KEY POINTS

- Variability in anatomic terminology, dissection protocols, and the use of embalmed as opposed to fresh frozen specimens has led to the controversy surrounding the anterolateral structures of the knee.
- The complex anatomy of the anterolateral knee is made up of the many layers of the iliotibial band, the underlying capsule, and its direct attachments to the lateral meniscus.
- The iliotibial band is composed of the superficial, middle, deep, and capsulo-osseous layers.
- Collectively these structures are termed the anterolateral complex of the knee.
- The anterolateral complex of the knee works synergistically with adjacent meniscal tissue and meniscal roots to resist internal tibial rotation.

INTRODUCTION

The goal of improving rotatory knee stability in patients undergoing anterior cruciate ligament (ACL) reconstruction has led to renewed interest in the extra-articular structures of the anterolateral knee and description of the proposed anterolateral ligament (ALL).[1–4] Although the principal function of the anterolateral knee structures in resisting internal tibial rotation is generally accepted, the exact itemized anatomic structures and their respective contributions to resisting internal tibial rotation remain unclear.[5]

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In examining the ever-expanding body of literature on the topic, differences in anatomic terminology have resulted in inconsistency in the orthopedic literature. Although some experts describe a distinct ligamentous structure at the anterolateral aspect of the knee, other scientific reports show that the observed resistance to internal tibial rotation is secondary to a multitude of anterolateral tissues working synergistically.[6] This confluence of tissues or anterolateral complex (ALC) of the knee is described in this review.[7]

THE LAYERS OF THE LATERAL ASPECT OF THE KNEE

The lateral structures of the knee conceptually are often grouped into enveloping layers. Seebacher and colleagues[8] grouped the anatomic structures of the lateral knee into 3 layers, analogous to Warren and Marshall's description of the medial structures of the knee.[9] In contrast to the medial side, the layered individual structures of the lateral side are more complex and at times difficult to discern.

Layer I consists of the iliotibial band (ITB) and its anterior and posterior expansions.[8] Layer II anteriorly is represented by the retinaculum of the quadriceps (patellar retinaculum). Posteriorly, layer II is incomplete and is represented by attachments to the lateral intermuscular septum, posterolateral capsule, and lateral head of the gastrocnemius. Layer III is chiefly composed of the tibiofemoral joint capsule, which posterior to the ITB divides into a superficial and deep layer. Housed between the superficial and deep capsular layers is the lateral collateral ligament (LCL), and medial to it, the inferior lateral geniculate artery.[8] The superficial capsular layer terminates posteriorly when it meets the fabellofibular ligament, and the deep layer forms the coronary ligaments to the lateral meniscus and then blends with the arcuate ligament further posteriorly.[8,10]

THE ANTEROLATERAL COMPLEX

Anterolaterally from superficial to deep the knee is enveloped by the ITB with its associated deeper layers, and the joint capsule. Collectively, these structures are termed the ALC.[7] The dominant structure encountered is the ITB and although appearing as a simple thick band of tissue attaching to the Gerdy tubercle, the ITB is in fact complex and composed of a multitude of layers.

THE SUPERFICIAL AND MIDDLE LAYERS OF THE ILIOTIBIAL BAND

The superficial layer of the ITB proximally is firmly adhered to the linea aspera via connections to the lateral intermuscular septum.[4] Distally, the anterior aspect of the superficial layer is identified by its characteristic curved fibers attaching to the lateral patella and patellar tendon.[11] These "arciform fibers," which blend with the fascia of the patella, were first described by Kaplan[12] and run at 70° to 80° compared with fibers heading toward the Gerdy tubercle.[4] In the literature, the anterior fibers of the superficial layer of the ITB have also been termed the "iliopatellar band" or "superficial oblique retinaculum."[13,14] The central fibers of the superficial layer distally insert in a fanlike fashion on and around the Gerdy tubercle[4] (**Fig. 1**). Further posteriorly, the superficial layer terminates as a fascia that reinforces the biceps femoris.[8,14]

Immediately deep and directly adherent to the superficial layer is the middle layer of the ITB, which can be identified only with careful sharp dissection and serves to reinforce the structural integrity of the superficial layer.[14] The middle layer can be identified by its characteristic fibers, which run from lateral proximal to medial distal, which is in contrast to the vertical nature of the superficial ITB fibers.[14]
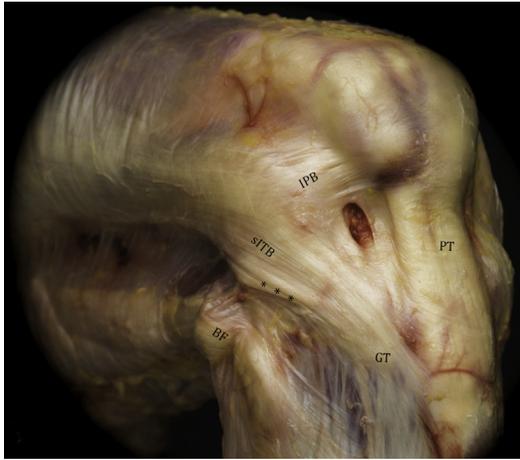
Fig. 1. The superficial iliotibial band (sITB) and posterior to this, the fascia of the biceps femoris (BF) muscle are depicted. Anterior to the sITB the iliopatellar band (IPB) inserts on the lateral patella and patellar tendon (PT). At 90° of knee flexion, the posterior part of the sITB becomes folded. GT, Gerdy tubercle. (*From* Herbst E, Albers M, Burnham JM, et al. The anterolateral complex of the knee: a pictorial essay. Knee Surg Sports Traumatol Arthrosc 2017;25(4):1010; with permission.)

THE DEEP LAYER OF THE ILIOTIBIAL BAND

The deep layer of the ITB lies posterior and medial to the superficial and middle layers. Its origin is at the lateral femoral supracondylar area and stretches approximately 6 cm proximally, just distal to the end of the lateral intermuscular septum.[14] Reflection of the superficial layer will reveal the deep layer of the ITB fanning out in the coronal plane and curving distally before becoming confluent with the aforementioned superficial and middle layers distally.

Close examination of the fibers, which make up the origin of deep layer of the ITB from distal to proximal, reveals discrete thickening in the supracondylar region. These deep fibers just distal to the intermuscular septum and in close proximity to the traversing superior geniculate vessels are termed the Kaplan fibers.[15] This deep femorotibial connection of the ITB was also described by Lobenhoffer and colleagues,[16] as they noted a distinct set of transverse running ITB fibers just distal to the intermuscular septum that were followed even farther distally by "retrograde fiber tracts," which traversed from the Gerdy tubercle back to the femur in a more arcuate fashion.

THE CAPSULO-OSSEOUS LAYER OF THE ILIOTIBIAL BAND

The capsulo-osseous layer of the ITB is considered a distinct layer by some, whereas other studies report it to be an indistinguishable component of the deep layer[4,6,10,14,16] (Fig. 2). Nonetheless, given its unique structure and proposed function, it deserves specific mention. The capsulo-osseous layer of the ITB is located more posteriorly compared with those that run superficial to it. At its posterior margin, the capsulo-osseous layer is continuous with the fascia of the gastrocnemius and plantaris muscles.[14] Posteriorly, there is also an attachment of the short of biceps femoris, which Terry and LaPrade[17] termed the biceps-capsulo-osseous iliotibial tract confluens. Distally, the capsulo-osseous layer inserts posterior to and distal to the Gerdy
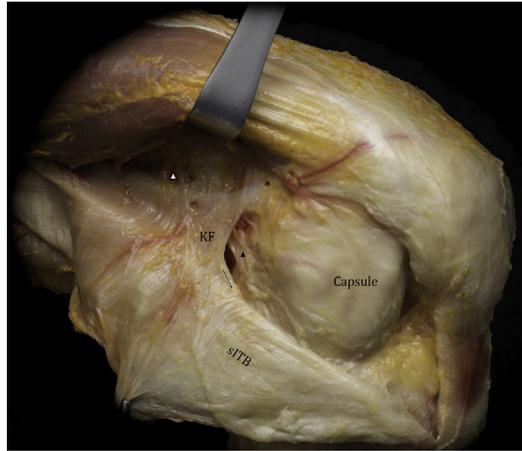
Fig. 2. Posterior reflection of the sITB and blunt dissection between the deep ITB (*black arrow*) and the anterolateral capsule reveals the capsulo-osseous layer (*black arrowhead*). In close proximity to branches of the superior genicular artery (*white arrowhead*), the Kaplan fibers (KF) can be seen originating from the distal femoral metaphysis and lateral supraepicondylar region (*asterisk* shows the accessory fiber bundles of the KF). (*From* Herbst E, Albers M, Burnham JM, et al. The anterolateral complex of the knee: a pictorial essay. Knee Surg Sports Traumatol Arthrosc 2017;25(4):1011; with permission.)

tubercle, and proximally its origin is located on the lateral supraepicondylar region bordering the lateral epicondyle.[4] As it runs to its aforementioned insertion, the capsulo-osseous layer lies immediately superficial to the anterolateral capsule of the knee joint.

THE ANTEROLATERAL CAPSULE

The lateral capsulo-ligamentous architecture has been described by Hughston and colleagues[18] and is divided into the anterior, middle, and posterior thirds. The structures of the anterior third include the capsule and overlying quadriceps retinaculum, stretching from the lateral border of the patella and patellar tendon to the anterior border of the superficial ITB. The superficial ITB and the layers deep to it, including the joint capsule, form the middle third capsular layer, which extends posteriorly to the anterior border of the LCL. The joint capsule of the knee naturally thickens to stabilize the lateral meniscus in the form of the meniscotibial and meniscofemoral ligaments[19,20] (**Fig. 3**). This middle third layer is anchored proximally at the femoral epicondyle and distally at the tibial joint line. The posterior third structures, which include the LCL, arcuate ligament, popliteus, and underlying joint capsule, are collectively termed the arcuate complex.[18]

THE "ANTEROLATERAL LIGAMENT"

The anatomic description of the ALL has varied in the literature. Claes and colleagues[1] described the ALL as a discrete ligament with attachments to the lateral meniscus, originating from the lateral femoral epicondyle and inserting just distal to the tibial joint line between the fibular head and Gerdy tubercle. In contrast, the ALL also has been described as a distinctly extracapsular structure originating 8.0 mm proximal and 4.3 mm posterior to the lateral epicondyle coursing superficial to the LCL with no direct
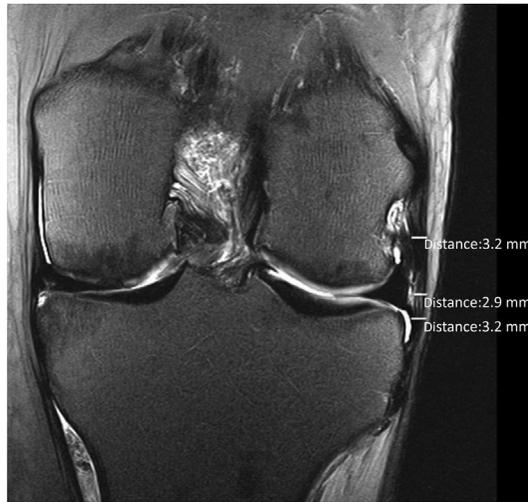
Fig. 3. A thickening of the lateral knee capsule forms the coronary ligament, which is made up of the meniscofemoral (*asterisks*) and meniscotibial (*double asterisks*) ligaments. Medial to the coronary ligament, the inferior genicular artery (*white arrowhead*) runs anteriorly. (*From* Herbst E, Albers M, Burnham JM, et al. The anterolateral complex of the knee: a pictorial essay. Knee Surg Sports Traumatol Arthrosc 2017;25(4):1012; with permission.)

attachments to the lateral meniscal rim.[21] This is contrary to alternate descriptions of the ALL as a thickening of the anterolateral capsule with an origin that is anterior and distal to the femoral epicondyle.[22] In a recent MRI study on human cadaveric specimens, such a thickening of the anterolateral capsule was identified in only 3 of 10 specimens. As measured on 3T MRI, the thickness of the anterolateral capsule at its greatest dimension never exceeded 3.3 mm[23] (**Fig. 4**). The overall prevalence of a capsular thickening or "ALL" has been reported to be from 12.5% to 100% in fresh frozen cadaver knee specimens in the recent literature.[3,23–26]

When comparing the proposed locations of the ALL with classic literature, it may be possible that investigators are referring to either the capsulo-osseous layer of the ITB or the mid-third capsular ligament, as described by Hughston and colleagues.[18] Terry and colleagues[14,17] described the capsulo-osseous layer of the ITB, which "acts as an anterolateral ligament of the knee," particularly as the knee approaches extension. This capsulo-osseous layer along with portions of the deep layer is what is likely the ligamentum femoro-tibiale laterale anterius described by Müller,[27] the "retrograde fiber tracts" of Lobenhoffer and colleagues[16] or what Hassler and Jakob[28] described as the ligamentum tractotibiale. The anatomic descriptions of these fiber tracts of the ITB (from lateral supraepicondylar to an area posterior to the Gerdy tubercle) would be in line with some of recent descriptions of the ALL.[21,29] However, none of the recent studies described the proximal continuity of these fiber tracts with the fascia of the lateral gastrocnemius and plantaris muscles.[14]

When compared with the deep and capsulo-osseus layer of the ITB, the anterolateral capsule provides little restraint to internal tibial rotation.[6,30] Biomechanical data have shown that the anterolateral capsule does not effectively transmit forces longitudinally between the tibia and femur like a ligament, but rather functions as sheet of fibrous tissue and aids in dissipating forces to neighboring structures.[31] During robotic pivot shift testing using human cadaveric specimens, the anterolateral capsule experiences

Fig. 4. Predissection coronal T2 MRI depicting a fresh-frozen cadaveric specimen with thickening of the lateral capsule and accompanying measurements. Measurements documented the thickness (in a medial–lateral plane) of the thickening proximally (measured at the caudal margin of the sulcus for the popliteus insertion), in the midportion (measured at the mid-meniscus level) and distally (measured at the level of the subchondral plate of the lateral tibial plateau). On this specimen, measurements equaled: proximal, 3.2 mm; midportion, 2.9 mm; and distal, 3.2 mm. (*From* Dombrowski ME, Costello JM, Ohashi B, et al. Macroscopic anatomic, histologic and magnetic resonance imaging correlation of the lateral capsule of the knee. Knee Surg Sports Traumatol Arthrosc 2016;24(9):2856; with permission.)

relatively low in situ forces compared with the ACL and overlying anterolateral tissues.[30] Although a thickening of the capsule anterolaterally can be appreciated in 30% to 40% of cases, biomechanical studies have shown its stiffness and ultimate load is much lower than comparable capsular tissue from the posteromedial aspect of the knee.[5] This is contrary to what would be expected if ligamentous tissues were present. This suggests that the capsule instead works synergistically with the layers of the ALC, adjacent meniscal tissue, and meniscal roots to control rotatory knee instability.[5,32,33]

SUMMARY

The anatomy of the ALC is multifaceted and conceptually can be divided into the superficial, middle, deep, and capsulo-osseous layers of the ITB, which overlie the anterolateral joint capsule, including the mid-third capsular ligament. Collectively, these structures form the ALC of the knee, which in conjunction with the ACL is believed to be important in preventing anterolateral rotatory instability. Future large-scale clinical studies will be necessary to better understand the multiple factors that influence anterolateral rotatory knee instability. As our knowledge of the anterolateral structures of the knee develops, the goal continues to be improved diagnosis and treatment of complex knee injuries. Ultimately, the goal will be improved outcomes for patients with rotatory instability secondary to ACL injury.

REFERENCES

1. Claes S, Vereecke E, Maes M, et al. Anatomy of the anterolateral ligament of the knee. J Anat 2013;223(4):321–8.

2. Kennedy MI, Claes S, Fuso FA, et al. The anterolateral ligament: an anatomic, radiographic, and biomechanical analysis. Am J Sports Med 2015;43(7): 1606–15.
3. Van der Watt L, Khan M, Rothrauff BB, et al. The structure and function of the anterolateral ligament of the knee: a systematic review. Arthroscopy 2015;31(3): 569–82.e3.
4. Vieira EL, Vieira EA, da Silva RT, et al. An anatomic study of the iliotibial tract. Arthroscopy 2007;23(3):269–74.
5. Rahnemai-Azar AA, Miller RM, Guenther D, et al. Structural properties of the anterolateral capsule and iliotibial band of the knee. Am J Sports Med 2016;44(4): 892–7.
6. Kittl C, El-Daou H, Athwal KK, et al. The role of the anterolateral structures and the ACL in controlling laxity of the intact and ACL-deficient knee. Am J Sports Med 2016;44(2):345–54.
7. Herbst E, Albers M, Burnham JM, et al. The anterolateral complex of the knee: a pictorial essay. Knee Surg Sports Traumatol Arthrosc 2017;25(4):1009–14.
8. Seebacher JR, Inglis AE, Marshall JL, et al. The structure of the posterolateral aspect of the knee. J Bone Joint Surg Am 1982;64(4):536–41.
9. Warren LF, Marshall JL. The supporting structures and layers on the medial side of the knee: an anatomical analysis. J Bone Joint Surg Am 1979;61(1):56–62.
10. Kaplan EB. Some aspects of functional anatomy of the human knee joint. Clin Orthop 1962;23:18–29.
11. Merican AM, Amis AA. Anatomy of the lateral retinaculum of the knee. J Bone Joint Surg Br 2008;90(4):527–34.
12. Kaplan EB. Surgical approach to the lateral (peroneal) side of the knee joint. Surg Gynecol Obstet 1957;104(3):346–56.
13. Fulkerson JP, Gossling HR. Anatomy of the knee joint lateral retinaculum. Clin Orthop Relat Res 1980;153:183–8.
14. Terry GC, Hughston JC, Norwood LA. The anatomy of the iliopatellar band and iliotibial tract. Am J Sports Med 1986;14(1):39–45.
15. Kaplan EB. The iliotibial tract; clinical and morphological significance. J Bone Joint Surg Am 1958;40A(4):817–32.
16. Lobenhoffer P, Posel P, Witt S, et al. Distal femoral fixation of the iliotibial tract. Arch Orthop Trauma Surg 1987;106(5):285–90.
17. Terry GC, LaPrade RF. The biceps femoris muscle complex at the knee. Its anatomy and injury patterns associated with acute anterolateral-anteromedial rotatory instability. Am J Sports Med 1996;24(1):2–8.
18. Hughston JC, Andrews JR, Cross MJ, et al. Classification of knee ligament instabilities. Part II. The lateral compartment. J Bone Joint Surg Am 1976;58(2):173–9.
19. Hughston JC, Andrews JR, Cross MJ, et al. Classification of knee ligament instabilities. Part I. The medial compartment and cruciate ligaments. J Bone Joint Surg Am 1976;58(2):159–72.
20. Corbo G, Norris M, Getgood A, et al. The infra-meniscal fibers of the anterolateral ligament are stronger and stiffer than the supra-meniscal fibers despite similar histological characteristics. Knee Surg Sports Traumatol Arthrosc 2017;25(4): 1078–85.
21. Dodds AL, Halewood C, Gupte CM, et al. The anterolateral ligament: anatomy, length changes and association with the Segond fracture. Bone Joint J 2014; 96B(3):325–31.

22. Caterine S, Litchfield R, Johnson M, et al. A cadaveric study of the anterolateral ligament: re-introducing the lateral capsular ligament. Knee Surg Sports Traumatol Arthrosc 2015;23(11):3186–95.

23. Dombrowski ME, Costello JM, Ohashi B, et al. Macroscopic anatomical, histological and magnetic resonance imaging correlation of the lateral capsule of the knee. Knee Surg Sports Traumatol Arthrosc 2016;24(9):2854–60.

24. Roessler PP, Schuttler KF, Stein T, et al. Anatomic dissection of the anterolateral ligament (ALL) in paired fresh-frozen cadaveric knee joints. Arch Orthop Trauma Surg 2017;137(2):249–55.

25. Shea KG, Milewski MD, Cannamela PC, et al. Anterolateral ligament of the knee shows variable anatomy in pediatric specimens. Clin Orthop Relat Res 2016; 475(6):1583–91.

26. Shea KG, Polousky JD, Jacobs JC Jr, et al. The anterolateral ligament of the knee: an inconsistent finding in pediatric cadaveric specimens. J Pediatr Orthop 2016; 36(5):e51–4.

27. Müller W. Das Knie. Form, Funktion und ligamentaere Wiederherstellungschirurgie. Berlin/Heidelberg/New York: Springer; 1982.

28. Hassler H, Jakob RP. On the cause of the anterolateral instability of the knee joint. A study on 20 cadaver knee joints with special regard to the tractus iliotibialis (author's transl). Arch Orthop Trauma Surg 1981;98(1):45–50 [in German].

29. Daggett M, Busch K, Sonnery-Cottet B. Surgical dissection of the anterolateral ligament. Arthrosc Tech 2016;5(1):e185–8.

30. Bell KM, Rahnemai-Azar AA, Irarrazaval S, et al. In-situ forces in the anterolateral capsule resulting from a simulated pivot shift test. Orthopaedic Research Society Annual Meeting. Lake Buena Vista (FL), March 5, 2016.

31. Guenther D, Rahnemai-Azar AA, Bell KM, et al. The anterolateral capsule of the knee behaves like a sheet of fibrous tissue. Am J Sports Med 2016;45(4):849–55.

32. Musahl V, Citak M, O'Loughlin PF, et al. The effect of medial versus lateral meniscectomy on the stability of the anterior cruciate ligament-deficient knee. Am J Sports Med 2010;38(8):1591–7.

33. Shybut TB, Vega CE, Haddad J, et al. Effect of lateral meniscal root tear on the stability of the anterior cruciate ligament-deficient knee. Am J Sports Med 2015;43(4):905–11.