Injuries of Posterolateral Corner of the Knee: History, Mechanism of Injury and Diagnosis

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Abstract

Injuries to the posterolateral corner (PLC) comprise a significant portion of knee ligament injuries. A high index of suspicion is necessary when evaluating the injured knee to detect these sometimes occult injuries. Moreover, a thorough physical examination and a comprehensive review of radiographic studies are necessary to identify these injuries. In this sense, stress radiographs can help to objectively determine the extent of these lesions. Non-operative and operative treatment options have been reported depending on the extent of the injury. Complete PLC lesions rarely heal with non-operative treatment, and are therefore most often treated surgically.

KeyWords:Anatomical, Fibular collateral ligament, Knee, Posterolateral, Popliteus reconstruction, Reconstruction.

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Introduction.

The precise prevalence of posterolateral corner (PLC) knee injuries is unknown, presumably because of a large number of injuries remaining undiagnosed, and differences in the study of polytrauma and athletic populations **(1).**The incidence of posterolateral knee injuries in patients with acute knee ligament injuries with a hemarthrosis was 9.1%. It also verified that most PCL and posterolateral corner injuries occur in combination with other ligament injuries**(2)**.

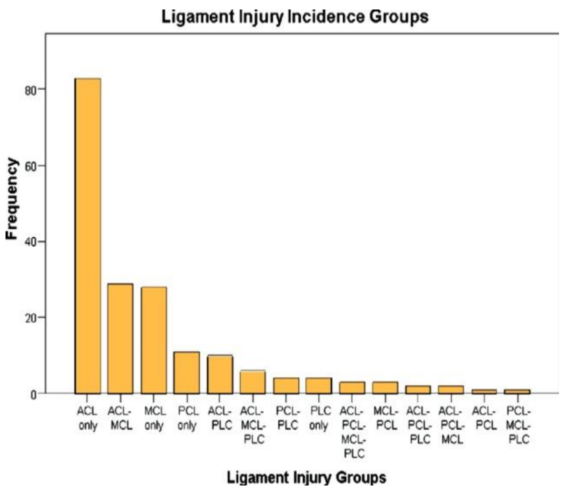

Figure 1. Epidemiology of knee ligament tear combinations in 187 patients with acute knee injuries **(2).**

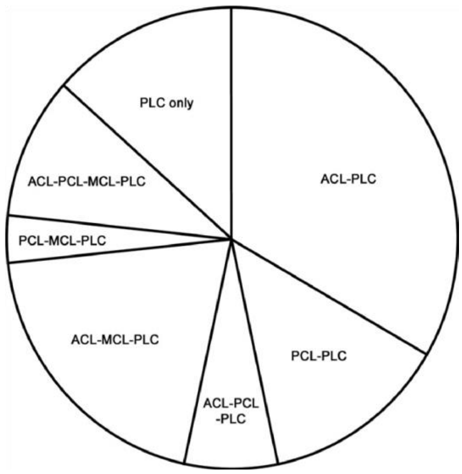

Figure 2: Breakdown of posterolateral knee injury patterns in 30 patients with acute injuries **(2).**

In a recent study of 106 multi ligamentous knee injuries, Becker et al revealed that the most common (43%) injury pattern was a combined disruption of the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), and PLC. PLC injuries were more prevalent than previously reported and were highly associated with peroneal nerve injury (25%) **(3).**

History and Injury Mechanism

The first step in reaching a correct diagnosis of posterolateral rotatory instability is to elicit an accurate history, including the mechanism of injury and presenting symptoms. In the acute setting, the patient is usually able to recount what exactly happened to the knee at the time of injury. Common mechanisms of injury include a posterolaterally directed blow to the anteromedial aspect of the proximal tibia, with resultant hyperextension of the knee; a direct blow to a flexed knee; a noncontact mechanism with hyperextension and external rotation of the knee; or a high energy trauma. In cases of high-energy trauma or a multisystem injury, the history may be difficult to obtain and is not always helpful in making the diagnosis. In cases of chronic injury, it is often useful to ask the patient to “tell me about your knee.” The patient will often describe associated symptoms of pain in addition to outlining specific aggravating factors, which exacerbated the feeling of instability **(3).**

A thorough history helps to avoid neglecting possible injuries to the PLC of the knee. Pain on the posterolateral aspect of the knee is a typical symptom in the isolated acute PLC injuries **(4).**

Patients may also have common peroneal nerve injuries and present with paresthesia or numbness as well. They often show functional instability when the knee is in extension, such as knee giving way into hyperextension during activities like walking down and up the stairs. Symptoms of the posterolateral injury include a wide range of oppressive pain, ecchymosis, edema, and hardening **(4).**

Physical Examination

Several examination techniques for the knee ligaments that were developed before advanced imaging remain as accurate or more accurate than these newer imaging modalities. Advanced imaging can be used to augment a history and examination when necessary, but should not replace a thorough history and physical examination **(5).**

The clinical diagnosis of PLC lesions is difficult to achieve even with the broad spectrum of physical exam maneuvers available to identify them thus, imaging studies gain importance helping diagnosis**(6).**

As in all musculoskeletal assessments, when evaluating PLC injuries we follow the protocol: Look, Feel, Move, Stability, Special Tests, and Neurovascular Examination **(1)**.

It is important to be mindful that PLC injuries are often combined with other ligamentous injuries, especially those of the PCL. The PLC injury may be obscured by other associated instability patterns. Therefore, if there is a clinical suspicion of PLC injury based on the history, the structures in question should be thoroughly investigated with a meticulous physical examination. Needless to say, a thorough neurovascular examination is a critical importance given the high incidence of injury to those structures. Particular attention should be paid to the integrity of the popliteal vessels and the function of the peroneal nerve. If there is any suspicion of dislocation, calculation of the arterial brachial index should be performed to assess the vascular status of the limb. Further vascular studies (eg, arteriography) should be obtained as necessary **(3).**

Look

Examination of the injured limb should include an evaluation of the overall limb alignment and gait, where possible. In the acute setting, it is not always possible for the patient to stand or ambulate. Although, the state of the skin is often quite revealing as to the direction, force, and mechanism of injury, pay particular attention to observe the anterior aspect of the tibia for the presence of bruising; this is a common site for a hematoma in the setting of a PCL or PLC injury as a result of direct impact to the anterior or anteromedial aspect of the tibia following a fall on the flexed knee or as a result of a direct blow. In addition, be mindful to inspect the posterior aspect of the knee for ecchymosis or swelling, which is also instructive as to the extent of the injury. One should also rule out any evidence of active bleeding, gross malalignment, or open injury **(3)**.

Bruising in the popliteal fossa may indicate damage to the wellvascularized posterior structures. Interposition of soft-tissue or bony fragments within the joint may manifest itself clinically as a visible lack of knee extension. Excessive varus or valgus angulation of the knee should also be noted. Color asymmetry between the two feet may suggest an associated vascular injury. With the patient supine, observing the knee in 90-degree flexion from the side may reveal a posterior tibial sag, most notable when compared with the contralateral, uninjured limb, signifying a posterior cruciate ligament (PCL) injury. The tibial tubercles are useful visual landmarks for comparison **(1)**.

Standing

Patients with a posterolateral injury are likely to show unusual alignment of the lower extremity. In standing position, they may present with a varus alignment of the knee **(4)**.

Gait

When the static stabilizers of the knee are injured, the dynamic stabilizers cannot function properly due to the convexity of the lateral condyle of the femur and the lateral plateau of the tibia. This causes a varus thrust gait in the stance phase, resulting in abnormal gait. The varus thrust of the knee is seen during the loading response phase of gait in the presence of a chronic posterolateral knee injury **(4).**

Usually, the gait pattern is accompanied by a lift-off of the lateral compartment of the knee, which increases medial compartment joint stress and consequently results in wear of the medial compartment cartilage if untreated **(4).**

Sometimes patients show fixed knee gait resulting from adaption to the instability of the knee joint**(4)**.

This varus thrust gait, in which the knee joint is subluxated in varus upon foot strike, may be readily noted on examination, particularly in the setting of chronic instability. However, the examiner should be careful to consider that some patients may have learned to compensate with a flexed knee gait pattern or may have an underlying varus knee deformity with medial compartment collapse rather than lateral opening, which can obscure the physical examination findings **(5)**.

Feel

In a conscious patient, knee palpation is useful in pinpointing the location of tenderness and any subtle injuries that may not be obvious on inspection. Anatomically directed palpation should include evaluation of the extensor mechanism, the medial collateral ligament (MCL), the lateral collateral ligament (LCL), the fibular head, the iliotibial (IT) band, Gerdy tubercle, and the medial and lateral joint lines. With the knees in 90-degree flexion in the supine position, the anterior joint line is carefully palpated to evaluate for a decrease in prominence of the tibial plateau in relation to the distal femur that occurs with a posterior tibial sag. This is often referred to as the tibial "step-off test" or "thumb sign." The tibia normally lies 1 cm anterior to the distal femur in the flexed, resting position, and the uninjured knee may be used for comparison .When the anterior aspect of the tibial plateau lies posterior to the femoral condyles, combined PCL and PLC damage should be suspected **(7).**

Palpation of the knee requires a subtle gradient of force application. The examination should commence with the normal side. The process complements the visual inspection. Tenderness to palpation and induration about the lateral and posterolateral aspect of the knee is indicative of injury **(3)**.

The final palpation is conducted with slightly more force to identify tenderness and/or gaps in the underlying soft tissue. It is critical that the patient is aware that you will be probing with increased vigor and can expect a certain degree of discomfort. Placing the leg in a figure of-"4" position is very helpful and allows for easier identification and palpation of the lateral structures of the knee, in particular the LCL (fig.3). In this position, the lateral meniscus, the anterolateral aspect of the tibia, the ITB, the long head of biceps femoris, and the extensor mechanism may be examined without difficulty**(3).** 4492

Figure 3: (Figure-of-"4" position) this position is very effective in identifying the surface anatomy of the lateral structures of the knee, in particular the lateral collateral ligament**(3).**

Move

In the acute setting, knee range of motion may be difficult to assess because of pain unless the patient is sedated or unconscious. When able, active and passive knee range of motion should be measured. Any clear block to flexion– extension should alert the examiner to the possibility of an intra-articular bony fragment or associated soft-tissue pathology (e.g., a displaced meniscal tear) **(1).**

Stability

With pain as the major limiting factor, assessment of ligamentous stability can be challenging in acute injuries around the knee. Associated injuries in the same limb can also add to the difficulty. A complete physical examination should include dedicated stability assessments of the ACL, PCL, MCL, LCL, PLC, and PMC. Varus or valgus laxity with the knee in full extension indicates a PCL injury in addition to LCL/MCL disruption **(8).**

Any gross instability during examination requires immediate splinting of the limb to minimize further damage to the surrounding structures **(1).**

Neurovascular Examination

Arguably the most important part of the physical examination in the acute setting is a thorough assessment of the neurovascular structures at risk with a multiligament knee injury. In a recent systematic review, Medina et al., reported that vascular injuries occur in approximately 18% of all knee dislocations while nerve injury occurs in 25%**(9).**

Vascular Injury

Early identification and treatment are the primary goal in the management of a vascular injury, as this minimizes destruction and improves the final outcome. While the absence of a pulse is the clearest sign of a vascular injury, the presence of distal pulses does not rule out an underlying popliteal artery injury. The initial examination should include symmetry of distal pulses, capillary refill, color, and temperature, as well as adjunctive tests, such as the Ankle Brachial Pressure Index (ABI). Furthermore, serial examinations may be necessary because it is possible to develop a thrombosis hour to days after the initial injury **(10).**

Neurologic Injury

A careful neurological examination must include the function of the common peroneal nerve, as it is the most common nerve injured because of its proximity to the PLC of the knee. Altered sensation to the dorsal surface of the foot represents superficial peroneal nerve involvement, while the deep peroneal nerve supplies the first dorsal web space. The motor components can be examined by assessing the power of ankle eversion (superficial peroneal nerve) and dorsiflexion of the ankle and toes (deep peroneal nerve). Tibial nerve damage in PLC knee injuries is rare because of the relative mobility of the tibial nerve and its lack of fixed points around the knee joint. An accurate neurological assessment may be difficult in the polytrauma patient and serial neurologic examinations are more important in this setting**(1).**

Special Clinical tests

There are a wide variety of special tests, which may be carried out to assess the LCL and PLC. This part of the examination should include tests for both varus and rotational deformities. The key factor is to choose a series of tests, which are comprehensive enough to assess the structures under investigation and are also reproducible to the examiner. Listed below are preferred tests **(3).**

(1) Dial test
(2) External rotation recurvatum test
(3) Posterolateral drawer test
(4) Posterolateral external rotation test
(5) Reverse pivot shift test
(6) Varus stress test ***(1)***

Dial test

The dial test is one of the most important physical examinations used to diagnose injury of the posterolateral structures. With the patient positioned in prone position, external rotation of the tibia and thigh-foot angle are assessed. This test is conducted in 30° and 90° of knee flexion (fig.4). In the case of an isolated PCL injury, more than 10° of external rotation of the injured knee is present at 30° of flexion, but not at 90° of flexion. When a PCL injury is combined, more than 10° of external rotation in the injured knee is present at both 30° and 90° of flexion**(4).**

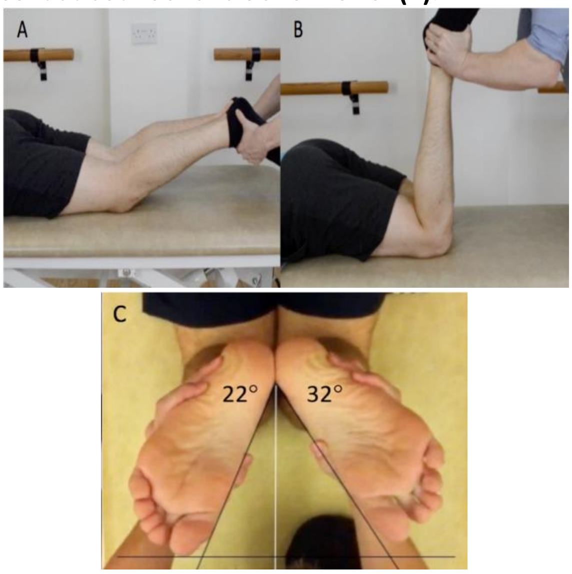

Figure 4: The dial test performed in prone position at 30° (A) and 90° (B) of knee flexion. 10° increased external rotation (right leg) at 90° knee flexion(C) **(11).**

(2)External rotation recurvatum test

External rotation recurvatum test is the most basic special test for PLC injury. The examiner supports the relaxed lower extremity by the great toe and examines the position of the knee (fig.5). Relative hyperextension (which can be measured with a goniometer or heel-height comparison), tibial external rotation, and knee varus alignment compared with the contralateral side may indicate PLC injury. The sensitivity of this test ranges from 33% to 94%**(5).**

Figure 5: Recurvatum deformity: holding the leg by the foot or toe, the knee is seen to hyperextend and falls into varus. This finding is indicative of a posterior cruciate ligament rupture and injury to the posterolateral corner **(3).**

(3)Posterolateral drawer test

This test is conducted by applying posterolateral force on the proximal tibia with the hip flexed to 45°, the knee flexed to 90° and the tibia rotated 15° externally in supine position (fig.6). When the tibial condyle shows more external rotation than the lateral femoral condyle, it indicates the presence of a posterolateral injury **(4).**

Figure 6: Posterolateral external-rotation test at 90 **(12).**

(4) Posterolateral external rotation test

The addition of rotation to the posterior drawer is used as a further test to assess the integrity of the PCL and PLC of the knee. The key determinant in drawing conclusion from these tests is quantifying the ratio of translation to rotation that occurs, which should be compared with posterior drawer in neutral rotation. The patient is positioned supine with the hips flexed to 45 degrees and the knees flexed to 90 degrees. The foot is fixed in slight external rotation and posterior directed force is applied to the anterior tibial tuberosity**(8).**

In this position the PCL relaxes so that there can be rotatory and translator posterolateral laxity. The ratio of translation to rotation should be compared with that observed when the posterior drawer in the neutral position. Pure rotatory laxity occurs with an isolated PLC injury. There is an increase in external rotation but posterior translation will not increase with external rotation of the foot, as the PCL is intact. The result is a decrease in the ratio of translation to external rotation. In the case of a PCL rupture without injury to the PLC, application of a posterior drawer in this position will result in increase in the ratio of posterior translation to external rotation as the center of rotation is displaced peripherally**(3).**

The posterolateral external rotation test is a combination of the dial test and the posterolateral drawer test. Posterolateral subluxation of the tibia is checked under the simultaneous application of posterior and external rotation forces on the knee joint. Subluxation at 30° of flexion, but not at 90° of flexion, indicates the presence of an isolated posterolateral injury. When a PCL injury is combined, subluxation occurs at both 30° and 90° of flexion **(4).**

(5) Reverse pivot shift test

This test is performed with the knee flexed to 40° and the tibia in external rotation. As the knee is extended, the tibia is reduced with a clicking sound (fig.7). This indicates the presence of a PLC injury. However, the test has a false positive rate of up to 35% when performed under anesthesia **(4).**

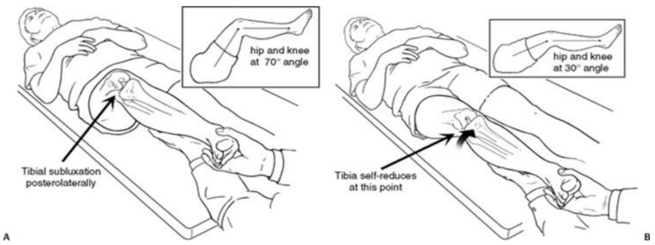

Figure 7: Reverse pivot shift test. A, examiner lifts the supine patient's leg by grasping it at the ankle and gently applying abduction and an axial load. B, this motion flexes the knee while allowing external rotation of the tibia as a posterior translation force is applied (arrow). As the knee goes into flexion, posterolateral subluxation of the tibia can be palpated. This is in contrast to the pivot shift maneuver, in which the subluxation is anterior and occurs near extension **(12).**

(5) Varus stress test

varus stress test at 20° to 30° of knee flexion helps to diagnose posterolateral instability of the knee. When the LCL is intact, no increase in varus gapping is seen with the knee is at 20° to 30° of flexion. When other structural injuries to the popliteus tendon or PFL are combined, increased varus gapping may be observed. The leg is placed over the examining table with the knee flexed between 20° and 30°. The examiner's fingers are placed over the joint line stabilizing the distal femur. Then a varus stress is loaded on the knee. To determine the amount of instability, varus gapping is assessed on the stress radiograph **(4).**

If the patient can reach hyperextension, it is the ideal position to start. Stability in this position infers that the lateral capsuloligamentous structures and the PCL are intact. This finding alone is extremely informative. However, laxity in this position to varus angulation is a worrying sign, indicating disruption of the PLC and an associated cruciate injury **(8).**

Isolated cruciate injuries do not affect varus stability. At 0-degree flexion, the ACL and PCL are sufficiently slackened to allow diagnostic evaluation of lateral capsular injuries by application of varus angulation. Further flexion to 30 degrees, facilitates examination of the isolated LCL because, in this position, the PLC in addition to the cruciate ligaments are relaxed. Isolated injuries to the posterolateral structures usually result in maximum varus opening at 30 degrees of flexion, but PLC patterns do occur where there is minimal varus gapping but significant rotational instability (eg , popliteus injury, popliteofibular ligament injury) **(13).**

Figure 8: Varus deformity of a right knee under varus stress testing in full extension. Significant opening of the lateral joint line in this position is suggestive of injury to the posterolateral corner, the lateral collateral ligament, and associated cruciate ligament injury **(3).**

(6)Standing Apprehension Test

Ferrari at al described the use of the standing apprehension test to detect posterolateral instability of the knee. The patient stands with the knee slightly bent and internally rotates the torso away from the leg, producing an internal rotation of the femur on the tibia. If the patient experiences apprehension or instability, the test is considered positive. The authors considered the test to be 100% sensitive, but this estimation was based on a small patient cohort, and all of the patients had positive dial tests at 90 knee flexion, indicating injury to the PCL and PLC **(5).**

Prone Examination of Knee

The prone examination affords the opportunity of assessing the posterior aspect of the knee. Initial observation is carried to identify the presence any scars, swellings, atrophy, or bruising on the posterior aspect of the lower leg. Extra-articular bruising is often easier to appreciate posteriorly, as it typically accumulates here, as the lower limb is usually in a supine, dependent position following injury. This position also facilitates further testing of rotational stability through the dial tests **(3).**

Plain radiography

A standard knee series, including bilateral standing anteroposterior (AP), AP flexion 45 degrees' weight-bearing, lateral, and Merchant patellar radiographs, should be evaluated for any evidence of avulsion fractures, tibial subluxation, and associated knee injuries. Common avulsion injuries include the "arcuate" sign (i.e., fibular head fracture), femoral popliteus avulsion, Segond fracture, or Gerdy tubercle avulsion **(14).**

It is also important to scrutinize radiographs for the presence of osteoarthrosis, which may be present in the setting of chronic injury and, if advanced, may preclude significant ligamentous reconstruction **(3).**

In the event of having access to plain radiographs performed before reduction of a dislocated knee, these should be scrutinized closely to assess the direction of the dislocation. If there is any suggestion of malalignment in the setting of chronic multi ligamentous instability, long leg standing radiographs should be performed to assess the mechanical axis and plan for corrective osteotomies should they be required **(3).**

Stress radiography has been gaining popularity for the diagnosis of multi ligamentous knee injuries. It involves the application of a standardized force to the knee to produce abnormal joint displacement. It has been demonstrated to be a reliable measure of posterior laxity in patients with PCL injuries, in addition to being a good predictor of concomitant PLC injuries **(15).**

In their study, LaPrade et al concluded that clinicians should be suspicious of an isolated LCL injury if opening on clinician-applied varus stress radiographs increases by approximately 2.7mm and a grade III PLC injury if values increase by approximately 4.0mm **(16).**

Several techniques have been described to deliver a posteriorly directed force during stress radiography to assess the integrity of the PCL **(17).**

The Telos device and kneeling have been shown to be superior to the other methods for reproducibly demonstrating posterior knee instability **(18).**

Schulz and colleagues have reported that subjects with isolated PCL injuries demonstrated 5 to 12mm of increased posterior displacement compared with the uninjured extremity. Subjects with combined posterior knee injuries to the PCL, PLC, and/or posteromedial corner had increased posterior displacement measuring >12mm compared with the contralateral side **(19).**

Stress radiography Varus stress and kneeling PCL stress radiographs are very helpful in the diagnosis of PLC injuries. LaPrade et al. assessed varus stress radiographs with the knee at 20° of flexion to provide objective measures of lateral compartment gapping. They reported that an increased opening of more than 4 mm may indicate a grade III PLC injury. In addition, the kneeling PCL stress radiograph also facilitates objective quantification of isolated or combined PLC injuries table 1 **(4).**

Table 1: Instability Evaluation Using Stress Radiography **(4).**

Variable	**Degree of injury**
Varus stress radiograph (mm)	
<2.7	Normal knee or minor sprains
2.7–4	Complete LCL tear
>4	Complete posterolateral injury
PCL stress radiograph (mm)	
<4	Variation in normal knee or minor sprains
4–12	Isolated PCL injuries
>12	Combined injuries of PCL & PLC

Ultrasound of the posterolateral corner Knee

The current primary imaging modality for evaluation of the softtissue structures of the knee is magnetic resonance (MR) imaging. Ultrasonography (US) offers several unique strengths over MR imaging that make it a promising technique for the evaluation of certain disorders of the knee. First, US has higher spatial resolution than MR imaging, which may be helpful in evaluating the superficial structures of the knee in detail. Second, US allows for dynamic assessment, which can be particularly helpful in differentiating partial from complete tears involving the quadriceps and patellar tendons. Third, the ability to interact with patients during US evaluation allows one to obtain a relevant history and guide the US examination to identify the cause of specific patient complaints. US also allow easy comparison with the contralateral knee, which can be very helpful for problem solving. Fourth, US may be the modality of choice in evaluating patients with contraindications to MR imaging and claustrophobia. Finally, US is lower cost than MR imaging and has the added advantage of portability. The primary limitation of US of the knee is that it is operator dependent and requires proper training and experience for accurate image acquisition and interpretation. Further, limitations of US include incomplete evaluation of the deep structures of the knee, particularly the cruciate ligaments, the menisci, and the majority of the articular cartilage. Especially for detection of abnormalities of cruciate ligaments, MR imaging remains the investigation of choice. US, unlike MR imaging, cannot evaluate bone marrow edema or intramedullary bone lesions **(20).**

US evaluation of the knee is primarily performed with the patient in the supine position, with the obvious notable exception of evaluation of the posterior structures, for which the patient lies prone. Scanning is performed with a high-frequency (ideally, 12 MHz) linear transducer, although a lower frequency (7–9 MHz) transducer is sometimes better suited for evaluating the deep posterior structures**(20).**

Magnetic resonance imaging (MRI)

MRI has become the gold standard imaging modality for assessing the multiligamentous injured knee. The ability of MRI to identify associated tendon, ligament, and meniscal injury is unparalleled in comparison with other imaging modalities. Furthermore, the specific site of ligamentous injury, proximal, distal, or mid-substance can be clearly defined. The information garnered from MRI scans is invaluable for preoperative planning. In addition, MRI is extremely useful in offering clues as to the mechanism of injury, particularly with the location of bone bruising patterns **(3).**

MRI test can be beneficial when an injury of the posterolateral structures is difficult to diagnose clinically. It helps to identify PLC structures. Especially, the T2-weighted coronal oblique view is more useful in the evaluation of the posterolateral structures than the traditional coronal or sagittal view. MRI is also helpful to evaluate acute or subacute PLC injuries **(21).**

The medical literature describes that MRI has an accuracy of up to 95% for identifying major injury PLC structures, namely, lesions of the lateral collateral ligament, popliteus muscle tendon and popliteal fibular ligament **(22).**

Yu et al. (23), showed that for better visualization of the PLC structures, an oblique coronal T2 cut should be performed.

LaPrade et al. (24), in a protocol including in all cuts the fibular head, obtained high sensitivity for PLC lesions and reinforced the best view of LCL, PMT and LPF in the oblique coronal plane. It is considered the gold standard for defining the presence or absence of PLC lesions the intraoperative identification of the damaged structures.

However, in clinical practice it is still difficult to diagnose injuries on such structures, even with MRI. unlike the lesions of the central pivot of the knee, peripheral lesions are less diagnosed by imaging **(6).**

The injury of lateral collateral ligament is described in MRI reports in 57.5% of cases, and the popliteus muscle tendon in only 24.2%, and this cannot be the determining factor for surgical indication for reconstruction **(6).**

Although MRIs are extremely useful, they only provide static images, and are incapable of determining the limits of motion or the function of the affected knee. Therefore, history and physical examination should always precede MRI and guide the interpretation of findings. A systematic approach should to be adopted during the interpretation of scans to avoid missing significant injuries. It should be noted, that MRI is less reliable and accurate in diagnosing chronic multiligamentous injuries, as a previously torn ligament, which has healed with scar may appear morphologically intact although physiologically incompetent **(3).**

Standard views facilitate the identification of the structures that need to be identified on the lateral and posterolateral side of the knee; the ITB, LCL, biceps femoris, popliteus complex, and capsular structures. Injury may occur to all or a variety of these structures. It is critical, however, to recognize injury to the key stabilizers, such as the LCL, the conjoined tendon of the biceps femoris, and the popliteofibular ligament. Thin-slice coronal oblique images through the entire fibular head and styloid also may be used to improve the accuracy as well as sensitivity and specificity of identifying the popliteofibular, arcuate, and fabelofibular ligaments **(22).**

Meniscal injuries are important to recognize in the context of multiligamentous knee injuries**(25).**

The high energy involved in this injury pattern frequently results in meniscal damage, including root avulsions **(26).**

The presence of a displaced meniscal tear may dictate that early intervention is warranted. Meniscal root avulsions may also be overlooked given the complexity of the injury; however, failure to recognize these and address them at the time of surgery may have a negative effect on outcome**(3).**

Lateral Collateral Ligament

At magnetic resonance (MR) imaging, the LCL is consistently seen as a low-signal-intensity band coursing from the lateral aspect of the distal femur to the lateral aspect of the proximal fibula (fig., 9 &10). Although the J-shaped bursa interposed between the LCL and distal biceps femoris tendon is described in cadaveric studies, it is not readily visualized with imaging **(27).**

Injuries, however, are well depicted with MR imaging. They are typically best characterized in the axial and coronal planes and include soft-tissue avulsions from the femoral and fibular attachment sites; complete or partial intrasubstance tears; peri ligamentous edema resulting from a sprain; osseous avulsion from the fibular head; and, in the setting of a chronic injury, thickening of the ligament **(28).**

Figure 9: Coronal proton density–weighted MR image shows the LCL (arrow) extending from just posterior to the femoral epicondyle to the lateral aspect of the fibular head, where it merges with the biceps femoris tendon. The popliteus tendon (arrowhead) underlies the LCL at the level of the popliteus sulcus**(28).**

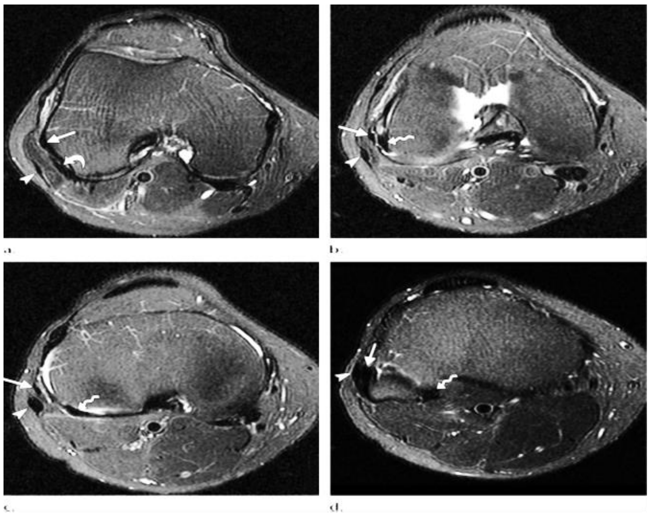

Figure 10: Consecutive axial T2-weighted fat-suppressed MR images show the normal course and MR imaging appearance of the LCL (straight arrow), biceps femoris tendon (arrowhead),and popliteus tendon(wavy arrow in b–d).The origin of the LCL is immediately anterior to the femoral attachment of the lateral head of the gastrocnemius tendon(curved arrow in a) **(28).**

Popliteus Musculotendinous Complex

The tendinous portion, which is typically readily identified on MR images, is hypointense, and the muscular component is intermediate in signal intensity (fig., 11&12). Injuries may occur along any portion of the popliteus musculotendinous complex but most commonly involve the myotendinous junction and are classified as strains, partial tears, or complete tears **(29).**

Imaging has a vital role in the diagnosis and treatment management of high-grade myotendinous injuries of the popliteus musculotendinous complex owing to inherent difficulties in visualizing this region with arthroscopy and the challenge in detecting these injuries clinically, since they are commonly associated with a complex PLC injury that often “clouds” the clinical picture. Avulsion of the tendon at the femoral attachment can occur, and the presence or absence of an attached osseous fragment should be reported, as this may alter the surgical technique used (fig., 13&14). fabella, are sesamoid bone found in the popliteus tendon, should not be mistaken for an avulsion fracture or fabella **(30).**

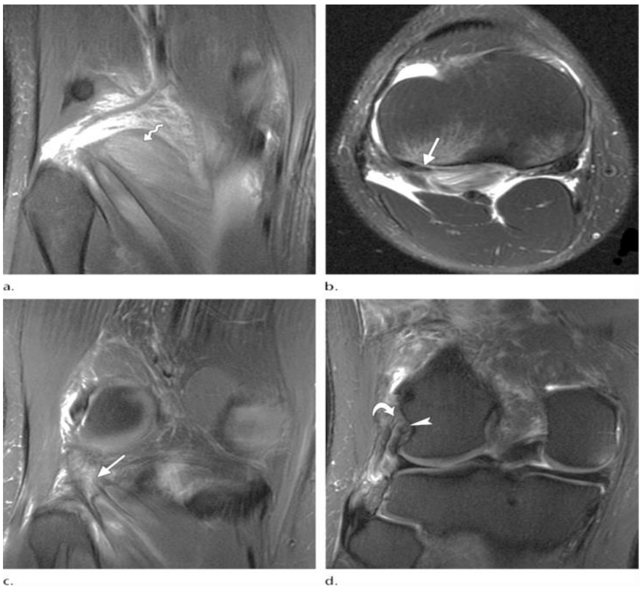

Figure 11: Popliteus injuries. (a , b) Coronal proton-density–weighted (a) and axial T2weighted (b) fat-suppressed MR images in a 17-year-old boy show a popliteus muscle strain, with intramuscular edema (arrow in a)extending to the myotendinous junction (arrow in b). (c , d) Coronal proton-density–weighted fat-suppressed MR images in a 31-year-old man show a more severe injury involving the myotendinous junction of the popliteus (arrow in c), in addition to a partial tear at the insertion of the popliteus tendon (arrowhead in d). The patient also sustained a partial tear at the origin of the LCL **(curved arrow in d) (28).**

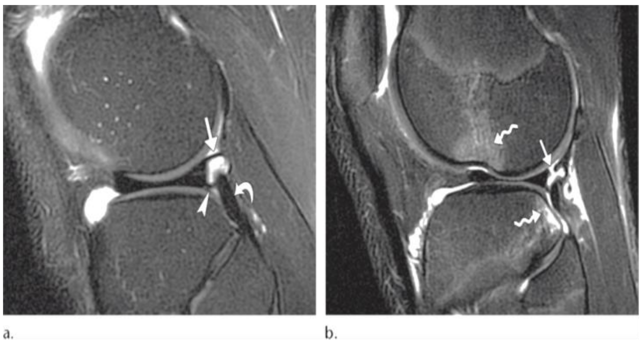

Figure 12: Popliteomeniscal fascicles. (a) Sagittal T2-weighted fat-suppressed MR image in a 25-year-old man shows the normal posterosuperior (straight arrow) and anteroinferior (arrowhead) popliteomeniscal fascicles forming the roof and floor of the popliteus hiatus, respectively. The popliteus tendon (curved arrow) is seen as it begins its course into the hiatus. (b) Sagittal T2-weighted fat-suppressed MR image in a 33year-old man shows a torn posterosuperior popliteomeniscal fascicle (straight arrow). This injury has a high association with tears involving the posterior horn of the lateral meniscus. The patient also suffered an anterior cruciate ligament injury (not shown), with associated “kissing” contusions (wavy arrows) involving the lateral femoral condyle and posterior aspect of the lateral tibial plateau**(28).**

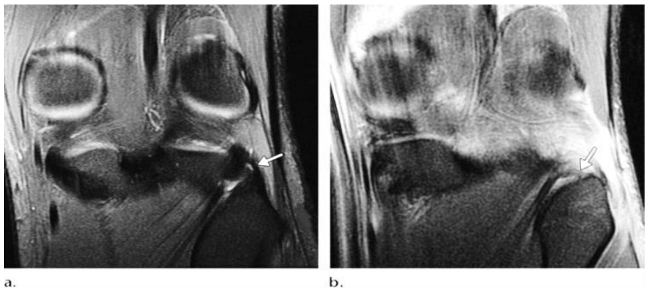

Figure 13: Normal PFL and PFL tear. (a) Coronal proton-density–weighted fatsuppressed MR image in a 27-year-old woman shows an intact PFL (arrow) extending from the myotendinous junction of the popliteus to the medial aspect of the fibular styloid process. (b) Coronal proton-density–weighted fat suppressed MR image in a 20year-old man shows, in contrast, increased intrasubstance signal intensity within the PFL (arrow) and surrounding soft-tissue edema, which are consistent with a partial tear **(28).**

Figure 14: Avulsed PFL in a 19-year-old man. (a , b) Sagittal T2-weighted (a) and coronal proton-density–weighted (b) fat-suppressed MR images show avulsion of the PFL (arrow), with associated underlying bone marrow edema (arrowhead) along the medial aspect of the fibular styloid process. (c) Sagittal T2-weightedfat-suppressed MR image demonstrates a concomitant injury to the posterior cruciate ligament (arrow) with a large attached avulsed fracture fragment (arrowhead.) PLC injuries are commonly associated with injuries to other stabilizing structures, particularly the cruciate ligaments. (d) Lateral radiograph better depicts both the small avulsion fracture off the fibular styloid process (I.e, arcuate fracture) (arrow) at the insertion site of the PFL and the tibial avulsion fracture (arrowhead) at the insertion site of the posterior cruciate ligament **(28).**

Arcuate and Fabellofibular Ligaments

The arcuate ligament can be viewed as a thickening or reinforcement of the posterolateral capsule **(31).**

It has an inverted Y configuration, with the medial and lateral limbs attaching to the apex of the fibular styloid process, just lateral to the PFL. The lateral (upright) limb runs superiorly along the joint capsule on its way to the lateral femoral condyle. The medial, or arcuate, limb courses in a superomedial direction, crossing over the popliteus tendon to merge with the posterior capsule and oblique popliteal ligament. The identification of at least one limb in 48%–71% of specimens has been reported in cadaveric studies **(32).**

Interestingly, the lateral limb is more commonly seen in the absence of the fabella; the converse is true for the medial limb. The fabellofibular ligament appears as a focal thickening of the distal edge of the capsular arm of the short head of the biceps femoris muscle. It originates from the lateral margin of the fabella or in the absence of a fabella, from the posterior aspect of the supracondylar process of the femur **(33).**

Regardless of its origin, it runs vertically, parallel to the LCL, to insert onto the tip of the fibular styloid process, lateral to the attachment of the PFL and posterior to the attachment of the biceps femoris tendon **(28).**

Even when they are present, the arcuate and fabellofibular ligaments are difficult to visualize on MR images **(34).**

On axial and sagittal MR images, the arcuate ligament may appear as a thin low-signal-intensity structure coalescing with the posterolateral capsule and located deep to the inferior lateral genicular artery, overlying the popliteus tendon. The ligament is typically more conspicuous on non– fat-saturated MR images, as it is surrounded by adipose tissue. Injury can be inferred if one identifies an area of increased pericapsular signal intensity surrounding the posterolateral capsule on fat-suppressed fluidsensitive MR images. With more severe injuries, disruption of the posterolateral capsule may be identified **(28).**

Assessing the integrity of the fabellofibular ligament is quite challenging and at times not possible. At MR imaging, the ligament is best seen in the coronal or sagittal plane posterior to the arcuate ligament and inferior lateral genicular vessels. On axial MR images, the ligament is seen immediately anterior to the lateral head of the gastrocnemius tendon. The injury patterns seen on MR images include those of avulsion from the fibular styloid process, partial- and complete-thickness tears, and strains. These injuries often occur in conjunction with an avulsion injury of the direct arm of the short head of the biceps femoris tendon **(35).**

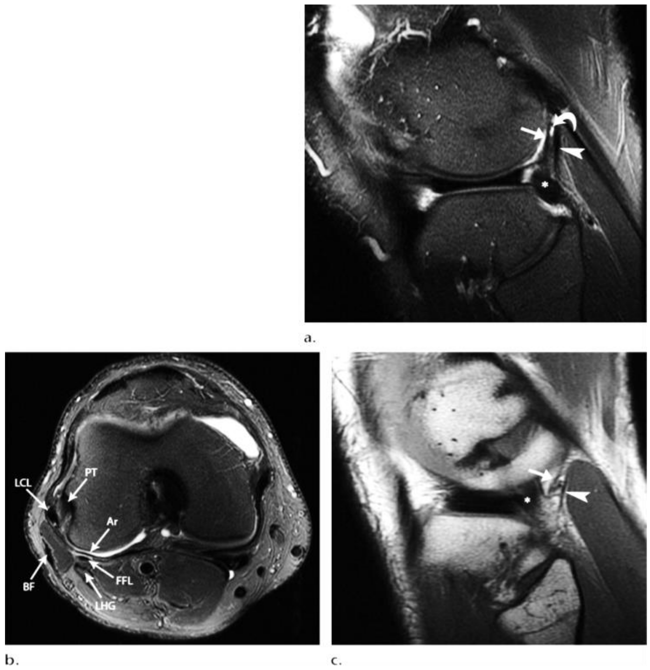

Figure 15: Arcuate and fabellofibular ligaments in a 22-year-old man. (a) Sagittal T2-weighted fat-suppressed MR image shows the lateral inferior genicular vessels (curved arrow) coursing between the arcuate (straight arrow) and fabellofibular (arrowhead) ligaments. These vessels serve as an important landmark for localizing these ligaments. The popliteus tendon (*) also can be seen. (b) Axial T2-weighted fat-suppressed MR image obtained just above the joint line demonstrates the normal cross-sectional anatomy of the PLC of the knee. Ar = arcuate ligament, BF = biceps femoris tendon, FFL = fabellofibular ligament, LHG = lateral head of the gastrocnemius muscle, PT = popliteus tendon. (c) Sagittal proton-density–weighted non–fat suppressed MR image lateral to the image in a show the arcuate (arrow) and fabellofibular (arrowhead) ligaments coursing posterior to the popliteus tendon (*). These ligaments are often more conspicuous on non–fat-suppressed MR images, as they are surrounded by adipose tissue **(28).**

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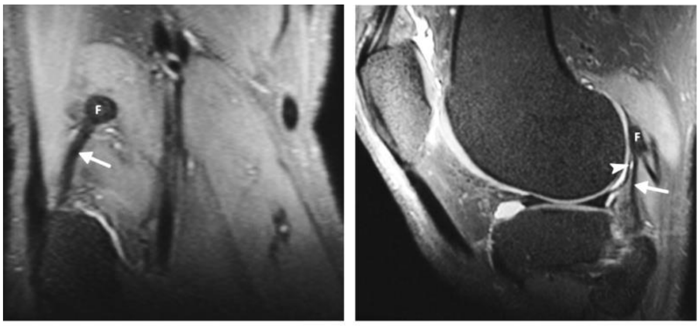
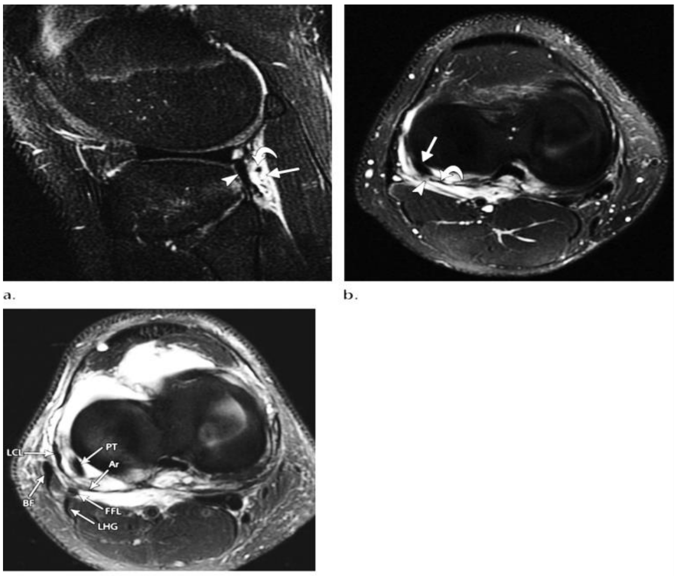


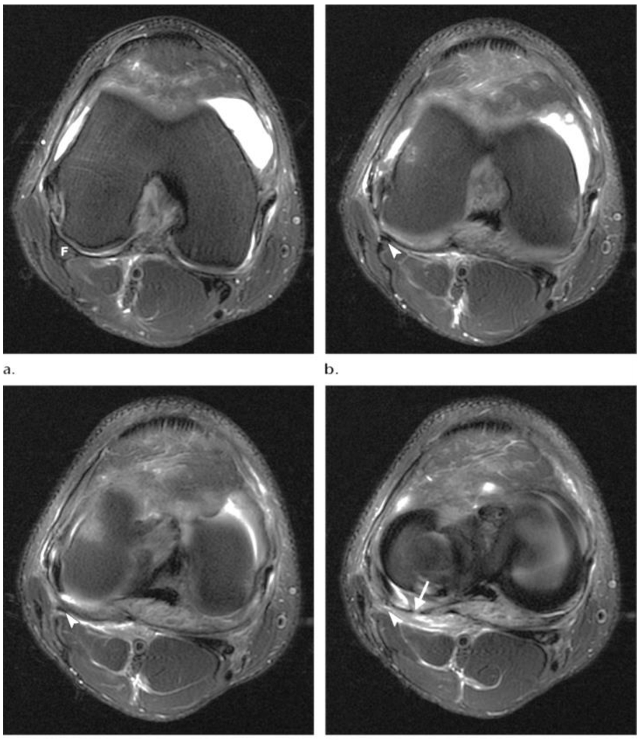
a. b.

Figure 16: Fabellofibular ligament in a 32-year-old man. Reconstructed coronal (a) and sagittal (b) proton density–weighted MR images show the fabellofibular ligament (arrow) extending from the fabella (F) to the fibular styloid process. The lateral inferior genicular artery (arrowhead in b) is seen just deep to the ligament **(28).**



a. b. c.

Figure 17: Arcuate ligament injuries. (a) SagittalT2-weighted fat-suppressed MR image in a 28-yearoldman shows soft-tissue edema (straight arrow) along the PLC, behind the popliteus tendon (arrowhead) surrounding the lateral inferior genicular artery (curved arrow) in the anatomic location of the arcuate and fabellofibular ligaments. (b) AxialT2-weighted fat-suppressed MR image in the same patient shows the arcuate ligament (curved arrow), which is discontinuous (arrowhead) just posterior to the popliteus tendon (straight arrow). (c) AxialT2weighted fat-saturated MR image in a 23-yearoldman who has partial tearing of the arcuate (Ar) and fabellofibular (FFL) ligaments. In this case, the ligaments are intact, with increased intrasubstance signal intensity and peri ligamentous edema. BF =biceps femoris tendon, LHG = lateral head of the gastrocnemius muscle, PT = popliteus tendon **(28).**



a. b. c. d.

Figure 18: Ruptured fabellofibular ligament in a 31-year-old woman. Serial axial T2-weightedfat-suppressed MR images show the proximal fabellofibular ligament (arrowhead in band c) originating from the fabella (F). At the level of the joint line, the fabellofibular ligament is no longer visualized (arrowhead in d) where there is soft-tissue edema along the PLC of the knee and focal disruption of the arcuate ligament (arrow in d) **(28).**

Biceps Femoris Tendon

At MR imaging, several tendons slip of the biceps femoris tendon can appear to represent a single unit and potentially merge with the distal LCL to form a conjoined structure. Coronal and axial MR images best depict injuries to the biceps femoris tendon, which include tendinous and osseous avulsion from the fibular head; tears of the myotendinous junction; and more subtle partial tears, which have intrasubstance or peritendinous high signal intensity on fluid-sensitive MR images**(28).**

a. b.

Figure 19: Biceps femoris tendon. (a) Coronal proton-density–weighted MR image in a 17-year-oldgirl shows the normal imaging appearance of the distal biceps femoris tendon (arrow). (b) Coronal proton-density–weighted fatsuppressed fluid-sensitive MR image in a 22-year-old man shows increased intrasubstance signal intensity and disruption (arrow) of a portion of the fibers of the distal biceps femoris tendon, which are consistent with a partial-thickness tear **(28).**

Computed Tomography (CT)

CT scans continue to play a role in the assessment of PCL and PLC injuries **(36).** Their value is probably greatest in the assessment ligamentous injury with associated fractures or avulsions. In addition, in the setting of revision surgery, CT scans, and in particular 3-dimensional reconstruction can accurately identify the location and size of the tunnels **(3).**

Classification

PLC injuries may be classified based on the time interval from injury (acute or chronic) or in reference to the presence of any associated injuries (isolated or combined), or recognized injury patterns (multiligamentous knee injuries) **(1).**

PLC injuries can be classified according to the damage to the posterolateral structures or the degree of posterolateral instability. The following two classifications are most commonly used**(4).**

Bleday et al. and Fanelli and Larson classified the PLC injuries into type A, B, and C based on damage to structures (Table 2). Type A injuries involve the PFL and popliteus tendon. Clinically, only an increase in tibial external rotation is observed. Type B injuries affect the PFL, popliteus tendon, and LCL. Mild varus opening is observed in the varus stress test at 30° of knee flexion along with an increase in tibial external rotation. Type C injuries involve the PFL, popliteus tendon, LCL, lateral capsular avulsion, and cruciate ligament disruption. Marked varus instability is seen in type C injuries at 30° of knee flexion **(37, 38).**

The Hughston classification is based on the assessment of varus instability or rotational instability under varus stress force with the knee in full extension (Table 3). Grade I represents minimal tearing of a ligament with no abnormal motion. Grade II injury shows partial tearing with slight or moderate abnormal motion. Grade Ш injury refers to complete tearing with marked abnormal movements. Despite subjectivity and lack of relation to anatomic cutting studies, this classification method is still important in determining treatment choices **(13).**

Table 2: Classification of Damage in Posterolateral Structures **(4).**

Classification	Scale of damage	Damaged structure
Type A	10°increase in external rotation of the tibia	PFL, popliteus tendon
Type B	10°increase in external rotation of the tibia' Slight varus relaxation (5– 10 mm increase in varus load test)	PFL, popliteus tendon LCL
Type C	10° increase in external rotation of the tibia Severe varus relaxation (>10 mm increase in varus load test)	PFL, popliteus tendon LCL, capsule avulsion, cruciate ligament

Table 3: Classification of Posterolateral Instability Assessed by Varus or Rotational Instability **(4).**

Classification	Varus or Rotational instability	PCL injury
Grade I	0–5 mm or 0°–5°	Intact PCL
Grade II	5–10 mm or 6°–10°	Intact PCL
Grade III	>10 mm or >10° (soft endpoint)	PCL rupture

Examination under Anesthetic (EUA)

EUA should always be a concomitant part of the arthroscopic examination. Subtle laxities may become much more apparent with complete muscle relaxation. As usual, examination with the well leg should be performed initially. A comparison should be made between the EUA findings and those in the office to constantly try to improve one's technique and diagnostic accuracy. In addition, it is often useful to film the examination for further scrutiny and to compare and contrast the effect of surgical reconstruction. Ideally, the same systematic approach should be used and recorded contemporaneously. The EUA findings are an important addition to the operative note. The EUA is particularly useful when examining a patient who had a decreased range of motion (flexion <90 degrees) at initial presentation. The PCL can only be truly assessed with certainty at this angle. It is not uncommon to discover a PCL injury at EUA, which had previously gone undiagnosed. This obviously has significant implications for surgical planning, particularly in relation to the requirement for allograft, and may perhaps delay surgery. Therefore, it is important to always keep an open mind to the possibility of a PCL injury, particularly is a seriously injured knee with reduced range of motion **(3).**

Arthroscopy

Arthroscopy provides intra articular information of posterolateral structures, such as the popliteus complex, coronary ligament of the lateral meniscus, and posterolateral capsule. It helps to decide the appropriate treatment and provides accurate anatomical information in surgical treatment **(4).**

A drive through sign occurs when there is more than 1cm lateral joint opening under varus stress to the knee joint, which can be confirmed with arthroscopy. Also, popliteal hiatus widening during internal rotation of the tibia, tears of the inferior and superior popliteomeniscal fascicle, and abnormal popliteomeniscal motion during rotation may be observed in arthroscopy **(39).**

The "lateral gutter drive-through," visualized during diagnostic arthroscopy, is described as entering of the arthroscope into the posterolateral compartment through the interval between the popliteal tendon and the lateral femoral condyle. A positive sign indicates (1) the presence of femoral avulsion tears of the popliteal tendon or concomitant lateral collateral ligament, (2) the presence of repairable posterolateral corner tears, and (3) the enablement of mini-open surgery for the repair of these avulsion tears with a recess or reattachment procedure **(40).**

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