4 Clinical and Arthroscopic Evaluation of the Posterior-Cruciate-Ligament-Injured Knee

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Introduction

Although the posterior cruciate ligament (PCL) is the strongest ligament of the knee, it is rarely reconstructed in isolation [1, 2]. It has generally been accepted that multi-ligamentous knee injuries involving the PCL require operative intervention [1]. Yet, the treatment of PCL injuries in isolation is less clearly defined and remains somewhat controversial.

Isolated tears of the PCL have traditionally been treated nonoperatively with relative success [3–5]. As such, the requirement for operative intervention for isolated PCL injured knees has been reported to be as low as 3 % [5]. Indeed, there are numerous examples of high-level athletes, who have sustained PCL injuries and have returned to preinjury levels without surgical intervention in the short to intermediate term [6]. Nonetheless, long-term clinical studies have reported that non-operative treatment frequently leads to early-onset osteoarthritis of the patellofemoral and medial compartments and an overall deterioration in knee function [7–11]. Therefore, it is becoming clear that whereas some patients may cope reasonably well with a deficient PCL, others have significantly reduced knee function and require operative intervention to regain knee stability [12, 13].

A key element in assessing a patient with an injured PCL, whether in isolation or part of a multi-ligamentous injured knee, is to determine the extent of knee instability and the functional limitations this places on the patient. The acuteness of the injury also needs to be considered as part of this process. The assessment not only encompasses a thorough history and physical examination but also requires advanced imaging. This chapter provides a comprehensive review of the steps required to provide a clinical and arthroscopic evaluation of a patient with a PCL injured knee.

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History

> "We all pay lip service to a careful history, but how many of us are patient enough to elicit one?" Alan Graham Apley [14]

A good history provides the first clue in solving the mystery of the multi-ligamentous injured knee. A majority of mechanical disorders almost diagnose themselves to the attentive listener. Let the patient tell his/her own story. It is often helpful in taking a history to differentiate between an acute and chronic injury by asking the following open-ended questions:

Acute injury—Tell me what happened to your knee?
Chronic injury—Tell me about your knee?

The 'history' like all good stories should have a beginning, middle and an end. Start with the index trauma, which is of critical importance. By exploring the mechanism of injury, one can often ascertain the structures at risk; e.g. PCL injuries typically occur by direct impact to the anterior aspect of the tibia with a flexed knee or by hyperextension, hyperflexion, or rotational injuries with associated varus or valgus stress [15]. Particular attention should be given to the energy or velocity imparted to the knee during the injury; was the injury a result of a motor vehicle accident, a sporting injury, or an ultralow velocity mechanism [16]?

Following the initial injury, the examiner needs to discover what happened next: Did the knee swell up immediately? Could the patient bear weight? Did the knee feel unstable? Or worse, was the knee dislocated and needed to be reduced? Was there any concern about the blood supply to the foot? Enquire as to what treatment was initiated acutely and which investigations were performed.

In concluding the history, explore with the patients the current symptoms they are suffering, including pain, stiffness

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and instability. Pain alone is incredibly important and may be the overwhelming symptom in patients with chronic injury. Interrogating the patient as to the nature of pain is very beneficial in directing treatment. Enquiry should also hone in on the functional limitations the patient endures; what can you not do today that you were able to do prior to the injury? Do you trust your knee?

Physical Examination

A well-performed, systematic and clearly documented physical examination is a key component to diagnosing and treating a multi-ligamentous injured knee.

Physical examination represents a quick, sensitive and reproducible method to establish an anatomical diagnosis, provide a realistic prognosis and direct further investigations. It should be considered as the primary investigation in the evaluation of an injured patient, preceding other radiological investigations.

Life, Limb, Joint

Given the high incidence of vascular and neurological injury associated with multi-ligamentous knee injuries, assessment of the neurovascular status takes primacy in terms of the initial assessment of the limb [17]. Based on the clinical suspicion ascertained from the history, the specific ligamentous injury is identified primarily by comparing the excursion of the tibia on the femur in the affected and unaffected knee. To this end, nature has been considerate by providing a normal side for comparison. Assessing for the presence of pathology to the knee involves imparting stress to the knee through a range of motion.

The concept of 'look, feel, move' provides a useful and simplistic framework for the systematic assessment of the injured limb, ensuring that relevant findings are not overlooked.

Look

The entire limb should be inspected, paying particular attention for the presence of skin changes, abrasions, ecchymosis, or old scars. In the acute setting, one should rule out any evidence of active bleeding, gross mal-alignment or open injury.

The 'dimple sign' over the medial aspect of the knee is indicative of a knee dislocation that may require open reduction, and may occur as a result of buttonholing of the medial femoral condyle through the anteromedial joint capsule or entrapment of the adductor magnus tendon (Fig. 4.1) [18, 19].

Fig. 4.1 An intra-operative clinical photograph revealing extensive soft-tissue injury on the posterior aspect of the knee with an associated recurvatum deformity

The state of the skin is also 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 haematoma in the setting of a PCL injury as a result of direct impact to the anterior aspect of the tibia following a fall on the flexed knee. In addition, be mindful to inspect the posterior aspect of the knee, which is also instructive as to the extent of the injury (Fig. 4.2). The shape of the joint and upper and lower limb segments, their general alignment and any atrophy or swelling (localized or diffuse) should be noted; all of this preceding the 'laying on of hands'.

Feel

Vascular Assessment

The physical examination continues with an evaluation of the vascular status of the lower extremity. Be observant for signs of vascular injury (Table 4.1). Examine the temperature of the distal extremity. Palpate for both the dorsalis pedis and posterior tibial pulses. Hard signs should alert the

Fig. 4.2 Ecchymosis on the medial aspect of the knee with a positive 'dimple' sign (*white arrow*), indicative of an irreducibly dislocated knee with soft-tissue interposition between the femur and tibia

Table 4.1 Signs of vascular injury

Hard signs	Active haemorrhage
	Distal ischemia
	Expanding haematoma
Soft signs	Limb colour
	Capillary refill

treating surgeon to the need for emergent vascular imaging and involvement of a vascular surgeon. Soft signs, on the other hand, are less reliable; however, at the very least they should heighten the clinical suspicion and prompt the use of further vascular studies.

Neurological Assessment

Assessment of neurological function in the setting of knee dislocation can be challenging. In the context of a multisystem injury, the compliance of the patient may be compromised by a head injury or intoxication. The peroneal nerve is the most commonly injured nerve, due to its proximity, with less frequent injury to the tibial nerve [20]. Both the sensory and motor function of these nerves must be evaluated and documented, particularly before and after any manoeuvres or intervention.

The Form of the Knee

Palpation of the knee requires a subtle gradient of force application. The examiner should commence with the normal side with sufficient pressure to feel the subtleties of the knee's form. The process complements the visual inspection.

Increasing pressure may be applied to distinguish induration—the hardness of the different tissue planes. Induration provides insight into the severity and site of the injury. It is often helpful to bend the knee during this process to localize the source of the injury, and identify specific anatomical structures.

The skin, soft tissues and bones should be palpated methodically in an orderly manner to distinguish between normal and altered anatomy. The precise relationship of tender points to the joint line and ligamentous attachments is instructive in identifying the site of the lesion.

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 vigour and can expect a certain degree of discomfort. It is important not to neglect the extensor mechanism of the knee, in particular the inferior pole of the patella, which, if tender, may indicate a concomitant injury to the PCL, which may have resulted from an anteriorly applied force; e.g. a dashboard injury.

Move

Examination of the knee should consist of active and passive motion. It is helpful to ask the patient to move the well leg within the range of motion that is comfortable and possible, which provides the standard for comparison. In an acutely injured knee, this portion of the examination may be painful. The examiner should be confident and decisive and try to avoid excessive force, which can induce pain and cause guarding or even further injury.

Ask the patient to move the injured leg within the limits of comfort. This process is important in demonstrating the range of motion available to position the leg for the ligamentous examination. Passive movement of the joint may be carried out gently to assess any resistance to full extension or further flexion. Focus on the effect of passive movement by looking at the patient's face.

Limits of Motion

An initial assessment of the limits of motion is very important. First, start by asking the patient to fully extend the knee. An inability to fully extend the knee may indicate meniscal pathology, hamstring spasm or a comprised extensor mechanism. This assessment is very beneficial also in ascertaining the need for acute surgical intervention or the requirement for preoperative physical therapy to improve the range of motion.

Flexion, both active and passive, is tested next. Note the limits of motion with each test and try to identify the location of any discomfort. Knee flexion of at least 90° is required to be able to carry out a conclusive examination of the PCL. If this angle cannot be achieved initially, the patient should be re-examined sequentially following physical therapy until it is reached. Ice may be helpful in reducing swelling and pain and facilitate an improved physical examination. Failing this, an examination under anaesthetic (EUA) may be warranted. Joint line tenderness on maximal flexion may indicate meniscal pathology, which should not be overlooked.

Special Tests

There are a myriad of special tests, which may be carried out to assess the knee. The key factor is to choose a series of tests, which are comprehensive enough to assess the entirety of the knee and are also reproducible to the examiner. Listed below are preferred tests of the authors.

Varus/Valgus Stability

If the patient can reach hyperextension, it is the ideal position to start. Stability in this position infers that the medial and lateral capsuloligamentous structures and the PCL are intact. This finding alone is extremely informative. However, laxity in this position to either varus or valgus angulation is a worrying sign, indicating disruption of key ligamentous structures. If in hyperextension the knee is lax to varus angulation, then the posterolateral corner and the PCL are probably disrupted (Fig. 4.3). Likewise, if in hyperextension the joint is lax to valgus angulation, the medial capsuloligamentous structures and the PCL are probably disturbed (Fig. 4.4).

Fig. 4.3 Valgus instability in hyperextension: Valgus opening in full extension with no end point. This finding is indicative of injury to not only the medial structures but also the posteromedial capsule and likely the posterior cruciate ligament

Fig. 4.4 Testing of varus stability in full extension: The knee is tested in full extension to assess if there is lateral and posterolateral corner instability

At 0° flexion, the ACL and PCL are sufficiently slackened to allow diagnostic evaluation of medial or lateral capsular injuries by application of varus and valgus angulation. Further flexion to 30° facilitates examination of the isolated medial and lateral collateral ligaments (LCLs) because, in this position, the posterolateral and posteromedial corners, in addition to the cruciate ligaments, are relaxed.

Anteroposterior Translation

Anteroposterior glide is best determined with the fingers. Prior to performing any dynamic manoeuvres, be confident that you can palpate both the medial and lateral joint line. As the examination of both posterior and anterior drawers is conventionally performed in the same position, one must be able to distinguish between subtle changes in anteroposterior translation.

> An anterior drawer is only present when one has proved that the posterior drawer is absent. Werner Müller [21]

The first component to these series of tests is to assess the relationship of the tibial plateau to the femur in the sagittal plane. Position the patient supine with the hips flexed to 45° and the knee at 90° of flexion. Prior to performing any tests, keen surveillance is essential. Flex both knees together, and inspect the silhouette of the knee in the sagittal plane, from each side (Fig. 4.5). Begin with the uninjured side. The key structures to observe are the anterior tibial tubercle and the association with the patellar tendon and the anterior aspect of the patella. In the presence of a disrupted PCL, and more often than not a concomitant posteromedial or posterolateral lesion, the tibial plateau will be translated posteriorly with respect to the femur, which is termed 'posterior sag'.

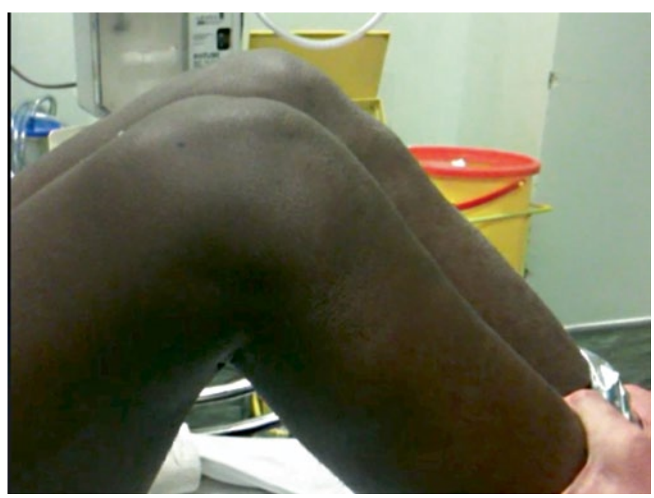

Fig. 4.5 Inspection of relative tibial translation: The patient is placed supine on the table with hips flexed to 45° and knees to 90°. Observe the silhouette of the knees. Note the loss of the contour of the joint line and prominence of the tibial tuberosity on the right knee compared to the opposite side, suggesting posterior subluxation of the tibia

Fig. 4.6 Posterior drawer testing in neutral rotation. The patient is supine with the knees flexed to 90°. A posterior force is exerted anteriorly on the proximal tibia. Translation at the joint line can be appreciated with the thumbs

Müller also describes a test where the patient is asked to actively extend the knee from the flexed position [21]. The force of the quadriceps will translate the tibia anteriorly to allow the knee to straighten, which is visible from the sagittal position. This test is also known as the 'quadriceps active' test. A modification of this test is performed by holding the foot and asking the patient to contract his/her quadriceps against resistance.

Pure posterior glide involves symmetrical posterior translation of both tibial plateaus with neither internal nor external rotation. This is a rare situation. Posterior drawer alone without any peripheral lesions is due to an isolated PCL lesion, which is not a common finding. Peripheral structures compensate for the absence of a PCL and give rise to a hard end point at the extreme of posterior translation [22]. The accuracy of the interpretation can, therefore, be uncertain.

Table 4.2 IKDC—Grading of joint translation

Normal	Nearly normal	Abnormal	Sev. abnormal
0–2 mm	3–5 mm	6–10 mm	>10 mm

Associated posteromedial or posterolateral lesions also influence the response to posterior translation. A soft end point is typically present in this circumstance. Failure to discriminate between this finding and an anterior drawer is not unusual, as injury to the anterior cruciate ligament (ACL) is a more common finding.

The Posterior and Anterior Drawer Test

The foot is fixed firmly in a neutral position with the knee flexed to 90°. The posterior aspect of the proximal tibia is held with both hands, placing the fingers into the popliteal fossa (Fig. 4.6). The movement for posterior drawer first requires the joint to be reduced to a neutral position. It is, therefore, advisable to place the thumbs of each hand on either side of the patellar tendon so that one can palpate any posterior subluxation and to confirm that the joint is in neutral alignment. Feel the tightness of the hamstrings with the index and middle fingers and ask the patient to relax. The tibia is then pulled forward in order to feel the anterior shift of the tibial plateau. The tibia is then pushed backwards by applying a force with the thumbs on the tibial tuberosity. This manoeuvre is gently repeated, as required. It is important to be conscious of the end point in the anterior and posterior direction. Observe for a change in shape of the joint with each sequential movement. It is possible to increase the force of the anterior pull by placing the thumbs against the femoral condyle and levering the tibia forward. The parallel orientation of the thumbs on either side of the patellar tendon also facilitates detection of any rotatory movement, which may occur in addition to anteroposterior glide. The extent of translation can be quantified according to the International Knee Documentation Committee (IKDC) values (Table 4.2) or based on grading of the step-off (Fig. 4.7) [23].

Rotatory Stability

The appreciation of increased rotatory excursion requires careful attention to detail and can be subtle. Failure to diagnose and rotatory instability may result in failed surgical treatment and a poor prognosis. The pathophysiology of injuries to the posteromedial and posterolateral corners can be difficult to interpret with physical examination, and, therefore, it is advisable to spend some time teasing out abnormalities that are detected.

The Anteromedial Rotatory Drawer

The patient is supine with the hip flexed to 45°, the knee flexed at 90° and the foot fixed on the examining table in 15° of external rotation. In this position, the ACL and collateral ligaments are lax, which permits anterior and lateral

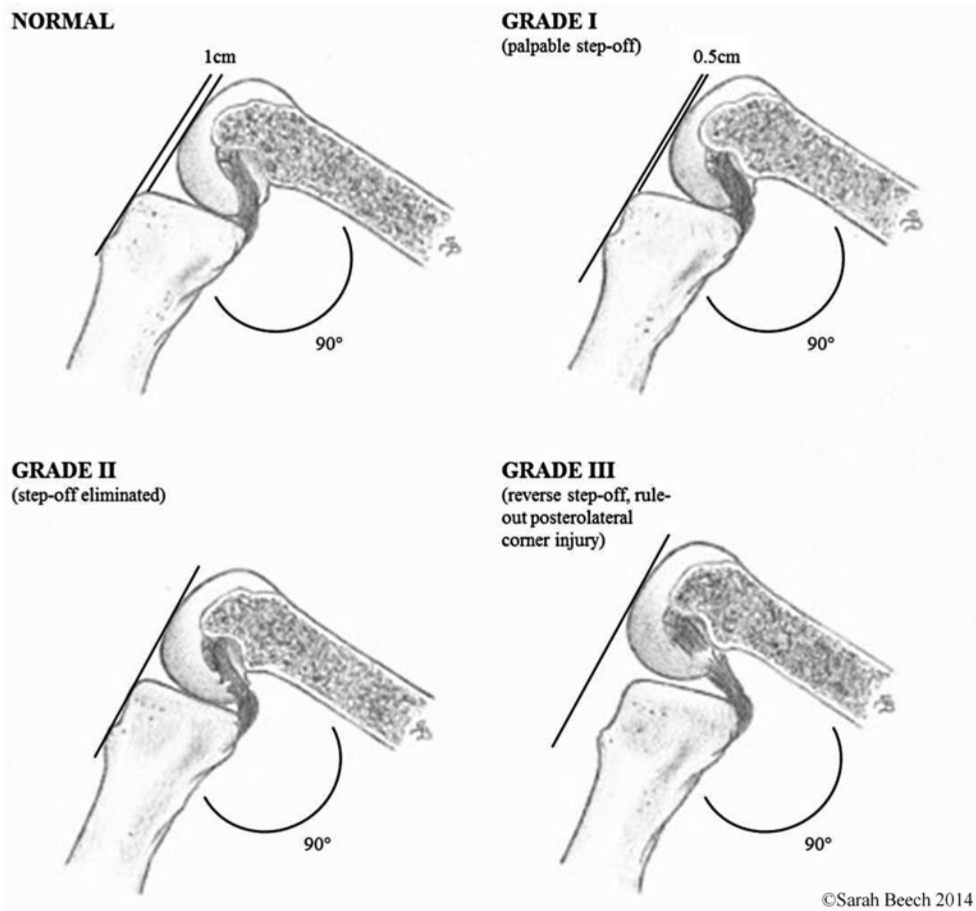

Fig. 4.7 Assessment of step-off in the PCL-deficient knee as classified by Petrie and Harner [23]. *PCL* posterior cruciate ligament. (Figure courtesy of Sarah Beech)

displacement of the medial tibial plateau. An anteriorly direct force is applied to pull the tibia directly forward. Depending on the severity of injury to the medial capsule, the medial collateral ligament (MCL) and the ACL, there will be a progressive increase in the pathological external rotation of the tibia with respect to the femur. The medial tibial plateau glides forward while the lateral plateau hardly moves at all. The axis of rotation occurs around the PCL on the lateral wall of the medial femoral condyle. If the ACL is intact, this drawer is purely rotational. Slocum, who was the first to describe this test in 1968, stated that greater than 30° external rotation should be considered pathological [24]. Accordingly, it is very important to rule out the presence of hypermobility of the contralateral limb to avoid false positive results. The quantification of this test, as proposed by Slocum, falls outside the IKDC classification, and is listed in Table 4.3.

Table 4.3 Slocum classification of rotatory instability

1+	Half a thumb—13 mm
2+	Between half and three quarters of a thumb—13–19 mm
3+	Greater than three quarters of a thumb—> 19 mm

The Anterolateral Rotatory Drawer

This test is performed in the same position with the foot internally rotated. A positive drawer in this position is indicative of a deficient ACL, which according to Noyes is the first restraint to anterior shift in internal rotation. This manoeuvre also examines the integrity of the anterolateral femoral tibial ligament [25]. Anterolateral rotation is only possible if these fibres are deficient.

Posterior Rotatory Stability

The addition of rotation to the posterior drawer is used as a further test to assess the integrity of the PCL and posterior corners 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 to posterior drawer in neutral rotation. In internal rotation, the PCL tightens and apposes the surface of the tibia to the femur, preventing any posterior sliding of the medial tibial plateau. If the PCL is ruptured the axis of rotation shifts from a central position to a lateral position, provided the posterolateral structures are intact. This results in the medial tibial plateau translating posteriorly to a greater extent than the lateral tibial plateau. Translation predominates over rotation.

This is defined, therefore, as a posteromedial translatory rotatory laxity.

The Posterolateral Rotatory Drawer

The patient is in the same position as for all other drawer tests. The foot is fixed in slight external rotation and posterior directed force is applied to the anterior tibial tuberosity [26]. In this position, the PCL relaxes so that there can be rotatory and translatory posterolateral laxity. The ratio of translation to rotation should be compared to that observed when the posterior drawer is in the neutral position. Pure rotatory laxity occurs with an isolated posterolateral corner 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 posterolateral corner, application of a posterior drawer in this position will result in increase in the ratio of posterior translation to external rotation as the centre of rotation is displaced peripherally.

The Posteromedial Translatory Rotatory Drawer

Internally rotating the foot tightens the PCL at 90° of knee flexion, resulting in coaptation of the femur and tibia, which prevents posterior sliding of the medial tibial plateau. Application of a posteriorly directed force to the anterior tibia, in this setting, will result in a hard end point, thereby confirming the presence of an intact PCL. However, if the PCL is deficient, coaptation does not occur and the axis of rotation shift laterally, provided the posterolateral structures are intact, which will result in a greater degree of medial-to-lateral tibial subluxation. In the absence of a PCL and a disrupted posterolateral corner, the axis of rotation is more centrally located, allowing posterior translation of the lateral tibial plateau along with the medial tibial plateau [27]. It is, therefore, necessary to assess the magnitude of the relative translation between the lateral tibial plateau and the medial tibial plateau. The more this ratio increases, the more posterior laxity become global.

The Lachman Test

The Lachman test is one of the most sensitive tests to assess ACL integrity when performed by experienced hands [28]. This test does require practice to master and relies upon having a relaxed and compliant patient. The advantage this test has over the anterior drawer relates to the fact that it is not always possible to flex the patient's knee to 90° in an acutely injured knee, in the setting of an effusion or haemarthrosis, whereas flexion to 30° is normally attainable. The reflex contraction of the hamstrings can be strong, particularly in an athletic population, and has a greater effect on preventing anterior translation at higher degrees of flexion. Finally, the bony osteology of the medial compartment and the addition of the secondary restraints, provided by the medial meniscus and posterior oblique ligament (POL), are more effective in resisting anterior translation at 90° than 30°.

The examination is performed with the patient supine and the examiner on the side of the knee to be examined. With the patient relaxed, the knee is placed in 30° of flexion. While stabilizing the femur with one hand, place the other hand on the posterior aspect of the upper tibia and apply an anterior force to draw the tibia forward on the femur (Fig. 4.8). When the test is positive, there is an anterior shift of the tibia with respect to the femur with a soft end point. This is in contrast to a hard end point when the ACL is still intact. A soft end point, which occurs with increased anterior excursion, denotes that the ACL is ruptured without doubt. However, a hard end point is more difficult to interpret as it may not indicate that the ACL is intact for two reasons—the ACL may be simply attenuated and stretched and tighten at a greater degree of tibial excursion, or the secondary peripheral structures are compensating to produce the hard end point. In this test, as in any test, it is very important to compare with opposite side to rule out any congenital laxity and quantify the side-to-side difference in translation.

The Recurvatum Test

Testing in full extension may also reveal a recurvatum deformity, which points to a posterolateral lateral injury or

Fig. 4.8 The Lachman test: The knee is flexed to 30°. The proximal tibia is pulled anteriorly with one hand while the femur is held steady with the opposite hand

possibly even a posteromedial injury. Classically, the description of this test involves the examiner lifting the patient's great toe and observing the relative amount of genu recurvatum present [29]. The amount of relative knee hyperextension present should be compared to the contralateral normal knee and may be measured by a goniometer or heel-height differences. In addition to the hyperextension seen, the tibia commonly rotates into external rotation and a varus alignment is often noted at the knee (Fig. 4.9). A positive finding of this test should alert the examiner to the possibility of a posterolateral corner injury, which is typically with an associated cruciate ligament injury [30, 31].

Fig. 4.9 Recurvatum deformity: Holding the leg by the foot or toe, the knee is seen to hyperextend. This finding is indicative of a PCL rupture and suggestive of an injury to the posterolateral corner of posteromedial structures. *PCL* posterior cruciate ligament

Prone Examination of Knee

The prone examination affords the opportunity of assessing the posterior aspect of the knee. Initial observation is carried out to identify the presence of 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.

The Dial Test

The dial test is performed to determine the amount of external rotation of the tibia, which occurs on the femur. Conventionally, it is used to differentiate between isolated posterolateral corner injury and a combined PCL and posterolateral corner injury. The test is performed by flexing both knees to 30° and maximally externally rotating both feet (Fig. 4.10). Compare the uninjured side to the affected side and assess for any increase in rotation. The test is repeated at 90° of flexion. An isolated posterolateral corner is diagnosed if there is a positive dial test at 30° with a normal dial test at 90°. A positive dial test at 90° usually indicates a combined posterolateral corner and cruciate ligament injury, but it may also indicate a severe medial knee injury, which can be isolated or combined with a PCL disruption.

Functional Tests

Of particular importance, is the use of functional and dynamic examinations, which require the assumption of different

Fig. 4.10 The dial test: The patient is positioned prone. A comparison of external rotation of both feet is made at (**a**) 30° and (**b**) 90° of flexion

positions; standing, walking, or running gives the examiner a keener appreciation of the limitation of function of the joint and the patient. It is vital to recognize mechanical mal-alignment, which may have a significant influence on the outcome of a soft tissue reconstruction and may point to the requirement for bony correction. Pay particular attention to a thrust when the patient is walking. Adequate exposure to appreciate subtle compensatory movement of the lower limb when ambulating is very important. In complex instabilities, it is often beneficial to film functional activities and to examine them in slow motion. A comparison can be made postoperatively to assess any changes with treatment.

Diagnostic Studies

Vascular Studies

Aside from physical examination, additional vascular studies may be warranted in the context of an acute knee dislocation or multi-ligamentous injury. Many surgeons advocate that an ankle-brachial index (ABI) be performed in all patients suspected of having a knee dislocation [32]; however, this is not universal practice. The ABI is a fast and reliable test with relatively no associated morbidity to the patient. The ABI is recorded by means of a Doppler ultrasound probe by measuring the systolic pressure in the affected leg at a level just proximal to the ankle and dividing this value by the systolic pressure in the ipsilateral arm. A value of >0.9 has been found to be a reliable marker of normal arterial patency. Further investigation by arteriography or imaging with vascular reconstructions is indicated in the presence of abnormal physical findings and an ABI <0.9.

In a systematic review of patients who sustained vascular injury following a knee dislocation, Medina et al. identified that selective angiography was the most frequently used diagnostic modality (61 %, 14 of 23), followed by non-selective angiography and duplex ultrasonography (22 %, 5 of 23), ABI (17 %, 4 of 23) and magnetic resonance (MR) angiography (9 %, 2 of 23) [17]. As is evident from this review, considerable debate still exists regarding the optimal diagnostic method for detecting vascular injury. Historically, conventional angiography has been regarded as the gold standard for diagnosis and was routinely ordered following knee dislocation. More recently, many authors now advocate the use of selective angiography, suggesting only those patients with abnormal pulses or ABI undergo angiography [33–36]. Supporters of the routine angiography would argue that the grave clinical consequences of a missed vascular injury diagnosis, while those of the latter cite the accuracy of non-invasive screening exams as well as the costs and risks associated with angiography [17].

Imaging Studies

Plane Radiography

A standard knee series, including bilateral standing antero-posterior (AP), AP flexion 45° weight bearing, lateral and Merchant patellar radiographs, should be evaluated for any evidence of avulsion fractures, tibial subluxation and associated knee injuries (Fig. 4.11). In the event of having access to plain radiographs performed prior to reduction, these should be scrutinized closely to assess the direction of the dislocation.

If there is any suggestion of mal-alignment 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 (Fig. 4.12).

Stress Radiography

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 reliable measure posterior laxity in patients with PCL injuries, in addition to being a good predictor of concomitant posterolateral corner injuries [37, 38].

In their study, LaPrade et al. concluded that clinicians should be suspicious of an isolated fibular collateral ligament injury if opening on clinician-applied varus stress radiographs increases by approximately 2.7 mm and a grade-III posterolateral corner injury if values increase by approxi-

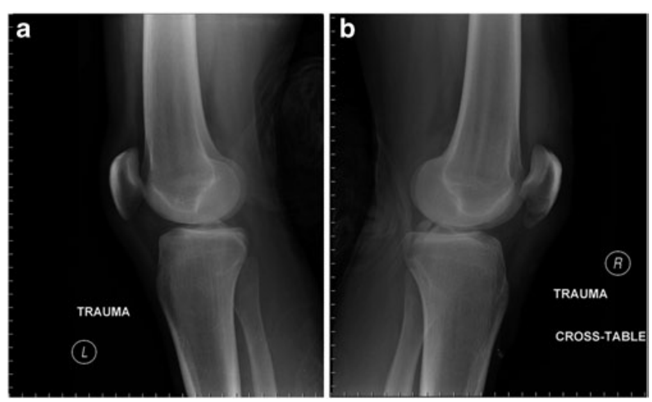

Fig. 4.11 **a** Lateral radiograph of the left (*unaffected*) knee. Note the position of the tibia with respect to the femur. **b** Lateral radiograph of the PCL injured knee. There is an avulsion fracture of the tibia insertion of the PCL (*large white arrow*) with posterior subluxation of the tibia (*black arrow*). Also, note the fracture to the inferior pole of the patella (*small white arrow*). *PCL* posterior cruciate ligament

Fig. 4.12 Long-leg film of bilateral limbs. Used to assess the mechanical axis of both lower limbs to determine the requirement of osteotomies in the treatment of multi-ligamentous knee injuries

mately 4.0 mm [37]. Several techniques have been described to deliver a posteriorly directed force during stress radiography to assess the integrity of the PCL [39–43]. These methods have included hamstring contraction, gravity assisted, the Telos device (Austin and Associates, Fallston, Maryland), and single-leg kneeling [41, 44–46]. The Telos device and kneeling have been shown to be superior to other methods for reproducibly demonstrating posterior knee instability [40]. Schulz et al. have reported that subjects with isolated PCL injuries demonstrated 5–12 mm of increased posterior displacement compared with the uninjured extremity. Subjects with combined posterior knee injuries to the PCL, posterolateral corner and/or posteromedial corner had increased posterior displacement measuring >12 mm compared with the contralateral side [47].

In a further study using stress radiographs to diagnose medial-sided injuries, LaPrade et al. concluded that a grade-III medial collateral ligament injury should be suspected with greater than 3.2 mm of medial compartment gapping compared to the contralateral knee at 20° of flexion, and this injury will also result in gapping in full extension [48].

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) has become the gold standard imaging modality for assessing the multi-ligamentous injured knee. The ability of MRI to identify associate tendon, ligament and meniscal injury is unparalleled with other imaging modalities. Furthermore, the specific site of ligamentous injury, proximal, distal or mid-substance, can be clearly defined (Fig. 4.13). 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 (Fig. 4.14). Finally, the state of the cartilage may also be ascertained which may be helpful as a prognostic indicator. However, one must interpret MRIs with a degree of caution, particularly in the setting of chronic PCL injuries. Tewes et al. reported that MRI scans are unreliable to assess for chronic PCL tears and should not be used to infer functional status in cases with chronic injuries [49].

While 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 MR imaging and guide the interpretation of findings. A systematic approach should to be adopted during the interpretation

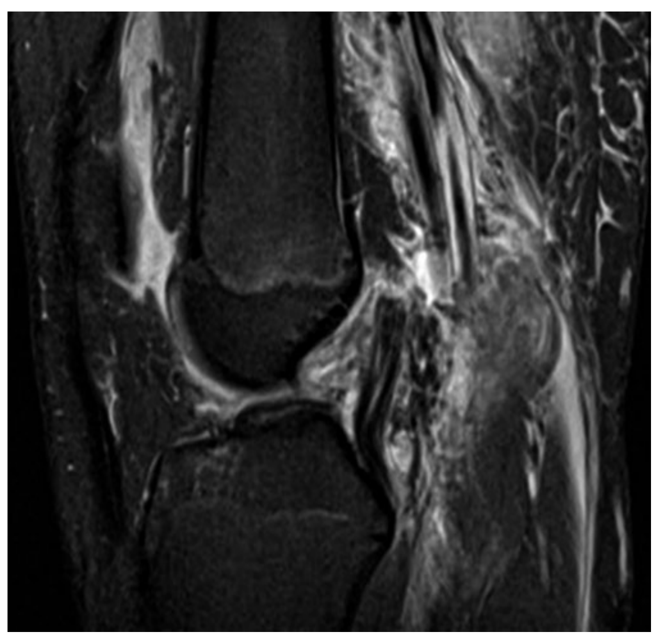

Fig. 4.13 T2 Sagittal MRI of the right knee, demonstrating an acutely injured PCL. The femoral origin of the PCL has been torn off (*white arrow*), and there is evidence of increased signal in the substance of the ligament (*yellow arrow*). *PCL* posterior cruciate ligament

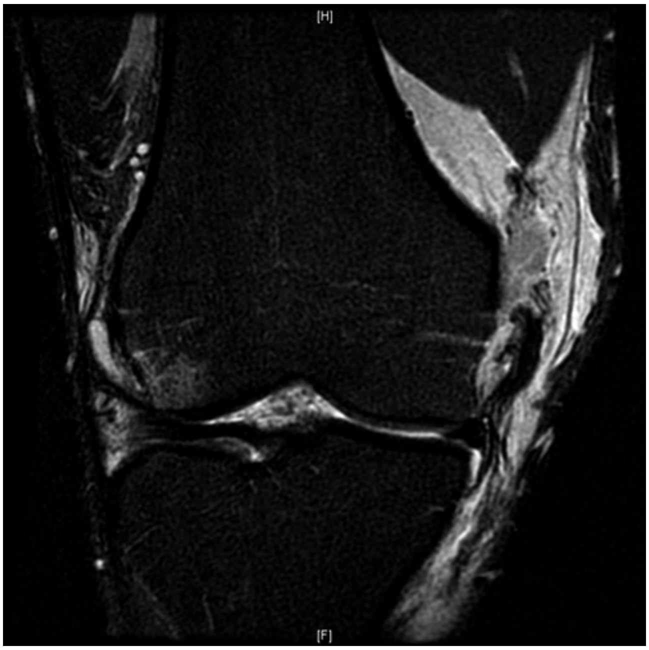

Fig. 4.14 3-Tesla T2 Coronal view of the right knee, demonstrating an acute tear of the proximal medial collateral ligament with lateral-sided bone bruising to the lateral femoral condyle. The injury sustained was a traumatic valgus load

Fig. 4.15 T1 Sagittal image of the right knee. The *white arrow* marks the avulsed fragment of bone along with the PCL from the tibial insertion

of scans to avoid missing significant injuries. It should be noted, that MRI is less reliable and accurate in diagnosing chronic multi-ligamentous injuries, as a previously torn ligament, which has healed with scar, may appear morphologically intact although physiologically incompetent.

Characterization of PCL injury by MRI requires three planes of view—axial, coronal and sagittal. Dedicated coils improve signal-to-noise ratio and a small field of view helps with spatial resolution and a small field of view (10–14 cm) helps to improve spatial resolution [50]. Higher magnet strength has also resulted in improved image quality.

The PCL is best visualised in the sagittal oblique plane. PCL tears may be categorized into intra-substance, partial, complete or avulsion. Intra-substance tears are characterized by oedema and haemorrhage within the ligament. Partial tears demonstrate an interruption of a portion of one of the margins of the ligament and may present with a circumferential ring of haemorrhage. Complete tears show a loss of continuity of the tendon and may include increased signal at the margins of the tear. Avulsions are usually found at the tibial insertion and the PCL will be retracted along with its bony fragment (Fig. 4.15).

On the medial side of the knee, the key structures that should be visualized are the superficial MCL, the deep MCL and the medial meniscus. Observe for the presence and location of signal change, which is indicative of oedema and haemorrhage. The continuity of the medial structures, the MCL, POL, the menisco-femoral and meniscotibial ligaments should be ascertained. Although it is possible to grade injuries based on MRI, this should always be correlated with clinical examination.

The structures that need to be identified on the lateral and posterolateral side of the knee on MRI are the iliotibial band (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.

The ITB, the terminal extension of the tensor fascia lata, inserts distally onto Gerdy's tubercle. It is uncommon to injure the ITB, but discontinuity or significant injury to this structure represents a very high energy injury.

Meniscal injuries are important to recognize in the context of multi-ligamentous knee injuries [51]. The high energy involved in this injury pattern frequently results in meniscal damage, including root avulsions [52]. 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 the outcome.

Computerized Tomography

Computerized tomography (CT) scans continue to play a role in the assessment of PCL injuries [53]. Their value is probably greatest in the assessment of ligamentous injury with associated fractures or avulsions (Fig. 4.16). In addition, in the setting of revision surgery, CT scans, and in particular 3D reconstruction, can accurately identify the location and size of the tunnels.

Examination Under Anaesthesia

The examination under anaesthesia (EUA) should always be a concomitant of the arthroscopic examination. Subtle laxities may become much more apparent with complete muscle relaxation. As usual, examination with the good 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 noted.

The EUA is particularly useful when examining a patient who had a decreased range of motion (flexion <90°) 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 in a seriously injured knee with reduced range of motion.

Arthroscopic Evaluation

A thorough diagnostic arthroscopic evaluation should be carried out as part of any ligament reconstruction procedure. It is important to employ a methodical approach to avoid overlooking subtle injuries to the posterolateral and posteromedial corners, the menisci and all articular surfaces. Ensure that all compartments of the knee are adequately scrutinized and, if necessary, probed.

A key factor in successful diagnosis in the multi-ligamentous injured knee is getting adequate visualization of the entire knee. A standard 4-mm 30° arthroscopy is used initially. However, surgeons embarking on this surgery should be familiar using a 70° arthroscope and adept at gaining access to the posteromedial and posterolateral aspect of the knee. In addition, one should be prepared to make accessory portals posteromedially and posterolaterally, as necessary.

The patient is placed supine on the operating table. Prior to using a tourniquet, it is vital to be aware of the vascular status of the patient and whether any emergent revascularization procedure was carried out. If there are no vascular issues, a tourniquet should be placed high on the thigh. The knee should be held in the position the surgeon is most familiar and comfortable with, ensuring that adequate flexion can be achieved, and there is sufficient space proximally for making accessory portals.

The authors use an outflow portal routinely on the lateral aspect of the suprapatellar pouch, which is particularly useful for venting the knee and improving visibility in the acutely injured knee. A standard anterolateral parapatellar portal is used for the arthroscope and an anteromedial parapatellar portal for the instruments. A systematic approach is used to explore the patellofemoral joint, the femoral notch

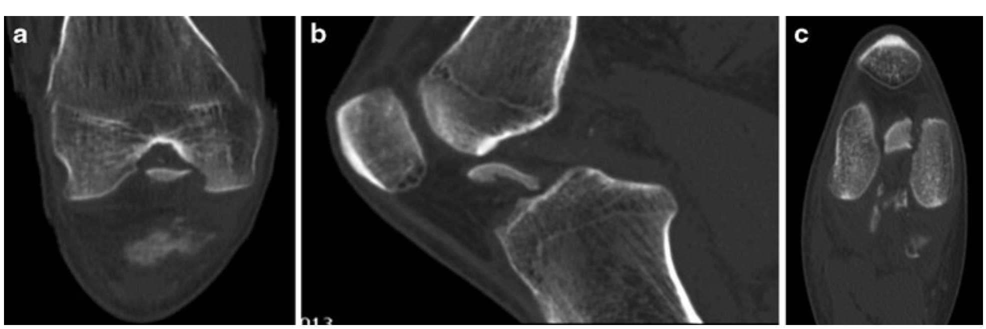

Fig. 4.16 **a** CT scan—coronal image of a right knee, demonstrating a femoral side PCL avulsion fragment from the medial wall of the lateral wall of the medial femoral condyle. **b** CT scan—sagittal image of right knee, demonstrating an avulsed fragment of bone within the femoral notch. **c** CT scan—axial image of the right knee, showing a comminuted avulsion fracture of the lateral wall of the medial femoral condyle at the origin of the PCL. *CT* computerized tomography, *PCL* posterior cruciate ligament

and medial and lateral compartments. A list of the specific structures in each compartment is provided in Table 4.4. Discussed below are some of the specific findings related to PCL injuries and other discoveries suggestive of associated knee pathology.

Table 4.4 Checklist for arthroscopic assessment of the PCL injured knee

Patellofemoral joint	Haemarthrosis/haemosiderin deposition
	Arthrofibrosis
	Patella chondrosis
	Medial patellofemoral ligament injury
	Trochlear chondrosis
Lateral gutter	Lateral gutter drive through
	Popliteal tendon avulsion
	Loose bodies
	Meniscal extrusion
Medial gutter	Deep MCL avulsion
	Meniscal extrusion
	Loose bodies
Femoral notch	ACL injury—torn, empty wall sign, injection
	Pseudo-laxity ACL
	PCL injury—torn, injection, loss of tension
	Posteromedial drive through sign
Lateral compartment	Lateral drive through sign
	Meniscotibial (coronary) ligament of lateral meniscus
	Popliteal meniscal fascicle (Posterosuperior and inferior)
	Popliteus tendon
	Horns of lateral meniscus (posterior and anterior)
	Meniscofemoral ligaments (Wrisberg and Humphreys)
	Articular cartilage (femoral condyle and tibial plateau)
Medial compartment	Medial drive-through sign
	Meniscotibial ligament of medial meniscus Meniscocapsular ligament (femoral)
	Horns of medial meniscus (posterior and anterior)
	Articular cartilage (femoral condyle and tibial plateau)

MCL medial cruciate ligament, *ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament

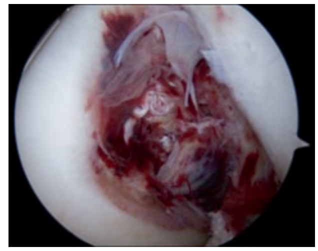

Fig. 4.17 Arthroscopic image from anterolateral portal of an acutely torn PCL. *PCL* posterior cruciate ligament

A number of arthroscopic findings, specifically related to the multi-ligamentous injured knee, have been described. Immediately upon introduction of the arthroscope into the suprapatellar pouch, one gets an impression of the general state of the knee. The presence of a haemarthrosis is indicative of an acute injury; whereas haemosiderin staining and a scarred, thickened synovium herald a more chronic process. The patellofemoral articulation is important to explore initially to assess the presence of associated articular lesions, which may be acute from the initial trauma or chronic as a result of altered biomechanics in a PCL-deficient knee.

On examination of the femoral notch, one should observe for injection of the femoral footprint of the PCL or the presence of haematoma around a frankly torn PCL (Fig. 4.17). In a chronic injury, there may be an abundance of amorphous scar tissue in the notch, which should be removed with care to delineate the bundles of the PCL. Examine the ACL for concomitant injury and also for the presence of the pseudo-laxity (Fig. 4.18); this phenomenon occurs as a result of posterior subluxation of the tibia and an apparent redundancy of the ACL. It is not uncommon for this to be mistaken as a torn ligament. By applying an anterior translation under visualization, the normal contour of the ligament is restored.

The drive-through sign was first described in the posterolateral knee ligament injuries as the ability to pass the arthroscope easily between the lateral femoral condyle and the tibial plateau due to excessive opening of the lateral

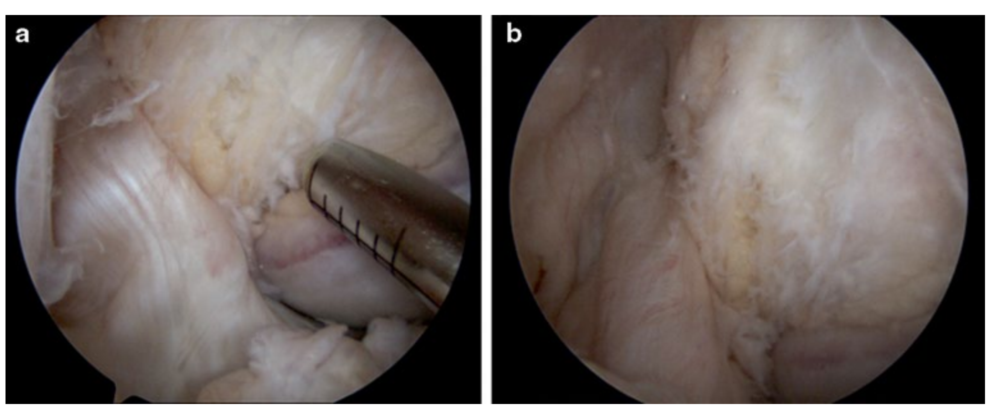

Fig 4.18 **a** Arthroscopic image of the ACL, demonstrating 'pseudo-laxity' due to the posterior subluxation of the tibia in the setting of a chronically injured PCL. **b** A normal appearance of the ACL following the application of an anterior translation force to reduce the tibia. *ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament

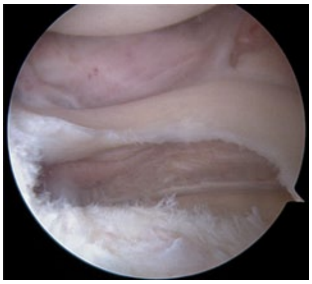

Fig. 4.19 An arthroscopic image of the lateral drive-through sign of a left knee with a combined PCL and PLC injury. *PCL* posterior cruciate ligament, *PLC* posterolateral corner

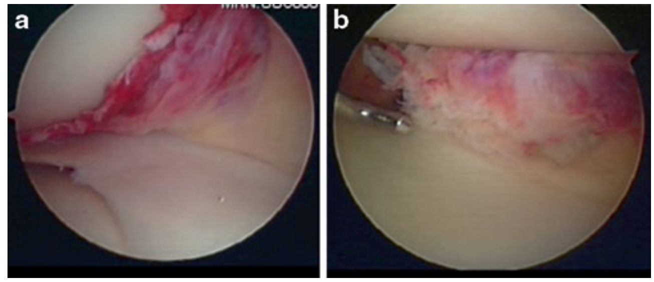

Fig. 4.20 **a** Arthroscope image of the medial compartment of the knee, demonstrating a tear the medial capsule with invagination of the capsule into the joint superior to the medial meniscus. **b** Arthroscopic image of the lateral compartment in a posterolateral corner injury. Note the presence of a torn lateral capsule

compartment [54] (Fig. 4.19). Feng et al. have also described a lateral gutter drive-through sign in the arthroscopic knee surgery as the entry of the arthroscope into the posterolateral compartment through the interval between the popliteal tendon and the lateral femoral condyle to indicate the presence of posterolateral corner peel-off lesions [55, 56].

In addition, a posteromedial drive-through sign has also been reported, demonstrating a very high positive predictive value (91.7%) for the diagnosis of PCL injury, in particular grade-III ruptures [57]. The posteromedial compartment can be viewed either through a posteromedial portal or through the intercondylar notch from the anterolateral or anteromedial portal. When the posteromedial compartment is viewed through an anterolateral portal via the intercondylar notch, the arthroscope passes the space between the medial femoral condyle and the PCL. In the majority of patients with an intact PCL, this passage of the arthroscopy typically necessitates a slight degree of knee flexion and valgus stress due to the limited space between the medial femoral condyle and the PCL. However, when there is PCL insufficiency, the arthroscope passes easily between the medial femoral condyle and the PCL as a result of an enlarged space; valgus stress or manipulation with a trocar at 80–90° of knee flexion is not required. A number of authors have documented this occurrence in patients with partial or complete PCL deficiency [58–60].

It is also extremely important to assess the lateral and medial compartments for the presence of meniscal pathology. The meniscofemoral and meniscotibial ligaments should be explored for the presence of tears or in more severe cases incarceration of the capsule (Fig. 4.20). Particular attention should be given to visualize the meniscus roots, which are commonly torn in multi-ligamentous injury [51, 52]. Sonnery-Cottet et al. have recently claimed that a lesion to the posterior horn of medial meniscus often goes undiagnosed and report on the value of assessing the posterior horn of the medial meniscus by visualization through the posteromedial portal to improve the accuracy of the diagnosis [61]. To gain access to the posteromedial compartment, the arthroscope is introduced through the anterolateral portal deeply into the notch and underneath the PCL; it may be necessary to use a blunt trocar.

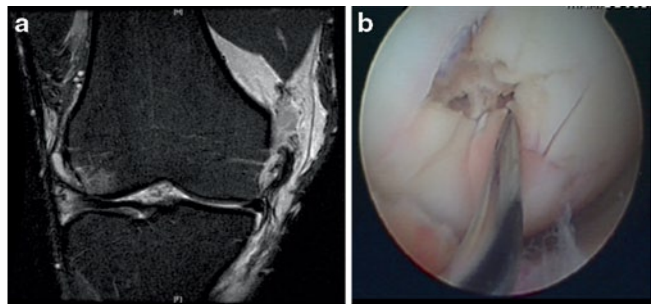

Fig. 4.21 **a** T2 coronal MRI of right knee—observe the increased signal on the lateral femoral condyle which is suggestive of impaction of the lateral compartment following a valgus injury. **b** Arthroscopic image of the lateral femoral condyle in the same patient. Note the devastating cartilage injury as a result of impaction. *MRI* magnetic resonance imaging

At all times, be aware of the integrity of the articular cartilage in all compartments. Seek to correlate any suspicious lesions on MRI with direct visualization and probing. Cartilage lesions may vary from minor scuffing to osteochondral fractures to degenerative changes in a chronic situation (Fig. 4.21).

Summary

The initial assessment of PCL injured knees is challenging and requires attention to detail to avoid missing concomitant pathology. An awareness of the mechanism of injury is vital and an important starting point in the quest to discover the extent of the injury and provide appropriate treatment. The treating physician needs patience, vigilance and a variety of diagnostic tools to reach a precise diagnosis. Each injury should be approached in a methodical and systematic manner to ensure an accurate initial assessment and ultimately improve outcomes.

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