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The extensor apparatus of the knee joint and its peripheral vasti : anatomic investigation and clinical relevance

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Summary. Anatomic dissections of the vastus medialis m. in 115 fixed thigh specimens always demonstrated a clear separation between a long head of the muscle (VML) inserted at the base of the patella and a short head (VMO) inserted at its medial margin. The plane of separation was identified by a branch of the femoral n. in every case. In 17 instances, the localization of the nerve was superficial; in 57, it was in the areolar fascial plane; and in 41 instances in lay deeply between the muscles. The ramification of the branch of the femoral n. traversing the plane of separation showed 4 types of variation. Dissections of the vastus lateralis m. in 42 specimens always demonstrated a separation into 2 heads: a long head inserted at the base of the patella (VLL) and a short head inserted at its lateral margin (VLO). The directions of the individual heads of the quadriceps femoris m. were angulated in relation to the long axis of the femur. The deviations were between 10° and 17±8 laterally for the vastus lateralis longus m. (VLL), between 26° and 41° laterally for the vastus lateralis obliquus m. (VLO), between 15° and 18° medially for the vastus medialis longus m. (VML), and between 46° and 52° medially for the vastus medialis obliquus m. (VMO). The results demonstrate great variation in the distal parts of the medial and lateral anterior thigh m.

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Nomenclature and abbreviations: RF = rectus femoris m.; *VI* = vastus intermedius m.; *VML* = vastus medialis longus m.; *VMO* = vastus medialis obliquus m.; *VLL* = vastus lateralis longus m.; *VLO* = vastus lateralis obliquus m.

L'appareil extenseur du genou et les muscles vastes : investigations anatomiques et conséquences cliniques

Résumé. Cent quinze dissections cadavériques du m. vaste médial ont montré de façon constante une séparation nette entre une portion longue du muscle qui s'insère à la partie supérieure (VML) de la rotule et une portion courte (VMO) qui s'insère au niveau de son bord interne. Dans chaque cas le plan de séparation a pu être identifié par une branche du n. fémoral. Dans 17 cas, le nerf était superficiel, dans 57 autres cas il se trouvait dans le plan du fascia et dans 41 cas, il était situé dans la profondeur entre les faisceaux musculaires. Les ramifications de cette branche du n. fémoral présentent 4 types de variations. 42 autres dissections du muscle vaste latéral ont montré une séparation en 2 portions : une portion longue s'insérant à la partie supérieure de la rotule (VLL) et une portion courte s'insérant au niveau de son bord externe (VLO). Les directions prises par les différents faisceaux du m. quadriceps forment un angle variable par rapport à l'axe du fémur, cet angle est de 10 à 17° en dehors pour la longue portion du m. vaste latéral (VLL), de 26 à 41° en dehors pour la portion oblique du m. vaste latéral (VLO), de 15 à 18° en dedans pour la longue portion du m. vaste médial (VML) et de 46 à 52° pour la portion oblique du vaste médial (VMO). Ces résultats montrent de grandes variations entre les parties distales des m. vastes médial et latéral.

Key words : Extensor apparatus — Knee joint — Vastus medialis obliquus m. — Vastus lateralis obliquus m. — Anatomic investigation

Knee joint pain in adolescents and young adults is often attributable to an abnormal gliding process or instability of the patella. This is to be differentiated from capsular and ligamentous injuries of the knee joint, lesions of the menisci and loose bodies.

The cause of the knee joint instability can be found in modifications of the bony, ligamentous or muscular structures. Experimental studies have refuted the notion that an increase of load bearing on the femoropatellar joint is the cause of patellofemoral pain [3, 6, 23, 31].

Patellar tracking could be the beginning of a new clinical picture. The positive and negative pressures on different areas of the cartilage lead to pathologic deterioration and patello-femoral arthrosis. This offers a fresh insight into chondromalacia patellae, with modifications of the extensor muscles of the knee joint identified as the cause. Further research into the extensors seemed called for.

A review of the function of the patella indicated its importance in improving the gliding process and protection of the anterior knee-joint against direct trauma.

Our anatomic investigation revealed, in addition to the general structure of the extensor m., 2 additional but always dissectable parts of the vastus medialis and vastus lateralis muscles. These are:

- on the medial and distal aspect, the oblique fibers of the vastus medialis m., running into the quadriceps tendon, the superomedial quadrant of the patella, the anterior medial capsule and the more longitudinally oriented superficial fibers. Their selective role is alignment. This part has been called the vastus medialis obliquus m. (VMO) [24, 25, 26];
- a comparable part of the vastus lateralis m., which is inserted into the lateral third of the base and into the superolateral two-thirds of the patellar border, the vastus lateralis obliquus m. (VLO) [27].

Clinical experience has shown that, though there is a bony and ligamentous predisposition to patellar instability, the existence of well-balanced extensors prevents changes from appearing during gliding. These observations underline the importance of the central part of the quadriceps femoris m. to patellar alignment.

Experimental explorations of cadaver knee joints have shown that the medial and lateral vasti, including their peripheral parts VMO and VLO, are the most relevant. However, little clinical research has been conducted into their precise function, which formed the subject of our investigation.

According to the Nomina Anatomica, the quadriceps femoris m. has 4 parts: rectus femoris; vastus intermedius; vastus lateralis, and vastus medialis m.

According to the recent orthopedic-traumatologic literature, the vastus medialis is divided into 2 parts with different functions. The long head, inserted more proximally into the base of the patella, is described as the vastus medialis longus (VML). The head inserted more distally into the medial border of the patella is called the vastus medialis obliquus m. (VMO) [10, 15, 16, 20, 23, 25, 28, 29, 30].

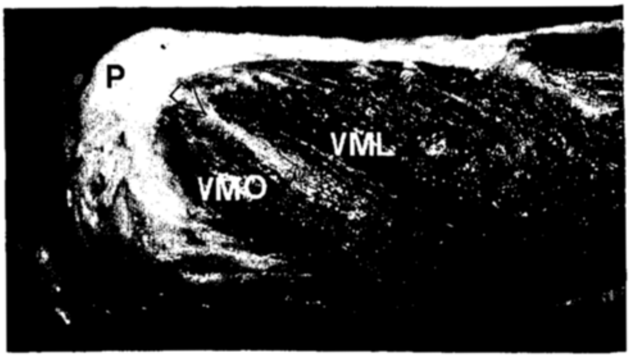


Fig. 1
Areolar fascial plane (→) at the boundary of VML and VMO; patella *(P)*

Fascia aréolaire (→) entre VML et VMO; patella *(P)*

This study considers the anatomic criteria for distinguishing two parts of the vastus medialis m., and whether the vastus lateralis m. is also composed of not one but two muscular parts.

Materials and methods

In total, 157 fresh or fixed cadavers were examined: 115 for dissection of the vastus medialis m. and 42 for the vastus lateralis m. The dissections also served to determine the deviation of the direction of pull of individual muscle parts from the long axis of the shaft of the femur.

Muscle dissection

To differentiate the 2 parts of the vastus medialis and vastus lateralis m., the fascia was dissected with special attention to possible superficial nerve branches running in the boundaries of the "long" and "oblique" muscle parts. Three levels of dissection were performed: superficial, within the area of the fascial plane, and following the muscle up from its point of insertion.

Direction of pull of the peripheral vasti

To determine the direction of pull of single muscles in relation of the femoral axis, a thread was stretched in the direction of the central fibers between the middle of the patellar insertion and the center of their origin in the linea aspera and the intertrochanteric line (VML, VLL) or the medial femoral condyle and the tendon of the

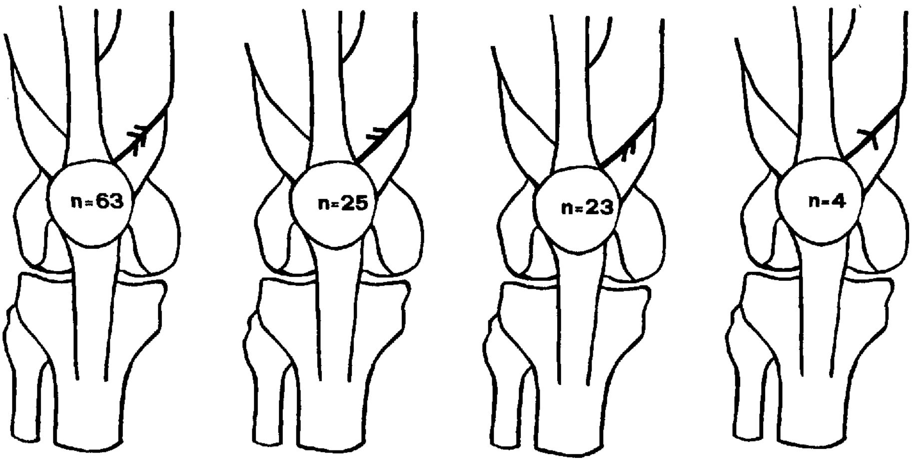


Fig. 2
Variations of branching of a branch of the femoral n. in the plane of separation between VML and VMO

Variations des branches du n. fémoral dans le plan de séparation entre VML et VMO

adductor magnus m. (VMO), or the fascia lata, the intermuscular septum and the Kaplan fibers VLO [12, 13] (Table 1).

After dissection, another thread was tightened from the vastus intermedius m. over the center of the entire frontal surface of the femur, parallel to the shaft axis. This thread was used to measure the variations of the angle of the peripheral vasti from the axis of the femoral shaft.

Results

Muscle dissections

In all 115 dissections, the VML and VMO could be differentiated by means of a nerve branch which runs between the two parts of the muscle. In 17 cases, the nerve was superficial; in 57, it was in an areolar fascial plane (Fig. 1); and in 41 it lay deeply between the muscle fibers (Table 2).

In those dissections which did not show any superficial boundary, a superficial nerve branch was always found in the same place in the areolar fascial plane. The nerve running between the VML and VMO is always a branch of the femoral nerve and extends to the medial capsular ligament of the knee joint.

In terms of nerve branches at the boundary of the VMO and VML, 4 variations could be differentiated: in 63 cases, 1 or more branches going to the VML and also to the VMO were found; in 25 cases, 1 or 2 branches to the VML were found, while in another 23 cases 1 or more branches were connected only with the VMO. In 4 specimens, 2 branches lying next to each other were found, the anterior having a branch to the VML, the posterior having a branch to the VMO (Figs. 2, 3).

Differentiation between the long and oblique parts of the vastus lateralis (VLL and VLO) could be made in all 42 cases if the areola fascial plane is considered as the boundary plane. In 37 cases the areolar fascial plane was clearly recognizable.

In 5 cases it was necessary to dissect in depth from the origin of the VLO at the intermuscular septum and the fascia lata, to find a fascial plane of different thickness (Table 3) (Figs. 4, 5).

Table 1. Origin and insertion of the peripheral vasti

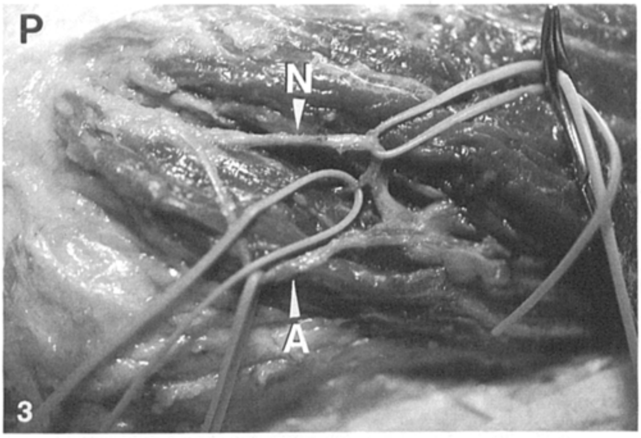
Origin	Insertion	
Linea aspera and intertrochanteric line	base of patella (medial side)	VML
Medial condyle of femur, vasto-adductor lamina	medial rim of patella	VMO
Linea aspera Greater trochanter	base of patella (lateral side)	VLL
Fascia lata intermuscular septum Kaplan fibers	lateral rim of patella	VLO

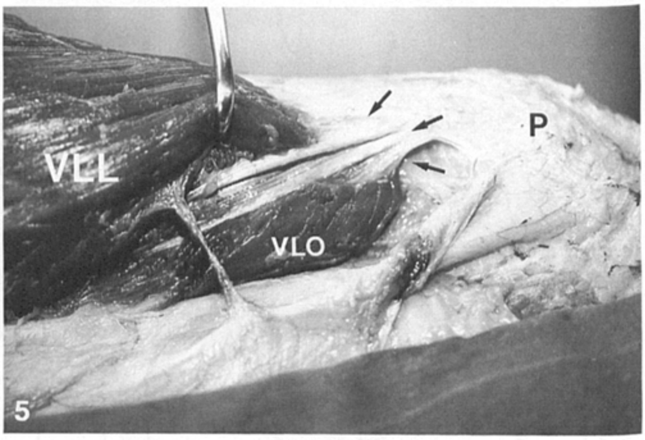
Table 2. Determination of boundary of VML and VMO

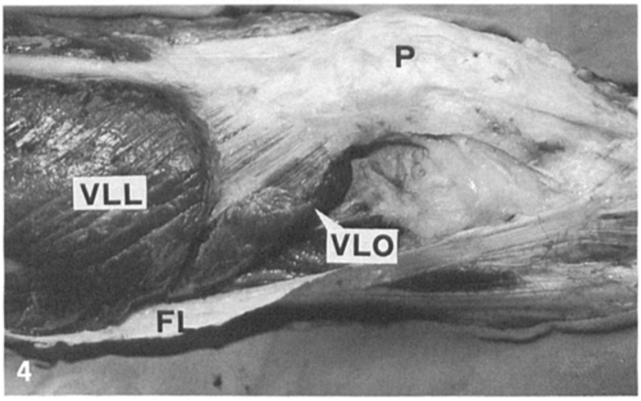
Superficialy situated nerve	n= 17
Dense fascial plane	n= 57
Deeply situated nerve	n= 41
Total	n=115

Table 3. Determination of the boundary of VLL and VLO

Dense fascial plane	n=37
Dissectable fascial plane	n= 5
Total	n=42







Figs. 3, 4, 5
3 Nerve *(N)* and concomitant a. *(A)* in the depth of the boundary between VMO and VML 4 Insertion of VLL and VLO at the patella *(P)*. *Arrow:* insertion of the vastus lateralis obliquus m. at the fascia lata *(FL)*, the intermuscular septum and the Kaplan fibers 5 Another form of the VLO (→) with its insertion at the patella *(P)*

3 Nerf *(N)* et a. satellite *(A)* séparant en profondeur VML et VMO 4 Insertions de VLL et VLO sur la patella *(P)*. La *flèche* indique l'insertion du m. vaste latéral oblique sur le fascia lata *(FL)* le septum intermusculaire et les fibres de Kaplan 5 Autre aspect du VLO (→) avec ses insertions sur la patella *(P)*

Direction of pull of the peripheral vasti

For the VML, the deviation of the direction of pull (main direction of fibers) from the long axis of the femur showed an average of 16.8°. For the VMO the deviation was 48.9° medially. For the VLL the deviation was 12.5° laterally, and for the VLO the deviation was 32.4° laterally. Table 4 gives the standard deviations of the standard factors (Table 4) (Figs. 6, 7).

Discussion and clinical relevance

The results of anatomic research showed that the two peripheral portions of the quadriceps femoris m. consist of 2 independent muscles, both functionaly and anatomically.

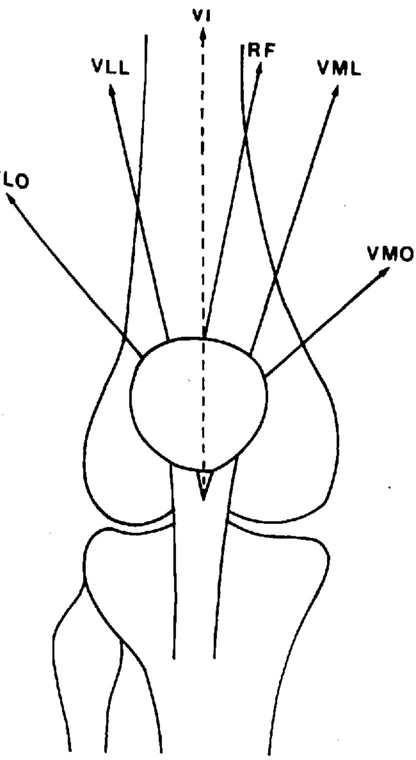
Table 4. Main direction of the peripheral vasti deviation from axis of femoral shaft

	Average deviation in degrees	Standard deviation of standard factors
VML	16.8°	0.8°-1.6°
VMO	48.9°	1.0°-3.5°
VLL	12.5°	0.7°-2.2°
VLO	32.4°	1.2°-3.6°

In the case of the VMO, our findings are consistent with those of other authors based on clinical and surgical experience [3, 5, 6, 11]. Before our first description of the VLO [27] we could find no discussion of this structure in the anatomic or clinical literature. The distinctive anatomic characteristics are the different fiber tracts and the different sites of origin and insertion of the muscle.

Earlier, we investigated the direction of pull as a function of the extensor m. in determining patellar alignment [23, 24, 26].

The present investigation indicates that there is a functional as well as an anatomic difference between the VML and VMO. The main function of the VMO is not terminal extension as claimed by other authors, but as an antagonist to the effects of the VLL and VLO forces in influencing patellar alignment [5, 6]. We made no individual measurements of the VLO because definitive anatomic proof was provided by the earlier experimental study. The direction of pull of the VLL and VLO in relation to the vastus medialis muscle seems to indicate a similar function. At the boundary of the VLL and VLO no significant nerve dissection corresponding to



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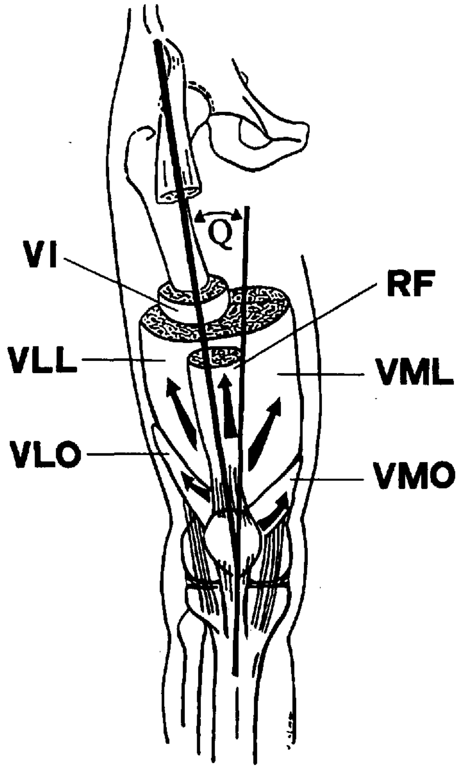

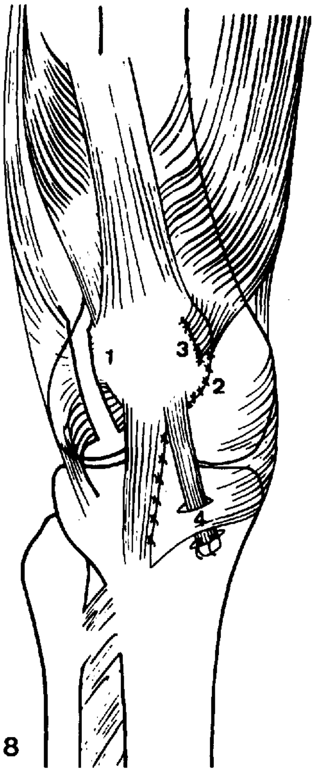

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Figs. 6, 7, 8
6 Direction of pull of the quadriceps m. **7** Direction of pull of the parts of the quadriceps m. in relation to the axis of the femur and the "Q"-angle **8** Operative technique of Slocum and Larson (1964) for recurrent dislocation of patella *1* lateral release *2* reefing of medial patellar retinaculum *3* VMO-plasty and *4* splitting of the medial third of the patellar tendon and its medial transfer

6 Axes de traction du m. quadriceps **7** Axes de traction des différents chefs du m. quadriceps par rapport à l'axe du fémur, et angle "Q" **8** Schéma de l'opération de Slocum et Harson (1964). *1* relâchement externe *2* remise en tension de l'aileron interne *3* plastie du VMO *4* libération du 1/3 médial du tendon rotulien et sa transposition interne

that of the VML and VMO was possible. Whether this is of functional importance or not is impossible to say. Because, as stated, the extensors (here specifically the peripheral vasti) are highly important for patellar alignment, conclusions may be drawn from the results of this research to facilitate the assessment and therapy of patellar instability. The VML and VLL function mainly as extensors of the knee joint; the most important role of the VMO and VLO is probably in adjustment of the patella in the patellofemoral joint. The VMO works together with the medial capsular-ligamentous structures — the patellar retinaculum with the patello-tibial and patello-femoral ligaments — to counter lateral subluxations of the patella [24], whereas a powerful VLO might favor lateral subluxation of the patella if it is caused by an outwardly sloping lateral femoral condyle. The risk is of course increased if the medial capsular and ligamentous structures are injured, inadequate, or frail due to a lesion of the VMO.

An abnormal gliding process of the patella (habitual subluxation) leads to a femoropatellar arthrosis, which is possibly the beginning of a pathogenic sequence ending in arthrosis of the entire knee joint [31]. Ficat's patellar syndrome [3] includes a state characterized by pain, friction, limitation, effusion, instability and locking.

Both physiotherapy and operative treatment are recommended for the cure of patellar instability.

Physiotherapy implies intensive strengthening and selective training of the muscle bellies of the extensor and flexor m., and only if this fails is operative treatment indicated. This consists of a lateral retinacular release and a so-called "VMO-Plasty" (moving the VMO insertion at the patella distally and medially to optimize its function of medial patellar pull as shown in the figure). The VMO-Plasty follows the direction of pull of the VMO and merely optimizes its function (Fig. 7).

A number of operative methods are available to prevent recurrent dislocation of the patella. Their common feature is readjustment of the glide-path of the patella by procedures on the proximal (peripheral vasti, retinacula) and distal structures (patellar tendon and possibly the pes anserinus) [1, 2, 4, 7, 8, 9, 14, 17, 18, 19, 21, 22]. In our own experience, the operative technique of Slocum and Larson [28] (as shown in Fig. 8) has proved satisfactory in recent years. This purely soft tissue operation affects the influence of the capsular and ligamentous structures and the muscles of the gliding process of the patella. The method comprises lateral release (i.e., section of the lateral retinaculum), reefing of the medial retinaculum, the VMO-Plasty described above as well as splitting of the medial third of the patellar tendon and its medial transfer with fixation to the periosteum. The aim of this operative technique is the medialization and medial tilting of the patella to displace the patellar to medially. The present anatomical survey should introduce the terms "vastus medialis obliquus muscle" and "vastus lateralis obliquus muscle" as 2 additional anatomical and functional parts of the quadriceps femoris muscle to the Nomina Anatomica, and should contribute to recognition of the importance of the extensor m. — especially the peripheral vasti VMO and VLO — in alignment of the patella in its gliding process and in deciding on conservative or surgical methods of treatment. On the other hand, muscle balance between the VMO and VLO could avoid manifestation of knee-joint instability despite ligamentous or bony predisposition.

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