**Diplomarbeit**

# Anatomical Description of the Anterolateral Ligament of the Knee


eingereicht von

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# Eidesstattliche Erklärung

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# Zusammenfassung

Hintergrund: Das anterolaterale Ligament (ALL) des Kniegelenks ist eine häufig untersuchte Struktur in aktuellen biomechanischen und anatomischen Studien. Dieses Band könnte ein anterolateraler Stabilisator des Kniegelenks sein und nicht diagnostizierte ALL Verletzungen könnten zu persistierender Knieinstabilität nach isolierter Rekonstruktion des vorderen Kreuzbandes (VKB, engl. ACL) führen. Derzeit ist jedoch wenig bezüglich potentieller Geschlechtsunterschiede in Bezug auf das ALL und seine Pathologien bekannt. Diese wären jedoch von großem Interesse, da ACL-Rupturen häufiger beim weiblichen Geschlecht auftreten und bekannt ist, dass andere anatomische Parameter, wie etwa der Q-Winkel, bei den Geschlechtern unterschiedlich sind.

Ziel der Studie war es daher die anatomischen Charakteristika des ALL mit dem Hauptaugenmerk auf Geschlechtsunterschiede zu evaluieren.

Material & Methoden: Achtzig gepaarte untere Extremitäten von erwachsenen Körperspendern welche mittels Thielscher Methode konserviert worden waren bildeten das Studienkollektiv. Die komplette Beinlänge (TLL) wurde zwischen der Spitze des Trochanter major femoris und der Spitze des Malleolus lateralis vermessen. Nach Entfernung der Haut und des Subkutangewebes wurde der laterale Anteil der Gelenkkapsel inspiziert und die Länge des ALL in Extension vermessen. Die Länge des Ligamentum collaterale laterale (LCL) wurde in Streckstellung vermessen und die ACL-Länge in 120° Flexion.

Ergebnisse: Zweiundvierzig untere Extremitäten wurden von weiblichen und 38 von männlichen Körperspendern gewonnen. Das ALL war bei den weiblichen Präparaten (Mittelwert: 32,8 mm; SD: 5,2; Spannweite: 22,9-41,3) signifikant ($p = 0,044$) kürzer im Vergleich zu den männlichen Extremitäten (Mittelwert: 35,7 mm; SD: 7,1; Spannweite: 24,6-53,1). Auch das ACL war bei Männern (Mittelwert: 35,8 mm; SD: 2,8; Spannweite: 28,1-41) signifikant ($p = < 0,001$) länger im Vergleich zu Frauen (Mittelwert: 31,7 mm; SD: 4,6; Spannweite: 23,4-41,3). Bezüglich der Länge des LCL gab es keinen signifikanten ($p = 0,084$) Geschlechtsunterschied (Frauen: Mittelwert von 45,2 mm; SD: 6,7; Spannweite: 30,6-59,2/Männer: Mittelwert von 47,9 mm; SD: 6,9; Spannweite: 35,8-62). Die ALL-Länge korrelierte signifikant positiv mit der Länge des ACL (p = < 0,001) und der Länge des LCL (p = < 0,001). Es bestand keine signifikante Korrelation mit der TLL (p = 0,888) und der Körpergröße (p = 0,046). Die ACL-Länge korrelierte positiv mit der Länge des LCL (p = < 0,001), der TLL (p = 0,002) und der Körpergröße (p = < 0,001) wohingegen das LCL weder mit der TLL (p = 0,124) noch mit der Körpergröße (p = 0,243) korrelierte. TLL und Körpergröße korrelierten signifikant positiv (p = < 0,001).

Schlussfolgerung: Die ALL-Länge der weiblichen Körperspender war signifikant kürzer im Vergleich zum männlichen Kollektiv. Der Längenunterschied war jedoch ohne klinische Relevanz. Die Länge des ALL korrelierte signifikant positiv mit der ACL- und LCL-Länge jedoch nicht mit dem Geschlecht. Daher ist eine geschlechtsspezifische Betrachtungsweise obsolet.

## Abstract

Background: In the recent decade, the anterolateral ligament (ALL) of the knee has received increased attention in anatomical and biomechanical studies. The structure might have an impact on the anterolateral stability of the knee and undetected injuries of the ALL could lead to persistent knee instability after isolated anterior cruciate ligament (ACL) reconstruction. However, the current literature lacks information concerning potential gender differences regarding anatomical characteristics and pathologies of the ALL. However, this might be essential since it is known that ACL-ruptures occur more commonly in female than in male athletes.

The aim of this study was to evaluate the anatomical characteristics of the ALL in a large collective with the main focus on potential gender differences.

Material & Methods: The study sample included 80 paired adult human cadavers' lower extremities, embalmed using Thiel's method. After measurement of the total leg length (TLL), which was defined as the interval between the apex of the greater trochanter of the femur and the distal tip of the lateral malleolus, the skin and subcutaneous tissues were removed. The lateral portion of the knee capsule was inspected with regard to the existence of an ALL. Its total length was taken in extension. The length of the lateral collateral ligament (LCL) was taken in extension and the length of the ACL was measured in 120° flexion.

Results: Forty-two cadavers were gained from female and 38 from male donors. The ALL was significantly ($p = .044$) shorter in females (mean length: 32.8 mm; SD: 5.2; range: 22.9-41.3) than in males (mean length: 35.7 mm; SD: 7.1; range: 24.6-53.1). The ACL was also significantly ($p = < .001$) longer in males (mean length: 35.8 mm; SD: 2.8; range: 28.1-41) when compared to females (mean: 31.7 mm; SD: 4.6; range: 23.4-41.3). However, there was no significant ($p = .084$) gender difference concerning the length of the LCL (females: mean of 45.2 mm; SD: 6.7; range: 30.6-59.2/males: mean of 47.9 mm; SD: 6.9; range: 35.8-62). The ALL correlated significantly positively with the ACL ($p = < .001$) and the LCL ($p = < .001$). There was no significant correlation with the TLL ($p = .888$) and the body size ($p = .046$). The ACL correlated positively with the LCL ($p = < .001$), the

TLL (p = .002) and the body size (p = < .001). The LCL did not correlate with TLL (p = .124) or donor's height (p = .243). Further, TLL and donor size correlated significantly positively (p = < .001).

Conclusion: Absolute differences in the ALL's length reach a statistically significant difference between the sexes, however without clinical relevance. The length of the ALL correlates significantly positively with the ACL- and LCL-length.

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# List of Abbreviations

| | |
|---|---|
| ACL | anterior cruciate ligament |
| ALL | anterolateral ligament |
| LCL | lateral collateral ligament |
| LE | lateral epicondyle of the femur |
| MCL | medial collateral ligament |
| PT | popliteus tendon |
| TLL | total leg length |

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# I. INTRODUCTION

In 1879, the anterolateral ligament (ALL) of the knee, also known as the "midthird lateral capsular ligament" or "anterolateral femorotibial ligament" (Rasmussen et al. 2016), was first described by Dr. Paul Segond as a "pearly, resistant, fibrous band" (Pomajzl et al. 2015, Segond 1879).

In the recent decade, the ALL has received increased attention in anatomical (Caterine et al. 2015, Claes et al. 2013, Daggett et al. 2016, Helito et al. 2013, Runer et al. 2016, Vincent et al. 2012) and biomechanical studies (Dodds et al. 2014, Helito et al. 2014b, Nitri et al. 2016, Parsons et al. 2015, Saiegh et al. 2017, Sonnery-Cottet et al. 2016, Spencer et al. 2015, Zens et al. 2015).

The structure might have an impact on the anterolateral stability of the knee and undetected injuries of the ALL could lead to persistent knee instability after isolated anterior cruciate ligament (ACL) reconstruction (Claes et al. 2014, Helito et al. 2014a, Saiegh et al. 2017, Sonnery-Cottet et al. 2015).

Up to now, statements concerning the ALL's anatomical characteristics vary broadly in the literature. Data about its prevalence range from 43% (Saiegh et al. 2017) up to 100% (Zens et al. 2015). Reports about the ligament's precise points of origin and insertion as well as its relation to adjacent structures are inconsistent and disagreements exist whether the ALL is a part of the knee capsule or a distinct extracapsular structure. These discrepancies may be traced back to different embalming methods and dissection techniques.

Moreover, the current literature lacks information concerning potential gender differences regarding anatomical characteristics and pathologies of the ALL. However, this might be essential since it is known that ACL ruptures occur more commonly in female than in male athletes (Prodromos et al. 2007).

The aim of this study was to evaluate the anatomical characteristics of the ALL in a large collective with the main focus on potential gender differences. To avoid possible distortions through specimen preparation, we used cadavers which had been embalmed by use of Thiel's method (1992a,b), which simulates stable lifelike soft tissue conditions. Further we aimed to correlate the ALL's length with the ACL, the lateral collateral ligament (LCL), the total leg length (TLL), and the height of the donors.

# II. ANATOMICAL BACKGROUND

## II.1. GENERAL CONSIDERSATIONS

The knee joint represents a composed and the biggest joint of the human body (Anderhuber et al. 2012, Platzer 2009, Schiebler & Korf 2007). It is formed by the distal part of the femur, the proximal portion of the tibia and the dorsal surface of the patella (Anderhuber et al. 2012, Platzer 2009).

The femoral condyles glide on the superior articular surface of the tibia and build the femorotibial articulation which functionally acts as a trochoginglymus. The biconvex femoral condyles have a spiral curvature which increases from the anterior to the dorsal side. (Anderhuber et al. 2012) Here, the medial condyle tends to be wider on its anterior aspect whereas the medial condyle shows a consistent width (Platzer 2009). The proximal articular surface of the tibia tends to be concavely shaped in comparison. This incongruence is balanced through the menisci. The second component of the knee joint is the femoropatellar articulation formed by the dorsal surface of the patella and the femur. (Anderhuber et al. 2012, Platzer 2009)

## II.2. BONY COMPONENTS

### II.2.1. Femur

The femur represents the longest (length of 40 to 50 cm) and strongest long bone of the human skeleton (Anderhuber et al. 2012, Tandler 1919).

Only its most distal parts, two roles of spiral curvature, participate in the construction of the knee joint. These are called the medial and lateral condyles of the femur. (Anderhuber et al. 2012)

In each of their centres of curvature the medial and lateral epicondyles are located. These form the origins of the medial and lateral collateral ligaments. (Anderhuber et al. 2012, Tandler 1919)

The medial and lateral condyles are separated through the intercondylar area which is terminated proximally by the intercondylar line. Here, the cruciate ligaments find their insertion. (Anderhuber et al. 2012, Tandler 1919)

The distal edge of the femur includes three articular surfaces. These are the patellar surface at its ventral portion, which enables the gliding of the patella at the femur. It is formed by the intersection of both femoral condyles. The further articular surfaces of the femur are situated on the medial and lateral condyle. (Anderhuber et al. 2012)

### II.2.2. Patella

The patella is a flat bone which is of wedge shape in transverse section. Its base is situated proximally and its apex distally. Being embedded in the insertion tendon of the quadriceps femoris muscle, it acts as its sesamoid bone. (Anderhuber et al. 2012)

Its dorsal or articular surface consists of a larger lateral and a smaller medial articular facet, separated through a crest. The articular surface articulates with the patellar surface of the femur. (Anderhuber et al. 2012, Tandler 1919)

While being fixed in the extension apparatus of the knee, the patella is forced more intensively to the femoral articular surface during flexion (Appel & Stang-Voss 2008).

The cartilage cover of the patella decreases the friction between the bone and the tendon. Further the patella guides the tendon and prevents, together with the medial and lateral patellar retinacula, its lapsing. (Anderhuber et al. 2012, Appel & Stang-Voss 2008)

### II.2.3. Tibia

The tibia represents the bearing bone of the lower leg. Its length ranges approximately between 30 and 40 centimetres. (Anderhuber et al. 2012, Appel & Stang-Voss 2008)

Its proximal portion, the so-called tibial head, which in situated on the tibial corpus, turns laterally into the medial and lateral tibial condyles. These wear the superior articular surfaces. The intercondylar eminence is situated between the superior articular surfaces, consisting of two blunt tubercles which are called medial and lateral intercondylar tubercles. Ventral, respectively dorsal to the intercondylar eminence, the anterior and posterior intercondylar areas can be found. (Anderhuber et al. 2012)

## II.3. CARTILAGE

The knee joint has the largest articular surfaces and the thickest cartilage portions in the human body. Concerning the total of 100 $cm^2$ of articular cartilage, 61% of these can be found at the distal femur and 13% at the patella and the tibial head. The thickest cartilage is situated at the dorsal portion of the patella (mean of 2.5 mm with maximum values up to 7 mm). The cartilage portion at the patellar surface of the femur is at a mean of 2.2 mm and approximately 1.6 mm at the centre of the femoral condyles, articulating with the tibial head. Regarding the articular surface of the tibia, this has a mean cartilage thickness of 2.2 mm at its lateral condyle and of 1.7 mm at the medial condyle. (Benninghoff & Drenckhahn 2003)

## II.4. JOINT CAPSULE

The joint capsule consists of a fibrous and a synovial stratum which are separated through fat deposits (Platzer 2009). It includes far more synovial stratum than any other articulation due to its extension (Braus 1929).

The fibrous stratum of the joint capsule inserts approximately 1 cm distal to the outside edge of the cartilage on the superior articular surface of the tibia. On the femur, it lies laterally on the condyles and is fused with the quadriceps tendon and the patella. Dorsally, it reaches the intercondylar line.

The synovial stratum is fixed to the cartilage rim of the tibia on the ventral, medial and lateral sides. On the dorsal side, it courses between the articular facets of the tibia. Since it surrounds the anterior intercondylar area, both of the cruciate ligaments are located extra-articular but intra-capsular. On the femur, it inserts on the intercondylar fossa, the posterior and lateral cartilage rims of the condyles and on the edge of the patellar surface. Ventro-proximally, the synovial stratum merges into the suprapatellar bursa and further covers the infrapatellar fat pad while inserting on the anterior intercondylar area. (Anderhuber et al. 2012)

## II.5. LIGAMENTS

### II.5.1. Patellar ligament

This ligament represents the continuation of the insertion tendons of the quadriceps femoris. Some of its fibres course superficial to the patella and connect to deeper fibres, connecting the patellar apex to the tibial tuberosity (Figure 1). (Anderhuber et al. 2012, Platzer 2009)

### II.5.2. Medial collateral ligament (MCL)

The MCL (Figures 1 & 2) originates from the medial femoral epicondyle and inserts on the medial plateau of the tibia. It is a strengthened portion of the joint capsule (Tandler 1919) and lies deep to the tendons of the superficial pes anserinus from which it is separated by the anserine bursa. The MCL is of triangular shape and may be separated into two portions. The anterior part is separated from the medial meniscus through a small gap containing a bursa. However, the posterior portion is intensely fixed to the meniscus. (Anderhuber et al. 2012, Platzer 2009, Schiebler & Korf 2007)

### II.5.3. Lateral collateral ligament (LCL)

The LCL (Figures 1 & 2) extends from the lateral femoral epicondyle (LE) to the fibular head. It intersects the popliteus tendon (PT) and a neurovascular bundle which courses between the LCL and the fibrous part of the joint capsule. (Anderhuber et al. 2012) The ligament shows no connection to the meniscus or the joint capsule (Platzer 2009, Schiebler & Korf 2007).

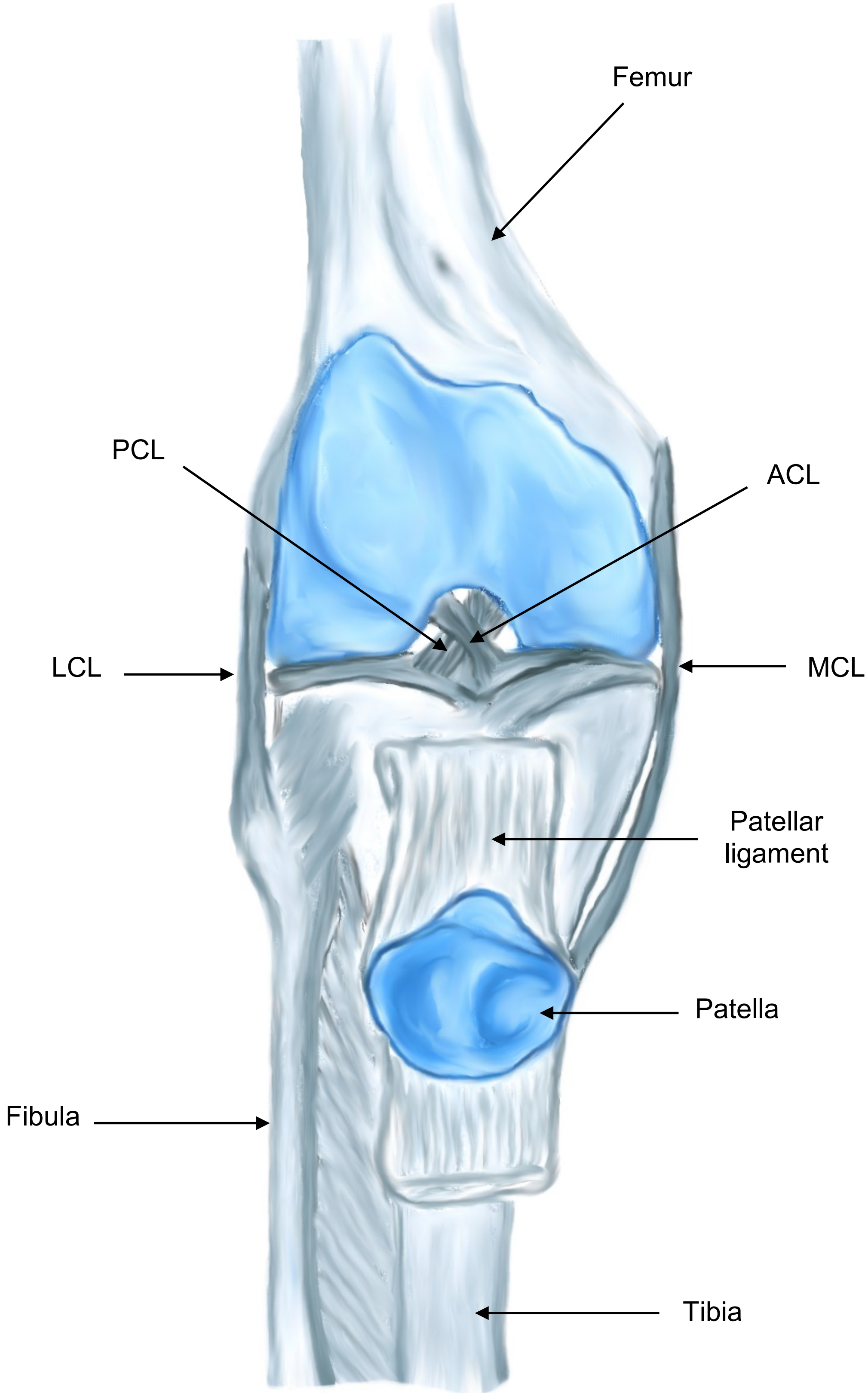


**Figure 1: Knee from the ventral aspect** (ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament)

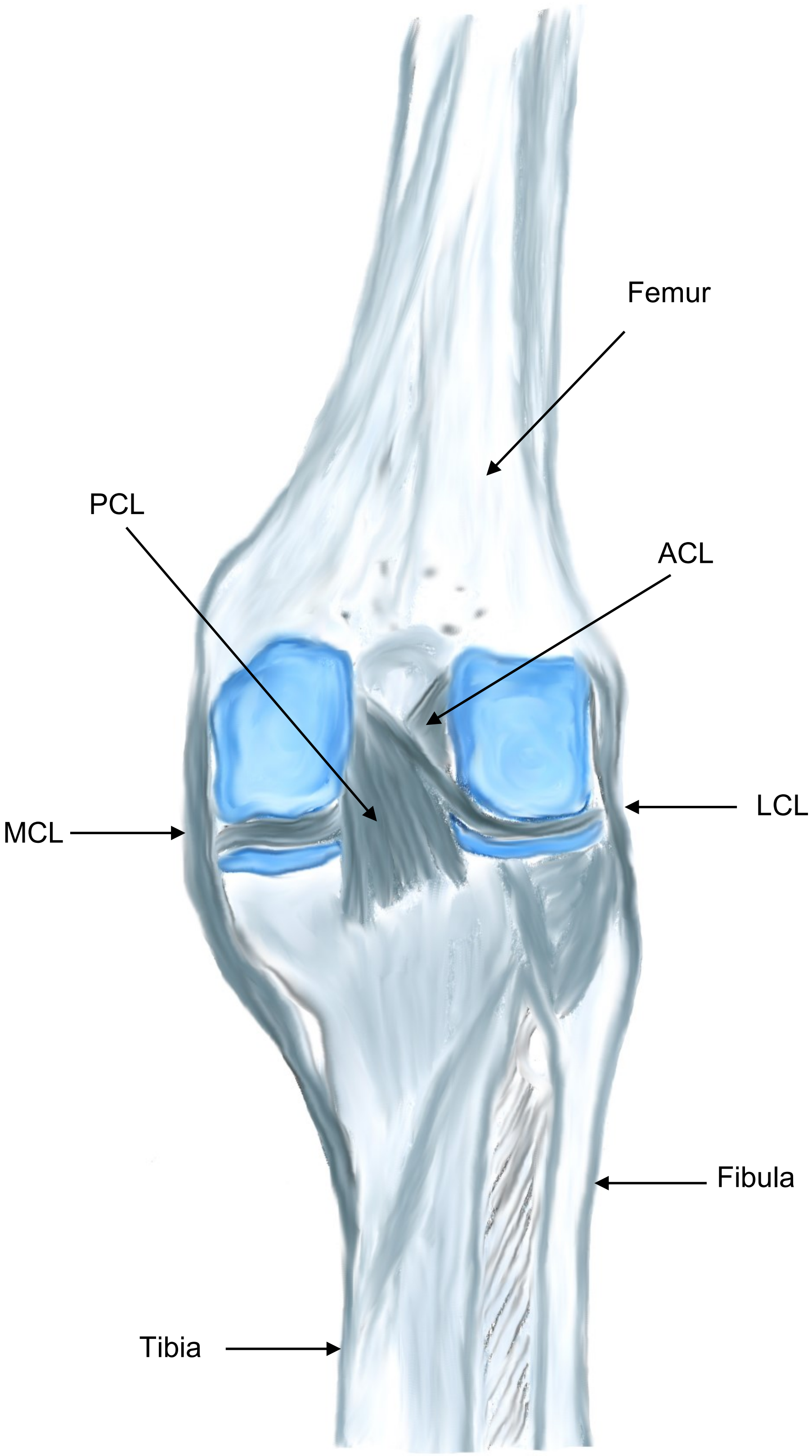


**Figure 2: Knee from posterior** (ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament)

### II.5.4. Oblique popliteal ligament

This ligament strengthens the dorsal part of the knee capsule. It is part of the tendon of the semimembranosus muscle and courses from distal medial to proximal lateral (Figure 4). (Anderhuber et al. 2012, Schiebler & Korf 2007)

### II.5.5. Arcuate popliteal ligament

It reinforces the dorso-lateral portion of the knee capsule. It courses parallel to the LCL however it remains inside the joint capsule (Figure 4). (Anderhuber et al. 2012)

### II.5.6. Longitudinal retinacula of the patella

Besides the patella, the capsule is strengthened by the medial and lateral retinacula of the patella (Figure 3), both originating from fibres of the quadriceps femoris reaching the tibial tuberosity. Superficial and deep fibre tracts may be distinguished. (Anderhuber et al. 2012)

### II.5.7. Transversal retinacula of the patella

These course from the lateral side of the patella to the deep portion of the iliotibial tract. The prevalence of a medial transverse retinaculum has been stated to be 30%. This can be traced from the medial margin of the patella to the medial femoral epicondyle. (Anderhuber et al. 2012)

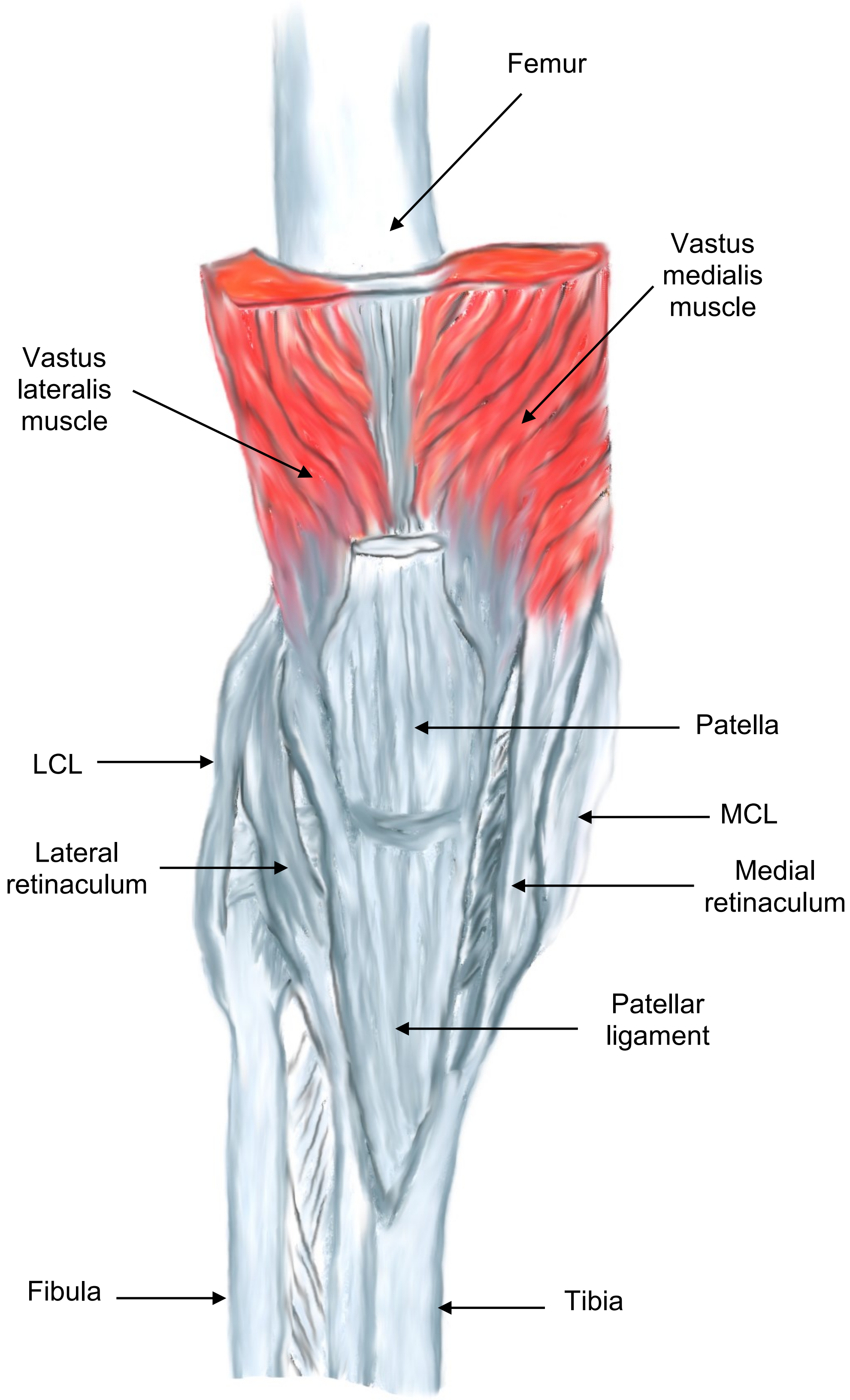


**Figure 3: Ventral side of the knee including patellar tendon** (LCL, lateral collateral ligament; MCL, medial collateral ligament)

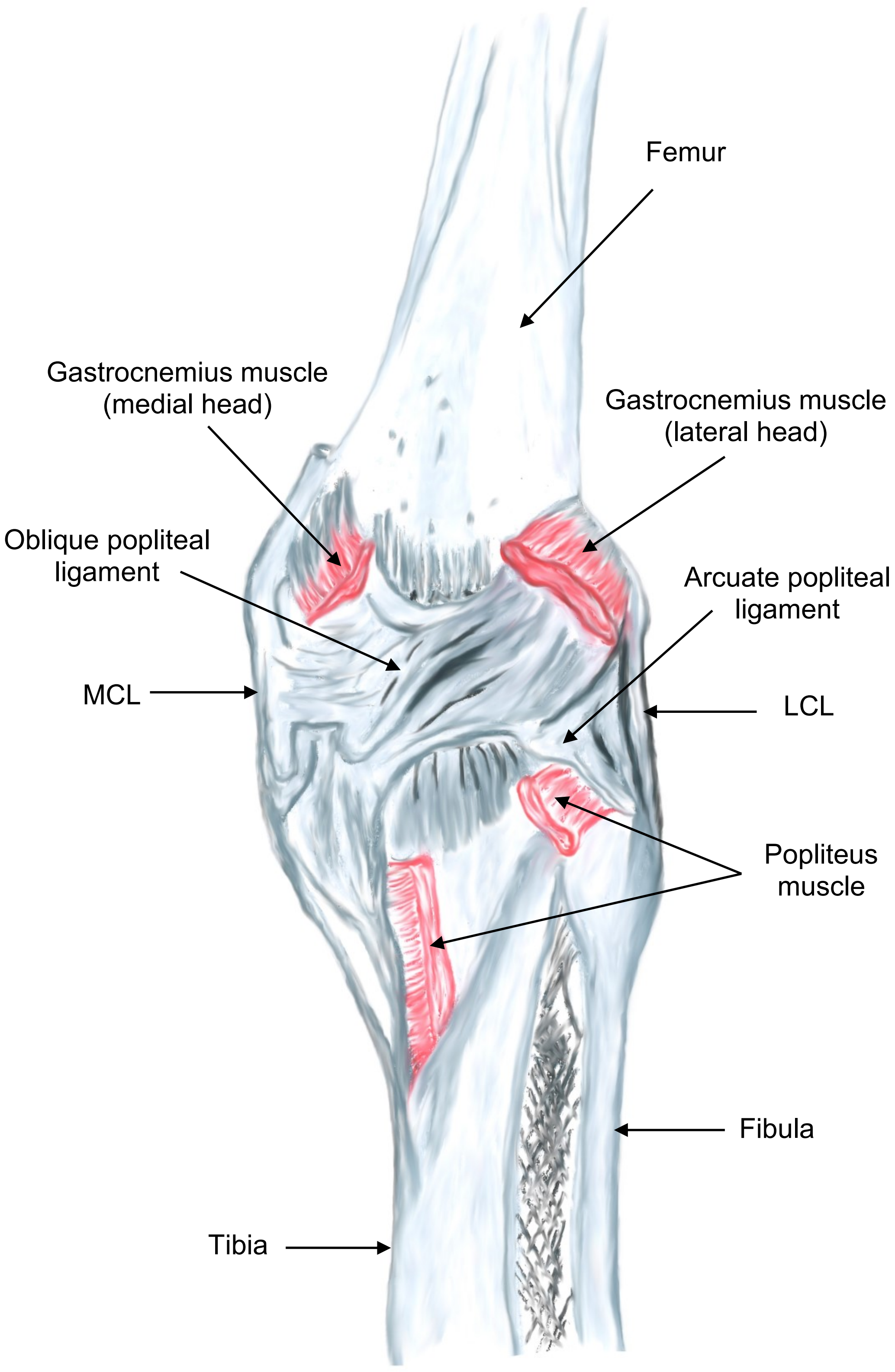


**Figure 4: Dorsal aspect of the knee capsule** (LCL, lateral collateral ligament; MCL, medial collateral ligament)

### II.5.8. Cruciate ligaments

The cruciate ligaments (Figures 1 & 2) are situated between the synovial and fibrous layers of the knee capsule (outside die joint but inside the capsule). (Anderhuber et al. 2012, Benninghoff & Drenckhahn 2003, Platzer 2009)

The ACL originates from the anterior intercondylar area of the tibia and inserts at the internal surface of the lateral femoral condyle (Anderhuber et al. 2012, Braus 1929). It may be divided into three fibre tracts (anteromedial, intermediate and posterolateral bundle). Its fibres show a high torsion which results in the most posterior insertion of the parts which originate at the most ventral part of the tibia and vice versa. (Tandler 1919)

The posterior cruciate ligament is of greater dimension in comparison to the ACL. It originates from the posterior intercondylar area and the dorsal surface of the tibia and can be traced to the internal side of the medial femoral condyle. It consists of two parts (anterolateral and posteromedial bundle). (Anderhuber et al. 2012)

## II.6. MENISCI

These are C-shaped respectively semilunar discs consisting of fibrous cartilage which are situated between the femoral and tibial articular surfaces. Their anterior and posterior horns are fixed to the intercondylar area of the tibia (Figure 5). (Anderhuber et al. 2012, Benninghoff & Drenckhahn 2003)

The medial meniscus is of semilunar curvature and connects to the dorsal portion of the LCL. Via the so-called “coronary ligament” it is fixed to the anterior rim of the tibial head. (Anderhuber et al. 2012) It has a width of 2 to 8 mm (Sieglbauer 1940).

The lateral meniscus is circular and shows a smaller curvature radius when compared to its medial equivalent (Anderhuber et al. 2012, Tandler 1919). Therefore, its anterior and posterior horns are located close to one another anterior and posterior to the lateral intercondylar tubercle (Benninghoff & Drenckhahn 2003).

Its width is usually greater in comparison to the medial side (Tandler 1919) with a range from 12 to 16 mm (Sieglbauer 1940).

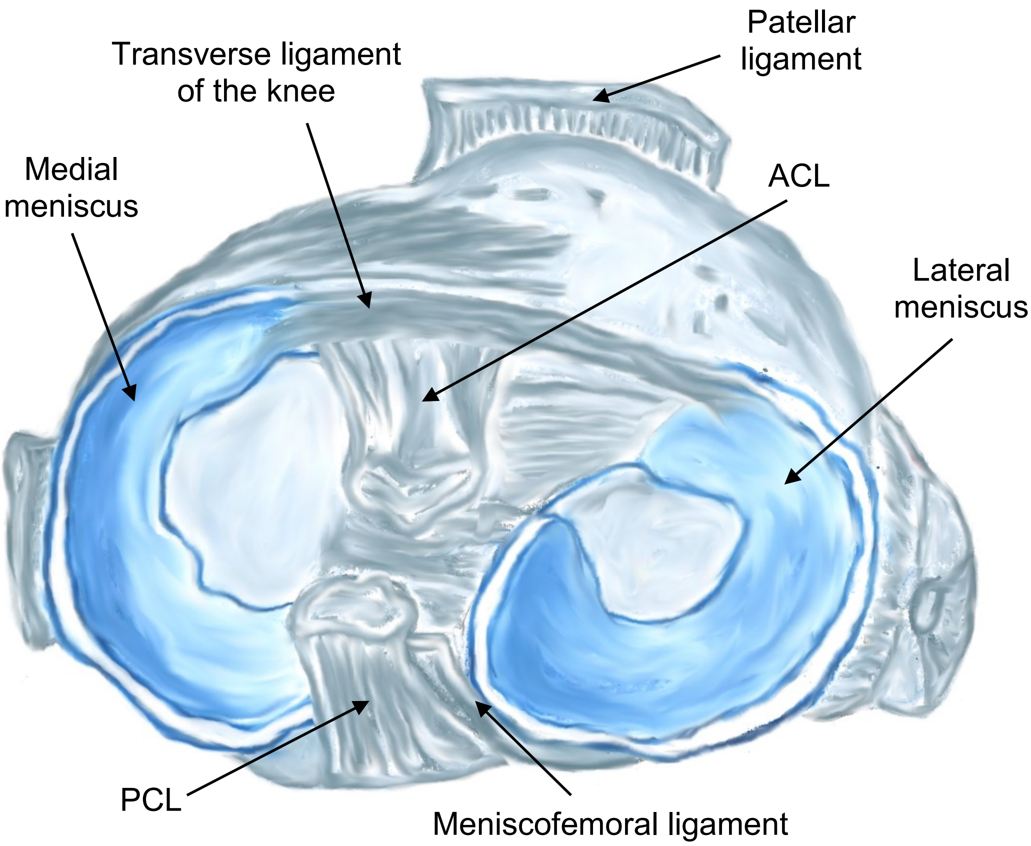


**Figure 5: Superior surface of the tibia** (ACL, anterior cruciate ligament; PCL, posterior cruciate ligament)

The meniscofemoral ligament, which was originally described by Wrisberg, connects its posterior side to the femoral insertion point of the posterior cruciate ligament. Both menisci are connected through short ligaments extending between their ends (anterior and posterior) and the anterior and posterior intercondylar areas. Infrequently, both menisci may be fixed to the patella via so-called meniscopatellar ligaments. (Anderhuber et al. 2012) The anterior parts of the menisci may further be connected via the transverse ligament of the knee which courses through the infrapatellar fat pad (Anderhuber et al. 2012, Benninghoff & Drenckhahn 2003, Sieglbauer 1940).

Their vascular supply is guaranteed through ramifications of the middle genicular artery whereas the central portion receives its supply from the synovia.

The menisci compensate the incongruence of the articular surfaces of the femur and the tibia and enlarge the pressure transmission surface. During flexion, the menisci are moved to the dorsal aspect of the joint by the femoral condyles. Due to the lack of connection to the LCL, the lateral meniscus shows a greater range of motion (Sieglbauer 1940).

## II.7. JOINT SPACE

On the anterior side of the joint space the infrapatellar fat pad can be found between the synovial and fibrous stratum (Platzer 2009). It is of triangular shape in section (Anderhuber et al. 2012). It extends between the lower margin of the patella and the infrapatellar synovial plica through which it connects to the ACL (Benninghoff & Drenckhahn 2003). The latter lies between the intercondylar fossa and the median part of the infrapatellar fat pad. On the lateral side of the infrapatellar fat pad and the infrapatellar synovial plica, the plicae alares can be found. (Platzer 2009)

## II.8. MUSCULAR COMPONENTS

### II.8.1. Quadriceps femoris muscle

The quadriceps femoris muscle is the sole extensor muscle of the knee joint and consists of four heads (rectus femoris, vastus medialis, vastus lateralis, vastus intermedius). These unite and insert through one common tendon at the patella and finally through the patellar ligament at the tibial tuberosity. (Anderhuber et al. 2012, Tandler 1919).

The innervation of the muscle is provided by the femoral nerve (Appel & Stang-Voss 2008) whereas it receives its blood supply through the lateral circumflex femoral artery and the perforating branches of the profunda femoris artery (Anderhuber et al. 2012).

The quadriceps femoris muscle acts as an extensor of the knee joint and due to the highly situated origin of the rectus femoris muscle as a flexor of the hip joint (Anderhuber et al. 2012, Appel & Stang-Voss 2008).

- The rectus femoris consists of two heads, the caput reflexum and the caput rectum. The caput rectum originates from the anterior inferior iliac spine and the caput reflexum from the acetabular fossa. The muscle inserts at the central portion of the patella and further on through the patellar ligament at the tibial tuberosity. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)
- The vastus medialis originates from the intertrochanteric line, the medial ridge of the linea aspera, the medial supracondylar line and from the tendons of the adductor longus and magnus muscles. It inserts at the medial border of the patella and ultimately through the patellar ligament at the tibial tuberosity. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)
- The vastus lateralis originates from the intertrochanteric line, the major trochanter, the gluteal tuberosity, the lateral ridge of the linea aspera and the lateral intermuscular septum of the femur. The muscle inserts at the lateral border of the patella and through the patellar ligament at the tibial tuberosity. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)
- The vastus intermedius originates from the ventral and lateral surfaces of the femoral diaphysis and the lateral intermuscular septum of the femur. Distally, the articularis genus muscle splits off. Its fibres assist in tightening the knee capsule and it inserts at the suprapatellar bursa. The further fibres of the vastus intermedius insert at the lateral border of the patella, respectively via the patellar ligament at the tibial tuberosity. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)

### II.8.2. Biceps femoris muscle

The biceps femoris muscle consists of a long and a short head. The long head originates from the ischial tuberosity together with the semitendinosus muscle and the sacrotuberous ligament. Its short head originates from the median part of the lateral ridge of the linea aspera and the lateral intermuscular femoral septum. It inserts via a large tendon at the fibular head. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)

The long head receives its neural innervation through the tibial nerve whereas the short head is innervated by the common peroneal nerve. The medial circumflex femoral artery, the perforating branches of the profunda femoris artery and the popliteal artery provide the vascular supply. (Anderhuber et al. 2012)

The biceps femoris enables extension of the hip as well as flexion and external rotation of the knee joint (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919).

### II.8.3. Gracilis muscle

The gracilis muscle has its origin at the inferior ramus of the pubic bone and the ischial ramus. It inserts at the medial surface of the medial tibial condyle through the pes anserinus superficialis. Here, its tendon is separated from the tendon of the sartorius muscle through a small bursa. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)

Its innervation is performed by the obturator nerve and it receives its blood supply from the obturator artery (Anderhuber et al. 2012).

The gracilis muscle performs flexion and adduction of the hip joint when the knee is in extension. It performs internal rotation and flexion of the knee. (Anderhuber et al. 2012, Appel & Stang-Voss 2008)

### II.8.4. Semitendinosus muscle

The semitendinosus muscle originates from the ischial tuberosity. It shares its origin tendon with the long head of the biceps femoris muscle. It inserts at the medial surface of the medial tibial condyle through the pes anserinus superficialis. Its insertion tendon intersects the MCL. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)

The muscle is innervated by the tibial nerve and it gains its blood supply from the perforating arteries of the profunda femoris artery (Anderhuber et al. 2012).

The semitendinosus muscle leads to extension of the hip joint, as well as flexion and internal rotation of the knee (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919).

### II.8.5. Semimembranosus muscle

The semimembranosus muscle originates from the ischial tuberosity. Its insertion tendon mostly consists of five parts. The main portion inserts at the dorso-medial surface of the medial tibial condyle. The medial part of the insertion tendon inserts at a groove at the medial portion of the medial tibial condyle and is covered by the MCL. A further tendon part inserts at the medial border of the tibia. The median portion of the insertion tendon joins the oblique popliteal ligament, the lateral portion inserts at the fascia of the popliteus muscle. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)

The tibial nerve innervates the semimembranosus muscle. The perforating arteries of the profunda femoris artery guarantee the vascular supply. (Anderhuber et al. 2012)

The semimembranosus performs an extension of the hip joint as well as flexion and internal rotation of the knee. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)

### II.8.6. Sartorius muscle

The sartorius muscle originates at the anterior superior iliac spine and inserts through the pes anserinus superficialis at the medial surface of the medial tibial condyle. Its insertion tendon forms the most superficial part of the pes anserinus superficialis. (Anderhuber et al. 2012, Platzer 2009)

Its innervation is performed by the femoral nerve and its vascular supply by the femoral artery (Anderhuber et al. 2012).

The sartorius performs flexion, external rotation and abduction of the hip joint and flexion and internal rotation of the knee (Anderhuber et al. 2012, Platzer 2009, Schiebler & Korf 2007).

### II.8.7. Popliteus muscle

The origin of the popliteus muscle is located at the dorsal surface of the tibia, proximal to the soleal line. Its insertion is situated proximal at the lateral femoral condyle. (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919)

The tibial nerve innervates the muscle and the popliteal artery provides its blood supply (Anderhuber et al. 2012).

The popliteus muscle is a flexor of the knee joint (Anderhuber et al. 2012, Appel & Stang-Voss 2008, Tandler 1919).

## II.9. BURSAE

Around the knee joint, diverse bursae, whereof some have connection to the articular cavity, can be found. (Platzer 2009)

- The suprapatellar bursa is situated proximal to the patella and covered by the quadriceps tendon. It is connected to the joint capsule in most of the cases, whereas this fusion usually takes place directly after birth. In approximately 15% of all cases, the bursa remains unconnected. (Braus 1929) Its wall is tensed by the articularis genus muscle (Anderhuber et al. 2012, Braus 1929). It may be divided into a lateral and medial compartment through a septum and it is the largest bursa of the joint (Anderhuber et al. 2012, Platzer 2009).
- The anserine bursa is situated beneath the tendons of the gracilis and the semitendinosus (Braus 1929).
- The semimembranosus bursa lies beneath the insertion tendon of the semimembranosus muscle and usually communicates with the joint space (Anderhuber et al. 2012, Platzer 2009).
- The prepatellar bursae do not show connections to the articular cavity and act as sliding devices for the skin against the patella.
- The subcutaneous and deep infrapatellar bursae are situated (without connection to the joint) between the skin and the patellar ligament and the latter and the tibia and the infrapatellar fat pad, respectively. (Anderhuber et al. 2012)

# III.ALL

## III.1. BACKGROUND

The ALL, also referred to as the “midthird lateral capsular ligament” or “anterolateral femorotibial ligament” (Rasmussen et al. 2016) was primarily described by Segond in 1879 and reported as a “perly, resistant, fibrous band” (Pomajzl et al. 2015).

It has received increased attention as a potential stabiliser of the knee, preventing anterolateral subluxation of the tibia on the femur, in the recent literature. However, anatomical and functional descriptions vary considerably. Discrepancies exist whether the ALL is a capsular structure or an extracapsular ligament, its relations to adjacent structures (e.g. the lateral meniscus) are described differently and its precise points of origin and attachment differ widely. (Pomajzl et al. 2015) Further, some authors have stated that the ALL is rather a capsular thickening than an independent structure (Saiegh et al. 2017).

## III.2. PREVALENCE

Concerning the prevalence of the ALL, high discrepancies can be observed in the literature. Saiegh et al. (2017) reported a rate of 43% (6/14) and Runer et al. (2016) of 45.5% (20/44). In Claes et al.’s (2013) dissection study, all but one of their dissected cadavers (97%) showed an ALL. Helito et al. (2013) and Zens et al. (2015) each reported a prevalence of 100% (20/20 and 6/6, respectively). Vincent et al. (2012) found the ligament as a clearly defined structure in all of their 30 patients undergoing total knee arthroplasty.

These varying reports may be traced back to discrepancies in the definition of the ALL’s bony insertion points as suggested by Pomajzl et al. (2015).

## III.3. RECENT ANATOMICAL DATA

The following chapter presents the current anatomical knowledge about the ALL gained from anatomical studies with larger sample sizes.

Claes et al. (2013) studied a sample of 41 cadaveric knees. Here, the ALL was found in 97% of all cases (40/41) as a structure at the anterolateral side of the knee connecting the femur and the tibia. In 100%, the origin of the ligament was situated at the most prominent part of the LE, anterior to the origin of the LCL and posterior to the insertion of the PT. In most of the cases, the ALL's most superficial fibres coursed to the lateral intermuscular septum of the thigh. Furthermore, fibres at the dorsal part of the proximal portion of the ALL connected to the LCL in many specimens. The ALL was strongly connected to the lateral meniscus via a meniscofemoral and a meniscotibial portion. After removal of the ligament from the meniscus, the lateral inferior geniculate artery and its accompanying vein could be found between these two structures. Regarding its insertion, this was always located posterior to Gerdy's tubercle. Broadly speaking, the insertion was situated at the middle of the line between Gerdy's tubercle and the tip of the fibular head. The ALL had a mean length of 41.5 mm (SD 6.7) in 90° flexion and 38.5 mm (SD 6.1) in extension. Its mean width was 8.3 mm (SD 2.1) at its origin and 11.2 mm (SD 2.5) at the tibial insertion. At the level of the joint space, the average width was 6.7 mm (SD 3.0). The ALL's average thickness was 1.3 mm (SD 0.6) at the joint line. The interval between the proximal cartilage rim of the lateral tibia and the ALL was at a mean of 6.5 mm (SD 1.4).

In Runer et al.'s (2016) study, 44 specimens underwent dissection. The ALL could be found in 45.5% (20/44) of all cases and presented as an extracapsular structure. It originated from the LE, posterior (55%) or together (45%) with the LCL. In most of the specimens, fibres originating from the posterior aspect of the ALL connected to the LCL. As in Claes et al. (2013), the ALL's insertion was situated at the midpoint of the line between Gerdy's tubercle and the fibular head. The interval between the insertion point and the tibial cartilage rim was at a mean of 8.9 mm (SD 2.3). In 30%, fibres of the ALL connected to the crural fascia. The mean width of the ALL was 7.2 mm (SD 1.8) at the origin, 5.6 mm (SD 1.3) at the joint line and 12.2 mm (SD 3.0) at its insertion point. In total extension, the average length of the ALL was 42.2 mm (SD 6.2). The thickness of the structure was 1.2 mm (SD 0.3) at the height of the joint line.

Dodds et al. (2014) dissected a sample of 40 fresh-frozen cadaveric knees. The ALL was found in 83% (33/40) as an extracapsular structure. Its origin was situated 8 mm proximal and 4.3 mm posterior to the LE. Authors found fibre connections between the ligament and the lateral meniscus. Its attachment was located posterior to Gerdy's tubercle and anterior to the fibular head. Here, connections between the ALL and the LCL through thin fibres could be observed in several specimens.

Daggett et al. (2016) examined the ALL in 52 cadavers. The ligament was present in all dissected knees and constantly overlapping the origin of the LCL at its attachment on the femur. The ALL's origin was situated directly on the LE in 23% (12/52), slightly posterior and proximal to it in 58% (30/52) and completely proximal and posterior to the LE in 19% (10/52). The mean width of the femoral origin was 11.85 mm (SD 2.16).

In Helito et al.'s cadaver study (2013), 20 knees were dissected whereas the ALL was found in 100%. Its origin was anterior and distal to the proximal part of the LCL. Authors found two attachment sides of the ALL whereas one was proximal to the lateral meniscus (between the anterior horn and the corpus) and the other was located on the tibia on the line between Gerdy's tubercle and the fibular head (at a height of 38% starting from the fibular head). The later attachment was located at a mean distance of 4.4 mm (SD 1.1) from the cartilage rim of the tibia head. The ligament had a mean length of 37.3 mm (SD 4.0) and a mean thickness of 2.7 mm (SD 0.6).

Caterine and colleagues (2015) used both, magnetic resonance imagining and dissection for analysis of the ALL. Here, 10 specimens were used for both test methods and further nine knees for additional anatomical description. The ALL could be identified in all cadavers. Regarding the relationship with the LCL, the ALL originated either anterior and distal or posterior and proximal to it. In all of the specimens, the ALL was connected to the lateral meniscus. The ligament had a mean width of 4.8 mm (SD 1.4) at its origin and of 11.7 mm (SD 3.3) at its tibial attachment. Its average thickness was 1.4 mm (SD 0.6). The insertion point at the tibia was situated on the line between Gerdy's tubercle and the fibular head however it was more often closer to Gerdy's tubercle than to the fibular head.

## III.4. RECENT BIOMECHANICAL DATA

The ALL's function has risen current interest. The following section summarises the most recent biomechanical studies concerning its role during knee mechanics.

Nitri and colleagues (2016) had the hypothesis that following combined ACL and ALL injuries, combined reconstruction of both ligaments would reduce the internal rotation and axial plane translation laxity in comparison to singular ACL repair. Ten fresh-frozen knees were evaluated with simulated pivot-shift tests in a robotic model. Differences were measured for knees with intact ALL and reconstructed ACL, deficient ALL with reconstructed ACL and knees which had undergone reconstruction of both ligaments. All types were compared with values of intact knees. Authors found a significantly increased rotatory stability and significantly reduced axial tibial plane translation in knees with restoration of both ligaments when compared to specimens with ACL reconstruction and ALL deficit.

Spencer et al. (2015) aimed to investigate the impact of the ALL on rotational knee kinematics and to evaluate possible influences on knee mechanics of ALL reconstruction when compared to lateral extra-articular tenodesis. A sample of 12 specimens was utilised. Authors found no statistically significant reduction of internal rotation or anterior translation after ALL reconstruction. However, following lateral extra-articular tenodesis, a significant decrease in anterior translation was found.

Parsons and colleagues (2015) tested the anterior drawer (134 N) on eleven knee specimens at flexion angles between 0° and 90° and internal rotation (5 N) at the same flexion degrees. The forces on the ACL, ALL and LCL were measured. With increasing flexion, the impact of the ALL on internal knee rotation increased statistically significantly. In comparison the contribution of the ACL decreased significantly. This was especially visible at flexion angles greater than 30° which lead the authors to the conclusion that the ALL was an essential stabiliser during internal rotation angles starting at this flexion degrees.

Helito and colleagues (2014b) postulated that the ALL might show greater tension with increasing flexion due to increasing length at higher degrees of knee flexion. During their study, origin and insertion points of the ALL were marked in 10 specimens. Next, computed tomography scans were performed at 30°, 60° and 90° of flexion and the intervals between the markers were measured at each range. Length changes between the intervals were compared. Here, the length increased with knee flexion, whereas the significantly highest change took place between 60° and 90°.

Saiegh et al. (2017) evaluated whether injury of the ALL would have an influence on the tibiofemoral translation or rotation during knee tests in a sample of 14 cadaveric knees with additional ACL deficit (six out of 14 had an ALL). Authors measured the degree of tibiofemoral translation and rotation by use of a navigation system. Specimens were each tested after sectioning of the ACL, ALL and combined section of both ligaments. The combination of the ALL and ACL injury did not increase tibiofemoral instability when compared to the singular ACL injured knee.

Sonnery-Cottet et al. (2016) aimed to determine the impairment of the ACL, the ALL and the iliotibial band in rotational control of the knee in 12 fresh-frozen specimens. Knees were tested in internal rotation at 20° and 90° flexion via a simulated pivot-shift test. The ACL, ALL and the iliotibial band were cut in section. The ALL induced a significant increase in internal rotation following sectioning of the ACL as well as of the iliotibial band and may therefore provide rotational control in combination with the further two tested structures.

Zens and colleagues (2015) tested the ALL's length changes during passive knee motion in six cadavers. Length changes were measured at flexion degrees between 0° and 90° as well as during internal and external knee rotation at various angles (0°, 15°, 30°, 45°, 60°, 75° and 90°). Length changes were presented as percentages with regard to the neutral position. With increasing flexion, the ALL had a significant increase of length (mean: + 0.15% per degree). Internal rotation increased and external rotation decreased the ALL's length significantly. The maximal length change was evaluated at 90° flexion and 25° internal rotation (+ 33.77%).

# IV. MATERIAL & METHODS

## IV.1. SPECIMENS

A total of 103 paired adult human cadavers' lower extremities donated to science, embalmed with Thiel´s method (Thiel 1992a,b; Thiel 2002), were investigated. All investigated cadavers were donated to the Department of Macroscopic and Clinical Anatomy of the Medical University Graz under the approval of the Anatomical Donation Program of the Medical University of Graz and according to the Austrian law for donations.

Extremities showing obvious signs of interventions or pathologies in the area of interest were excluded from the survey (n = 23). Data regarding gender, age and size were extracted from the respective donor files.

## IV.2. DISSECTION PATTERN AND MEASUREMENTS

Primary, the TLL, which was defined as the interval between the apex of the greater trochanter and the distal tip of the lateral malleolus, was measured in each specimen. Dissection was started by performance of an approximately 20-cm skin incision centred at the median of the lateral aspect of the flexed knee. From here, two rectangular cutaneous flaps were dissected in the ventral and dorsal direction. Following removal of the subcutaneous tissue, the iliotibial tract was incised transversely at approximately 5 cm proximal to the joint space and dissected distally to its insertion at Gerdy's tubercle. Following identification of the LCL with the knee in slight varus stress, the proximal portion of the LCL was inspected with regard to the existence of ligamentous fibres running from this region (including zenith of the LE as well as anterior/posterior to the LCL's femoral insertion point) to the proximal tibia posterior to Gerdy's tubercle. This ligamentous characteristic was identified as the ALL. Following identification of the ALL, all of its fibres were carefully dissected.

The total length of the ALL, which was defined as the interval between its femoral and tibial insertion points, was taken in extension. The relation of its proximal portion to the LCL was inspected regarding overlapping of the two ligaments. The ALL's width was measured at its femoral and tibial insertions and at the height of the centre of the femorotibial joint space. For a schematic depiction, see Figure 6. Concerning the distal insertion of the ligament, the distances between the centre of the ALL and Gerdy's tubercle and the apex of the fibula were evaluated. Additionally, ligament's thickness was evaluated at its broadest part. Furthermore, the specimens were inspected regarding fibrous connections between the ALL and the lateral meniscus.

The length of the LCL, which was defined as the distance between its femoral insertion at the LE to its attachment point at the fibular head, was taken in extension and its thickness was evaluated at the ligament's broadest part.

For depiction of the ACL, a medial parapatellar approach was performed. A longitudinal straight midline incision was done, starting from approximately 5 cm proximal to the superior patellar pole to the tibial tuberosity. Following subcutaneous dissection, access to the joint was gained by incision between the quadriceps tendon and the patellar ligament and the vastus medialis and the medial patellar retinaculum. The infrapatellar fat pad was excised and the patella was dislocated in a lateral direction to overview the ACL. Its length (interval between anterior intercondylar area of the tibia and the internal surface of the lateral femoral condyle) was measured in 120° flexion.

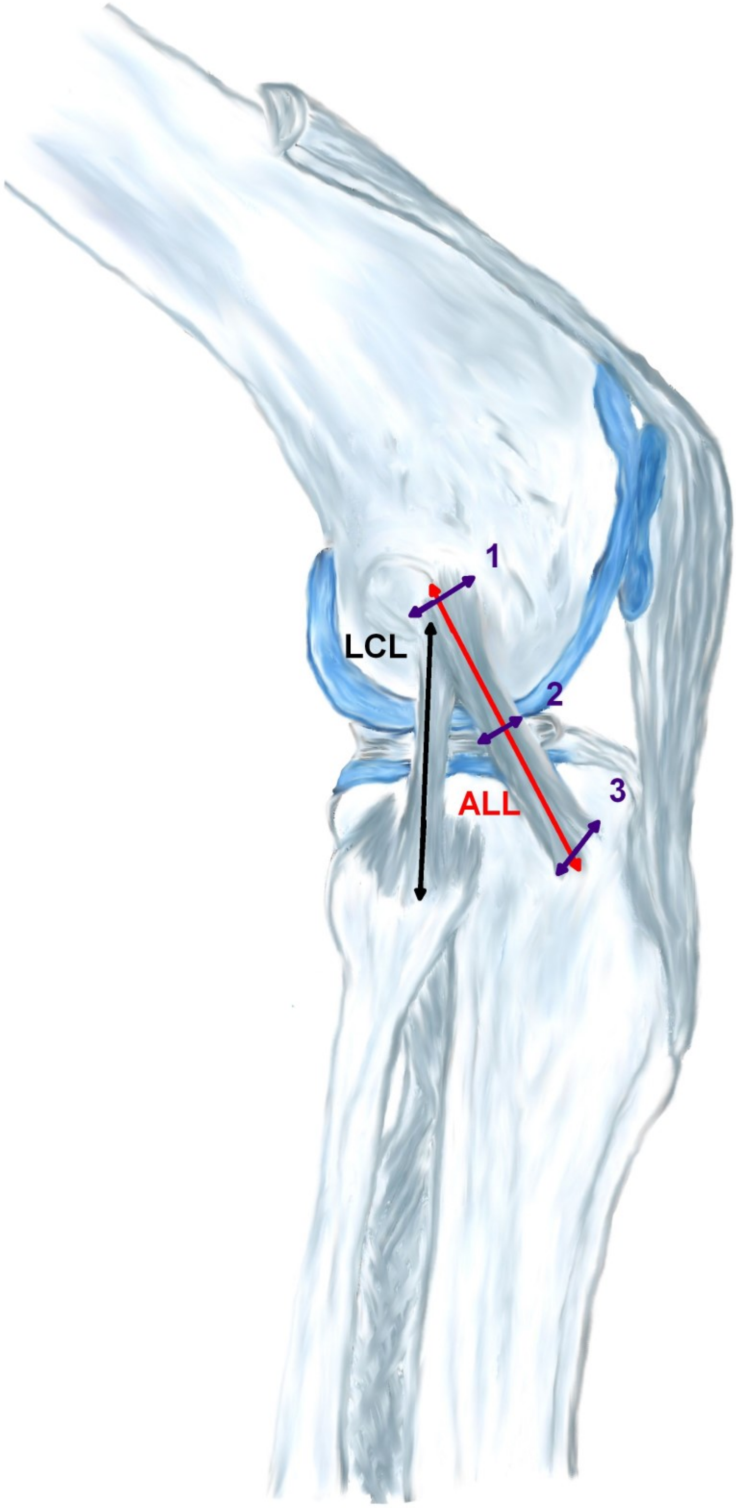


**Figure 6: Measurement pattern** (ALL, anterolateral ligament; LCL, lateral collateral ligament; 1, width at femoral insertion; 2, width at height of joint space; 3, width at height of tibial insertion)

## IV.3. STATISTICS

Measurements were taken with a digital calliper rule and in millimetres. The measured data were exported to Microsoft Excel spreadsheets (Microsoft Excel 2010; Microsoft, Redmond, WA, USA) for descriptive statistical analysis. Continuous variables are presented as mean and standard deviation (SD), median, minimum and maximum, categorical data as frequencies and percentages.

The collected data were analysed using the statistical software R (R Core Team 2016). Differences of the respective measurements were investigated using paired t-tests. A p-value $< .05$ was regarded as statistically significant.

## IV.4. LITERATURE RESEARCH

For detailed depiction of the current and elder literature regarding the ALL, an extensive research was essential. This was performed via studies of the available resources of the library of the Institute of Anatomy of Graz. Moreover, literature research was expanded by use of common search engines like PubMed, Google Scholar and Google Books. The utilised keywords included anterolateral ligament, knee ligaments, knee anatomy, knee morphology and knee biomechanics.

# V. RESULTS

## V.1. SAMPLE CHARACTERISTICS

The study sample included 80 knees from 40 human adult body donors with a mean age of 79.7 years (SD: 10.33; range: 56-95).

The mean height at time of death was 166.3 cm (SD: 9.3; range: 151-185) for the total collective.

Forty-two were gained from female and 38 from male donors. The mean age of the female collective was slightly higher (83.5 years; SD: 9.8; range: 56-95) when compared to the male sample (75.4 years; SD: 9.2; range: 57-93). The mean height was 158.2 cm (SD: 3.5; range: 151-165) in the female and 175.2 cm (SD: 3.9; range: 165-185) in the male subgroup.

## V.2. QUALITATIVE ANALYSIS

The ALL could be found in all of the 80 extremities meeting the inclusion criteria as a structure connecting the femur with the tibia (Figure 7). Hereof, this characteristic was a tight, ligamentous structure in 80% of all cases, whereas in 20% it was a membranous capsule enhancement.

In the majority of the cases (78/80), the ALL originated from the zenith of the lateral femoral epicondyle, overlapping the origin of the LCL. In each one case, the ALL's origin was located ventral or proximal the LCL.

The ligament coursed obliquely to the anterolateral side of the proximal tibia. In 96% (77/80), a connection between the ALL and the lateral meniscus could be observed. This was not present in two cases (3%) and could not be evaluated due to calcifications in one specimen (1%). In 56.3% (45/80), the lateral inferior geniculate artery was found between the lateral meniscus and the ALL after its detachment (Figure 8).

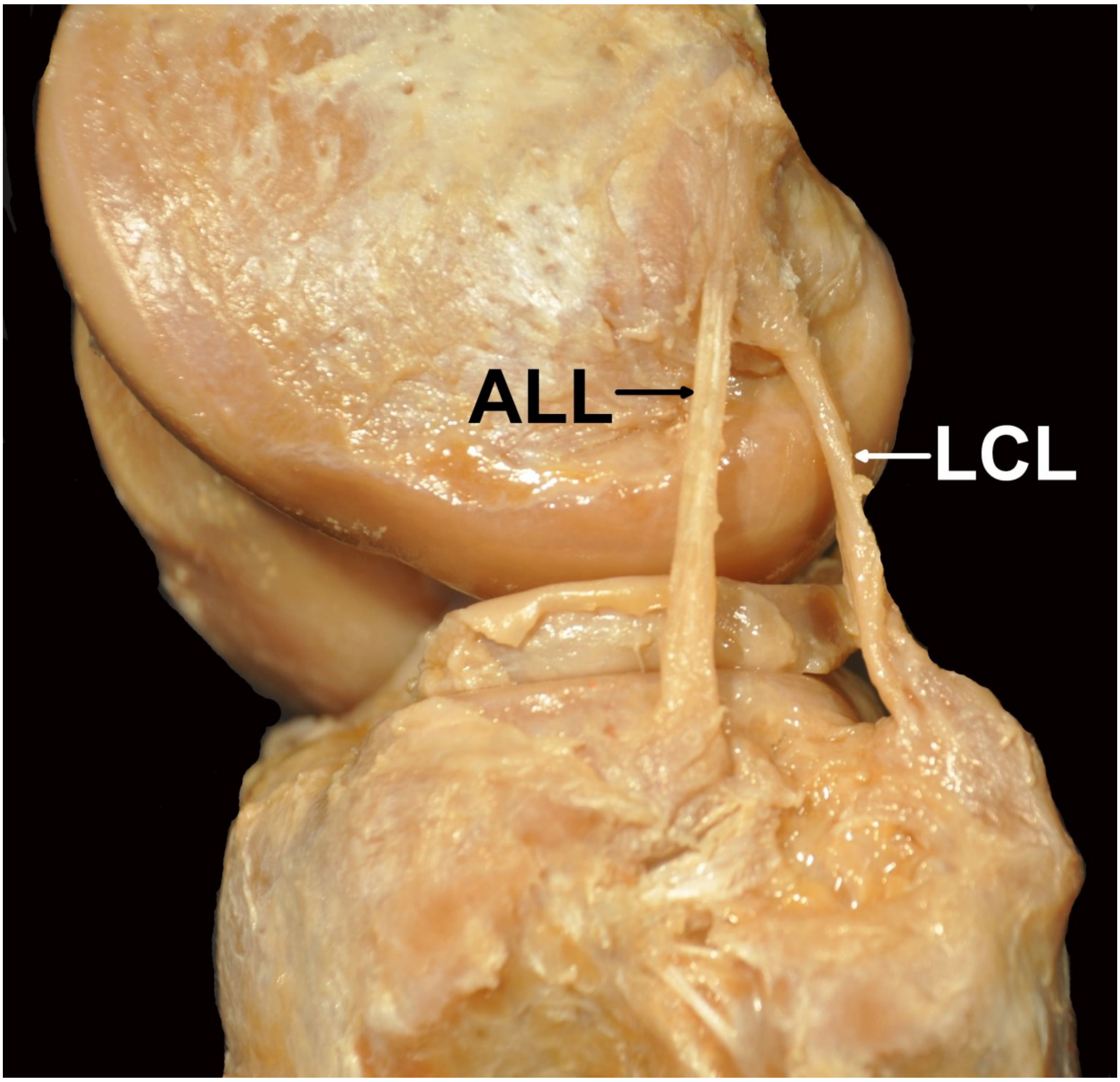


**Figure 7: ALL in a specimen** (ALL, anterolateral ligament; LCL, lateral collateral ligament)

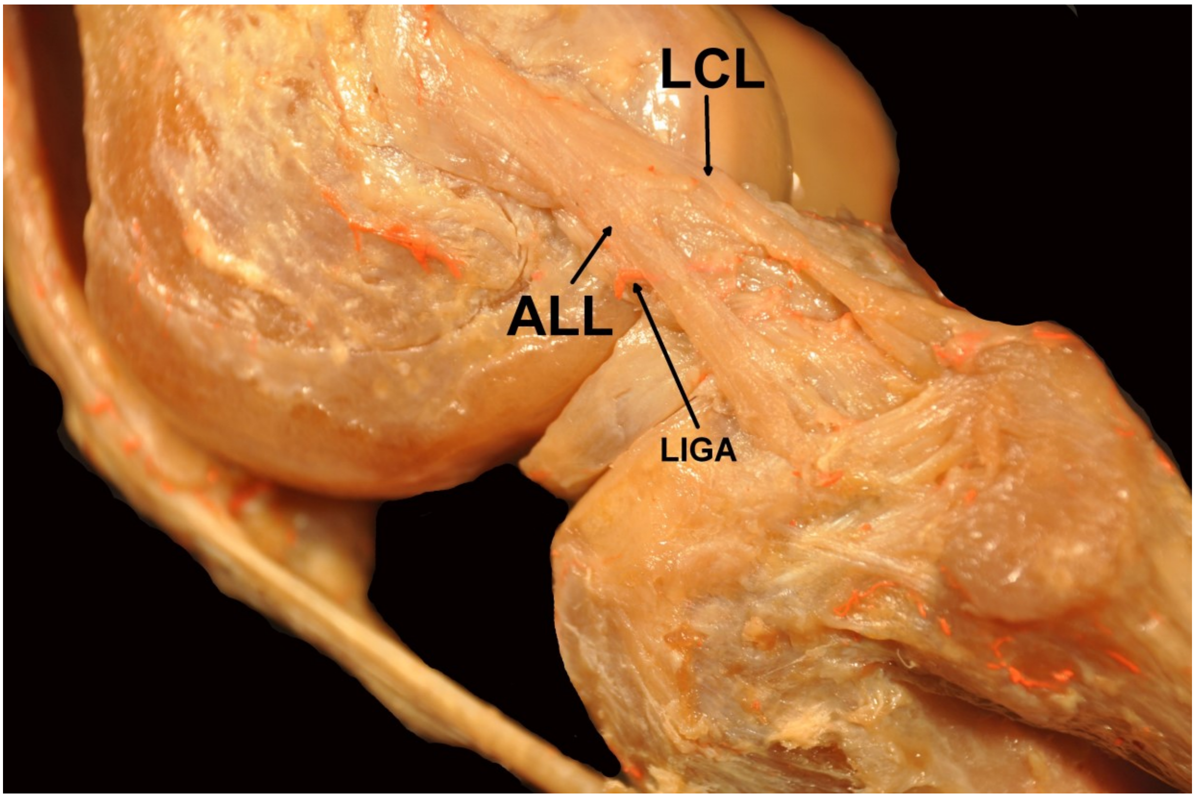


**Figure 8: Depiction of the lateral inferior geniculate artery** (ALL, anterolateral ligament; LCL, lateral collateral ligament; LIGA, lateral inferior geniculate artery)

## V.3. GENDER ANALYSIS

Detailed descriptive results for the collective are displayed in Tables 1-3. Male body donors were statistically significantly (p = < .001) taller (mean height: 175.2 mm; SD: 3.9; range: 165-185) when compared to the female collective (mean height: 158.2 mm; SD: 3.5; range: 151-165). In accordance, the TLL was significantly (p = < .001) longer in males (mean: 806.2 mm; SD: 45.1; range: 720-897) in comparison to females (mean: 748.3 mm; SD: 44.3; range: 660-818).

Further, the ALL was significantly (p = .044) shorter in females (mean length: 32.8 mm; SD: 5.2; range: 22.9-41.3) than in males (mean length: 35.7 mm; SD: 7.1; range: 24.6-53.1). The ACL was also significantly (p = < .001) longer in males (mean length: 35.8 mm; SD: 2.8; range: 28.1-41) when compared to females (mean: 31.7 mm; SD: 4.6; range: 23.4-41.3). However, there was no significant (p = .084) gender difference concerning the length of the LCL (females: mean of 45.2 mm; SD: 6.7; range: 30.6-59.2/males: mean of 47.9; SD: 6.9; range: 35.8-62).

## V.4. CORRELATION ANALYSIS

Concerning correlations in the total sample, the ALL correlated significantly positively with the ACL (p = < .001) and the LCL (p = < .001). There was no significant correlation with the TLL (p = .888) and body size (p = .046).

The ACL correlated positively with the LCL (p = < .001), the TLL (p = .002) and the body size (p = < .001). The LCL did not correlate with the TLL (p = .124) or donor’s height (p = .243). Further, TLL and donor size correlated significantly positively (p = < .001).

| n = 80 | | | | ALL width | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Distance GT** | **Distance FH** | **ALL length** | **Femoral insertion** | **Joint space** | **Tibial insertion** | **ALL thickness** | **TLL** | **LCL length** | **LCL thickness** | **ACL length** |
| **mean** | 16.1 | 2.6 | 34.2 | 8.9 | 9.3 | 10.2 | 2.6 | 775.8 | 46.5 | 4.7 | 33.6 |
| **SD** | 4.0 | 3.6 | 6.3 | 1.8 | 1.6 | 1.5 | 0.8 | 53.2 | 6.9 | 1.2 | 4.4 |
| **min** | 7.4 | 0 | 22.9 | 5 | 5.5 | 6.6 | 1.5 | 660 | 30.6 | 1.7 | 23.4 |
| **max** | 26.7 | 14.2 | 53.1 | 12.5 | 13 | 13.3 | 4.9 | 897 | 62 | 10.5 | 41.3 |

**Table 1: Descriptive characteristics of the total collective** (ALL, anterolateral ligament; FH, fibular head; GT, Gerdy's tubercle; LCL, lateral collateral ligament; TLL, total leg length)

| n = 42 | | | | ALL width | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Distance GT | Distance FH | ALL length | Femoral insertion | Joint space | Tibial insertion | ALL thickness | TLL | LCL length | LCL thickness | ACL length |
| mean | 14.7 | 1.8 | 32.8 | 8.5 | 9.1 | 9.8 | 2.3 | 748.3 | 45.2 | 4.6 | 31.7 |
| SD | 3.6 | 3.1 | 5.2 | 1.8 | 1.6 | 1.5 | 0.6 | 44.3 | 6.7 | 0.9 | 4.6 |
| min | 7.4 | 0 | 22.9 | 5 | 5.5 | 6.6 | 1.5 | 660 | 30.6 | 2.5 | 23.4 |
| max | 21.9 | 11 | 41.3 | 11.1 | 12 | 13 | 4.1 | 818 | 59.2 | 7 | 41.3 |

**Table 2: Characteristics of the female collective** (ALL, anterolateral ligament; FH, fibular head; GT, Gerdy's tubercle; LCL, lateral collateral ligament; TLL, total leg length)

| n = 38 | | | | ALL width | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Distance GT | Distance FH | ALL length | Femoral insertion | Joint space | Tibial insertion | ALL thickness | TLL | LCL length | LCL thickness | ACL length |
| mean | 17.6 | 3.5 | 35.7 | 9.4 | 9.6 | 10.7 | 2.8 | 806.2 | 47.9 | 4.9 | 35.8 |
| SD | 3.9 | 3.9 | 7.1 | 1.7 | 1.6 | 1.4 | 0.9 | 45.1 | 6.9 | 1.5 | 2.8 |
| min | 11 | 0 | 24.6 | 6 | 5.9 | 8 | 1.5 | 720 | 35.8 | 1.7 | 28.1 |
| max | 26.7 | 14.2 | 53.1 | 12.5 | 13 | 13.3 | 4.9 | 897 | 62 | 10.5 | 41 |

**Table 3: Descriptive characteristics of the male donors** (ALL, anterolateral ligament; FH, fibular head; GT, Gerdy's tubercle; LCL, lateral collateral ligament; TLL, total leg length)

# VI. DISCUSSION

The aim of this study was to evaluate the anatomical characteristics of the ALL in a large collective with the main focus on potential gender differences. Further we aimed to correlate the ALL's length with the length of the ACL, the length of the LCL, the TLL and the height of the donors.

The ALL was significantly ($p = .044$) shorter in females (mean length: 32.8 mm; SD: 5.2; range: 22.9-41.3) than in males (mean length: 35.7 mm; SD: 7.1; range: 24.6-53.1) and the ACL was also significantly ($p = < .001$) longer in males (mean length: 35.8 mm; SD: 2.8; range: 28.1-41) when compared to females (mean: 31.7 mm; SD: 4.6; range: 23.4-41.3). However, there was no significant ($p = .084$) gender difference concerning the length of the LCL (females: mean of 45.2 mm; SD: 6.7; range: 30.6-59.2/males: mean of 47.9 mm; SD: 6.9; range: 35.8-62).

Claes et al. (2013) reported a mean length of the ALL of 38.5 mm in total extension and Helito et al. (2013) of 37.3 mm, whereby these authors did not mention the joint position at time of measurement. Runer et al. (2016) evaluated a mean ALL length of 42.2 mm in extension. Our mean value for the total collective (mean: 34.2 mm) was slightly lower when compared to the reported data.

Concerning correlations in the total sample, the length of the ALL correlated significantly positively with the ACL length ($p = < .001$) and the LCL length ($p = < .001$). There was no significant correlation with the TLL ($p = .888$) and body size ($p = .046$). The length of the ACL correlated positively with the LCL length ($p = < .001$), the TLL ($p = .002$) and the body size ($p = < .001$). The LCL length did not correlate with the TLL ($p = .124$) or donor's height ($p = .243$). Further, TLL and donor size correlated significantly positively ($p = < .001$).

Regarding the prevalence of the ALL high discrepancies can be observed in the literature. Runer et al. (2016) and Saiegh et al. (2017) found a rate of 45.5% and 43%, respectively whereas Claes et al. (2013) reported a prevalence of 97% and Helito et al. (2013), Vincent et al. (2012) and Zens et al. (2015) of even 100%. Our results are comparable to the latter since we found the ALL in all of the 80 examined extremities. However, it must be stated that this was a ligamentous structure in solely 80% and a thin capsular thickening in 20%, which will likely not contribute to anterolateral knee stability.

With respect to the femoral origin of the ALL, Daggett et al. (2016) found a constant overlapping of this part with the origin of the LCL. In Claes et al. (2013) the origin of the ligament was situated at the most prominent part of the LE, anterior to the origin of the LCL in 100% of all studied specimens. In comparison, in our sample, the ALL overlapped the origin in 97.5% (78/80) and was situated ventral in one case and proximal to the LCL in one further specimen.

Further, connections between the lateral meniscus and the ALL have been reported by different authors (Claes et al. 2013, Dodds et al. 2014). We observed these in 96% (77/80). They were not present in two cases (3%) and could not be evaluated due to calcifications in one specimen (1%).

The lateral inferior geniculate artery could be commonly found between the ALL and the lateral meniscus in Claes et al.'s (2013) cadaver study. In this study, the vessel could be found in 56.3% (45/80) of all cases.

With respect to the tibial insertion point of the ALL, Caterine et al. (2015) and Claes et al. (2013) described this as situated in the middle of the line between the fibular head and Gerdy's tubercle. In contrast, we found the ALL much closer to the fibular head.

Claes et al. (2013) stated a mean width of 8.3 mm of the ALL's femoral insertion which is well comparable to our value (mean: 8.9 mm). At the height of the joint space, we evaluated a mean width of 9.3 mm which differs widely from reported data by Claes et al. (2013) who found a mean of 11.2 mm or Runer et al. (2016) who reported a mean of 5.6 mm. In our sample, the width at the tibial insertion proved to be greater (mean: 10.2 mm) when compared to the results of Claes et al. (2013) who stated a mean of 6.7 mm.

In Claes et al. (2013), the ALL's average thickness was 1.3 mm and this was 1.2 mm in Runer et al. (2016) at the height of the joint space. In our sample the mean thickness was 2.6 mm which is in accordance with Helito et al. (2013) where authors reported an average of 2.7 mm.

# VII. CONCLUSION

Absolute differences in the ALL's length reach a statistically significant difference between the sexes, however without clinical relevance. The length of the ALL correlates significantly positively with the ACL- and LCL-length.

# VIII. REFERENCES


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