REVIEW ARTICLE

# The lateral stability of the knee, A review of the clinical Anatomy of the Popliteal hiatus and its clinical pathologies

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**Abstract**

As a modified hinge joint, the knee joint facilitates the erect posture and greater mobilization of the human body. Varus-valgus angulation, external-internal rotation, and anterior-posterior stability are primarily maintained by the tibial bony eminences, menisci, and the congruencies of the femoral and tibial articular surfaces. The primary restrainer for the valgus angulation is the medial collateral ligament (MCL). The primary restrainer for varus angulation is the lateral collateral ligament (LCL). Even though the LCL is the principal lateral stabilizer for the knee, it is supported by the surrounding ligaments, muscles, and tendons. Non -uniformity in the nomenclature of these structures and complexity in the anatomical arrangements lead to complexity of understanding and clinical interpretation. The popliteus is a very small muscle but a unique muscle to the knee with specialized functions. It is highly vulnerable to injuries during trauma with posterior lateral corner injuries of the knee. Proper history of the injury and clinical assessment will help in a proper diagnosis. However acute pain in the knee may interfere with a proper clinical diagnosis. During total knee arthroplasty, special care should be taken to minimize the iatrogenic popliteal ligament injuries during bone cuts and lateral release in soft tissue gap balancing.

## Introduction

The knee joint is a modified hinge joint that helps to achieve an erect posture and greater mobilization of the human. It is a complex structure with a femorotibial joint and a patella femoral joint. It is a synovial hinge joint and the largest joint in the human body. The femorotibial joint bears the body weight. It helps the mobilization with the greatest range of movements with internal, and external rotation (in the transverse plane), flexion, extension (in the sagittal planes), and varus, valgus stress (in the frontal plane). The patella-femoral joint gives the frictionless transfer of quadriceps contraction to leverage the tibia. Stress forces applied to the knee joint are very high during the function of the knee. The stability of the knee depends on the integrity of the knee's bony articulation, ligamentous, and muscular structures.

The ligamentous stability is maintained by the extra-articular medial collateral ligament (MCL), Lateral collateral ligament (LCL), and illio tibial band with fibrous joint capsule. The intra-articular anterior cruciate ligament (ACL), and posterior cruciate ligament (PCL) had given the anterior-posterior motion stability. The two bony articulations in the joint with stabilizing ligaments facilitated the weight loading, and weight transmission of the knee joint in addition to flexion and extension. The knee joint acts as a static and dynamic stabilizer for running, walking, and jumping. Both medial and lateral stability of the knee is maintained by static and dynamic stabilizers. The knee joint stability in rotational planes, coronal and sagittal planes is primarily maintained by the tibial bony eminences, collateral ligaments, cruciate ligaments, menisci, and the congruencies of the femoral and tibial articular surfaces. The primary restrainer for the valgus angulation is the medial collateral ligament (MCL). MCL acts as the inner side stabilizer of the knee and attaches to the posterior superior aspect of the medial femoral epicondyle. And distally it gives two attachments to the medial surface of the proximal tibia. The LCL is the lateral side stabilizer of the knee, and it is a cord-like structure that proximally attaches to the lateral epicondyle of the femur, behind the popliteus grove. LCL distally attaches 1cm below the head of the fibula in the lateral aspect. Anterior and posterior cruciate ligaments and semilunar-shaped menisci further enhance medial and lateral stabilization of the knee.

The human knee is a complex joint with considerably different properties in the sagittal, frontal, and trans-verse planes.

The medial meniscus is larger with an open curve that encloses the horns of the lateral meniscus. The lateral meniscus is attached to the intercondylar area of the tibia immediately in front and behind the tibial eminence.

A complex arrangement of ligaments, tendons, and muscles maintains the lateral stability of the knee. The complexity of

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structures and variances in nomenclature resulted in difficulty in understanding the functional anatomy of the lateral ligament stability. The purpose of this paper is to clarify the complexities of understanding the lateral stability of the knee.

In the anterolateral aspect, the principal joint stabilizers are the joint capsule and the iliotibial tract. The posterior lateral stabilization is a complex structural arrangement. In addition to the LCL, biceps femoris, popliteal tendon, arcuate ligament complex, popliteal menisci femoral ligament(PMFL) and popliteal fibular ligaments (PFL) act as postero lateral stabilizers. The anterior lateral part of the capsule is reinforced by the superior and inferior patella retinacular fibers and the vastus lateralis muscle and extends back to the lateral collateral ligaments and distally to the tibial condyles.

The posterior lateral corner stability has been explained as three-layer stability . Layer -1 is the outer layer, which forms anteriorly by the iliotibial band and posteriorly by the bicep femoris tendon. Layer -II is the middle layer, formed by the patellofemoral ligament, lateral patellar retinaculum, and lateral collateral ligament. Layer -III is the inner layer formed by the popliteal muscle and tendon, arcuate ligament, fabella, fabella, fabella fibular complex, and lateral joint capsule.

The posterior capsular attachment to the lateral tibial condyle is interrupted by the emerging popliteal tendon (Figure1). The oblique popliteal tendon which arises as an elongation of the semimembranosus tendon merges with the posterior capsule and strengthens the posterior capsule (Figure1). A "Y-shape" condensed collagen band called an "arcuate" ligament starts from the fibular head and courses over the popliteus to merge into the posterior capsule. Its medial extension fibers join the fibers of the oblique popliteal ligament (Figure 1). During its course over the popliteus tendon, get firmly attach to the musculotendinous junction of the popliteus muscle. The arcuate ligament complex helps to stabilize the knee posterior laterally . They primarily maintain the rotational stability and coronal and sagittal stability of the knee. Internally the capsule is attached to the lateral meniscal outer ring and merging with the coronary ligaments and attaching to the lateral tibial condyles.

Poplitio fibular ligament is a well dominant anatomical structure in the lateral knee (Figure 1). It is the one of the main stabilizers of the lateral knee . It stabilizes the posterior translation of the knee, varus angulation and external rotation of the knee (Torzilli, Maynard and Warren, 1995). It originates just proximal to the myotendinous junction of the popliteus and inserts to the medial styloid of the fibular head and merges into the lateral collateral ligament attachment. Morphological appearance can vary as single, double or Y-shaped as describe by (K. Natsis et al., 2012). Posterior limb of the PFL inserted proximally in to the anterior PMF and stabilizes the lateral meniscus (Stäubli and Birrer, 1990).

Higgins 1894 first describes the popliteal muscle and its attachment to the lateral meniscus . In 1950 Last did an analytical description of the popliteal muscle and its tendinous fibers attachment to the head of the fibula and lateral meniscus . The popliteus muscle is a posterior lateral corner stabilizer of the knee. It is a unique feature of this muscle its origin is distal to its insertion. In the literature there are controversies about the origin and insertion of the popliteus muscle. The popliteus muscle originates from the posterior surface of the tibia, above the soleal line, and below the tibial condyles (Figure1). It moves obliquely towards the lateral condyle of the femur with the formation of a cord-like tendon and attaches just below the lateral epicondyle of the femur known as popliteal sulcus. Popliteus tendon is located in the posterior lateral corner of the knee. It inserts onto the floor of the popliteal fossa and forms it (Figure 1). During its course it's give attachments to the posterior horn of lateral meniscus (the popliteal meniscal ligament)and popliteal fibular ligament to the fibula (Figure 2) Popliteus tendon traverses an extra synovial, extraarticular course . But popliteal tendon attachment at femoral condylar is intra capsular. It is partly intra synovial at the level of lateral meniscus .

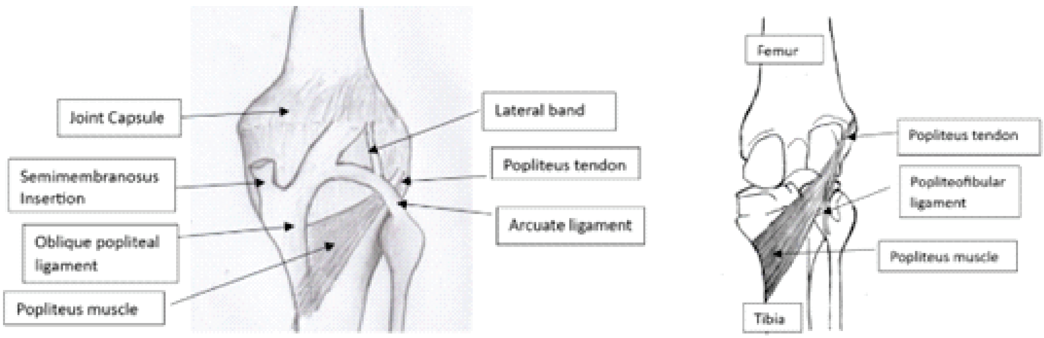


**Figure 1**

Bio mechanically polpliteal complex act as a static and dynamic stabilizer of the knee. When the foot is on the ground and knee is fixed in full extension, the popliteus acts as an external rotator of the femur and as a lateral retractor of the lateral meniscus. But when the foot is off ground and knee is flexed it acts as an internal rotator of tibia. Popliteus action on lateral meniscus during knee flexion, prevents its impingement during knee movements.

In phylogenetic origin, among the lower vertebrate's popliteus attached to the fibular head. And fibula articulates with the distal femur with a fibular meniscus. In the phylogenetic development due to the upright posture in humans, fibula head migrates distally and fibula meniscus evolved as popliteal tendon .

Musculotendinious kinesthetic studies of the popliteus muscle shows, popliteus has an inherent ability of stiffness regulation during the tonic and phasic activation of the muscle. It has shown human popliteus has 50% slow oxidative, 15% fast oxidative glycolytic and 35% fast glycolytic muscle fibers . This muscle fiber distribution supports the tonic regulatory posture control and sudden phasic position changes in function during locomotion.

***Significance of popliteal hiatus in the lateral posterior corner stability of the knee.***

The complex structure of the popliteal hiatus is formed by the combination of the popliteal tendon, joint capsule, lateral meniscus, and the fascicles of the lateral meniscus (Figure 3). The popliteal tendon traverses through the popliteal hiatus before the popliteal tendon starts its intraarticular course .

Posterior corner stability of the lateral knee is integrated with the consistency of the integrity of structures of the popliteal hiatus, joint capsule and lateral meniscus. Cohn in his study described, popliteal hiatus as a constant structure of the lateral meniscus at the mid coronal plane. He schematically described popliteomeniscal fascicles (PMF) including the superior fascicle, inferior fascicles and the borders of the popliteal hiatus. He elaborated the significance of popliteal hiatal structures to the lateral stability of the knee . During the flexion and extension movements of the knee, popliteomeniscal fascicles (PMF-Figure 3 and 4) control the motion of lateral meniscus.

Popliteal hiatus has been described as an “aperture” in the continuation of the attachment of joint capsule to the lateral meniscus (Figure 4). There are three fibro fascicular connections which form peripheral string like attachment from popliteal tendon to the lateral meniscus outer border.

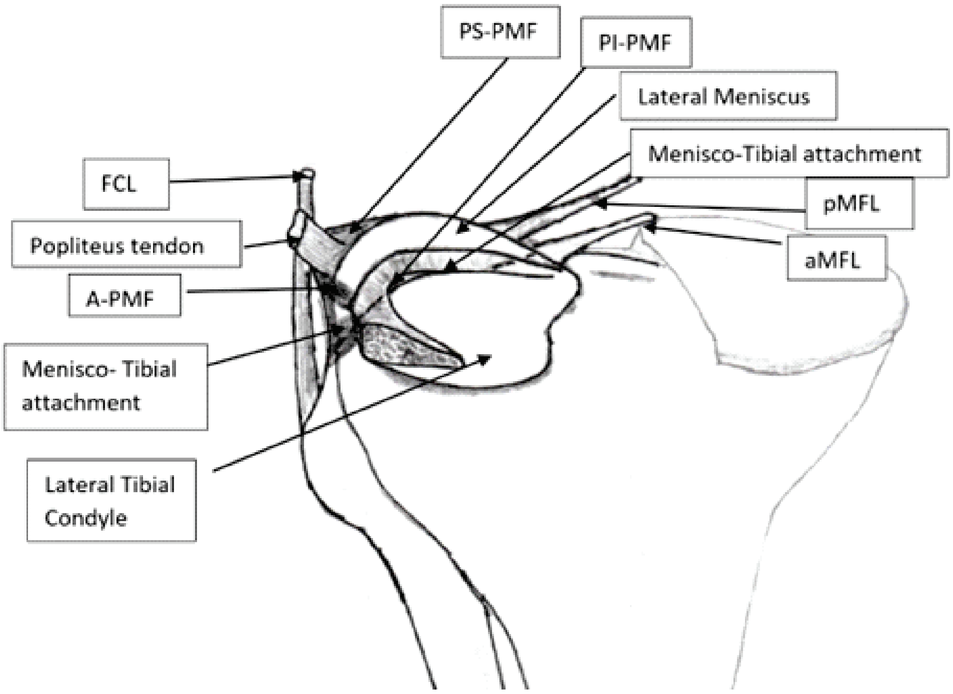


**Figure 2:** Illustrate the anterior superior view of the posterior lateral corner of the knee. Anterior popliteomeniscal fascicles (A-PMF), Posterior superior popliteomeniscal fascicles (PS-PMF),Posterior inferior popliteomeniscal fascicles (PI-PMF), Posterior cruciate ligament (PCL), Anterior Meniscofemoral ligament (aMFL), Posterior Meniscofemoral Ligament (pMFL) and Fibular Collateral ligament (FCL)

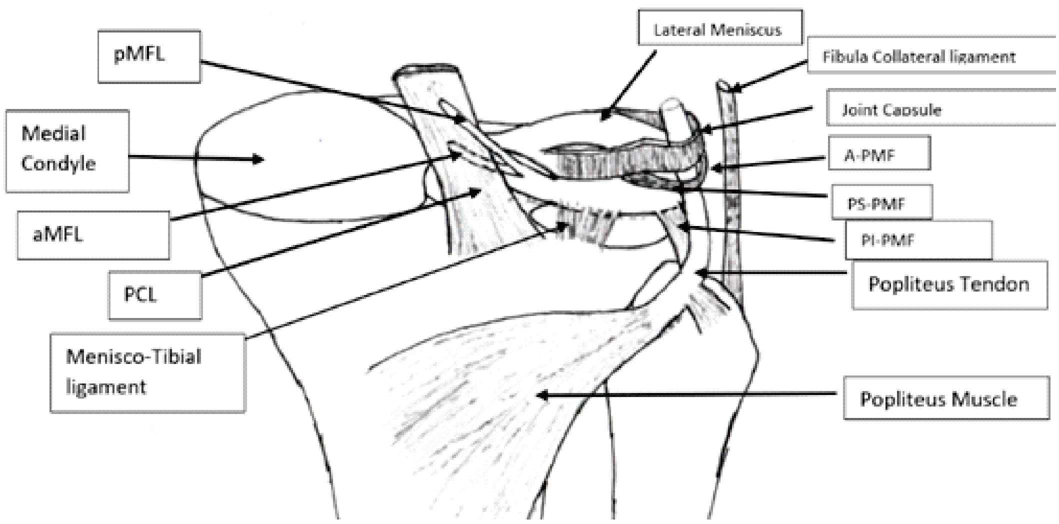


**Figure 3:** Illustrate the posterior superior view of the posterior lateral corner of the knee. Anterior popliteomeniscal fascicles (A-PMF), Posterior superior popliteomeniscal fascicles (PS-PMF), Posterior inferior popliteomeniscal fascicles (PI-PMF), Posterior cruciate ligament (PCL), Anterior Meniscofemoral ligament (aMFL), Posterior Meniscofemoral Ligament (pMFL).

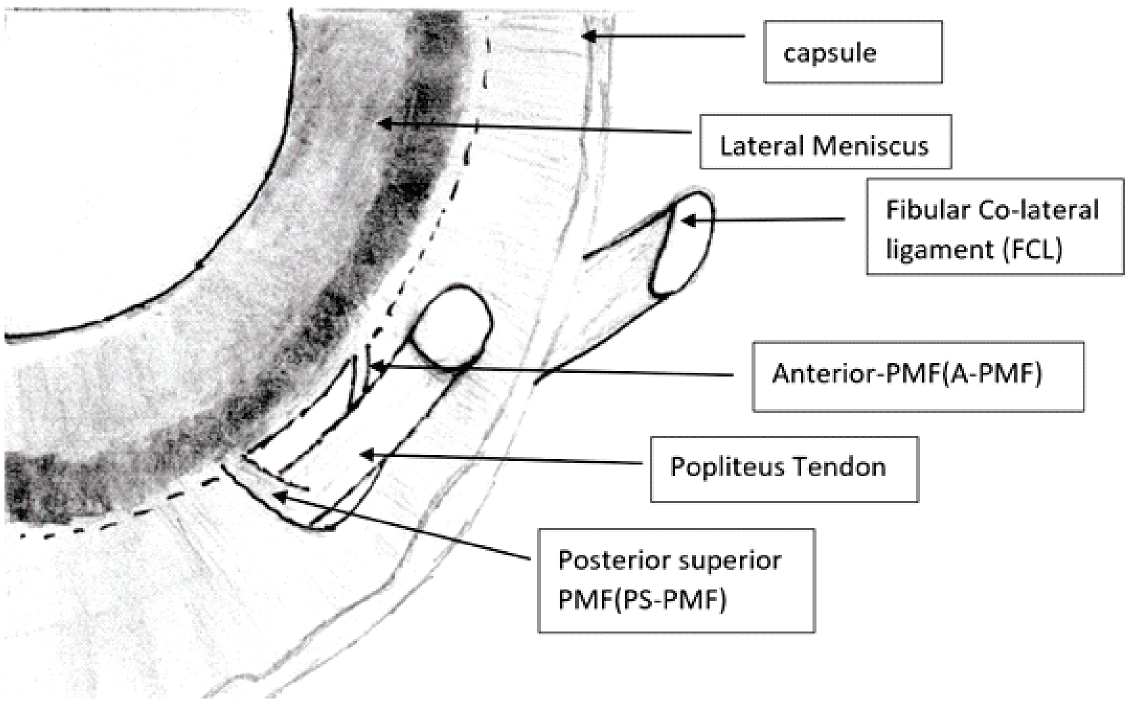


**Figure 4.** Illustrate the superior view of the popliteal hiatus.

They are called popliteomeniscal fascicles (PMF) (Figure 2 and 4). It provides stability to the non-tethered part of the lateral meniscus and gives a static and dynamic stability to the lateral meniscus and popliteus tendon. The nomenclature of this fascicles are not very constant among the authors.

Popliteal hiatus is a more or less a transverse conical shape hiatus. This hiatus is formed with a superior aperture and an inferior aperture. The apex of the conical hiatus is placed anteriorly, and base is placed posteriorly. Anterior border of the superior aperture is formed by the anterior PMF (A-PMF) . Posterior corner of the superior aperture formed by the by the posterior-superior PMF(PS-PMF), postero inferior corner is formed by the posterior- inferior PMF(PI-PMF), laterally by the joint capsule and medially by the superior lateral border of the lateral meniscus (Figure 4). Because of its oblique course, ill-defined anatomy, nomenclature of A-PMF is inconstant. Some authors named it as anterior inferior PMF due to the course of inferior medial portion of the popliteus tendon to the outer surface of the lateral meniscus. Because of its superior attachment to the lateral meniscus some authors named it as anterior superior PMF . However, the anterior PMF is the most appropriate name because it is anteriorly and superiorly placed structure. And it is the only anterior attachment of the popliteus hiatus. It is reasonable to name as anterior PMF(A-PMF) rather than as the antero superior PMF or antero inferior PMF. The nomenclature of the PMFs at postero superior corner of the hiatus as posterio-superior PMF(PS-PMF) and the posterior inferior corner as posterior- inferior PMF(PI-PMF) are constant in the literature.

The lateral meniscal inferior outer margin attaches to the outer border of tibial plateau with lateral meniscotibial ligament (LMTL) (Figure 3). Posteriorly it continues as the posterior meniscotibial ligament (PMTL) and intersected with the posterior cruciate ligament (PCL) insertion posteriorly. LMTL start at the mid meniscal point of the inferior border and extend anteriorly. The LMTL is also refereed as the "coronary ligament" . Even though they are called ligaments, there are basically a mere thickening of connective tissues. There is no proper ligamentous attachment between the superior and inferior borders of the meniscus with joint capsule except at popliteal hiatus as described above. Inferior aperture of the popliteal hiatus is supported anteriorly by the lateral meniscotibial ligament (LMTL), posteriorly by the posterior meniscotibial ligament (PMTL), medially margin by the inferior border of lateral meniscus and laterally margin by the popliteus tendon (Figure 3).

Popliteal hiatus is connected distally with tip of fibula by popliteofibular (PFL) ligament and meniscofibular fascicle (MFF) (Figure 2). PFL is a constant and identifiable ligament, but MFF is an inconsistent in presence and merely a thickening of fibrous tissue.

Anterior popliteomeniscal fascicles (A-PMF)( Figure 3 and 4) originates from the inferior medial portion of popliteus tendon and inserts to the outer surface of the lateral meniscus anteriorly just anterior to mid coronal plane of the lateral meniscus. It follows the oblique course of the popliteus tendon from postero- inferior to antero superior. Inferiorly it merges with meniscofibular fascicle (MFF) and attaches to the fibular head.

Posterior superior popliteomeniscal fascicles (PS-PMF) (Figure 3 and 4), originates from the posterior surface of the popliteal tendon and attaches to the posterior superior border of the lateral meniscus near the posterior horn. With the margins of posterior superior PMF(PS-PMF) and postero inferior PMF(PI-PMF), it forms the popliteal recess.

Posterior inferior popliteomeniscal fascicles (PI-PMF) ( Figure 2 and 3) connects the deep medial part of popliteal tendon to the inferior outer margin of lateral meniscus. Some authors suggest it merely replaced the coronary ligament and given an indirect attachment to the meniscus for stability .

Meniscofibular fascicle (MFF) is basically a capsular thickening of the postero lateral corner of the knee. It is a tape like fibrous band extending from the inferior outer border of the lateral meniscus , directed distal and posteriorly towards the head of the fibula . On its path it crosses popliteal tendon obliquely blend anteriorly with anterior PMF and LMTL. It appears to be an interposition of soft tissue layer in between the outer border of tibial plateau and medial surface of popliteal tendon. It functional component is not very clear but seems to be a protector of lateral meniscus on extreme extension of the knee and reinforce the posterior lateral part of the lateral coronary ligament.

***Clinical significance of Popliteal hiatus and Its structures:***

Various injury mechanisms of force loading on lateral compartment of the knee can result in the destabilization of popliteal hiatal complex.

Iatrogenic injuries during surgical procedures can damage the popliteal hiatal complex structures.

High energy traumatic injuries can destabilize the posterior lateral corner of the knee. Knee injuries following sports and motorcycle riding are highly suggestive for posterior lateral corner damage. Especially the varus angulation force, extensive external rotation of tibia, posterior translation of tibia. Especially the forced hyperextension or flexion when tibia is externally rotated can result for popliteal hiatal complex injuries. These injuries can be isolated or combination injuries of popliteal tendon, popliteomeniscal fascicles (PMF), popliteofibular ligament, meniscofemoral ligament. Or it could be a combination of multiple tissue injuries and resulting complex posterior corner injuries. Isolated injuries are rare and most of the time it is a complex injury in the posterior lateral corner of the knee.

Most of the posterior lateral corner injuries are associated with other complex injuries of the knee eg compete knee dislocations, anterolateral knee injuries and fractures in the distal femur or proximal tibia.

The correct clinical and radiological diagnosis of posterior lateral corner injuries are challenging. However, Magnetic resonance (MR) imaging has an important role in identification of posterior lateral corner injuries. Sometimes posterior lateral corner ligaments may not well be elaborated on MR images. Interpretation of MR images with normal anatomy and history of the mechanism is helpful to achieve a reasonable diagnosis. Inadequate treatment due to poor diagnosis can lead to lateral knee instability and chronic pain. Ignored or misdiagnosed posterior lateral corner injuries can lead for early degenerative changes in the knee.

Isolated popliteal tendon injuries are rare. Most of the time injuries happens at musculotendinous junction of the popliteus and extra-articular. Popliteal tendon tears can be intra-articular at the level of popliteal hiatus. Popliteus injuries are noted in 60%-68% of patients who had been operated for posterior lateral corner injuries . Complete tear of the popliteus is usually associated with multiple ligament injuries of the knee. Anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) injuries can mask the diagnosis of posterior lateral corner instability. Popliteal tendon tears are graded to 3 grades, stretching injuries are graded as Grade -I, incomplete tears of the tendon are considered as Grade-II tears. Grade -III are complete tears of the tendon. Grade-II and Grade-III are due to high energy trauma. Most of the popliteus tendon tears are extraarticular which involves the musculotendon junction or the muscle. Intraarticular tears are also being reported . Micro- trauma and repetitive stress of the tendon can result in tendinopathy of the popliteal tendon and clinically experiencing chronic pain around the posterior lateral corner of the knee. High energy twisting injuries of the knee can result for the avulsion of the femoral attachment with or without a separated bony fragment. The presence of the sesamoid bone “cyamella” may be able to be visualized with X-ray. It should be taken into consideration on interpretation of radiological investigations for posterior lateral knee pain.

In 2012 H.K. Shin et al postulated the popliteomeniscal fascicles (PMF) isolated tears can result in pain in the lateral compartment of knee, locking symptoms of the knee, giving way symptoms and osteochondral lesions of the posterior lateral condyles of the femur (Shin et al., 2012).

Tendinosis and tendinopathies of the popliteus can be seen due to the repetitive stress on the popliteus. Long standing downhill walking and running can load a repetitive stress on the popliteus muscle and tendon . On the downhill weight bearing phase, popliteus continuously act to prevent lateral rotation of femur and forward displacement of femur. Patient will present with posterior lateral knee pain and local

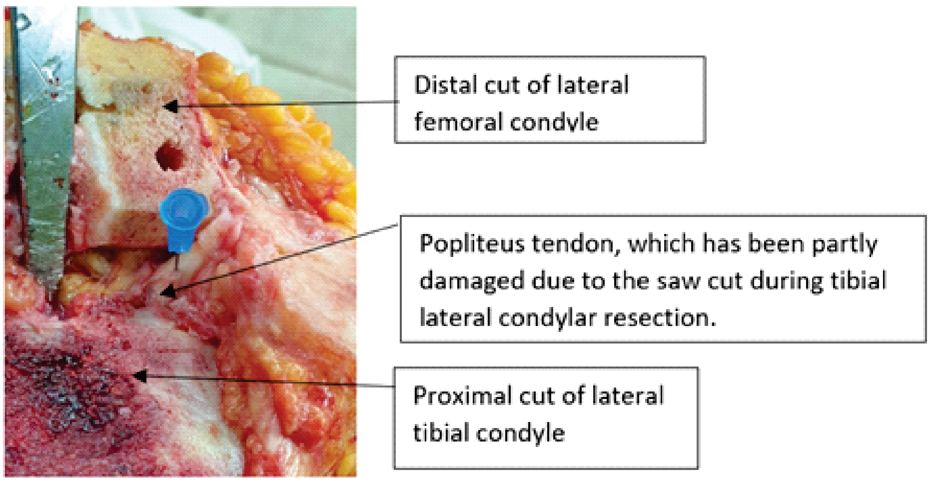


**Figure 5:** Illustrate an iatrogenic injury to popliteus tendon.

tenderness. MR images will show oedema of the tendon and fluid surrounding the tendon.

***Role of Popliteal hiatus in total knee arthroplasty.***

In total knee joint arthroplasty, during the bone cuts of the distal femur condyle and proximal tibial condyle, popliteus can get damage. During the resection of lateral meniscus, if the surgeon is not careful on resection, popliteus tendon can get damage (Figure 5). If the lateral release of the knee to be done surgeons have to be extremely care full to prevent popliteal tendon injuries. Popliteus tendon damage will result in lateral instability of the knee.

***Surgical tips for prevention of popliteal injuries during Total Knee arthroplasty.***

Before performing the distal femoral bone cuts, by sliding the resection check guide (angel wing) in the cutting slot of the universal cutting block of the femur will give an idea about the bone cut level and the insertion of popliteus tendon at lateral femoral epicondyle. It will help to prevent iatrogenic popliteal injuries.

When using the oscillating saw blade to prepare the proximal tibia, over penetration of saw blade to the posterior lateral corner can damage the popliteal tendon. This can be prevented by keeping a metal protector (small Hohmann Retractor) in the posterior lateral corner of the knee.

During the resection of lateral meniscus, by keeping a (2-3) mm lateral meniscus outer margin will protect the popliteal tendon. And this procedure will protect the popliteal hiatus and Popliteomeniscal fascicles (PMF), which are help full in the lateral stability of the knee.

Removal of excess bone cement particles in the posterior lateral corner is very important to reduce post operative knee pain and irritation of popliteal tendon due to bone cement remnants.

In cases of extensive valgus deformities of the knee, there will be a requirement for lateral release of knee ligaments to balance the soft tissue gap. In such cases complete removal of lateral meniscus, release of Popliteomeniscal fascicles (PMF) and release of the posterior-lateral joint capsule will be adequate to achieve the desirable soft tissue balance. The ultimate option is the control release of the popliteal tendon by pie-crusting with 18G needle rather than sacrificing it.

Osteoarthritic loose bodies and degenerative substances can pass through the popliteal hiatus to the popliteal bursae and result irritative symptoms or mechanical symptoms. Posterior lateral corner pain without a history of injury is suggestive for the diagnosis.

Other pathological conditions like synovial chondromatosis, synovial proliferations can continue to the popliteal peritendon area through the popliteal hiatus and to the popliteal bursae. It can trigger posterior lateral corner knee pain.

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