

Illustration of the connection between the vastus medialis obliquus muscle and the superficial medial collateral ligament of the knee: A human knee cadaveric study

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Abstract

Background: While the anatomy of the medial part of the knee has been extensively described, the muscular connections to the superficial medial collateral ligament (sMCL) have not been sufficiently studied. The purpose of this study is to describe the anatomy of the musculo-ligamentous connection between the sMCL and the Vastus Medialis Obliquus muscle (VMO), and to describe its anatomy.

Methods: Six Human Cadaveric knees were used in this study. Donors were 4 males and 2 females with a mean age of 49 years old. Dissection was performed in fixed knee extension and directed to show the area of the proximal attachment of the sMCL.

Results: A musculo ligamentous connection between the distal portion of the Vastus medialis Obliquus muscle and the sMCL has been identified in our entire specimens. The mean mid substance width of this connection was 9.75 (8.7 -10.8) mm, the mean length was 29.3 (22.2-36.4) mm and the mean thickness was 1.3 (0.9-1.7) mm.

Conclusion: The proximal femoral attachment of the sMCL is directly connected to the distal end of VMO. This connection may show that the sMCL can possibly assist in the dynamic stabilization of the knee during extension against valgus stress, through its tension by the contracted VMO muscle.

Keywords: Superficial Medial collateral ligament; Anatomy; Human Knee

1. Introduction

The medial knee stabilizers are the most frequently injured ligaments of the knee. Also, the medial collateral ligament (MCL) is injured in at least 42 % of knees with ligamentous injuries [1], being much more common in younger population and in males more than females [2]. Secondary to a mechanism of injury including forceful knee valgus stress and/ or external rotation, and with increased prevalence of injury during certain athletic activities such as soccer and skiing [3], MCL injury can occur in isolation, or in association with anterior cruciate ligament injury, and medial meniscus tears [4]. Classically, most of isolated MCL injuries could heal with conservative management, but high-grade or chronic injury may lead to chronic knee instability [5] and may necessitate surgical repair or reconstruction. Complete knowledge of the anatomy of the MCL could help in the management of medial side knee injuries, whether a conservative or surgical intervention was planned, to obtain favorable clinical results.

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1.1. Anatomical considerations

The medial side of the knee has been classically described as being three layered [6]. The first layer, being most superficial, includes the Sartorius muscle and its investing fascia. The second layer includes the sMCL, posterioroblique ligament(POL), medial patellofemoral ligament (MPFL) and the musculo-tendinous attachments of the Semimembranosus. The third and deepest layer consists of the deep MCL and the joint capsule.

The two components of the MCL (superficial and deep) lie in the middle and deepest layers respectively and are separated by a bursa [8].

The medial side of the knee contains both dynamic and static stabilizers that contribute to the resistance of valgus and rotational forces. Static stabilizers of the medial knee include the sMCL, the deep MCL and the POL[9]. The medial dynamic stabilizers are the Semimembranosus complex, the quadriceps, and the pes anserinus. The MCL is the main stabilizer against valgus stress at lower flexion angles, and is known to provide 78%of the restraining force against valgus injury at 25 degrees of knee flexion, and 57% of the restraining forces against valgus stress in full knee extension. The POL, ACL and posteromedial capsule aid to provide most of the remaining restraint in full extension[10].

The sMCL origin is a round to oval depression posterior and 65 proximal to the femoral epicondyle. Proximal and posterior to the sMCL origin, the superficial and central arms of the POL are attached to bone near to the medial gastrocnemius tubercle. The superficial and central arms of the POLrun distally to insert into the distal tibial expansion of the semimembranosus and its tibial attachment, the posteromedial aspect of the medial meniscus, the meniscotibial portion of the posteromedial capsule, and the posteromedial part of the tibia [11]. The medial patellofemoral ligament is afibrous structure that extends from a broad area along the supero media laspect of the medial border of the patella and also from terminal end of the VMO muscle, and run medially and posteriorly to insert into the bone and soft tissue between the medial femoral epicondyle and the femoral attachments of the adductor magnus tendon into the adductor tubercle offemur [10].

In his description of the anatomy of the knee, Muller W [13] noted thepresence of ligamentous connection between the vastus medialis muscle and its fascial covering, and the area of MCL origin around the medial femoral epicondyle (MFE). Muller W [13] stated that on the femur these ligamentous collagenous fibers are in close association with the normal ligament and even appear to be blended with it over part of their course, and they terminate directly or indirectly to the vastus medialis muscle, and aids in active tension of MCL during motion. Based on that, Indlicato P [7] has also mentioned that the MCL is dynamized by the contraction of the Vastus Medialis during active extension through this connection. However; the anatomy of this connection has not been described in any further literature. This Cadaveric study aims to identify and illustrate the anatomy of this connection.

2. Material and methods

2.1. Cadaveric Knees

Six frozen and unpaired human cadaveric knees were utilized for this study. All the cadaveric specimens were available in our medical schools for researchers. The specimens were 3 right and 3 left knees without known pre existing knee surgery, belong to 4 males and 2 females. The mean age of the donors was 49 years (range 47 to 52). Each specimen was frozen at -20°C and thawed overnight prior to dissection. Each knee was transected ~35 cm above and below the joint line. The specimen was then aligned in a full extension position which was maintained throughout the dissection and measurements.

2.2. Anatomical dissection

First, the skin and subcutaneous tissue were dissected. The pes anserinustendons (sartorius, gracilis, and semitendinosus tendon) and the MPFL were detached from their distal attachments during dissection. Identification of thes MCL in the middle layer of the medial knee compartment is done. The MCL origin around the medial epicondyle was identified and carefully raised and followed proximally to the direction of the vastus medialis. At this stage, a Musculo ligamentous connection between the sMCL and VM was identified and raised carefully off the bone. Measurements were performed using the digital caliber ruler device (range 0-150 mm, precision 0.02mm).

3. Results

3.1. Musculo-Ligamentous connection between the VMO and sMCL

In all our specimens, we have dissected and proven a musculo-ligamentous connection, closely related to the underlying bone that extends between theVMO muscle and the uppermost fibers and anterior border of sMCL at its origin around the medial epicondyle. (Fig 1,2,3-6).This connection consists of mainly ligamentous and few muscle fibers. It originates

from the posterior border of distal end of the VMO muscle proper and the fascia covering it above the medial epicondyle. Also it has contribution from the adductor fascia and tendon. Then it extends distally, being closely related to the underlying bone, to cover the superior most portion of the medial femoral epicondyle, blending with the most superficial fibers of superior and anterior border of sMCL fibers in a fan shaped manner. (Fig 1, 2, 4, 5).

The shape and size of this connection varies from a specimen to another, depending on the muscle mass and the length of the limb, being more defined in specimens with good muscle mass. The length of the ligamentous portion of this connection from its origin at the VM to its end at the sMCL ranged from 22.2 to 36.4 (average 29.3) mm. We have divided it into thirds and measured the antero-posterior width for each one third. The average widths were 12.6-15.7 (14.1) mm, 14, 1-17.5 (15.8) mm and 8.7 -10.8 (9.75) mm for the proximal, distal and middle parts respectively. The thickness of this connection was not uniform, being thicker and broader proximally then tapering distally till it ends in the sMCL. In our specimens, the average mid substance thickness was about 0.9-1.7 (1.3) mm. The ligamentous fibers measurements in this connection are summarized in table 1.

Table 1 Measurements of sMCL-VMO connection: Range, (Average)

Proximal insertion width	Distal insertion width	Mid substance Width	Length	Mid substance thickness	site
12.6-15.7 (14.1) mm	14.1-17.5 (15.8) mm	8.7 -10.8 (9.75) mm	22.2-36.4 (29.3) mm	0.9-1.7 (1.3) mm	Measurement

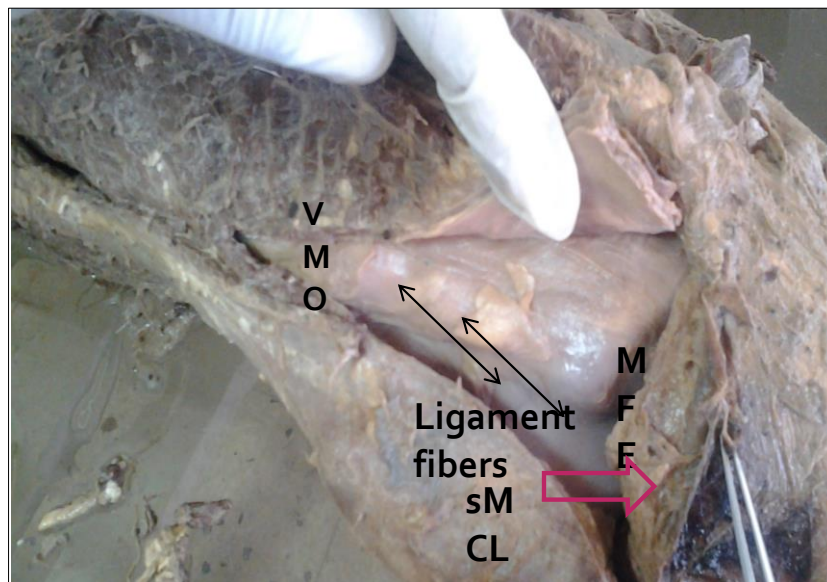


Figure 1 Cadaveric exposure showing the Medial Femoral Epicondyle (ME), the Vastus Medialis muscle (VM), the superficial Medial Collateral ligament origin (sMCL). The soft tissue structures were not elevated off the bone. Note the bright ligamentous fibers that originate from the undersurface and posterior border of VMO muscle and the fascia covering its tendon before joining the medial border of patella. Then it extends distally, to cover the medial femoral epicondyle (ME), and then to blend with the most superficial fibers of superior and anterior border of sMCL fibers at the level of their origin from the Medial epicondyle

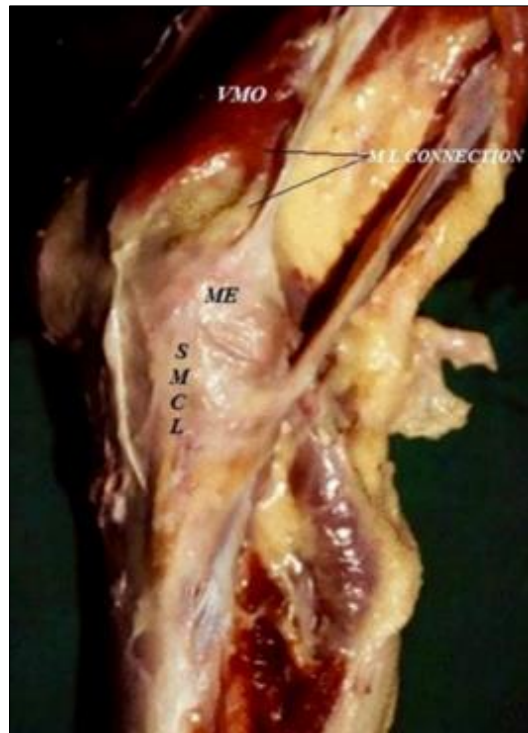


Figure 2 Cadaveric exposure of the medial knee shows the Musculo Ligamentous connection between the Vastus Medialis Obliquus (VMO) and the origin of the Superficial Medial Collateral Ligament (s MCL) from the Medial Epicondyle (ME). Note the contribution of the fascial covering VMO tendon to the connecting fibers. Reprinted with permission from Michel Bonnin: *The Knee Joint, Surgical techniques and strategies*, Springer – Verlag France, Paris, 2012 [3]

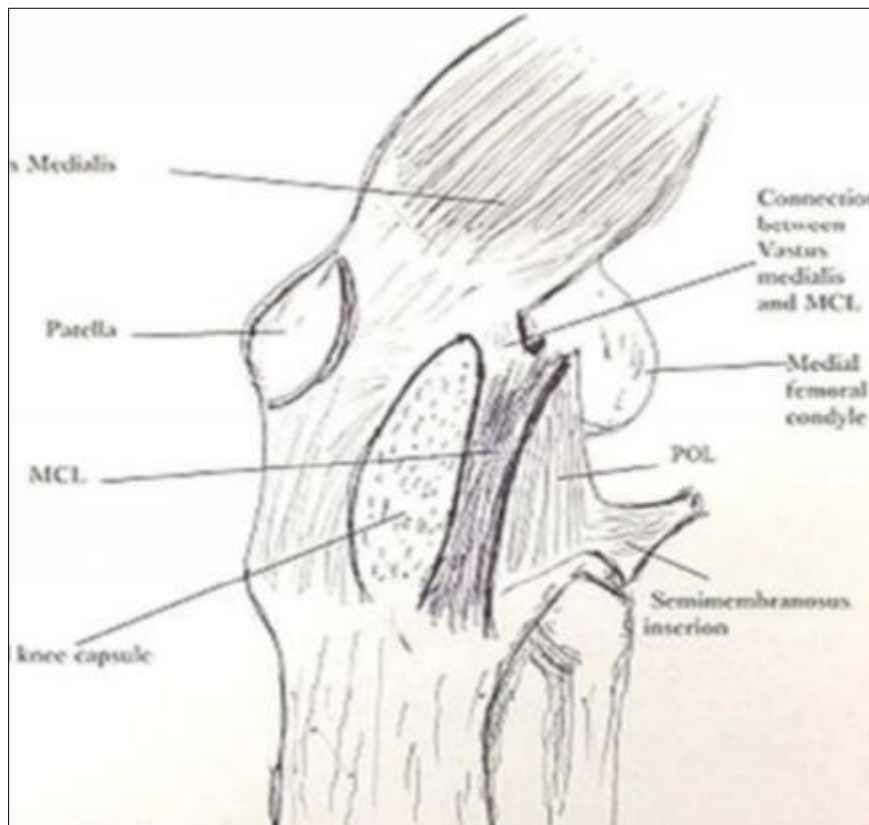


Figure 3 Simplified illustration of the connecting sleeve between the VMO and s MCL

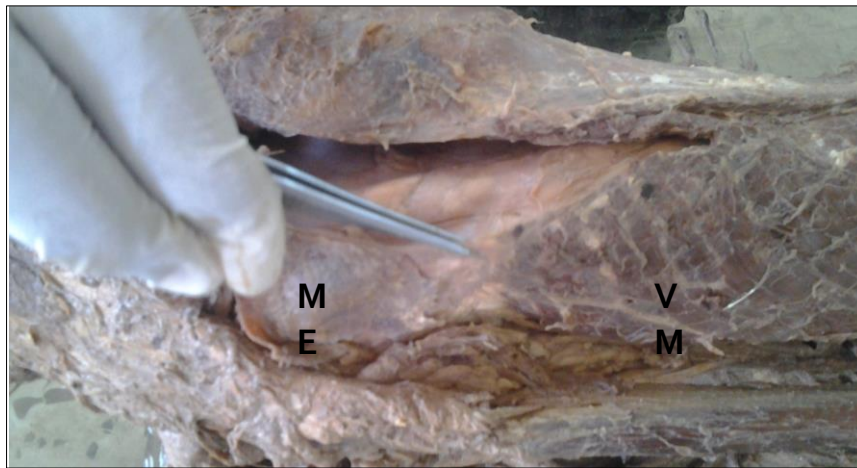


Figure 4 Cadaveric knee sample. Note the forceps pointed musculo ligamentous tissue that extends from the lower fibers of VMO to the area of sMCL origin from the medial epicondyle



Figure 5 Clinical photos, illustrating the connection between the s MCL and VMO, dissection done during a surgery for recurrent patellar dislocation

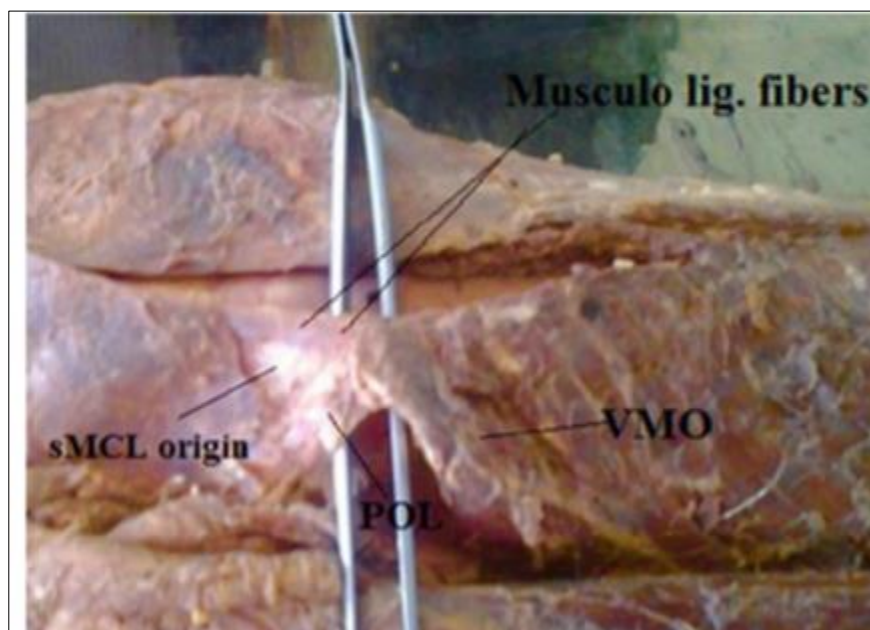


Figure 6 Cadaveric knee sample. Note the elevated musculo ligamentous connection from the distal end of Vastus Medialis to the sMCL origin from the medial epicondyle

4. Discussion

This study aims at determining the morphology of the connecting sleeve between the sMCL and the VMO. To our knowledge, there are no reports quantifying this connection except a short note by Muller W [13], who pointed out the existence of ligamentous collagenous fibers that can be traced beyond the ideal lines of the MCL origin. Muller W [13] mentioned that these fibers dynamize the MCL through its attachment to the Vastus Medialis and adductors, and stated that the sMCL fibers are protected from possible overstretching through its attachment to a dynamic, mobile structures as the muscle. In our study, we found that this connection to originate as muscular fibers from the VMO, and takes contributions from the adductor tendon and its covering fascia, to run distally as thin ligamentous fibers, closely related to the underlying bone to blend with the superior and anterior borders of the MCL at its origin from the medial epicondyle (Fig 1, 2, 4, 6). This connection may be overlooked due to many reasons; the first is that it arises from a small portion from the posterior border of most distal end of the VMO, and may be easily unnoticed in specimen with thin VMO muscle 171 mass. Also, this connection could be closely related to the underlying bone and often needs to be elevated carefully to expose it.

As mentioned in literature, the POL portion of the MCL was classically believed to assess in the dynamic stability of the knee during knee flexion, through its connection to the Semimembranosus tendon [16], while the sMCL itself was classically stated to be a static knee stabilizer. The presence of a direct connection between the sMCL and VMO may change the concept about the pure static function of the sMCL. Moreover, we found that in specimens with a well-defined VMO muscle mass, and subsequently more defined connecting fibers; the anterior portion of the s MCL which receives the insertion of this connection is more prominent and thicker than the rest of the s MCL. That's why we believe that the anterior portion of the s MCL is adynamized portion through its connection to the active structures. Injuries to knee ligaments are very common. It has been estimated that the incidence could be at 2/1000 people per year in the general population with a much higher incidence in those who are involved in sports activities. Ninety percent of knee ligament injuries involve the anterior cruciate ligament (ACL) and the medial collateral ligament [12]. Basic science and clinical studies have revealed that a ruptured MCL can heal spontaneously [16], however, laboratory studies have shown that its ultra-structure and biochemical composition may remain significantly changed [14].

Furthermore, the mechanical properties of the ligament substance remain substantially inferior to those of normal ligaments even after years of remodeling [11]. Thus, there has been a tremendous need for knowledge regarding ligament anatomy to better understand ligament injuries, healing and remodeling in hope to develop new and improved treatment strategies.

The limitless ability of the dynamized portion of the ligament to be strengthened by training may lead to increased ability to adapt higher performance, and could explain why the well-trained athletes suffer fewer injuries than fewer ones, and why less lower extremity muscle mass was associated with greater laxity and less stiffness in frontal and transverse planes. This also may contribute to the disproportionately higher laxities and reduced stiffnesses observed in females in these planes more than males, and why instabilities are particularly disabling in individuals with poor muscular strength [13, 18]. Muller W [13] postulated that flail knee after poliomyelitis is a consequence of laxity of the "rigid" ligaments due to chronic overstretching, when they can no longer be protected from excessive stress by an actively dynamized ligament component Shultz et al [19], concluded that transverse plane laxity and stiffness, or varus and valgus instabilities, may be modifiable through strength training interventions that promote changes in muscle characteristics (e.g. muscle cross-sectional area) thus contribute to more dynamic joint stability during sport activity. Through its connections to the static structures, a good muscle function could add considerable dynamic properties to the static structures and increase its ability to withstand stresses. Although, the biomechanical value of such small connection between the VMO and the sMCL might be less likely to significantly affect the knee stability, we believe that proper rehabilitation program for the medial knee instability should focus on increasing the VMO muscle mass and hence increasing the efficiency both the dynamic and static knee stabilizers functions. We admit several limitations of this study. First, is being only a descriptive study, while a biomechanical assessment of these findings would be most appropriate for investigating its value. Second, more specimens are needed to properly assess the size of such connection. We believe that more specimens and biomechanical assessment would be most appropriate to illustrate such anatomical connection. In summary, this study describes the anatomy of musculo ligamentous connection between the VMO and the sMCL in human knee specimens. More work is needed to quantitatively determine the biomechanical value of this connection in dynamization of the MCL during various degrees of knee movement.

5. Conclusion

The proximal femoral attachment of the sMCL is directly connected to the distal end of VMO. This connection may show that the sMCL can possibly assist in the dynamic stabilization of the knee during extension against valgus stress, through its tension by the contracted VMO muscle.

Compliance with ethical standards

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Conflict of interest

None to declare.

Statement of informed consent

All the cadaveric specimens were available in our medical schools for researchers and under full authorization from our hospitals board and health authorities. Approval of this study was obtained from our institutional review board.

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