The Anterior Oblique Ligament description in the knee anteromedial compartment

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Abstract

Purpose: To describe a ligamentous structure in the anteromedial region of the knee identified in a series of anatomical dissections of cadaveric specimens.

Methods: Sixteen cadaveric knees were dissected to study the medial compartment. Exclusion criteria were signs of trauma, previous surgery, signs of osteoarthritis and poor preservation state. The main structures of this region were identified during medial dissection. After releasing the superficial medial collateral ligament (sMCL) of the tibia, the Anterior Oblique Ligament (AOL), was isolated. The morphology of the structure and its relationship with known anatomical parameters were determined. For the statistical analysis, the means and standard deviations were calculated for continuous variables. A 95% confidence intervals was defined as significant. Student's t-tests were used for continuous variables.

Results: After dissection a distinct ligamentous structure (AOL) was found in the medial region of the knee. This structure was found in 100% of the cases, was located extracapsularly and originated in the anterior aspect of the medial epicondyle, running obliquely toward the tibia. When crossing the joint, the ligament presented a fan-shaped opening, exhibiting a larger area at the tibial insertion. The AOL had a mean thickness of 6.83 ± 1.34 mm at its femoral origin and 13.06 ± 1.91 at its tibial insertion. It had a significantly ($p = 0.0009$) longer mean length with the knee at 90° of flexion (33.82 ± 9.50 mm) than with the knee in total extension (26.56 ± 9.48 mm), indicating that the ligament is tensioned in flexion.

Conclusion: A structure was identified in the anteromedial compartment of the knee with a ligamentous appearance originating in the medial femoral epicondyle and with tibial insertion anterior to the sMCL.

Clinical relevance: This study demonstrates the anatomy of a new medial structure of the knee. As a result, there will be a better understanding of the stability of the knee.

Introduction

Anteromedial rotatory instability (AMRI) of the knee was first described by Slocum and Larson in 1968¹. This is a valgus movement associated with external rotation of the tibia relative to the femur. It occurs when the medial tibial plateau subluxates anteriorly relative to the adjacent femoral condyle². One of the main mechanisms of anterior cruciate ligament (ACL) rupture is the association of valgus with discrete flexion and external rotation of the tibia relative to the femur^{3,4}, which increases the frequency of the association of ACL injury and medial compartment injury, described in approximately 24% of the total cases of ACL injury⁵.

The posteromedial corner of the knee, represented by the posterior horn of the medial meniscus, posterior oblique ligament (POL), an arm of the semimembranosus, meniscotibial ligaments and the popliteal oblique ligament, is an important restrictor of AMRI over the entire range of motion of the knee^{2,6}. However, the main restrictor of external tibial rotation in relation to the femur in the medial compartment is the superficial medial collateral ligament (sMCL)⁷. There is an “empty” space in the

region bound by the following limits: anterior border of the sMCL, medial border of the patellar ligament and distal border of the medial patellar retinaculum. In the literature, this seems to be a rarely explored area because several anatomical studies of the medial compartment of the knee do not mention any important structure in this space^{8,9,10,11,12,13}. Additionally, these studies do not mention the structure examined in the present study, except for the description by Slocum and Larson in 1968 citing an anterior ligamentous capsular portion¹.

The objective of this study is to describe a ligamentous structure in the anteromedial region of the knee identified in a series of detailed anatomical dissections of cadaveric specimens. The hypothesis of this study was that there is a ligament structure in the anteromedial region of the knee.

Methods

Between April and July 2020, 16 knees derived from transfemoral amputations performed exclusively for vascular reasons and with no signs or indications of trauma were dissected. The following exclusion criteria were applied: signs of trauma, previous surgery, macroscopic signs of osteoarthritis and poor preservation state; thus, 15 knees were studied. The knees were stored in 10% formaldehyde solution and refrigerated at 5.3 °C. The dissections were performed 2 to 21 days after amputation. The study was approved by the institution's research ethics committee.

For the statistical analysis, the means and standard deviations were calculated for continuous variables. A 95% confidence interval was defined as significant. Student's t-tests were used for continuous variables.

Dissection technique

The procedure was initiated with an extended hockey stick-shaped skin incision, and the femoral diaphysis, medial epicondyle and tibial diaphysis were used as reference points. Delicate opening of the subcutaneous tissue was performed until reaching the fascia of the vastus medialis muscle, which was not dissected. The tendon of the adductor longus muscle and the direct arm of the semimembranosus muscle were identified. A dense fascia was identified over the bone structures that was firmly adhered to the underlying structures, which was termed the medial bone fascia. After its longitudinal opening, the medial bone fascia was carefully detached anteriorly and posteriorly from the deep structures. The POL was identified, and based on the location of the medial epicondyle, the sMCL and the medial patellar retinaculum were located. Next, the tibial sMCL was released, and with the knee at 60° of flexion and the tibia slightly externally rotated, the structure examined in the present study was isolated, originating slightly anterior and distal to the medial epicondyle and inserted at 1 cm below the joint, anterior to the anterior border of the sMCL. (Figure 1) At this time, measurements were performed, relating the location of the studied structure to anatomical parameters (size in extension, size in 45° of flexion, size in 90° of flexion, thickness at the femoral insertion, thickness at the joint, thickness at the tibial insertion, distance from the center of the distal insertion to the anterior border of the sMCL, division of the distance between

the anterior border of the sMCL and the medial border of the patellar ligament into thirds and verification of the ligament into which the structure was inserted). As the entire ligament was isolated, it was noted that the ligament was superficial to the articular capsule and was intact after separation of the anterior oblique ligament (AOL).

The specimens were photographed using a 12-megapixel digital camera and measured using a digital caliper with 0.01-mm precision.

All specimens were identified according to sex, age, dissected side, date of amputation and date of dissection. The data collected were analyzed and interpreted using descriptive statistics.

Results

Qualitative description of the anterior oblique ligament

Of all 16 knees, only one was discarded. It was amputated due to vascular injury and was in an advanced state of decomposition. After dissection, a distinct ligament structure was found in all specimens in the medial region of the knee, between the femur and the tibia, with an oblique orientation. This structure was found in 100% of the specimens, located extracapsularly and easily distinguished from the articular capsule. In all cases, the origin of the AOL was thick and located directly on the anterior aspect of the medial epicondyle. Its fibers at this portion were slightly deep relative to the anterior border of the sMCL, and in all cases, both origins were confounded (Figure 2).

In all dissected specimens, the ligament ran obliquely toward the tibia. Its posterior and proximal fibers exhibited a close relationship with the anterior border of the sMCL. Upon crossing the joint, the ligament exhibited a fan-shaped opening, which reached its maximum at the tibial insertion. At the point of the joint, the ligament was easily detached from the joint capsule. Dissection was initiated in this region, and in all cases, the ligament was detached from the articular capsule without major difficulties and exhibited extracapsular localization. In its most distal, fan-shaped portion, the tibial insertion presented as a thick capsular insertion. When the distance between the anterior border of the sMCL and the medial border of the patellar ligament was divided into thirds, the distal insertion of the AOL always occurred in the posterior third.

Quantitative description of the anterior oblique ligament

The mean lengths of the AOL measured in neutral rotation and at 90° of flexion were 33.82 (± 9.50) mm and 26.56 (± 9.48) mm in extension, illustrating some tensioning of the ligament during midflexion. This increase in length during flexion was significant ($p = 0.0009$). During manipulation of the knee joint, we observed a maximal tension of the AOL during combined flexion and external rotation of the tibia. The mean width of the femoral origin was 6.83 (± 1.34) mm. The AOL narrowed near the level of the joint line, with an average width of 8.06 (± 1.86) mm. The AOL then broadened further distally, inserting into the proximal tibia with a width of 13.06 (± 1.91) mm.

The distal insertion of the AOL was located anterior to the anterior border of the sMCL. The mean distance from this border to the center of the tibial insertion of the ligament was 9.11 (± 1.91) mm. (Table 1)

Discussion

The main finding of this study was that a ligamentous structure, the AOL, in the medial region of the knee was found in all dissections. During cadaveric dissections performed to train fellows specializing in knee surgery and sports traumatology between March and April 2020, the presence of a structure with a ligamentous aspect was observed in the anteromedial region of the knee. This structure was found in all cases, and the idea of performing 15 dissections to better study this structure arose from this observation. After the initial cases were examined, it was also decided to study the specimens radiologically and histologically, and these investigations are in the final phase. This new structure is being identified in nuclear magnetic resonance sections, and its histological study is compatible with a ligamentous structure. Lastly, a biomechanical study is underway and currently in the early stage to evaluate the functional importance of this structure. With the understanding of AMRI and the development of the quadrant theory (described below), a better understanding the anteromedial region of the knee, which has rarely been described in the literature, is needed.

Why was this structure not previously described? One possible reason is that Warren and Marshall's 1979 description¹³ of the medial layers was used for a long time. Another reason is the location of the AOL, which is only identifiable after distal release of the sMCL. The properties of the sMCL insertion suggest that no structure is present between the sMCL and the patellar tendon. Using the present technique (disinsertion of the distal sMCL), the ligament was identified in all dissections performed (Figure 3). Another important finding regarding the existence of the AOL is the result of the ongoing histological study, which defined the isolated tissue as a ligamentous structure in specimens sent for histological evaluation.

The ACL trauma mechanism leads to known associated injuries, such as meniscal and collateral ligament injuries. sMCL injury is the most common among these associated ligament injuries and its incidence varies in the literature from 20% to 44%¹⁴.

In 2008, in an in vitro biomechanical study, Griffith et al.¹⁵ concluded that the sMCL is the ligament that most resists valgus and external tibial rotation in various degrees of joint flexion. In the same study, the POL was described as the ligament that most resisted internal rotation, especially at angles closer to total extension.

In a biomechanical study using cadavers in 2006, Robinson et al.⁸ suggested that the sMCL would be the main restrictor in the medial compartment of external rotation of the tibia. In addition, they suggested that the deep MCL would act secondarily, especially at angles beyond 30° of flexion. In total

extension, when sectioning the sMCL alone, the authors describe an increase of 3° in external rotation. At 90° of flexion, an increase of 9° occurs in the same rotation.

In 2016, Schafer et al.⁵ demonstrated the influence of the MCL and POL in pivot. The main finding regarding the POL is that, in the pivot-shift maneuver, it bears up to 47% of the original load carried by the ACL, resisting internal rotation. This finding demonstrates that the ACL, sMCL and POL, acting in coordination, resist the combination of movements of the pivot maneuver differently according to the degree of knee flexion. At 5°, the ACL acts practically alone, and the other two ligaments are secondary restrictors. At 15°, the ACL is still the most important ligament, but the sMCL and POL play a greater role. At 30°, the ACL and the POL lose importance, and the greatest restrictor becomes the sMCL.

ACL injury associated with capsular-ligamentous injuries of the medial portion of the knee is very frequent, and when medial laxity persists, the load carried by the ACL graft increases^{9,16,17}. This residual medial instability may result in failure of ACL reconstruction^{18,19,20}. AMRI certainly participates in the causes of ACL failure, generated by medial compartment failure. In 2020, Wierer et al.¹⁰ showed that the sMCL is the most important restrictor of anterior rotational instability. Certainly, AMRI has great importance if analyzed as a cause of ACL reconstruction failure, given that the main trauma mechanism occurs by the combination of valgus with external tibial rotation.

After identification of the structure, a histological and radiological MRI study was initiated (AOL visualized in x examined specimens). The authors studied the anatomy and biomechanics of the region^{5,8,9,10,16,17,18,19,21,22} and developed a reasoning termed the Theory of Tibial Quadrants, which facilitates the understanding of circumferential joint structures and rotational control (Figure 4). The tibial surface is divided into an anterior and posterior portion through a band that connects the femoral transepicondylar plane, the origin or near origin of the important ligaments that travel toward the tibia. In addition, the transepicondylar axis is closest to the center of rotation (flexion-extension) of the knee²³. The anterior and posterior hemispheres are thus presented. Using a line perpendicular to the articular transverse axis, the tibia can be divided into medial and lateral regions, totaling four quadrants. All ligament fibers found on the transepicondylar band in the medial region will exclusively provide stability in valgus (sMCL). Those found medially, anterior to the band, will be restricted to valgus and external rotation (anterior portion of the sMCL and AOL). Ligament fibers posterior to the band in the medial compartment will control valgus and internal tibial rotation (posterior portion of the sMCL, posterior horn of the meniscus, POL, arm of the semimembranosus, meniscotibial ligaments and the popliteal oblique ligament). All ligament fibers found on the transepicondylar band, on the lateral side of the tibia, exclusively control varus (lateral collateral ligament). Those found laterally and anterior to this band will control varus and internal tibial rotation (iliotibial tract and anterolateral ligament). Ligament fibers posterior to the band, in the lateral compartment, will control varus and external tibial rotation (popliteus tendon, popliteal-fibular ligament and posterior horn of the lateral meniscus). The diagonally opposite quadrants have a complementary function in rotational control. Understanding the importance of joint circumference in this control will certainly allow a better understanding of the need for peripheral

reconstructions complementary to the center pivot. It is evident that this knowledge will only be supported through biomechanical studies, which are already underway by the authors of the present study.

The study of noncontact ACL injury mechanisms is found in the literature in various forms, such as video analyses, interviews with patients with a history of injury, cadaveric studies, mathematical models and even measurements and estimates in near-injury situations²⁴. The most common mechanism is the association of valgus, with slight flexion, and external rotation of the tibia, which is well demonstrated in video studies of athletes^{3,24}. Similar to the great importance of studying the anterolateral ligament, the AOL deserves attention because it is located in the anteromedial quadrant of the tibia and restricts the external rotation of the tibia associated with valgus, the most frequent movement combination that causes ACL injury.

The strengths of the present study include the identification of a ligamentous structure not previously described, its visualization in all specimens studied and a detailed dissection described for its visualization. The limitations include the advanced age of the patients who provided the specimens and, in particular, the lack of biomechanical studies to assess whether this structure has functional importance.

Conclusions

A structure located in the anteromedial compartment of the knee and exhibiting a ligamentous appearance was identified. It was located deep to the sMCL, had an origin at the medial femoral epicondyle and a tibial insertion between the sMCL and the patellar tendon and was more evident with the knee at 60° of flexion and the tibia externally rotated. This structure (AOL) was found in all dissections performed.

Tables

Table 1. Measured in millimeters of the studied specimens

Specimen	1	2	3	4	5	6	7	8	9*	10	11	12	13	14	15	16	Mean
Thickness at the Tibial Insertion	12.74	13.87	12.24	11.30	13.20	12.47	17.79	13.65	X	13.67	12.24	13.65	8.62	14.39	12.54	13.56	13.06
																	±1.91
Thickness at the joint	9.81	8.98	8.57	7.02	7.94	9.97	11.28	8.84	X	9.84	6.39	6.87	5.01	8.43	4.77	7.12	8.06
																	±1.86
Thickness at the Femoral Insertion	7.45	7.83	6.21	5.82	6.40	8.48	6.90	6.53	X	6.48	5.92	10.05	5.97	6.86	4.15	7.40	6.83
																	±1.34
Length in 90° of flexion	28.96	31.19	31.86	30.65	28.12	27.14	34.36	28.92	X	35.35	44.70	42.38	35.88	44.45	32.33	31.15	33.92
																	±9.50
Length in 45° of flexion	24.76	29.78	29.59	26.19	25.93	24.98	31.27	26.42	X	31.98	41.36	40.07	31.26	41.57	29.35	30.52	31.00
																	±5.69
Length in extension	21.50	27.11	26.91	22.57	20.87	19.90	21.27	20.23	X	26.77	33.40	36.42	29.28	38.22	26.39	27.68	26.56
																	±9.48
Distance from the center of the distal insertion to the anterior border of the sMCL	9.43	10.15	8.35	9.75	11.23	10.43	9.96	11.10	X	10.48	8.03	10.98	6.25	6.22	5.24	9.17	9.11
																	±1.91

*discarded specimen

sMCL - superficial medial collateral ligament

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Declarations

Competing interests: The authors declare no competing interests.

Figures

Figure 1

During dissection the sMCL is detached distally and a slight external rotation of the knee is performed in 60° flexion. At that moment, the AOL is noted, originating anterior and distal to the medial epicondyle and inserting 1 cm below the joint.

Figure 2

AOL is an extracapsular structure easily distinguishable from the joint capsule. Its insertion is directly or anterior to the medial epicondyle. After crossing the joint the structure opens in a fan shape up to its maximum width at tibial insertion.

Figure 3

The AOL is located in the anteromedial region of the knee. Its insertion occurs close to the sMCL and after crossing the joint it opens in a fan shape until it inserts into the tibia.

Figure 4

Theory of Tibial Quadrants: The tibial surface is divided into anterior and posterior by a band that connects the transepicondylar plane of the femur, the origin of the important ligaments that are inserted in the tibia. With another perpendicular line we can divide the tibia into four quadrants. All ligaments contained in the medial region of the transepicondylar band are responsible exclusively for valgus restriction. Those found medially, anterior to the band are responsible for restricting the valgus and external rotation. Those found medially, posterior to the band are responsible for the restriction of the valgus and internal rotation. All ligaments contained in the lateral region of the transepicondylar band are responsible exclusively for the varus restriction. Those found laterally, anterior to the band will control the varus and the internal rotation. Finally, those found laterally, posterior the band are responsible for controlling the varus and external rotation.