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MINIREVIEWS

Overview of the anterolateral complex of the knee

Ignacio Garcia-Mansilla, Juan Pablo Zicaro, Ezequiel Fernando Martinez, Juan Astoul, Carlos Yacuzzi, Matias Costa-Paz

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Abstract

In the last few years, much more information on the anterolateral complex of the knee has become available. It has now been demonstrated how it works in conjunction with the anterior cruciate ligament (ACL) controlling anterolateral rotatory laxity. Biomechanical studies have shown that the anterolateral complex (ALC) has a role as a secondary stabilizer to the ACL in opposing anterior tibial translation and internal tibial rotation. It is of utmost importance that surgeons comprehend the intricate anatomy of the entire anterolateral aspect of the knee. Although most studies have only focused on the anterolateral ligament (ALL), the ALC of the knee consists of a functional unit formed by the layers of the iliotibial band combined with the anterolateral joint capsule. Considerable interest has also been given to imaging evaluation using magnetic resonance and several studies have targeted the evaluation of the ALC in the setting of ACL injury. Results are inconsistent with a lack of association between magnetic resonance imaging evidence of injury and clinical findings. Isolated ACL reconstruction may not always reestablish knee rotatory stability in patients with associated ALC injury. In such cases, additional procedures, such as anterolateral reconstruction or lateral tenodesis, may be indicated. There are several techniques available for ALL reconstruction. Graft options include the iliotibial band, gracilis or semi-tendinosus tendon autograft, or allograft.

Key Words: Anterolateral complex; Knee instability; Anterolateral ligament; Anterior cruciate ligament reconstruction

Core Tip: Although research on anterolateral ligament (ALL) has increased considerably in recent years, some debate remains regarding its anatomy and further refinement is still ongoing. Biomechanical studies have revealed that anterolateral structures contribute significantly to rotational stability of the knee and should be accounted for in the setting of an anterior cruciate ligament (ACL) injury. Surgical indications for ALL reconstruction are not currently evidence-based and the ideal graft type and fixation have not yet been determined. Further clinical research remains to be conducted to determine the most appropriate scenarios for augmentation of a primary ACL reconstruction with an anterolateral procedure to enhance patient outcomes.

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INTRODUCTION

The initial description of the anterolateral complex of the knee is attributed to various authors, and the anatomical details of the so-called anterolateral ligament of the knee have changed according to the historical context of each century. In 1752, Weitbrecht was the first to refer to a series of fibers that reinforced the lateral joint capsule of the knee and that, according to his observation, gave support to the external meniscus. One hundred years later, Henle described a group of fibers anterior to the external collateral ligament that inserted into the edge of the external meniscus, and that reinforced the joint capsule. The first anatomo-clinical approach was advanced by Paul Segond who described an avulsion fracture of the anterolateral portion of the proximal tibia associated with this ligament. Through a series of cadaveric dissections, he characterized the fibers of the ligament as a stringy, beaded, tough band that, according to his observation, tightened upon excessive internal rotation of the knee. Since then, the ligament has taken different names in the literature and numerous and non-specific descriptions have been made of the ligamentous capsule structures of the anterolateral region of the knee[1,2].

More than a century had to pass until the landmark works of Claes *et al*[3], Vincent *et al*[4] and Helito *et al*[5] when the term anterolateral ligament of the knee began to spread. From that time on, there has been a great deal of dispute surrounding the presence of the LLA and its possible role in the control of anterolateral rotational instability (ALRI) following anterior cruciate ligament (ACL) injury. Great emphasis has been given to a better understanding of these structures, including their anatomy, biomechanics, injury patterns, and the optimal strategies to treat any rotational laxity of the knee resulting from damage to these structures[6]. Lateral extra-articular tenodesis has re-emerged in popularity and several ALL reconstruction techniques have been developed in the attempt to lower the failure rate following ACL reconstruction[7-9]. The aim of this review is to outline the latest literature findings on the anatomy of the anterolateral complex, biomechanical findings, treatment of anterolateral lesions, and ALL reconstruction techniques. It is intended to provide information to readers on the most current approaches to help enhance patient outcomes following an ACL injury and subsequent reconstruction.

ANATOMY OF THE ANTEROLATERAL COMPLEX

The complex ligamentous capsule anatomy of the anterolateral region of the knee is given by the relative and multiplanar position adopted by its bony parts. To distinguish the anatomy of the antero-lateral ligament, it is necessary to understand the three-dimensional arrangement of the iliotibial band. In this anatomical complex, which has been widely described, the following layers can be recognized: Superficial layer of the reflected iliotibial band (sITB) (Figure 1A): It is found immediately deep to the subcutaneous cellular tissue and superficial to the vastus lateralis, easily identifiable by its pearly white color. Its main insertion on Gerdy's tubercle is distinguished distally. Its most anterior fibers are curved distally and insert on the lateral surface of the patella and the patellar tendon (iliopatellar band). Middle layer of the ITB (mITB): Made up of the patellofemoral ligament and the fascia of the quadriceps femoris. Its fibers, contrary to the vertical arrangement of the first layer, run obliquely from proximal and lateral to distal and medial. Deep layer of the ITB (dITB) (Figure 1B): It is localized posterior to the superficial layer. It is inserted into the distal femur, from its metaphyseal portion to the supracondylar area through the so-called Kaplan fibers. These fibers arrange transversely to the femur, which form the deep layer of the iliotibial band and, together with the superficial portion, have an important role in knee stability.

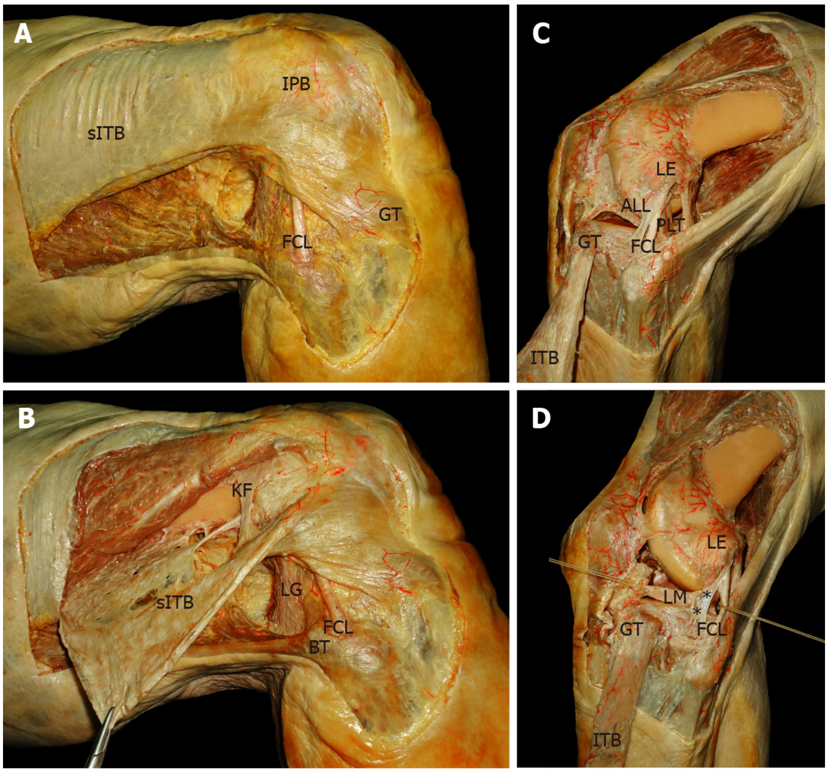

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Figure 1 Photograph of anatomical dissection of right and left cadaver knees. A and B: Right cadaver knee; C and D: Left cadaver knee. Asterisk: Coronary ligament which includes the meniscofemoral and meniscotibial ligament. sITB: Superficial iliotibial band; IPB: Iliopatelar band; GT: Gerdy's tubercle; FCL: Fibular collateral ligament; KF: Kaplan fibers; BT: Biceps tendon; LG: Lateral gastrocnemius muscle; LE: Lateral epicondyle; ALL: Anterolateral ligament; ITB: Reflected iliotibial band; LM: Lateral meniscus.

The Capsulo-osseous Layer of the ITB and the anterolateral capsule. There is still considerable controversy surrounding the terminology of the joint capsule that underlies the deepest layer of the ITB. Some authors proposed a capsular-osseous layer and described it as a medial retaining wall of the deepest layer of the ITB. Distally, the fibers run just proximal to Gerdy's tubercle, inserting posterior to the convergence between the superficial and deep layers of the iliotibial band[10]. The lateral joint capsule comprises a superficial layer and a deep layer, based on their relation with respect to the lateral collateral ligament (LCL). These layers converge anterior to the LCL. Hughston *et al*[1] divided the deep capsule into three parts: an anterior layer (of minor importance due to its thickness and negligible insertions), a posterior layer (made up of the posterolateral arcuate complex) and an intermediate layer called the "mid-third lateral capsular ligament" (a capsular thickening with distinct femoral and tibial bony insertions). The latter also has a firm attachment to the lateral meniscus. These fibers form the meniscofemoral and meniscotibial ligaments, also known as the coronary ligament[11].

All these descriptions overlap with those of the anterolateral ligament of the knee, and can be understood as the same structure[11-13]. In relation to its arrangement, its direction is from proximal and posterior to distal and anterior, inserted at the lateral epicondyle of the femur and the lateral articular margin of the external tibial condyle (Figure 1C). It is related to the lateral meniscus through the coronary ligament (Figure 1D). The proximal attachment is subject to debate, although most authors agree that it is located proximal and posterior to the center of the lateral femoral epicondyle[14].

IMAGING OF THE ANTEROLATERAL COMPLEX

X-radiographs

During the pivot shift phenomenon, internal rotation and anterior translation are responsible for the rupture of the ACL and for the load on other soft tissue structures attached to the lateral tibia, which will eventually could tear or avulse the lateral margin of the tibia (Segond fracture)[15]. There have been several studies that pointed out that the Segond fracture is caused by some capsule-ligamentous structure throughout the lateral aspect of the knee connecting the distal femur to the tibia[12,14,16,17].

Ultrasound

Visualization of the ALL on ultrasonography is challenging. Some studies showed that this structure could be identified at least partially on ultrasound. The sensibility of this method varied, among different authors, between 60% to 100%[18,19]. However, it was not easy to isolate the ALL from the adjacent structures like the anterolateral capsule and the iliotibial band (ITB). Performing the ultrasound examination with the knee in internal rotation and flexion may improve the visualization of this ligament structure[20]. Even though anterolateral ligament injuries can be diagnosed with ultrasound, this imaging method is not routinely utilized in the diagnostic algorithm of these patients.

Magnetic resonance imaging

Many authors studied how to identify the ALL by magnetic resonance imaging (MRI), most of them agreed that this structure is difficult to analyze along its entire length and that is best identified in the coronal plane[21]. Clear identification of the ligament is described in more than half of the cases, varying between 51% and 100% in most studies. However, other authors visualized the ligament in only 11% of the cases[22-24]. The femoral origin is difficult to visualize because it is not clearly distinguishable from the LCL and ITB[25]. In injured knees, soft tissue swelling and joint effusion can provide signal intensification that may allow enhanced visualization of the ALL[21,23]. The true utility of MRI is its capacity to identify involvement of the ALL following knee injuries to potentially guide in deciding ligament reconstruction alternatives. Abnormal ALL includes one or the combination of the following features: complete disruption, irregular contour and ligamentous edema. This findings can correlate with an increase in pivot shift test[26].

BIOMECHANICAL FINDINGS

A developing body of literature has examined the role of anterolateral structures in rotatory knee stability. Given the high complexity of this region of the knee, with its varying anatomical structures, biomechanical studies have shown uncertain results. In a controlled laboratory study, Zens *et al*[27] described the biomechanical properties of the ALL and found that the LLA becomes longer under flexion and internal rotation, while it becomes shorter under external rotation. The mean length change during internal rotation was also higher when the knee was flexed[27]. According to different studies, mean ultimate failure load ranged between 50 and 205 N, mean stiffness 20 to 42 N/mm, and mean ultimate strain 36%[27-29]. Sectioning of the ALL resulted in a statistically significant increase in anterior translation and internal knee rotation after ACL section[30-32]. However, a number of authors suggested that the ALL or anterolateral capsule plays just a minor role at physiologic ranges of tibial translation acting as a secondary stabilizer to anterolateral translation only after loss of the ACL[33-35]. Most biomechanical studies evaluated the anterolateral structures with preserved ITB. On the contrary, Kittl *et al*[26] showed that when Kaplan's fibers and the capsulo-osseous layer are disrupted, thus interrupting the functional unity of the ITB between the distal femur and the proximal tibia, the internal rotation of the tibia is substantially increased throughout range of motion[36]. Demonstrating a crucial contribution of the ITB to rotatory knee stability. In another study, Noyes *et al*[35] observed that sectioning of the ALL and the ITB in ACL-deficient knees converted 71% of the specimens to a grade 3 pivot shift as measured by composite tibiofemoral translations and rotations. These results emphasize the importance of approaching the anterolateral complex of the knee as a unit rather than the anterolateral ligament in isolation.

MANAGEMENT OF ANTEROLATERAL INJURIES

There is no agreement on the optimal treatment management strategy for anterolateral knee injuries and the possible long-term clinical impact of ALL insufficiency is currently unknown. As noted above, anterolateral structures contribute significantly to rotational knee stability and should be acknowledged in the setting of ACL reconstruction or revision surgery. Concomitant ACLR and ALL reconstruction (ALLR) significantly decreased internal rotation and tibial translation in the axial plane with respect to isolated ACLR in the presence of ALL deficiency[32]. The indication for lateral tenodesis or reconstruction procedures combined with ACL reconstruction is not clearly established in the literature and is typically based on surgeon's experience and judgment[13,37]. Based on the risk factors for graft failure and the indications suggested in the available evidence, Table 1 shows a list of 14-criteria divided into major and minor criteria to be consider when evaluating the need for performing a lateral tenodesis or ALL reconstruction procedures. Considerable clinical research has yet to be accomplished to identify the best-case scenarios for augmentation of a primary ACL reconstruction with an anterolateral procedure to maximize patient outcomes.

Table 1 List of 14-criteria divided into major and minor criteria to be consider when evaluating the need for performing a lateral tenodesis or anterolateral ligament reconstruction procedures

Major Criteria	Minor Criteria
ACL revision; pivot shift grade IIIpivot sports; competitive athlete or “elite”; age: ≤ 25 yr old	Hyperlaxity/recurvatum ≥ 10°; KT-1000 ≥ 8 mm side-side difference; instability ≥ 6 mo; medial meniscectomy and/or lateral meniscus root lesion; contralateral knee instability; Bmi ≥ 30; tibial plateau slope ≥ 10°; severe anterior tibial translation; presence of a ‘’lateral femoral notch sign’’ or an impaction of the lateral femoral condyle[39]; segond fracture

ACL: Anterior cruciate ligament; BMI: Body mass index.

Table 2 Anterolateral ligament reconstruction techniques

Ref.	Graft	Direction	Fixation site	Fixation angle	Graft fixation
Grassi *et al* [43]	ITB	Deep to the LCL	Proximal and posterior to the lateral femoral epicondyle	Neutral rotation/0°-90°	Interference screw
Mahmoud *et al*[47]	ITB	Deep to the LCL and then passed through the lateral distal intermuscular septum from posterior to anterior and adjacent to the femur	-	Neutral rotation/around 50° flexion	ITB is sutured to itself at physiological tension
Arnold *et al* [48]	ITB	Under the LCL and the Popliteus tendon	-	External rotation/90°-100°	Sutured with periosteal stitches to GT
Porter *et al* [49]	ITB	Around the proximal LCL	Posterior to the Gerdy tubercle	Neutral rotation/35°	Interference screw
Losee *et al* [50]	ITB	Deep to the LCL	The femoral tunnel originated at the attachment point of the lateral gastrocnemius and ended antero-distal to the LCL femoral insertion site	External rotation/30°	Sutured at the Gerdy tubercle
Dejour *et al* [42]	ITB	Over the LCL	Anterior to the junction of the femoral shaft and lateral femoral condyle	External rotation/30°	1 Cancellous screws
Ellison *et al* [51]	ITB	Deep to the LCL	Slightly anterior to its original harvest site at the Gerdy tubercle	External rotation/90°	Interference screw
Lee *et al*[52]	Allograft	Over the LCL	Femur: Proximal and posterior to the lateral femoral epicondyle/Tibia: Between the fibular head and Gerdy tubercle at approximately 10 mm below the joint line	Neutral rotation/30°	2 Interferences screws[1]
Sonnery-Cottet *et al* [41]	Gracillis (ACL and ALL)	Single femoral tunnel/graft is routed deep to the iliotibial band from the femur to the tibia, shuttled through a tibial bony tunnel and back proximally to the femur	Proximal and posterior to the lateral femoral epicondyle	Neutral rotation/extension	Fixed to the ACL graft
Dejour *et al* [42]	Double hamstrings (ACL and ALL)	Over-the-top	Proximal and posterior to the lateral femoral epicondyle	90	Stapples

ITB: Reflected iliotibial band; LCL: Lateral collateral ligament; GT: Gerdy’s tubercle; ACL: Anterior cruciate ligament; ALL: Anterolateral ligament.

SURGICAL TECHNIQUES

Several techniques have been described to perform an ALLR. The main goal is to control internal rotation and restore the normal knee kinematics. From a technical point of view, there are two surgical alternatives: a lateral extra-articular tenodesis (LET) or an "anatomical" reconstruction of the ALL. Different fixation sites, grafts, and fixation angles have been described (Table 2). Available evidence is based on mixed clinical and *in vitro* studies 9. No study has demonstrated improvement in objective or subjective outcomes of one procedure over the others[38]. Three recent systematic reviews with meta-analyses including only comparative studies have shown that the addition of a lateral extra-articular tenodesis procedure to an ACL reconstruction has been found to reduce rotational laxity control, but has no effect on anterior translation or patient-reported outcomes[9,39,40]. For the LET the most frequently used graft is the ITB and for the anatomical reconstruction the gracilis tendon or allograft.

The most frequent femoral insertion site is posterior and proximal to the lateral epicondyle. The ITB can be passed under or over the LCL. It can also be fixed anterior and distal to the epicondyle. Suture anchors, interference screws or cortical buttons can be used for graft fixation. Whichever technique is used, the most important consideration is to avoid the confluence of the tunnels with the ACL. This can usually be avoided easily by aiming the drill 30° proximal and 30° anterior. It is recommended to perform this step while directly visualizing the intra-articular femoral tunnel; positioning the arthroscope in the tunnel to confirm if necessary. Other techniques describe a mixture of intra-articular and extra-articular ACL reconstruction utilizing a unique graft through a single femoral tunnel as described by Sonnery-Cottet *et al*[41] or passing the graft over-the-top as described by Dejour *et al*[42], Grassi *et al*[43], Sarraj *et al*[44], Placella *et al*[45].

CONCLUSION

The findings outlined in the present mini-review contribute to the comprehension of the role of the anterolateral complex of the knee. Although research on ALL has increased considerably in recent years, some debate remains regarding its anatomy and further refinement is still ongoing. Biomechanical studies have revealed that anterolateral structures contribute significantly to rotational stability of the knee and should be accounted for in the setting of an ACL injury, especially in cases with a high degree of pivot shift or revision surgery. Surgical indications for ALL reconstruction are not currently evidence-based and the ideal graft type, fixation location and fixation angle have not yet been determined. Further clinical research remains to be conducted to identify the most appropriate situations for augmentation of a primary ACL reconstruction with an anterolateral procedure to enhance patient outcomes.

FOOTNOTES

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