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SPECIAL ARTICLE

A review on the role of the anterolateral ligament (ALL) in the knee joint stability

Una revisión sobre el papel del ligamento anterolateral (LLA) en la estabilidad de la articulación de la rodilla

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Summary

Background: It has been demonstrated that the anterolateral ligament (ALL) plays an important role in the Knee joint stability. However, because of the paucity of current literature on the native biomechanics of the ALL of the knee, this review, will summarizes the present literature related to various aspects of the ALL, especially the biomechanical ALL function with attention to its role in the knee joint stability.
Methods: An online search was performed for human literatures that reported role of the ALL in the stability of the knee joint. The electronic databases PUBMED, MEDLINE, and EMBASE were searched up to September 2020. Inclusion criteria included English language, human corpse study, and biomechanical or biomechanical studies of ALL knee function.
Results: The ALL was first described by French surgeon Paul Segond, in 1879. This "some years later" described structure was called the "anterolateral ligament" in 2007, by Vieira et al. Several studies suggest that the ALL passively, is important for stability of the knee. Briefly, the ALL is a capsular ligament located in the anterior part of the knee, in the deepest layer of lateral structures. Biomechanical reports have indicated that the ALL contributes to the overall rotational stability of the knee. Overall, biomechanical data are required in several aspects of anterior reconstruction, including insertion, fixed angle, and initial graft tension. It has been demonstrated that ALL mainly acts as an additional rotational stabilizer of the knee. In other words, it mainly controls internal tibial rotation, so is involved in the pivot shift phenomenon mechanism.
Conclusion: This fact that Segond fractures are linked to ACL tears is an indication of a knee-stabilizing performance of ALL. Biomechanical researchers suggest that ALL reconstruction may plays an important role in knee stability; thus it is essential for surgeons to understand the structure and function of this ligament.

Keywords: Anterolateral ligament, Knee joint, Stability.

Resumen

Antecedentes: Se ha demostrado que el ligamento anterolateral (LLA) desempeña un papel importante en la estabilidad de la articulación de la rodilla. Sin embargo, debido a la escasez de literatura actual sobre la biomecánica nativa del LLA de la rodilla, esta revisión, resumirá la literatura actual relacionada con varios aspectos del LLA, especialmente la función biomecánica del LLA con atención a su papel en la estabilidad de la articulación de la rodilla.
Métodos: Se realizó una búsqueda en línea de literatura humana que informara sobre el papel del LLA en la estabilidad de la articulación de la rodilla. Se realizaron búsquedas en las bases de datos electrónicas PUBMED, MEDLINE y EMBASE hasta septiembre de 2020. Los criterios de inclusión incluyeron el idioma inglés, el estudio de cadáveres humanos y los estudios biomecánicos o de la función de la rodilla del LLA.
Resultados: La LLA fue descrita por primera vez por el cirujano francés Paul Segond, en 1879. Esta estructura descrita "algunos años más tarde" fue denominada "ligamento anterolateral" en 2007, por Vieira et al. Varios estudios sugieren que el LLA, de forma pasiva, es importante para la estabilidad de la rodilla. Brevemente, el LLA es un ligamento capsular situado en la parte anterior de la rodilla, en la capa más profunda de las estructuras laterales. Los informes biomecánicos han indicado que el LLA contribuye a la estabilidad rotacional general de la rodilla. En general, se necesitan datos biomecánicos en varios aspectos de la reconstrucción anterior, como la inserción, el ángulo fijo y la tensión inicial del injerto. Se ha demostrado que la LLA actúa principalmente como un estabilizador rotacional adicional de la rodilla. En otras palabras, controla principalmente la rotación interna de la tibia, por lo que participa en el mecanismo del fenómeno de desplazamiento del pivote.
Conclusión: El hecho de que las fracturas de Segond estén vinculadas a las roturas del LCA es un indicio de la actuación estabilizadora de la rodilla de la LLA. Los investigadores biomecánicos sugieren que la reconstrucción del LLA puede desempeñar un papel importante en la estabilidad de la rodilla; por lo tanto, es esencial que los cirujanos comprendan la estructura y la función de este ligamento.

Palabras clave: Ligamento anterolateral, Articulación de la rodilla, Estabilidad.

Introduction

Knee joint stability is warranted by a several factors such as interaction of ligaments and muscles[1]. Anterior cruciate ligament, posterior cruciate ligament, medial and lateral collateral ligaments play the main role as passive stabilizers. Studies report that the anterolateral ligament (ALL) also passively, is important for stability of knee. The ALL was first described by French surgeon Paul Segond, in 1879[2], but, this forgotten again, and its role was recognized only some years ago. However, Segond described it as "a resistant, pearly, fibrous band, which, in an exaggeration of internal rotational movement, is always subjected to an extreme degree of tension" as well as a remarkably constant avulsion fracture pattern at anterolateral proximal tibial plateau that now called and referred to "Segond's fracture"[2,3]. Segond's fracture defined as an ALL avulsion those results in a bone fragment of the lateral proximal tibial plateau. This "some years later" described structure was called the "anterolateral ligament" in 2007, by Vieira et al.[4]. This topic has been the subject of many recent studies although it is still highly disputed with each other in the it's anatomic[5,6]. Claes et al.[5] published their descriptive anatomical results with reference to this structure as an important stabilizer of knee rotation, followed by various other studies on the detailed anatomy, epidemiology, biomechanics and clinical relevance of ALL[7-10]. Nowadays, it has been reported that the ALL is an anterior knee joint stabilizer that works to prevent anterolateral subluxation and anterior subluxation at certain flexion angles in the knee[11].

In spite recent improvements in surgical techniques and understanding of ACL anatomy, however, it has been proposed that the knee normal rotational stability is not fully restored by methods of reconstructive for ACL tears[12,13]. Because of the fact that there is a pathognomonic radiological sign for ACL injuries, on the other hand according to Mohtadi et al.[14] who, suggested an incidence of pivot shifts after reconstruction of ACL with either hamstring (single- and double-bundle) or patellar tendon graft, this high incidence of postoperative rotational instabilities was considered to investigate. Therefore, due to mentioned abnormal biomechanics, in the past few years, surgeons have more focus on anterolateral structures, so that the ALL of the knee has been investigated with regard to its anatomy and biomechanics[5,15,16]. Although several studies have been reported that the ALL is an important anterolateral stabilizer of the knee joint which prevents anterolateral and anterior subluxation at certain flexion angles in the knee, however, some concepts regarding the biomechanical function of the ALL are controversial, which is due to the variability in anatomic descriptions and methodology in biomechanical testing[15,17,18]. Considering the paucity of current literature on the native biomechanics of the ALL of the knee, this review, with this hypothesis that the ALL contributes to the stability of the knee and it can be clearly identified by anatomic dissection, will summarizes the present literature related to history of the ALL, its anatomic variances, imaging modalities, arthroscopic aspects and techniques for a possible anterolateral stabilization of the knee joint, and it tries to provide a review of the biomechanical ALL function with attention to relevant diagnostic and therapeutic strategies, especially its role in the knee joint stability.

Literature search

We conducted a comprehensive review of the English-language literature involved the role of the ALL in the knee joint stability. The electronic databases PUBMED, MEDLINE, and EMBASE were searched up to September 2020. Reference lists of published papers were then also hand-searched in an attempt to identify further studies. The following search protocol was used: anterolateral ligament, anterior lateral ligament, ALL, Segond fracture, biomechanical study, biomechanical function, history of ALL, imaging modalities, ALL reconstruction and knee joint stabilization. The search terms were then entered onto Google Scholar, to ensure that articles were not missed. Inclusion criteria included English, human corpse study, and biomechanical or biomechanical studies of ALL knee function. Papers were excluded if they were case reports or had a patient cohort, were not written in English, lacked documentation, non-human studies, narrative reviews, studies without clinical outcomes data, systematic reviews that did not pool data or perform a meta-analysis, and technique articles without outcomes. We then obtained full manuscripts for those studies that met the inclusion criteria.

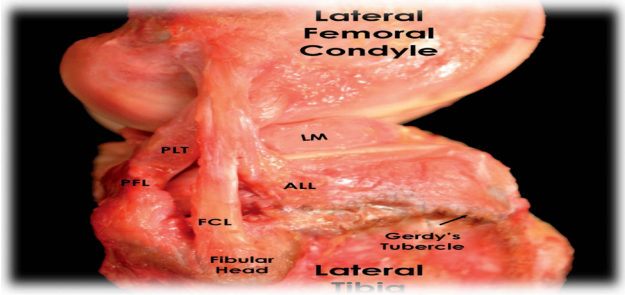
Anatomy of the ALL and historical aspects

The ALL was mentioned as a "pearly, resistant, fibrous band" for First time by Segond in 1879[2]. Then, Last in 1948[19] named this structure as short lateral ligament (SLL). Since the 1970s, the anatomic structure known as the ALL nowadays has been described various times in anatomic dissection studies[1]. Although, Johnson coined the term lateral capsular ligament[20], however, the term mid-third lateral capsular ligament, was first introduced by Hughston in 1976[21]. Fulkerson and Gosling, in 1980 while trying to describe the structures of the lateral retinaculum of the knee, noted an anterior slip of the lateral capsular ligament[22]. In 1986, Terry et al.[23] recognized the structure as being a capsulo-osseous layer of the iliotibial tract, which called it 'some sort of anterolateral ligament' meaning a combination of superficial and deep part of the iliotibial tract. The structure anterior oblique band named by Irvine et al.[24], in 1987 and it as well as correlated Segond's fracture to it. Then, Vieira et al.[4], in 2007 used the term "anterolateral ligament" (ALL) of

the knee and described the structure as being part of the iliotibial tract. Vincent et al.[25], in 2012, performed complete knee arthroplasty, citing ALL as a compatible structure attached to the lateral condyle of the femur, lateral meniscus, and lateral tibia. Claes et al.[5], in 2013, presented more detailed anatomical description[5,26].

There are several reports on investigating the extraarticular ligamentous structures in and around the knee. Although the ALL has been studied in a numerous researches, however, consensus regarding the exact structure of this ligament remains unclear[5,27,28]. It has characteristic ligament pattern of dense and well-organized collagen fibers and peripheral nerve structure with mechanoreceptors[7,25,29]. As can be seen in **figure 1** the proximal origin is close to the lateral epicondyle of the femur[27,30,31]. Tibial attachment is approximately 24.7 mm posterior to the center of Gerdy's tubercle and about 26.1 mm anterior to the fibula head[32]. The exact femoral origin is controversial, already reported as anterior-distal or posterior-proximal to the lateral collateral ligament, with blending fibers between these ligaments[5,7]. The current finding based on recent cadaveric dissection study is that the origin is located posterior and proximal to the lateral collateral ligament[10].

Figure 1: Anatomy of the anterolateral ligament adapted from Kraeutler et al.[32].



Fibular collateral ligament (FCL); Lateral meniscus (LM); Popliteo-fibular ligament (PFL); Popliteus tendon (PLT)

Imaging

Several studies reported that magnetic resonance imaging (MRI) and ultrasound were able to identify the structure of ALL[33,34]. Previous studies have demonstrated the identification of the ALL with ultrasound as a hyperechogenic and fibrillar structure, with a 97 to 100% detection rate[35-37]. The structure can be identified in MRI as a thin, linear, regular and low-signal band[38,39]. Meniscal and tibial insertions are the most clearly identified parts, and the femoral attachment, due to partial volume effect near the lateral epicondyle, is related to most MRI variations[7,33,40]. Although MRI evaluation of the ALL is already well described, however, the imaging findings of surgical techniques for the anterolateral complex of the knee have not been described in details by literatures[41-43]. Sonographic visualization of the ALL was first introduced by Cianca et al.[35] and Cavaignac et al.[36] using a GE P6 musculoskeletal ultrasound machine, which used ultrasonography, obtaining an ALL visualization rate of 100%. Recent studies reported that most of the ALL segments could be identified, making ultrasonography a useful examination for diagnosing the injuries of ALL[37]. Also it has been shown an ALL visualization rate of 75%, then observed that ultrasonography was unable to reliably identify the femoral and tibial origins[44]. An arthroscopic technique was described by Zein[45] also by Sonnery-Cottet et al.[46] that identifies the ALL and showed that the meniscotibial insertion of the ALL could be seen and touched with a probe on the lateral meniscus. Rezansoff et al.[47], using fluoroscopy, described the ALL femoral origin as overlying the posterior femoral cortical line, between the Blumensaat line and a line from the posterior condylar articular edge parallel to the Blumensaat line. These methods may be used more to control ALL regeneration during surgery[10,26].

Surgical considerations

Anterolateral extra-articular fixation techniques are much older than our current finding of ALL and its biomechanical function[1]. The finding behind extra-articular anterolateral reconstructions resides on the ALL biomechanics, resisting pivotshift phenomenon in the ACL-deficient knee[48,49]. It is suggested that reconstructions of extra-articular anterolateral performed in a context of ACL reconstruction augmentation procedure improves postoperative clinical result regarding residual pivot-shifting and anterolateral instability[50]. Drews et al.[51] hypothesized that ALL reconstruction resulted in a reduction of internal rotational laxity and to a load sharing with the ACL graft. They also reported that ALL reconstruction leads to an increase in ACL graft tension during continuous passive motion and with additional internal rotation moment. Combined ACL with ALL reconstructions have indicated good results, as measured by objective and subjective scores[52,53]. The results of laboratory study by investigated the effects of combined ACL with ALL reconstruction on rotatory instability of cadaveric knees have demonstrated that the combined procedures improved internal tibial rotation at low flexion angles (0-30°)[54]. Since reconstructions of ALL are majorly conducted combined with ACL reconstruction; therefore, it is suggested to achieve understanding with post-surgical ACL imaging, as it will be, in many cases, analyzed with the extra-articular procedure simultaneously[50]. As a result in those cases an anterolateral rotational stabilization or reconstruction of the ALL in combination with a reconstruction of the ACL should be noted to avoid treatment failures in terms of post-operative rotational stability[1]. There are many known techniques for anterolateral stabilization, which is a stabilizer of the internal tibial rotation or rotational stabilization of the knee joint, that some of them are presented in **table I**.

Table I: Some of the known procedures for anterolateral stabilization of the knee joint (adapted from[1,55]).

Author (s)	Year	Technique	Ref.
Ibrahim et al.	2017	Single bundle- Gracilis	(56)
Mogos et al.	2017	Double bundle-Gracilis	(57)
Sonnery-Cottet et al.	2015	Double bundle-Gracilis	(53)
Claes et al.	2013	Minimally invasive tenodesis with a gracilis graft with anatomical anchor fixation over the lateral femoral epicondyle and the anterolateral proximal tibial plateau.	(5)
Marcacci et al.	2009	Single bundle- semitendinosus tendon and Gracilis	(58)
Zaffagnini et al.	2006	Single bundle- semitendinosus tendon and Gracilis	(59)
Patella et al.	2002	"One-loop plasty": Iliotibial band (ITB) graft looped below the capsule through a femoral tunnel and proximally fixed with a staple and distally in a tibial cortico-cancellous groove.	(60)
Andrews and Sanders	1983	ITB is split into two isometric bundles distally, sutured up against the distal femur and tied medially creating a "neo" Ligament.	(61)
Ellison	1979	Distal ITB transfer	(62)
Losee et al.	1978	"Sling and reef" procedure	(63)
Galway et al.	1972	ITB graft with anchor fixation to the proximal tibia	(64)
Slocum and Larson	1968	Distal flap of the pes anserine conjoined tendons	(65)
Lemaire	1967	ITB is prepared femoral with preservation of the tibial insertion and then shuttled under the FCL and pulled through a lateral femoral tunnel	(66)

Table II: Characteristics of biomechanical, imaging, mixed cadaveric and clinical studies of ALL (adapted from[11,27,73])

Author (s)	Year	Conclusion	Ref.
		Biomechanical	
Drews et al.	2017	ALL does not function under passive motion and with no influence on tibial rotation.	(74)
Inderhaug et al.	2017	Significant increase in anterior tibial translation and internal tibial rotation with additional section of ALL to ACL.	(17)
Bonanzinga et al.	2016	No further increase in anterior tibial translation was found after ALL section. Significant increase of internal tibial rotation at 30° and 90° flexion only after additional ALL sectioning. ACL- and ALL-sectioned knees have significantly more acceleration of pivot shift than that in intact knees.	(15)
Spencer et al.	2015	ALL section had no significant impact on anterior tibial translation in ACL-deficient knees. ALL section had significant impact only on early pivot shift in ACL-deficient knees.	(75)
Parsons et al.	2015	ALL is important stabilizer of internal rotation at flexion angles greater than 35°. The ACL is the primary resister during anterior draw at all flexion angles and during internal rotation at flexion angles less than 35°.	(70)
Monaco et al.	2012	5.5° increase of internal tibial rotation at 30° flexion after additional ALL sectioning. No significant increase of anterior tibial translation after additional ALL sectioning.	(76)
		Imaging	
Gaunder et al.	2018	Patients with ACL injury on MRI do not have a tear of the ALL. The interobserver reliability of surgeons and radiologists is fair. musculoskeletal radiologists have higher intraobserver reliability when looking for an ALL tear.	(77)
Marwan et al	2018	ALL injury is highly prevalent among dislocated knees. Most of the injuries are of a high grade and involve the proximal, suprameniscal fibers of the ligament.	(78)
McDonald et al.	2017	Knees with ALL injuries may be in the "resting pivoted position" in almost 30% of cases, possibly requiring surgical treatment. This, however, needs further assessment because an ALL injury is not an independent predictor of anterior tibial subluxation.	(79)
Hartigan et al.	2016	ALL tears are currently unable to be reliably identified as torn or intact on standard 1.5-T MRI sequences. Proper imaging sequences are of crucial importance to reliably follow these tears to determine their clinical significance.	(80)
		Cadaveric	
Dodds et al.	2014	The ALL may control pivot shift and contribute to rotatory stability and associated with Segond fracture	(8)
Helito et al.	2013	The ALL attaches anteriorly and distally to the LCL. It has 2 distal attachments, one at the lateral meniscus and another between the Gerdy tubercle and the fibular head.	(9)
Vieira et al.	2007	The ALL is a well-defined functional and anatomic structure.	(4)
		Clinical	
Campos et al.	2001	The fibers of the anterior oblique band contribute to the pathogenesis of the Segond fracture and therefore have a stabilizing effect on the knee.	(81)
Irvine et al.	1987	The Segond fracture may occur by avulsion of the anterior oblique band.	(24)
Hughston et al.	1976	Anterolateral rotatory instability is primarily the result of a midthird lateral capsular ligament tear and can be accentuated by an associated ACL tear.	(21)

Stability of the knee joint

Biomechanical researchers suggest that ALL reconstruction may plays an important role in knee stability; thus it is essential for surgeons to understand the structure and function of this ligament. Biomechanical reports have indicated that the ALL contributes to the overall rotational stability of the knee. Overall, biomechanical data are required in several aspects of anterior reconstruction, including insertion, fixed angle, and initial graft tension[53]. It has been demonstrated that ALL mainly acts as an additional rotational stabilizer of the knee. In other words, it mainly controls internal tibial rotation, so is involved in the pivot shift phenomenon mechanism[1]. Primary biomechanical trials found a behavior near to isometricity between 0o to 60o flexion with a tightening of the ALL in internal rotation and relaxation in external rotation of the tibia[8]. Since the ALL length increases with internal tibial rotation, so the ALL is non-isometric, assuming an mean length of 35-40 mm and a thickness of 1-3 mm, and it is under tension during internal tibial rotation at 30° of flexion[10,30]. Dodds et al.[8] noted this stabilizing effect could not be seen in extension though, therefore, speculations about the influence of the ALL on the pivot shift were undertaken, due to its

rotational control. Also, a systematic review indicated a high correlation between clinical results and pivot shift grades[67]. Because of its connecting fibers to the lateral meniscus it was also stated that there may be a stabilizing effect of this structure, which preventing it from posterior dislocation[9,25]. In a biomechanical trial reported that doing an isolated ACL reconstruction could not restore anterior translation stability under a simulated pivot shift in comparison with the intact knee[68]. Additional ALL reconstruction with fixation at 75° and 88 N could decrease anterior tibial translation at all flexion angles[8,26,69-72]. Characteristics of biomechanical, reconstruction, imaging identification, cadaveric, structural and clinical studies of Anterolateral Ligament are summarized in **Table II**.

Conclusion

Several studies show that the ALL passively, is important for knee stability. Briefly, ALL is a capsular ligament located in the anterior part of the knee, in the deepest layer of lateral structures. Biomechanical reports have indicated that the ALL contributes to the overall rotational stability of the knee. Overall, biomechanical data are required in several aspects of anterior reconstruction, including insertion, fixed angle, and initial graft tension. It has been demonstrated that ALL mainly acts as an additional rotational stabilizer of the knee. In other words, it mainly controls internal tibial rotation, so is involved in the pivot shift phenomenon mechanism. Biomechanical researchers suggest that ALL reconstruction may plays an important role in stability of the knee; thus it is necessary for surgeons to understand the structure and function of this ligament.

Conflict of interests

The authors have no conflict of interest.

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