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Research article - Basic and applied anatomy

The anatomy of the medial collateral ligament of the knee and its significance in joint stability

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Abstract

The medial collateral ligament (MCL) is the most important stabilizer of the medial side of the knee together with the capsuloligamentous complex. As such, it has a distinctive role in joint stability, as far as its biomechanics are concerned, and major joint stability issues onset when it is injured or deficient. One of the main functions of the medial collateral ligament is mechanical as it passively stabilizes the knee and help in guiding it through its normal range of motion when a tensile load is applied. It exhibits nonlinear anisotropic mechanical behaviour, like all ligaments, and under low loading conditions it is relatively compliant, perhaps due to recruitment of "crimped" collagen fibres as well as to viscoelastic behaviours and interactions of collagen and other matrix materials. Continued ligament-loading results in increasing stiffness until a stage is reached where it exhibits nearly linear stiffness and beyond this it continues to absorb energy until it is disrupted. In addition, the function of the MCL has to do with its viscoelasticity which assists the maintainance of joint congruity and homeostasis. The treatment of grade III medial collateral ligament injuries (with gross valgus instability at 0° of flexion) is still controversial. The most severe injuries (especially with severe valgus alignment, intra-articular medial collateral ligament entrapment, large bony avulsions, or multiple ligament involvement) may require acute operative repair or augmentation. In addition, surgical reconstruction is indicated for isolated symptomatic chronic medial collateral ligament laxity. The optimal surgical treatment remains controversial. More studies with evidence of level I and II are required in order to clarify the pros and cons of any solution.

Key words

Medial collateral ligament, knee, anatomy, biomechanics, reconstruction, review

Introduction

The medial collateral ligament (MCL) is the most important stabilizer of the medial side of the knee together with the capsuloligamentous complex. As such, it has a distinctive role in joint stability, as far as its biomechanics are concerned, and major joint stability issues onset when it is injured or deficient (Drake, 2005).

The purpose of this review is to summarize MCL anatomy, to pinpoint its role in knee stability, as far as its biomechanics are concerned, and to present its main reconstruction techniques. Thus, emphasis will be given to laxity after MCL tears and synergy of the MCL complex and cruciate ligaments. The most significant question pre-

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sented is when and how to repair the MCL because of the controversy between conservative and surgical treatment. This problem presents because of the absence of any significant algorithm for decision making in the treatment of the MCL pathology.

Anatomy

The traditional anatomic description of the MCL regards it as a structure broadly attached by most of its surface to the fibrous membrane. Superiorly it is described attached to the medial femoral epicondyle inferior to the adductor tubercle, inferiorly,. it attaches to the medial surface of the tibia, above and behind the attachment of sartorius, gracilis and semitendinosus (Drake, 2005).

A more detailed presentation of the anatomy of the medial aspect of the knee by Warren and Marshall divides the underlying structures in three layers (Warren and Marshall, 1979). Layer 1 mainly consists superficially of the sartorius muscle and posteriorly of fatty tissue. More deeply one can find the gracilis and the semitendinosus tendons. Next, layer 2 is the plane of the superficial MCL made of parallel and oblique bundles of connective tissue fibres. The anterior part consists of parallel fibres from the medial femoral epicondyle to the medial surface of the tibia posterior to the pes anserinus. Posterior oblique fibres are connected to layer 3 fibres and form the posteromedial capsule of the knee joint.

According to Sinclair et al. (2011) ligament attachment strength can be attributed to several factors, including the ligament's area of attachment, regional thickness, and mineral content of the MCL. The MCL consists of two major components: an abundant extracellular matrix (ECM) and ligament cells embedded in the ECM. Benjamin et al. (1986) report that cells in ligaments like the MCL are arranged into a series of widely spaced rows with cytoplasmic extensions that extend from cells in one row to those in another. In addition Chi et al. (2005) showed that in addition to gap junctions, adherens junctions and desmosomes are also expressed by MCL cells both in vivo and in vitro and map to sites of cell–cell contact.

According to Laprade et al. (2007) and Bonasia et al. (2012), as far as the superficial MCL is concerned, the femoral attachment is elliptical and placed on average 3.2 mm proximal and 4.8 mm posterior to the medial epicondyle. The proximal tibial attachment is primarily to the semimembranosus tendon. The distal tibial attachment is anterior to the posteromedial crest of the tibia. The length from the proximal tibial attachment to the tibial joint line is 12.2 mm. The average distance of the distal tibial attachment is 94.8 mm from the femoral attachment, and 61.2 mm from the tibial joint line. The average distance from the distal tibial attachment to proximal tibial attachment is 49.2 mm.

In addition, according to Warren and Marshall (1979) the deep MCL is an anatomic component of the medial joint capsule. It consists of the meniscofemoral and meniscotibial ligaments. The meniscofemoral ligament is longer than the meniscotibial ligament and is found posterior and distal to the medial epicondyle. The meniscotibial component is shorter, thicker and attached distal to the medial tibial plateau.

According to Phisitkul et al. (2006) the ligament length and its insertion areas on the femur and tibia have been measured upon dissection of cadaveric human knees in full extension. The superficial MCL has been described by James (1978) as triangular in shape and with the proximal and distal parts composed of parallel fibres, whereas the middle part of the superficial MCL as composed of parallel and oblique fibres. They described the width of proximal and distal parts as similar in the anterior-posterior direction. The anterior portion does not seem to be connected to the medial meniscus and it is distinguished from the capsule of the knee joint. However, the posterior portion is connected very closely to the medial meniscus.

A number of anatomic studies have compared the two individual components of the MCL. LaPrade et al. (2007) showed that the distal tibial insertion area is larger than the femoral insertion area. Nevertheless, there is a debate in the description of the location of the femoral insertion of the superficial MCL. There are those authors who describe the femoral insertion of the superficial MCL as located on the medial epicondyle of the femur while others report that the femoral insertion site of the superficial MCL is located slightly proximal to the medial epicondyle. Brantigan and Voshell (1946) propose that a part of the superficial MCL is indistinguishable from the capsule, and anatomically and functionally is connected to the medial meniscus. Last (1948) also observed that the posterior part of the superficial medial ligament is attached to the medial meniscus. The attachment of the superficial MCL to the medial meniscus cannot be overemphasized since its removal during total knee arthroplasty can affect the stability of the superficial MCL and allow varus correction without further soft tissue release.

The deep medial collateral ligament is a layer and a part of the medial joint capsule. The deep MCL consists of the meniscofemoral and meniscotibial ligaments. The meniscofemoral ligament is longer than the meniscotibial ligament and its attachment is located posterior and distal to the medial epicondyle. The meniscotibial ligament is shorter, thicker and attaches just distal to the cartilage of the medial tibial plateau. According to Robinson et al the disagreement whether the oblique fibres in the posterior third are part of the superficial MCL - or a thickening of the capsule - has no practical significance. The most important point is that they seem to be a functional unit with links to the semimembranosus tendon sheath (Robinson et al., 2004).

Biomechanics and function

One of the main functions of the MCL is mechanical as it passively stabilizes the knee and helps in guiding it through its normal range of motion when a tensile load is applied. It exhibits nonlinear anisotropic mechanical behaviour, like all ligaments, and under low loading conditions it is relatively compliant, perhaps due to recruitment of “crimped” collagen fibres as well as to viscoelastic behaviour and interaction of collagen and other matrix materials. Continued ligament-loading results in increasing stiffness until a stage is reached where it exhibits nearly linear stiffness and beyond this it continues to absorb energy until it is disrupted (Frank, 2004).

In addition, the function of the MCL has to do with its viscoelasticity which assists the maintenance of joint congruity and homeostasis. Load and stress to the joint are diminished due to the action of the MCL and its inefficiency leads to constant deformation. The creep of the MCL is also an important parameter which is referred to as the deformation-elongation under a constant or repetitive load. The importance of creep cannot be underestimated since in knee reconstruction excessive creep could result in laxity of the joint thus predisposing it to further injury or prosthesis failure (Woo and Young, 1991). The MCL has also an important role affecting knee proprioception which concerns the conscious perception of limb position in space. In the human knee, proprioception is provided principally by receptors in the joint, muscle and cutaneous tissue (soft tissue). Strained ligaments evoke neurological feedback signals that then activate muscular contraction and this appears to play a role in joint position sense (Liu et al., 2010).

Biomechanically, the MCL is the main reacting ligament to valgus forces and a secondary restraint to rotation forces and posterior translation of the tibia. The superficial MCL is the main stability to valgus forces from full extension to full flexion of the knee. Resistance of the MCL against rotational forces starts being significant at 30^{o} of knee flexion with the relaxation of the posteromedial capsule. The superficial MCL is the main ligament for medial stability even when the deep MCL is inefficient. On the other hand, the posteromedial capsule is in tension and provides significant stability reacting to valgus forces, posterior tibial translation, and internal rotation with the knee extended (Fuss, 1992).

The action of the posterior oblique ligament is crucial for the stability of the knee joint. The posterior oblique ligament provides stability to tibial internal and external rotation at knee flexion and posterior stability to the tibia in knee extension. The role of the posterior oblique ligament becomes even more important when the MCL is deficient for both valgus and rotational stability (Fuss, 1991).

According to Wilson et al. (2012), despite differences in geometry and strength, there was no significant difference in stiffness of the MCL and lateral collateral ligament when tested in vitro. This means that stiffness is of secondary importance to biological structure. Biological structure seems to be similar for both ligaments.

In their biomechanical studies, Stein et al. (2009) showed that there are only some deep and tender fibrous bundles of the medial collateral ligament radiating into the medial meniscus proximally and posteriorly. Their findings suggest that there is no relevant influence of the medial collateral ligament on the stability of the medial meniscus.

In their thorough review, Robinson et al. (2004) suggest that the posteromedial capsule functions as a passive restraint to internal rotation of the tibia with the knee in extension. In addition, Hughston and Eilers (1973) suggested that the semimembranosus may play a role in the stability of the medial knee compartment. There is perhaps a relation to the proximity of the semimembranosus to the MCL for this function.

Treatment of MCL injury

Although there is significant knowledge on the MCL, its anatomy and biomechanics, there is a controversy concerning MCL injury treatment. The traditional rule expressed by Hughston and Eilers (1973) that injuries grade I and II should be treated conservatively and injuries of the grade III should be treated operatively does not seem to be adequate. Other factors affecting decision making should be MCL entrapment, bony avulsion, co-existence of other injuries (especially anterior collateral ligament tears), valgus knee misalignment and finally acute or chronic injury (Fetto and Marshall, 1978).

Additional controversy rises when treating an anterior cruciate ligament tear coexisting with an MCL tear. In this case most authors suggest conservative treatment of the MCL injury with surgical repair of the anterior cruciate ligament injury. The MCL is proposed to be treated surgically only if instability of the knee remains after the anterior cruciate ligament reconstruction (Marshall et al., 1977; Kannus, 1988; Indelicato, 1995).

According to Phisitkul et al. (2006) conservative treatment should consist of a hinged knee brace with weight bearing as tolerated and crutches for initial pain relief. Isometric and range of motion exercises should be encouraged immediately in order to ensure knee stability. Crutches are discontinued when the patient can walk without limping. Anti-inflammatory medication are used as a common practice by most physicians, but limited evidence support their use.

Surgical procedures for the MCL reconstruction comprise Kim ′s and Stannard ′s techniques who both use a semitendinosus graft looped around a k-wire in a femoral attachment (Kim et al., 2008; Stannard, 2010), Lind ′s technique using tunnels for the graft insertion into the femoral and the tibial insertion points with interference screws (Lind et al., 2009), Yoshiya ′s single-bundle technique (Yoshiya et al., 2005), Coobs′ technique for separate reconstruction of the MCL and posterior oblique ligament (Coobs et al., 2010), Borden ′s double-bundle technique using an anterior tibialis graft and certain variations to the above main techniques (Borden et al., 2002). All of them if executed properly seem to provide for adequate to excellent results.

What is particularly interesting in the literature is the absence of studies with high level of evidence concerning the outcome of these surgical techniques, their complications and their advantages and disadvantages in general. Therefore it is pretty difficult to make an unbiased conclusion as far as the comparison of these techniques is concerned. In addition, there is little evidence on the different effectiveness of the rehabilitation protocols depending on the preferred reconstruction technique. More data are required to evaluate which is the most efficient rehabilitation technique following each reconstruction method. In order to clarify such issues, multi-centre, randomized studies are necessary.

Conclusion

The attachment strength of the MCL can be attributed to several factors, including the ligament′s area of attachment, regional thickness, and mineral content.

The superficial MCL has a femoral insertion proximal and posterior to the medial epicondyle. The proximal tibial attachment is primarily to the semimembranosus tendon. The distal tibial attachment is anterior to the posteromedial crest of the tibia.

The deep MCL is an anatomic component of the medial joint capsule. It consists of the meniscofemoral and meniscotibial ligaments. The meniscofemoral ligament is longer than the meniscotibial ligament and is found posterior and distal to the medial epicondyle. The meniscotibial component is shorter, thicker and attached distal to the medial tibial plateau.

Biomechanically, the MCL is the main reacting ligament to valgus forces and a secondary restraint to rotation forces and posterior translation of the tibia. The superficial MCL is the main stability to valgus forces from full extension to full flexion of the knee. Resistance of the MCL against rotational forces starts being significant at 30^o of knee flexion with the relaxation of the posteromedial capsule. The superficial MCL is the main ligament for medial stability even when the deep MCL is inefficient.

The posterior part of the superficial medial ligament is attached to the medial meniscus. The attachment of the superficial MCL to the medial meniscus is important since its removal during total knee arthroplasty can affect the stability of the superficial MCL and lead to change preoperative planning and prevent further soft tissue release. Removing a medial meniscus during a total knee arthroplasty can loosen the MCL if the two are connected. This means that in a varus knee there is usually sufficient soft tissue release to correct for the varus deformity. However removing the medial meniscus does not always affect the MCL which then needs further release on its own. Basically what we do is to remove the medial meniscus and place the implants. Then we test the movement of the knee to see if any varus deformity remains. If this is the case we proceed with further MCL release.

Ethical standards

This article does not contain any studies with human participants or animals performed by any of the authors. All the authors declare to have no conflict of interest. No funds were received in support of this study. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

References

Benjamin M., Evans E.J., Copp L. (1986) The histology of tendon attachments to bone in man. J. Anat. 149: 89–100.

Bonasia D.E., Bruzzone M., Dettoni F., Marmotti A., Blonna D., Castoldi F., Gasparetto F., D'Elicio D., Collo G., Rossi R. (2012) Treatment of medial and posteromedial knee instability: indications, techniques, and review of the results. Iowa Orthop. J. 32: 173-183.

Borden P.S., Kantaras A.T., Caborn D.N. (2002) Medial collateral ligament reconstruction with allograft using a double-bundle technique. Arthroscopy 18: E19.

Brantigan O.C., Voshell A.F. (1946) Ligaments of the knee joint; the relationship of the ligament of Humphry to the ligament of Wrisberg. J. Bone Joint Surg. Am. 28: 66-67.

Chi S.S., Rattner J.B., Sciore P., Boorman R., Lo I.K. (2005) Gap junctions of the medial collateral ligament: structure, distribution, associations and function. J. Anat. 207: 145-154.

Coobs B.R., Wijdicks C.A., Armitage B.M., Spiridonov S.I., Westerhaus B.D., Johansen S., Engebretsen L., LaPrade R.F. (2010) An in vitro analysis of an anatomical medial knee reconstruction. Am. J. Sports Med. 38: 339-347.

Drake R.L., Vogl W., Mitchell A.W.M. (2005) Gray's Anatomy for Students. Elsevier Inc., Philadelphia.

Fetto J.F., Marshall J.L. (1978) Medial collateral ligament injuries of the knee: a rationale for treatment. Clin. Orthop. Relat. Res. 132: 206-218.

Frank C.B. (2004) Ligament structure, physiology and function. J. Musculoskel. Neuronal Interact. 4: 199-201.

Fuss F.K. (1991) Voluntary rotation in the human knee joint. J. Anat. 179: 115-125.

Fuss F.K. (1992) Principles and mechanisms of automatic rotation during terminal extension in the human knee joint. J. Anat. 180: 297-304.

Hughston J.C., Eilers A.F. (1973) The role of the posterior oblique ligament in repairs of acute medial (collateral) ligament tears of the knee. J. Bone Joint Surg. Am. 55: 923-940.

Indelicato P.A. (1995) Isolated medial collateral ligament injuries in the knee. J. Am. Acad. Orthop. Surg. 3: 9-14.

James S.L. (1978) Surgical anatomy of the knee. Fortschr. Med. 96: 141-146.

Kannus P. (1988) Long-term results of conservatively treated medial collateral ligament injuries of the knee joint. Clin. Orthop. Relat. Res. 226: 103-112.

Kim S.J., Lee D.H., Kim T.E., Choi N.H. (2008) Concomitant reconstruction of the medial collateral and posterior oblique ligaments for medial instability of the knee. J. Bone Joint Surg. Br. 90: 1323-1327.

LaPrade R.F., Engebretsen A.H., Ly T.V., Johansen S., Wentorf F.A., Engebretsen L. (2007) The anatomy of the medial part of the knee. J. Bone Joint Surg. Am. 89: 2000-2010.

Last R.J. (1948) Some anatomical details of the knee-joint. J. Bone Joint Surg. Br. 30: 683-688.

Lind M., Jakobsen B.W., Lund B., Hansen M.S., Abdallah O., Christiansen S.E. (2009) Anatomical reconstruction of the medial collateral ligament and posteromedial corner of the knee in patients with chronic medial collateral ligament instability. Am. J. Sports Med. 37: 1116-1122.

Liu F., Yue B., Gadikota H.R., Kozanek M., Liu W., Gill T.J., Rubash H.E., Li G. (2010) Morphology of the medial collateral ligament of the knee. J. Orthop. Surg. Res. 16: 69.

Marshall J.L., Fetto J.F., Botero P.M. (1977) Knee ligament injuries: a standardized evaluation method. Clin. Orthop. Relat. Res. 123: 115-129.

Phisitkul P., James S.L., Wolf B.R., Amendola A. (2006) MCL injuries of the knee: current concepts review. Iowa Orthop. J. 26: 77-90.

Robinson J.R., Sanchez-Ballester J., Bull A.M.J., Thomas R.W.M., Amis A.A. (2004) The posteromedial corner revisited. J. Bone Joint Surg. Br. 86: 674-681.

Sinclair K.D., Curtis B.D., Koller K.E., Bloebaum R.D. (2011) Characterization of the anchoring morphology and mineral content of the anterior cruciate and medial collateral ligaments of the knee. Anat. Rec. 294: 831-838.

Stannard J.P. (2010) Medial and posteromedial instability of the knee: evaluation, treatment, and results. Sports Med. Arthrosc. 18: 263-268.

Stein G., Koebke J., Faymonville C., Dargel J., Müller L.P., Schiffer G. (2009) The relationship between the medial collateral ligament and the medial meniscus: a topographical and biomechanical study. J. Am. Acad. Orthop. Surg. 17: 152-161.

Warren L.F., Marshall J.L. (1979) The supporting structures and layers on the medial side of the knee: An anatomical analysis. J. Bone Joint Surg. Am. 61: 56.

Wilson W.T., Deakin A.H., Payne A.P., Picard F., Wearing S.C. (2012) Comparative analysis of the structural properties of the collateral ligaments of the human knee. J. Orthop. Sports Phys. Ther. 42: 345-351.

Woo S.L, Young E.P. (1991) Structure and function of tendons and ligaments. In: Mow V.C., Hayes W.C. (eds.) Basic Orthopaedic Biomechanics. Raven Press, New York. Pp. 199-243.

Yoshiya S., Kuroda R., Mizuno K., Yamamoto T., Kurosaka M. (2005) Medial collateral ligament reconstruction using autogenous hamstring tendons: technique and results in initial cases. Am. J. Sports Med. 33: 1380-1385.