Anatomical Study and Re-Analysis of the Nomenclature of the Anterolateral Complex of the Knee Focusing on the Distal Iliotibial Band

Identification and description of the Condylar Strap

ABSTRACT **Background:** The capsulo-osseous layer, short lateral ligament, mid-third lateral capsular ligament, lateral capsular ligament and anterolateral ligament are terms that have been used interchangeably to describe what is probably the same structure. This has resulted in confusion regarding the anatomy and function of the anterolateral complex of the knee and its relation to the distal iliotibial band. **Purpose:** To characterize the macroscopic anatomy of the anterolateral complex of the knee, in particular the femoral condylar attachment of the distal iliotibial band (ITB). We identified a specific and consistent anatomical structure that was not accurately described previously, connects the deep surface of the ITB to the condylar area, and is distinct from the anterolateral ligament, the capsulo-osseous layer and the Kaplan fibers. **Study Design:** Descriptive laboratory study. **Methods:** Sixteen fresh-frozen human cadaveric knees were used to study the anterolateral complex of the knee. Standardized dissections were performed that included a qualitative and quantitative assessment of the anatomy through both anterior (n=5) and posterior (n=11) approaches. **Results:** The femoral condylar attachment of the distal ITB was not reliably identified by anterior dissection but was in all posterior dissections. A distinct anatomical structure, hereafter termed condylar strap (CS), was identified between the femur and the lateral gastrocnemius on one side and the deep surface of the ITB on the other, in all posteriorly dissected specimens. The structure had a mean thickness of 0.88 mm, and its femoral insertion was located between the distal Kaplan fibers and the epicondyle. The proximal femoral attachment of the structure had a mean width of 15.82 mm and the width of the distal insertion of the structure on the ITB was 13.27 mm. The mean length of the structure was 26.33 mm on its distal border and 21.88 mm on its proximal border. Qualitative evaluation of behavior in internal rotation revealed that this anatomical structure became tensioned and created a tenodesis effect on the ITB.

Conclusions: There is a consistent structure that attaches to the deep ITB and the femoral epicondylar area. The orientation of fibers suggest that it may have a role in anterolateral knee stability.

Clinical Relevance: This new anatomical description may help surgeons to optimize technical aspects of lateral extra-articular procedures in cases of anterolateral knee laxity.

Keywords: distal iliotibial band, distal iliotibial tract, anterolateral ligament, capsulo-osseous layer, Lemaire procedure.

What is known about the subject: There is a great deal of confusion in the literature regarding the anatomy of the anterolateral complex of the knee and its association with the distal ITB. This lack of consistency in nomenclature has led to confusion in anatomical and biomechanical studies where the use of non- standardised dissection protocols has resulted in different interpretations about anatomy and function. Furthermore, one of the limitations of previous anatomical studies is that they have typically used a single, anterior, surgical approach. This restriction to one type of approach limits the overall perspective that can be gained, risks inadvertently created tissue planes around tightly confluent structures and is subject to interpretation bias.

What this study adds to existing knowledge: The main findings of this study are that the anterior and posterior approaches provide very different perspectives of the anatomy of the distal ITB. The anterior approach (which has typically been used in isolation in the previous literature), failed to reliably identify the condylar attachment of the distal ITB. However, the posterior approach demonstrates that there is a consistent and distinct anatomical structure that attaches the deep surface of the ITB to the lateral part of the distal femur and the lateral gastrocnemius tendon. This structure has been termed the condylar strap (CS).

The qualitative evaluation of behavior in internal rotation revealed that the CS was in tension when the tibia was put in internal rotation. This suggests a potential role for this part of the distal ITB in the control of anterolateral knee laxity.

Introduction

During the last five decades, the Lemaire procedure has been performed in conjunction with intra-articular anterior cruciate ligament (ACL) reconstruction in order to control anterolateral laxity of the knee.[14] In the original technique, an 18 cm long by 1 cm wide strip of the ITB that remained attached to Gerdy's tubercle was harvested. The graft was passed deep to the fibular collateral ligament (FCL), then through a periosteal bridge and then through a femoral tunnel located proximal to the lateral femoral epicondyle. Then the graft came back again under the FCL to be sutured to itself or fixed in a tibial tunnel. The graft was fixed in external rotation, between 30° and 45° of flexion. This technique, and other types of lateral extra-articular procedures, including anterolateral ligament (ALL) reconstruction, have shown good results with respect to abolishing the pivot shift and reducing ACL graft rupture rates.[1,5,10,16,20] Despite these clinical results, the literature demonstrates that there is still a lack of consensus concerning the precise anatomy and biomechanics of the anterolateral structures of the knee.

Vincent et al[24] reported that several terms including capsulo-osseous layer, short lateral ligament, mid-third lateral capsular ligament, lateral capsular ligament, lateral femoro-tibial ligament,[17] ligamentum tracto-tibiale[7] and anterolateral ligament[2,8] have been used interchangeably in the literature to describe what is probably the same structure. Porrino et al highlighted that previous reports are also confusing with respect to the relationship of this structure with the iliotibial band.[18] This lack of consistency in nomenclature has led to confusion in anatomical and biomechanical studies where the use of non-standardised dissection protocols has resulted in different interpretations about anatomy and function.[2,4,12] Furthermore, one of the limitations of previous anatomical studies is that they have typically used a single, anterior, surgical approach.[9,13] This restriction to one type of approach limits the overall perspective that can be gained and therefore risks interpretation bias and also the inadvertent creation of artificial tissue planes around tightly confluent structures.

The aim of this study was to characterize the macroscopic anatomy of the anterolateral complex of the knee, in particular the femoral condylar attachment of the distal ITB, by using two separate standardized dissection protocols. In preliminary dissections, we had found that a specific and consistent anatomical structure which was not accurately described previously, connects the deep surface of the ITB to the condylar area, distinct from the anterolateral ligament, the capsulo-osseous layer and the Kaplan fibers. We hypothesized that this structure, which we called the "condylar strap", would be consistently found in human knee specimens.

Historical description of the iliotibial band

The history of description of the iliotibial band relies on some landmark papers. Early anatomists described the fascia lata as an important muscle of the lower limb but an accurate description of the distal insertion of the fascia lata was only reported during the last century and some inaccuracies and controversies are still present. Vesalius,[21] within his De Humani Corpori Fabrica, described the fascia lata. He grouped it with other muscles and called it the sixth muscle of the tibia but probably the most thorough and extensive works and reports on the anatomy and functions of the iliotibial band were written in 1843 by Jacques Maissiat.[11] The publication of his monograph was responsible for the widespread adoptions of the eponymous name, the band of Maissiat.[11] In the modern literature, the terms Iliotibial band and Iliotibial tract are commonly used.

In 1958, Kaplan described the iliotibial tract as intimately connected with the intermuscular septum and the linea aspera from the greater trochanter to the supracondylar tubercle of the lateral condyle of the femur.[11] He presented the iliotibial tract as free of bony attachments/connections except at the level of the upper portions of the femoral condyle and also at Gerdy's tubercle. In this landmark article, it was already clear that the ITB made a connection between the area of the lateral epicondyle and Gerdy's tubercle. However, it is interesting to mention that the descriptions of what would later be called the Kaplan fibers[21], as originally reported by Kaplan himself, were quite vague. One of the illustrations in his paper showed a connection between the ITB and the supracondylar area of the femur, oriented from proximal lateral to distal medial (Fig. 1).

Methods

The methodology of the current study comprised two main parts. For both parts, non-paired, fresh-frozen human cadaveric knees without evidence of previous injuries or surgery were used to perform a qualitative and quantitative study. Three authors (X, Y, Z) conducted the dissections together. These were performed in a standardized manner commencing with removal of the skin on the lateral side of the knee in order to create a large rectangular window.

In the first part of the study, five specimens were studied (mean age, 79 years; range, 65-87 years). The technique was performed in accordance with previous descriptions in the literature.[3, 6, 11, 15] A transverse incision was made in the ITB approximately 10 cm proximal to the knee joint. An anterior longitudinal incision of the ITB was done allowing to progressively reflect distally and posteriorly the ITB. As we flipped distally and posteriorly the ITB, we exposed progressively the vastus lateralis muscle and the deeper attachments of the ITB.

In the second part of the study, eleven specimens were studied (mean age, 82 years; range, 71-87 years). In contrast to the previous dissection, the iliotibial band was approached from posterior (Fig. 2 A).

To do so, the space between the biceps and iliotibial band was approached. The biceps muscle was retracted posteriorly allowing excellent visualization of the inter-muscular septum. A Kelly forceps was passed between the distal part of the ITB and the capsular structures. The correct plane was confirmed by the absence of resistance to instrument insertion. Then the Kelly forceps was moved from inferior (just proximal to the Gerdy's tubercle attachment of the ITB) to superior where the instrument was stopped by a robust structure, hereafter referred to as the condylar strap of the iliotibial band, connecting the deep part of the ITB and the femoral epicondylar area (Fig. 2 B).

At this stage of the dissection, an internal rotational force was applied between 30 and 60 degrees of knee flexion and a qualitative assessment of tension in the structure was made by pulling on it with forceps (Fig. 2 C).

Once the structure attaching to the deep part of the ITB and femoral epicondylar area was clearly identified, the next steps were to describe its precise relation to the anatomical structures already described in the literature. Fatty tissue was always encountered distal to the septum. This was excised cautiously. Progressive and careful dissection was used in order to identify the septum and the proximal and distal Kaplan fibers (Fig. 2 D); the terminology of proximal and distal Kaplan fibers was used according to the study of Godin et al.[6]

Only after clear identification of these previously described anatomical structures was the distal attachment of the ITB detached and redirected proximally allowing excellent visualization of the structure and a thorough qualitative assessment. Throughout the dissection, a Vernier caliper, with an accuracy of 0.1 mm was used to define and record the anatomy of this structure and its relationships to known anatomical structures.

The caliper was used to measure the following aspects of the structure: Width of the proximal attachment, thickness (measured one centimeter from the femoral attachment), length of the proximal and the distal border, width of the distal attachment to the ITB. Several distances were measured in order to precisely define the relationship with known anatomical structures of the lateral part of the knee. This included distances between the following: distal Kaplan fibers (proximal, middle and distal) and the proximal attachment of the structure, the lateral epicondyle and the proximal and distal attachment of the structure on the femur, middle of Gerdy's tubercle attachment of the ITB and proximal and distal attachment of the structure on the femur, distal attachment of the structure on the ITB (anterior border and posterior border) and the ITB attachment to Gerdy's tubercle. Finally, to investigate a potential correlation between the size of the structure and the size of the joint, these distances were calculated: width of femoral attachment of distal Kaplan fibers, distance between the epicondyle and the middle of Gerdy's tubercle, and surface of the distal attachment of the ITB on Gerdy‘s tubercle (calculated using the size of anterior, posterior and proximal borders of the attachment to Gerdy's tubercle). The measurements were performed with the knee in extension.

All data were assessed for normality using the Shapiro-Wilks test before analysis. Pearson Correlation coefficients (r) were used to analyze the association between the width of distal Kaplan fibers, the distance between the lateral epicondyle and the middle of Gerdy's tubercle and Gerdy's surface, as independent variables and the different anatomic characteristics of the structure. Statistical significance was set at $P < 0.05$. The statistical analyses were carried out using SPSS 22.0 program for OS X (SPSS, Inc., Chicago, IL, USA).

Results:

In all five anterior dissections, it was not possible to accurately identify the structure that attached to the distal ITB and femoral epicondylar region. In contrast, this structure was easily and reliably identified in all posterior dissections.

Qualitative anatomy

A distinct flat bundle of fibers was identified in all cadaveric specimens. These fibers coursed from proximal, femoral, to distal and deep into the ITB. The femoral attachment was located on an area sited proximal to the epicondyle, just proximal and anterior to the femoral insertion of the lateral gastrocnemius tendon (Fig. 3 A).

At this location, some expansions were noted in all knees. These expansions were extended to the lateral gastrocnemius muscle and plantaris tendons (Fig. 3 B). Due to the consistency and the shape of this structure, it was named the condylar strap (CS) of the ITB.

The distal attachment of the CS was located on the deep surface of the ITB. No direct connection between this structure and Gerdy's tubercle was identified. The superior genicular artery was identified as previously described. This was consistently located proximal to the CS (Fig. 4).

The proximal and the distal Kaplan fibers were consistently found in our study, according to the study of Godin et al.[6] The orientation of the Kaplan fibers was from lateral proximal (on the deep surface of the ITB) to medial distal (on the femur). In all specimens, the qualitative evaluation of behavior in tibial internal rotation revealed that the CS became tensioned and created a "tenodesis effect" on the ITB (See the online Video Supplement for this qualitative evaluation).

In every specimen, the anterolateral ligament could be identified.[2,8] As the purpose of our study was not focused on the ALL, only qualitative evaluation of this ligament was performed. In all specimens, the femoral insertion of the CS was found proximal to the femoral attachment of the ALL. In some cases, the proximal fibers of the ALL were inserted closely to the femoral insertion of the CS.

Quantitative anatomy

In all eleven specimens in which the iliotibial band was approached posteriorly, a clear anatomical structure, the condylar strap, was identified between the femur and the lateral gastrocnemius on one side and the deep surface of the ITB on the other side. A systematic measurement was performed. Descriptive data are presented as mean ± standard deviation (Table 1).

The mean thickness of the CS was 0.88 mm. The proximal attachment of the CS on the femur had a mean width of 15.82 mm and the width of the distal insertion of the CS on the ITB was 13.27 mm. The mean length of the CS was 26.33 mm on its distal border and 21.88 mm on its proximal border.

The femoral insertion of the CS was located between the distal Kaplan fibers (the proximal insertion was located at a mean distance of 8.08 mm from the center of the distal Kaplan fibers) and the epicondyle (the distal end of the CS was a mean of 14.26 mm from the epicondyle). In these specimens, the epicondyle, (with the knee in extension), was located a mean of 47.8 mm from the center of Gerdy's tubercle. In comparison, the distance between the femoral attachment of the CS and the center of Gerdy's tubercle was 63.23 mm and 52.62 mm, on the proximal and the distal end of the CS, respectively. The distance between the distal attachment of the CS to the ITB and the center of Gerdy's tubercle was 40.7 mm on the posterior border and 58.35 mm on the anterior border.

No significant correlations were detected between the width of distal Kaplan fibers and all the different anatomic characteristics of the CS. However, significant correlations were found between the distance from the lateral epicondyle to the middle of Gerdy's tubercle and Gerdy's surface, and three anatomical characteristics of the CS (Table 2).

Discussion:

The main findings of this study are that the anterior[9,13] and posterior approaches provide very different perspectives of the anatomy of the distal ITB and that the posterior dissection reliably demonstrates that there is a distinct anatomical structure, termed the condylar strap (CS), that attaches the deep surface of the ITB to the lateral part of the distal femur and the lateral gastrocnemius tendon. The qualitative "biomechanical" evaluation revealed that the CS became tensioned and created a "tenodesis effect" on the ITB. To the knowledge of the authors, this structure has not previously been described in this way and this finding is likely attributable to the use of a posterior approach.

In contrast to the findings of the current study, Terry, et al.[21] in 1986, described a capsulo-osseous layer, localized under the deep layer of the ITB. The authors stated that "Posteriorly, the capsulo-osseous layer forms a superficial arcuate whose proximal origin is continuous with fascia covering the plantaris and lateral gastrocnemius and whose distal tibial insertion is just posterior to Gerdy's tubercle on the lateral tibial tuberosity." In the current study, the CS that was identified was attached to the lateral condyle and had some expansions on the lateral gastrocnemius. Therefore, it is probably the case that the same anatomical structure is described in both studies, at least with respect to the proximal attachment. However, in the current study a direct attachment to the tibia was not identified. Instead, the fibers were attached to the deep surface of the ITB. Furthermore, in all specimens it was possible to measure the distance between the distal attachment of the fibers on the deep surface of the ITB and Gerdy's tubercle. The mean distance between the distal attachment of the CS on the ITB and Gerdy's tubercle was 40.7 mm on the posterior border and 58.35 mm on the anterior border. The current study demonstrates that these fibers blend with the deep surface of the ITB with an orientation that suggests that they contribute to the distal part of the ITB along with contributions from the superficial structures approaching from more proximally.

At the level of the CS, it was possible to separate the two main layers of the ITB, confirming the previous description of ITB layers. However, it was not possible to separate these layers in the last centimeters of the ITB, close to Gerdy's tubercle. Therefore, the distal part of the ITB should be considered as a one-layer entity, created by the unity of different layers and more proximal structures, including the CS with a condylar attachment identified in the current study. This is something that can be easily confirmed while performing a modified Lemaire procedure or any lateral tenodesis with the ITB band.[14] The layers are often visible during the ITB harvesting on the proximal part of the graft but never in the last few centimeters, close to the tibial attachment.

Anatomically, it is hard to reconcile the reason why Terry and other authors have described this capsule-osseous layer (COL) attached to Gerdy's tubercle.[21] In their article, Terry et al. didn't describe any structure like the one described later, the anterolateral ligament,[2,8,24] but they mentioned that the COL "functions as a medial retaining wall for the deep layer and allows the deep layer to extend its more anterior and proximal bony origin down onto the lateral capsule. It thus acts as an anterolateral ligament of the knee". In the current study, the structure of interest did not have any capsular attachment, its distal attachment was to the deep aspect of the ITB. Furthermore, in every case, the anterolateral ligament was identified as a distinct and separate entity as previously described by Claes.[2] Specifically, there was no connection between the ALL and the deep surface of the iliotibial band. This allows clarification that the ALL and the CS identified are clearly separated. However, it is the opinion of the authors that the COL defined by Terry et al. corresponds to a description combining these two structures. In fact, it is interesting that Terry mentioned that the COL "acts as an anterolateral ligament of the knee".[21] Nonetheless, these two anatomical structures are distinct and should not be described as a unique bundle. Therefore, it is proposed that the term "capsulo-osseous layer" should be abandoned, principally because it causes confusion by suggesting an anatomical association (capsular attachment) that has not been found to be present and because the terms "anterolateral ligament" and "condylar attachment of the distal ITB" clarify that these are anatomically discrete structures.

In Terry's study, the dissection was performed using an anterior approach. Upon initiating our anatomical study, five knee specimens were anteriorly dissected, assuming that a deep structure connects the ITB and the epicondyle area of the femur. Furthermore, our first approach was anterior, in keeping with the majority of the previously published literature on this topic.[9,13] However, it was always difficult to correctly dissect the structure that we can feel easily by finger, in the epicondylar region, through the ITB when the tibia is brought into internal rotation.

In the experience of the authors, the anterior and the posterior approach allowed a very different view of the deep anatomical structures. The posterior approach was associated with significant advantages in terms of visualization because the proximal attachment of the CS is spread over the condyle and the posterior surface of the lateral gastrocnemius. The anterior approach allows only a partial view of the bony attachment and no view of the gastrocnemius expansions.[9,13]

Moreover, during an anterior approach, posterior retraction of the ITB artificially creates a fold that forms a continuity between the condyle and Gerdy's tubercle, through the ITB, with an arch-like appearance. Even if we agree on some points with the previous descriptions, this aspect of an arch is a result of the anterior dissection that was performed.

Vieira et al[23] in 2007, reported an anatomical study with similar methodology to Terry et al[21] and confirmed the same conclusions. The photos of Vieira's anatomical dissection, mentioned the

"Capsular-osseous layer of the ITB with its origin at the supra-epicondylar region of the femur, the arched direction of its fibers, and the insertion lateral to Gerdy's tubercle".[23] On the basis of the current study, it is clear that the distal attachment of the COL on Gerdy's tubercle is actually the attachment of the ITB. Vieira, et al. [23] concluded that the capsulo- osseous layer can be considered as a true anterolateral ligament of the knee and that it forms, "in conjunction with the ACL, the figure of an inverted "U" or a horseshoe shape, being the ACL the medium portion of the "U" and the capsular- osseous layer of the ITB its lateral portion", according to Terry et al.[21] Although it is clear that some lateral structures can play a role, along with the ACL, to control the anterolateral rotatory laxity, the anatomical dissections performed in the current study did not demonstrate any connection between the proximal attachment of the CS that we have identified and the ACL or even any posterior structure which could connect them together. Therefore, if the two structures are "working" together, it is in a separate anatomical manner. It is important to clarify this point in order to avoid any over-interpretation for surgical application. More specifically, it should be highlighted that the Macintosh concept for surgical reconstruction in cases of anterolateral laxity should not be considered as a strict anatomical reconstruction of an existing inverted U- shape structure, even if it has demonstrated some clinical efficiency.

Lobenhoffer et al[15] in 1987, presented an anatomical study on the distal femoral fixation of the iliotibial tract. 100 knee joints were dissected. They concluded that there is a fiber bundle system with three main parts: 1. The supracondylar bundle oriented from proximal-lateral to distal-medial and fixed to the supracondylar area of the femur. 2. The fibers near to the septum with a transverse course between superficial tract and dorsolateral femur. 3. The retrograde tracts which connect Gerdy's tubercle with the dorsolateral femur and form an arc bridging the knee joint. All the dissections were performed from an anterior approach. What the authors described as the retrograde fiber tract appears to correspond directly to the COL previously described by Terry. Their description is more detailed concerning the proximal insertion with two types according to their position besides the septum. It is remarkable that they described this structure as either ''septum-like'' (78% of specimens) or ''ligament-like'' (22% of specimens).[15] It confirms the findings observed in the current study with a significant structure connecting the deep surface of the ITB and the lateral femur. Interestingly, the authors did not report an attachment to the lateral gastrocnemius. In contrast Godin et al reported that the proximal aspect of the capsulo-osseous layer was associated with the fascia surrounding the lateral gastrocnemius tendon, further supporting that all authors are describing the same anatomical structure.[6]

It is important to highlight that the connection between the CS and the proximal insertion of the lateral gastrocnemius tendon is difficult to interpret from this anatomical study. Despite that, through the connection with this muscle, a dynamic control of this CS and a proprioceptive role can be hypothesized. However, this anatomical study cannot present any conclusion on this topic and further study could be performed to evaluate this concept further.

Lobenhoffer et al. reported that the retrograde fibers connect Gerdy's tubercle with the dorsolateral femur and form an arc bridging the knee joint.[15] Although the authors of the current study agree with this statement from a functional perspective, due to the connection between the femur and Gerdy's tubercle, it is our opinion, that this occurs through the distal ITB because the fibers are attached directly to the ITB. Interestingly, in their published illustrations, they show the distal attachment of these retrograde fibers on the deep ITB and not on Gerdy's tubercle.[15] We believe that their interpretation and the lack of information concerning the posterior attachment of this structure, especially on the lateral gastrocnemius, is the result of the anterior approach of their dissection. However, it should be noted that Godin, et al. reported two distinct deep layers of the distal ITB that they called proximal and distal Kaplan fibers.[6] These findings are consistent with those of the current study. The distal Kaplan fibers were always proximal to the CS that we identified. However, Godin et al suggested that there may be a potential action of the proximal and distal Kaplan fibers in internal rotation control of the tibia, but it should be noted that their assessment was performed only after dissecting the ITB off the tibia.[6] Furthermore, in the current study, it was identified that Kaplan fibers are oriented from proximal lateral (at the deep surface of the ITB) to medial distal (on the femur) in all specimens. This seemingly precludes an important role in control of tibial internal rotation. In contrast, in the current study the fiber orientation of the identified CS was from proximal medial to distal lateral, making this structure more likely to be important in control of anterolateral laxity. This concept was also supported by the fact that it was tensioned by application of an internal rotation force in all degrees of flexion evaluated although clearly a more sophisticated biomechanical study would be required to validate these findings.

Claes et al[2] in his anatomical description of the anterolateral ligament, mentioned that both the “deep layer” and the capsulo-osseous layer should not be confused with the ALL. We are in complete agreement with this statement. In all of the specimens, the ALL could be clearly identified as a bundle superficial to the lateral collateral ligament with a proximal insertion quite close to the bony insertion of the CS identified. Vincent et al[24] reported their observation of the lateral anatomy during total knee arthroplasty procedures. They described “a relatively consistent structure in the lateral knee, linking the lateral femoral condyle, the lateral meniscus, and the lateral tibial plateau”. This structure seems to correspond to the ALL and not the structure that we have dissected because in the current study no attachment of the CS to the capsule or the lateral meniscus was identified.

We believe that the control of anterolateral knee laxity, in addition to the ACL, is probably the result of several anatomical structures. This study showed that, besides the anterolateral ligament, there is another anatomical structure, with a proximal condylar insertion and a distal insertion on the deep surface of the ITB. This is the reason why we termed this anatomical structure the condylar strap of the ITB. Its orientation, from proximal medial to distal lateral suggests that this structure may have a role in the control of internal rotation and anterior translation of the lateral tibial plateau. A potentially important biomechanical role was further suggested by the qualitative assessment of the CS. However, it was not possible to assess the strength of internal rotation control, especially in comparison with other structures like the ALL.

The limitations of this study include the small number of specimens evaluated. Despite that, the condylar strap was identified in all eleven specimens that were evaluated with a posterior approach. An anatomical study with higher number of specimens could help to confirm our results. The average age of the specimens was relatively high (mean age, 82 years; range, 71-87 years), suggesting that the quality of the tissue is lower than in younger population. However, we assume that if it was possible to accurately identify the condylar strap in all of the included specimens evaluated with a posterior approach, its identification in younger specimens would be even easier. Our main limitation was the absence of a quantitative biomechanical evaluation. We consider our anatomical study as a first step to identify a structure which was either underestimated or understudied previously in comparison to other anatomical structures. We acknowledge that the next step is to perform a biomechanical study assessing the exact role of the CS.

Conclusion

The distal ITB attaches to Gerdy's tubercle. Proximal to this, there is a consistent structure that attaches to the deep ITB and the femoral epicondylar area, that we have named the condylar strap of the ITB. This structure is clearly distinct from the anterolateral ligament and the Kaplan fibers. The capsulo-osseous layer previously described, probably includes both the CS and the ALL. The orientation of fibers and qualitative assessment of behavior in internal rotation suggest that the CS may have a role in anterolateral knee rotatory stability but further study is required to evaluate a potentially important biomechanical role.

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Legends:

Fig. 1. Original draw from Kaplan showing the connection between the ITB and the supracondylar area of the femur, oriented from proximal lateral to distal medial (with permission).

Fig. 2. Right knee specimen: A) Posterior approach. The space between the biceps and the iliotibial band was approached. The biceps muscle was retracted posteriorly allowing excellent visualization of the inter-muscular septum. B) The Kelly forceps was moved from inferior (just proximal to the Gerdy's tubercle attachment of the ITB) to superior where the instrument was stopped by a robust structure (asterisk) connecting the deep part of the ITB and the femoral epicondylar area. C) An internal rotational force was applied between 30 and 60 degrees of knee flexion and a qualitative assessment of tension in the structure was made by pulling on it with forceps. D) Progressive and careful dissection was used in order to identify the septum and the Kaplan fibers. Proximal (PKF) and distal (DKF) Kaplan fibers were always found proximal to the identified anatomical structure (black asterisk).

Fig. 3. Schematic representation of the distal femur of a right knee demonstrating A) the insertion sites of the condylar strap (CS) related to the known anatomical structures. DKF, distal Kaplan fibers; LGT, lateral gastrocnemius tendon; ALL, anterolateral ligament; FCL, fibular collateral ligament; LE, lateral epicondyle; PLT, popliteus tendon. B) the CS (white asterisk) connecting the deep portion of the iliotibial band (ITB) and the lateral epicondyle area. PKF, proximal Kaplan fibers; DKF, distal Kaplan fibers; LGT, lateral gastrocnemius tendon; ALL, anterolateral ligament; FCL, fibular collateral ligament.

Fig. 4. Right knee. The superior genicular artery (GA) was consistently located proximal to the CS (black asterisk). ITB, Iliotibial band detached from the Gerdy and redirected proximally; ALL, anterolateral ligament; FCL, fibular collateral ligament.

Table 1: Measurements of the identified CS Condylar Strap, its distance with other known structure and some anatomical variables.

Specimen's profile				**Condylar strap's measurements (mm)**					**Condylar strap's attachments (mm)**										**Anatomical independent variables (mm)**				
Specimen	**Side**	**Sex**	**Donor's Height (inches)**	**Condylar Strap's Thickness**	**Length of distal border condylar strap**	**Length of proximal border condylar strap**	**Width of distal insertion of condylar strap on ITB**	**Width of proximal attachment of condylar strap**	**Middle of DFK to the proximal attachment of condylar strap**	**Proximal end of DFK to the proximal attachment of condylar strap**	**Distal end of DFK to the proximal attachment of condylar strap**	**Proximal attachment of condylar strap to lateral epicondyle**	**Distal attachment of condylar strap to lateral epicondyle**	**Proximal attachment of condylar strap to the middle of Gerdy tubercle**	**Distal attachment of the condylar strap to the middle of Gerdy tubercle**	**Distance between posterior distal attachment on ITB and Gerdy**	**Distance between anterior distal attachment on ITB and Gerdy**	**Width of distal Kaplan fibers**	**Distance of epicondyle to middle of Gerdy**	**Anterior Gerdy border**	**Posterior Gerdy border**	**Proximal Gerdy border**
1	R	M	72.00	0.70	31.20	21.00	13.00	13.60	6.00	11.90	-8.50	21.90	20.20	69.40	64.20	50.50	65.50	14.10	57.20	17.30	22.20	18.50
2	R	M	73.00	0.80	30.70	23.90	9.60	13.50	-2.90	4.90	-10.40	26.20	18.60	68.70	59.70	59.30	62.60	11.30	45.30	16.30	15.40	14.10
3	R	F	61.00	1.00	21.60	12.30	7.60	15.60	10.40	14.80	5.10	17.20	13.70	56.40	45.20	42.20	53.90	10.50	41.50	12.10	14.30	13.50
4	L	M	72.00	0.70	32.00	33.70	11.10	15.40	8.10	13.80	5.20	17.40	6.70	68.80	57.30	31.90	56.90	12.30	57.30	16.30	17.20	16.80
5	L	F	64.00	0.60	23.40	17.50	13.80	14.10	3.20	5.50	-5.60	18.60	11.40	55.70	43.30	22.50	55.20	12.90	40.40	14.70	17.40	16.10
6	R	F	68.00	0.80	29.40	16.10	10.80	13.20	12.50	15.40	10.60	18.70	19.10	60.30	52.40	46.30	63.40	11.40	48.60	15.10	18.20	16.70
7	L	M	67.00	1.90	20.10	26.80	13.20	20.70	17.50	22.80	15.00	22.70	13.80	68.00	59.20	45.70	56.20	9.00	50.20	15.10	18.90	17.20
8	R	M	71.00	1.30	33.50	24.00	19.50	26.50	18.90	24.70	14.10	30.30	9.50	74.20	53.20	36.00	58.30	12.20	51.50	14.40	16.10	17.80
9	R	M	71.00	0.90	19.30	21.50	19.60	20.20	5.10	9.70	-8.20	13.60	18.40	64.50	50.60	40.60	62.60	12.60	55.30	13.80	16.40	16.00
10	L	F	60.00	0.40	27.40	19.90	13.50	13.20	1.50	3.70	0.00	20.40	13.40	56.60	46.50	42.20	54.70	5.30	37.70	13.40	17.50	15.80
11	R	F	60.00	0.60	21.00	24.00	14.30	8.00	8.60	13.30	4.10	15.90	12.10	52.90	47.20	30.50	52.50	12.00	40.80	10.70	12.60	12.60
Average			**67.18**	**0.88**	**26.33**	**21.88**	**13.27**	**15.82**	**8.08**	**12.77**	**1.95**	**20.26**	**14.26**	**63.23**	**52.62**	**40.70**	**58.35**	**11.24**	**47.80**	**14.47**	**16.93**	**15.92**
SD			**5.12**	**0.41**	**5.33**	**5.71**	**3.70**	**4.95**	**6.57**	**6.80**	**9.18**	**4.80**	**4.34**	**7.12**	**6.80**	**10.19**	**4.44**	**2.37**	**7.12**	**1.92**	**2.51**	**1.83**
MIN			**60.00**	**0.40**	**19.30**	**12.30**	**7.60**	**8.00**	**-2.90**	**3.70**	**-10.40**	**13.60**	**6.70**	**52.90**	**43.30**	**22.50**	**52.50**	**5.30**	**37.70**	**10.70**	**12.60**	**12.60**
MAX			**73.00**	**1.90**	**33.50**	**33.70**	**19.60**	**26.50**	**18.90**	**24.70**	**15.00**	**30.30**	**20.20**	**74.20**	**64.20**	**59.30**	**65.50**	**14.10**	**57.30**	**17.30**	**22.20**	**18.50**

Table 2: Correlation coefficients and p-values of the association between the independent variables and the different anatomic characteristics of the CS.

		Gerdy's Surface	Proximal attachment of condylar strap in the middle of Gerdy tubercule	Distal attachment of condylar strap in the middle of Gerdy tubercule	Distal anterior ITB
Distance of epicondyle to middle of Gerdy	Pearson Correlation (r)	0.666*	0.779*	0.731*	0.642*
	P value	0.025	0.005	0.011	0.033
Gerdy's Surface	Pearson Correlation (r)		0.627*	0.700*	0.646*
	P value		0.039	0.017	0.032

*Significant correlation (p<0.05)