Reconstruction of the Posterolateral Corner of the Knee

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Abstract

Injuries to the posterolateral corner of the knee present unique challenges to the orthopedic surgeon. In recent years, there has been an evolution in surgical techniques from nonanatomic sling procedures to anatomically based and biomechanically validated reconstructions. The purpose of this chapter is to review the clinically relevant anatomy and biomechanics of the posterolateral corner of the knee, to discuss the proper clinical evaluation to aid in diagnosis, and to describe anatomical reconstruction following these injuries.

Abbreviations

ACL	Anterior cruciate ligament
FCL	Fibular (lateral) collateral ligament
LGT	Lateral gastrocnemius tendon
PFL	Popliteofibular ligament
PCL	Posterior cruciate ligament

Introduction

The evaluation and treatment of injuries to the posterolateral corner of the knee has evolved substantially over the past few decades. These injuries present unique challenges to the orthopedic surgeon because of their reported rare occurrence and their often-complicated nature. It is estimated that only a quarter of posterolateral corner injuries are isolated (Geeslin and LaPrade 2011). Unidentified posterolateral corner instability in the setting of cruciate ligament reconstructions provides a source for residual knee laxity and increases the risk of graft failure (LaPrade et al. 2002). The annual rate of posterolateral corner injury has been estimated to be 9.1 in 100,000 (Gianotti et al. 2009), although more recent studies suggest that the reported lower incidence in the past may have been due to a lack of recognition of this injury rather than a rarity of its occurrence (LaPrade et al. 2007). It has been estimated that the incidence of posterolateral corner injuries in patients with a hemarthrosis is 9.1 % (LaPrade et al. 2007). In recent years, improved biomechanical-based research has led to an evolution in surgical techniques from nonanatomic sling procedures to anatomically based and biomechanically validated reconstructions (LaPrade et al. 2004a). The purpose of this chapter is to review the clinically relevant anatomy and biomechanics of the posterolateral corner, to discuss the proper clinical evaluation to aid in diagnosis, and to describe anatomical reconstruction following these injuries.

Clinically Relevant Anatomy and Biomechanics

A thorough understanding of the anatomy of the posterolateral corner of the knee is not only necessary for surgical reconstruction but is also required for proper interpretation of physical examination and radiographic findings. The anatomy of the posterolateral corner of the knee has been described in intricate detail in recent years (LaPrade et al. 2003). Despite over 28 identified structures in the posterolateral knee (LaPrade and Terry 1997; LaPrade et al. 2003), biomechanical studies have demonstrated that the main stabilizers are the fibular (lateral) collateral ligament (FCL), the popliteus tendon, and the popliteofibular ligament (PFL) (LaPrade et al. 2003).

The structures of the posterolateral corner provide stability to the knee against varus angulation, tibial external rotation, and hyperextension, serving a more prominent role with the knee at flexion angles less than 45°. As a result of observations that patients with chronic posterolateral corner injuries often had failed anterior cruciate ligament (ACL) or posterior cruciate ligament (PCL) reconstructions, biomechanical studies were performed to evaluate the effect of posterolateral corner instability on cruciate ligament reconstruction grafts. Sectioning of the FCL, popliteus tendon, and PFL was found to significantly increase loads on ACL grafts at 0° and 30° of knee flexion under varus stresses (LaPrade et al. 1999). Furthermore, it has been reported that fixation of the ACL graft prior to the posterolateral corner structures in a combined reconstruction leads to a significant increase in external rotation of the tibia (Wentorf et al. 2002). Additionally, significant increases in the force on a PCL reconstruction graft with varus loads at all angles of knee flexion have also been reported with sectioning of the posterolateral structures (LaPrade et al. 2002). Thus, identification of concomitant posterolateral corner injuries is imperative with ACL or PCL reconstructions in order to avoid graft failure.

Fibular Collateral Ligament

The FCL (Fig. 1) is approximately 70 millimeters (mm) in length (LaPrade et al. 2003). The femoral attachment of the FCL is not located directly on the lateral epicondyle, as it is commonly depicted in anatomical textbooks. Rather, it is located in a sulcus 1.4 mm proximal and 3.1 mm posterior to the lateral epicondyle. The FCL courses distally to attach to the lateral aspect of the fibular head, 8.2 mm posterior to the anterior edge (LaPrade et al. 2003).

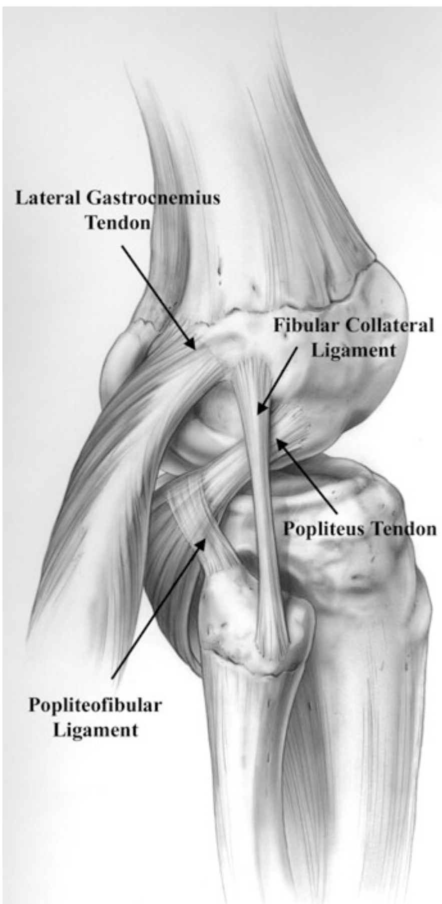

Fig. 1 Illustration of right knee demonstrating the anatomy of the fibular collateral ligament (*FCL*), popliteus tendon, and popliteofibular ligament (*PFL*) (Reprinted with permission from LaPrade et al. (2003))

Biomechanical studies of the posterolateral knee have reported that the FCL is the primary stabilizer to varus stresses (Gollehon et al. 1987; Grood et al., 1988; LaPrade et al. 2004b). While resisting varus angulation throughout the full range of motion of the knee, the FCL plays a more prominent role in extension. The PCL has been shown to provide a significant contribution to varus stability in the face of a combined grade III posterolateral knee injury (Grood et al. 1988; LaPrade et al. 2004b).

Popliteus Tendon

The popliteus tendon (Fig. 1), which arises from the popliteus muscle on the posterior aspect of the tibia, courses proximally around the posterolateral aspect of the knee joint, enters the joint capsule, and attaches to the anterior half of the proximal fifth of the popliteal sulcus intraarticularly (LaPrade et al. 2003). When measured from the musculotendinous junction, the average length of the popliteus tendon is 54.5 mm (LaPrade et al. 2003). The average distance between the femoral FCL and the popliteus tendon attachments has been reported to be 18.5 mm (Fig. 2; LaPrade et al. 2003). This distance is clinically important because it implies that reconstructions that use a single tunnel to combine the FCL and popliteus tendon attachments result in nonanatomic graft placement on the femur.

In addition to the FCL, the popliteus tendon also contributes to stability against external rotation. A reciprocal relationship has been demonstrated between the two structures, where the FCL resists a majority of external rotation loads with the knee in the extended position, while the popliteus tendon bears a larger portion of the load with the knee in the flexed position (Grood et al. 1988; LaPrade et al. 2004b). In conjunction with the posterior cruciate ligament, the popliteus tendon also

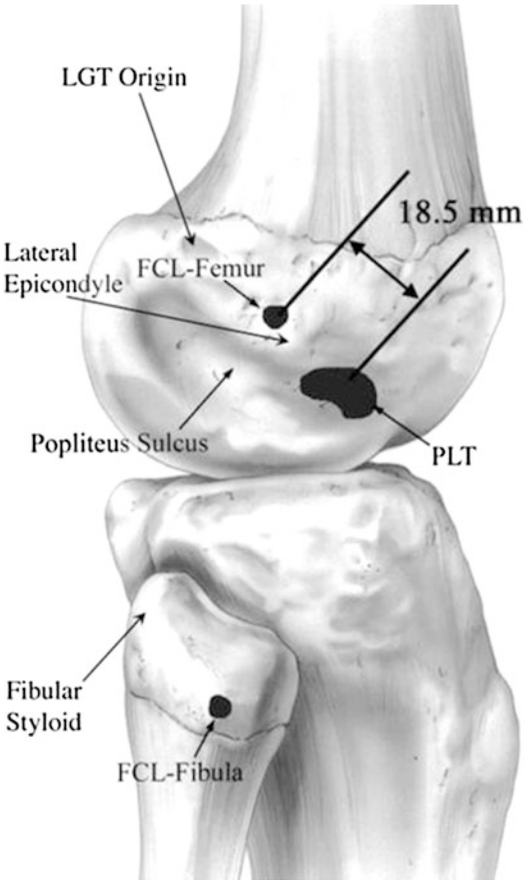

Fig. 2 Illustration of right knee demonstrating the average distance between the femoral attachment sites of the FCL and popliteus tendon. (*LGT* lateral gastrocnemius tendon) (Reprinted with permission from LaPrade et al. (2003))

contributes as a secondary stabilizer against posterior translation of the knee (Harner et al. 1998).

Popliteofibular Ligament

Termed the arcuate ligament in older literature, the PFL (Fig. 1) arises from the musculotendinous junction of the popliteus complex and courses disto-laterally to the fibular styloid. It has both an anterior and a posterior division, of which the posterior division is larger and stronger (LaPrade et al. 2003). The PFL has been reported to play an important secondary role in stabilization against varus and external rotation forces on the knee (Maynard et al. 1996; McCarthy et al. 2010).

Biceps Femoris

In addition to providing secondary and dynamic stabilization against varus forces to the knee, familiarity with the biceps femoris is important during surgical reconstruction of the posterolateral corner. The biceps femoris has two portions: the long and short heads. The long head of the biceps divides into a direct arm and an anterior arm approximately 1 centimeter (cm) proximal to its insertion on the fibular head (LaPrade et al. 2003). The direct arm attaches to the posterolateral aspect of the fibular head and provides a majority of the force transmission from the muscle body. The anterior arm passes superficial to the FCL to insert into a broad fascial aponeurosis on the anterolateral aspect of the proximal leg. As it passes the FCL, it forms an overlying bursa (biceps bursa) that serves as an important surgical landmark for identification of the distal portion of the FCL (LaPrade et al. 2003). Additionally, the common peroneal nerve can be easily identified with dissection just posterior to the posterior edge of the long head.

Iliotibial Band

The iliotibial band forms a broad fibrous layer on the lateral aspect of the thigh and knee as it travels from the tensor fascia lata muscle distally to attach to Gerdy's tubercle on the anterior aspect of the tibia. Because the iliotibial band has been reported to be injured in only 3 % of posterolateral knee injuries, it is an important surgical landmark for identification of both the FCL and popliteus tendon attachments on the femur (LaPrade and Terry 1997).

Clinical Evaluation

History

The clinical evaluation of the knee should begin with a thorough history including the mechanism, chronology, and nature of symptoms, presence of side-to-side instability, presence of catching or locking, previous knee injuries, and previous operations. When concern for a posterolateral corner injury exists, symptoms of paresthesias in the common peroneal nerve distribution or a foot drop should be assessed because common peroneal nerve injuries of some sort have been reported in up to one third of posterolateral corner injuries (LaPrade and Terry 1997). Standard assessment of pertinent past medical history, medications, allergies, tobacco use, and particularly goals of returning to sports activities should be included as well.

Physical Examination

While a complete knee physical examination needs to be performed, since 72 % of posterolateral knee injuries are associated with a concomitant ACL or PCL rupture (Geeslin and LaPrade 2011), physical examination maneuvers to assess for the posterolateral injuries include the external rotation recurvatum test, the varus stress test at both 0° and 30° of knee flexion, the dial test at both 30° and 90° of knee flexion, the posterolateral drawer test, and the reverse pivot shift test. Additionally, gait should be assessed to detect the presence of a varus thrust gait, particularly in patients with chronic posterolateral corner injuries. While originally reported to be pathognomonic for a posterolateral knee injury (Hughston and Norwood 1980), the external rotation recurvatum test was found to be positive in only 10 % of patients with an isolated posterolateral corner injury in a prospective study of 134 patients (LaPrade et al. 2008b). However, the test was found to be positive in all patients with a combined ACL and posterolateral corner injury (LaPrade et al. 2008b). Likewise, a positive dial test at both 30° and 90° of knee flexion indicates a probable combined PCL and posterolateral corner injury. Caution must be exercised, however, because chronic medial knee instability may result in a falsely positive dial test. In addition to the specific physical examination techniques used to examine for a posterolateral knee injury, it is important to recognize that these injuries most commonly occur in the presence of a concurrent cruciate ligament injury. In these circumstances, the posterolateral structures serve an important role to preventing additional increases in both anterior and posterior tibial translation. Thus, in the presence of excessive anterior laxity with an ACL tear or posterior laxity with a PCL tear, one must always be aware of the possibility of concurrent posterolateral knee injury.

Imaging

Imaging should include plain anterior-posterior and lateral radiographs to assess for the presence of bony Segond and arcuate avulsion fractures. Long leg alignment radiographs, especially important in patients with chronic posterolateral injuries, are recommended to assess for the presence of genu varus alignment and the need for corrective osteotomy. Varus stress radiographs serve as an important tool for the evaluation of posterolateral knee injuries. In all patients, bilateral varus stress radiographs should be obtained to objectively assess for the amount of lateral compartment gapping on the injured knee. It has been reported that increases of lateral compartment gapping of 2.7 mm are consistent with an FCL tear, while greater than 4.0 mm is consistent with a complete grade III posterolateral knee injury (LaPrade et al. 2008a). Additionally, high-resolution magnetic resonance imaging may be used in the identification of posterolateral knee injuries (LaPrade et al. 2000). The presence of an anteromedial bone bruise or a medial tibial plateau fracture has been reported to be concerning for a posterolateral knee injury (Geeslin and LaPrade 2011).

Treatment

While grade I and II posterolateral corner injuries can be treated nonoperatively in a hinged knee brace locked in extension for 3–6 weeks, surgical reconstruction is recommended for grade III injuries due to the significant risk for continued symptomatic instability (LaPrade and Terry 1997; LaPrade and Wentorf 2002). When concurrent

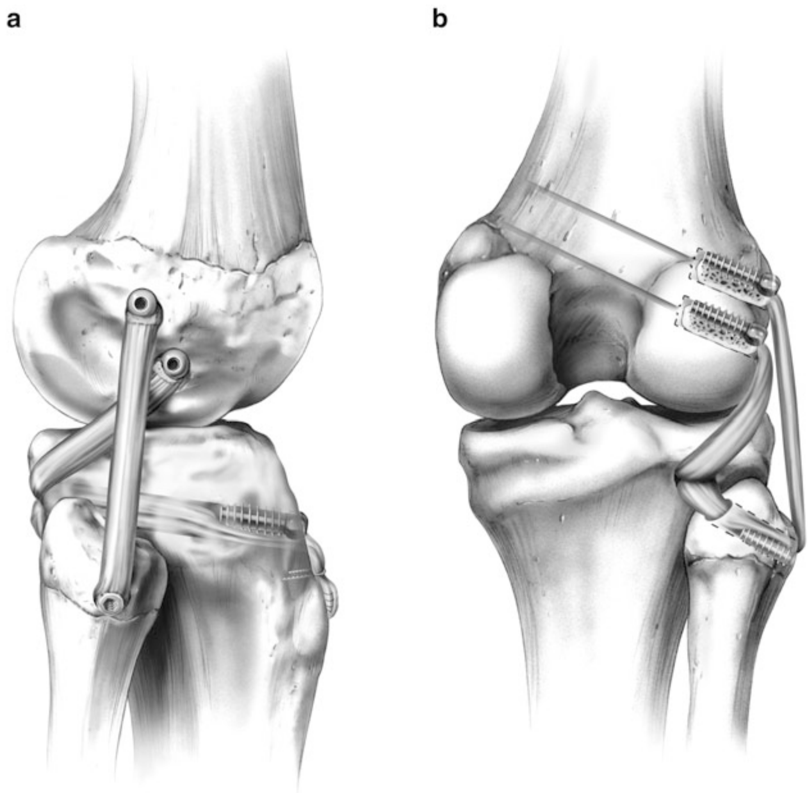

Fig. 3 Illustrations of lateral (**a**) and posterior (**b**) views of right knee anatomical posterolateral corner reconstruction (LaPrade et al. (2004a))

cruciate ligament rupture exists, combined repair is recommended to avoid the high risk of cruciate ligament graft failure with continuous posterolateral corner instability (LaPrade et al. 2002). While numerous reconstruction techniques for the posterolateral corner have been created, this section will focus on the author's preferred technique for anatomical posterolateral corner reconstruction (Fig. 3).

Surgical Approach

The patient is positioned supine on the operating table, and examination under anesthesia is performed to confirm suspected pathology. When concomitant intraarticular pathology exists, arthroscopy is delayed until after open dissection of the posterolateral corner to avoid anatomical distortion from fluid extravasation. The surgical approach begins with a hockey stick-shaped incision (Fig. 4) centered over the posterior aspect of the iliotibial band and coursed distally, slightly posterior to Gerdy's tubercle (Terry and LaPrade 1996). The dissection is carried down to the superficial layer of the iliotibial band and to the long and short heads of the biceps femoris. The common peroneal nerve is identified at the posterolateral edge of the long head of the biceps femoris, and neurolysis is performed. This starts approximately 6–8 cm proximal to the fibular head and extends distally to include release of the peroneus longus fascia distal to the fibular head. The nerve is retracted during the procedure to allow access to the interval between the lateral gastrocnemius tendon and the soleus muscle (LaPrade et al. 2004a).

Next, the distal aspect of the FCL is identified with a 2–3 cm horizontal incision through the biceps bursa, and a tag stitch is placed into the remnant ligament. Then, the anterior aspect of the long head of the biceps is dissected off the fibular head to isolate and identify the fibular collateral ligament attachment site on the lateral aspect of the fibular head. The proximal and distal

Fig. 4 Photo of lateral hockey stick incision used to approach posterolateral aspect of knee

Fig. 5 Right knee photograph of guide pin placement for fibular tunnel starting at FCL attachment site on lateral fibula directed toward PFL attachment on posteromedial fibular styloid

attachments of the PFL – the musculotendinous junction of the popliteus muscle and the posteromedial aspect of the fibular styloid, respectively – are found with blunt dissection in the interval between the lateral gastrocnemius tendon and soleus muscle (LaPrade et al. 2004a).

The tibial and fibular bony reconstruction tunnels are reamed through the midpoints of the ligament attachment sites. A guide pin is drilled from the distal FCL attachment site on the lateral aspect of the fibular head toward the distal PFL attachment on the posteromedial aspect of the fibular styloid (Fig. 5). While protecting the tip of the guide pin with a large Chandler retractor, a 6 or 7 mm diameter acorn reamer is reamed over this guide pin to create the fibular head reconstruction tunnel. The tibial reconstruction tunnel is prepared by drilling a guide pin from anterior to posterior, starting at the flat spot just distal and medial to Gerdy's tubercle and through to the popliteal sulcus on the posterolateral tibia, which demarcates the musculotendinous junction of the popliteus (LaPrade et al. 2004a). Again, using a large Chandler for protection, the tunnel is reamed with a 9 mm acorn reamer over the guide pin (Fig. 6). A passing suture is placed through the tunnel from anterior to posterior to facilitate graft passage later in the case.

Next, attention is turned to the femoral attachments of the fibular collateral ligament and popliteus tendon. The traction stitch within the fibular collateral ligament remnant is used to help identify its femoral attachment. An iliotibial band splitting incision is then performed for approximately 8–10 cm in length (Fig. 7). The attachment site of the fibular collateral ligament, slightly proximal and posterior to the lateral epicondyle, is then identified (Fig. 2). A guide pin is then drilled through this attachment site (Fig. 8). It is important to aim this eyelet pin so that it exits the anteromedial thigh anterior and proximal to the adductor tubercle (LaPrade et al. 2004a).

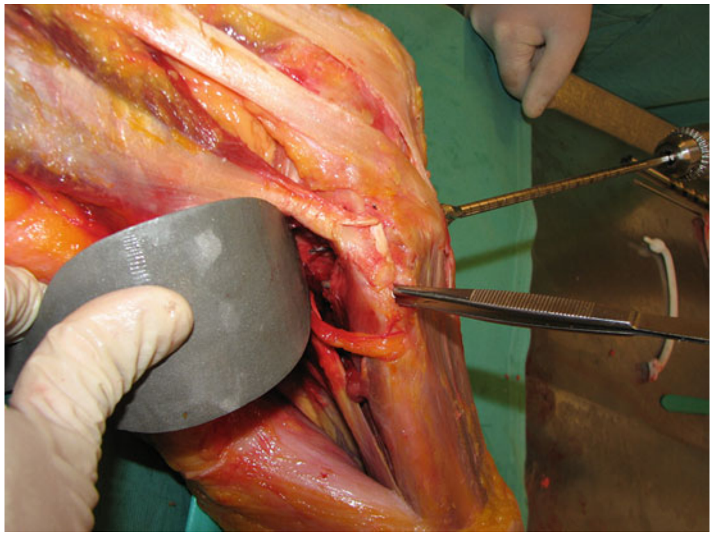

Fig. 6 Right knee photograph of anatomical specimen demonstrating reaming of tibial tunnel. Relationship of fibular tunnel (forceps) and tibial tunnel placement is shown posteriorly. A large Chandler retractor is protecting the common peroneal nerve

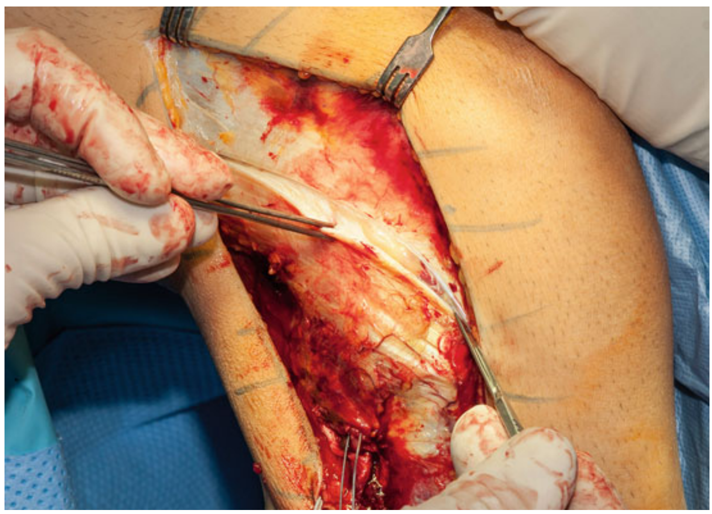

Fig. 7 Photo showing size and directionality of iliotibial band incision used to visualize the femoral attachments of posterolateral structures

This allows for placement of the tunnel such that it does not interfere or converge with any concurrent ACL graft reconstruction tunnels. Once the fibular collateral ligament pin is placed, the attachment site of the popliteus tendon is identified at the top fifth of the popliteal sulcus (Fig. 2). A small vertical incision is made through the joint capsule over the popliteal sulcus, which can usually be identified by palpation at this point in time. This popliteus guide pin should be drilled parallel to the FCL tunnel.

Once both pins are in place and prior to reaming, correct placement should be validated by measuring between the two attachment sites, for which the average distance is 18.5 mm (Fig. 2; LaPrade et al. 2003). After determined to be correctly placed, a 9 mm diameter acorn reamer is used to create closed socket tunnels to a depth of 20–25 mm. Individual passing sutures are then placed into the tunnels to facilitate graft passage later.

Reconstruction Graft Preparation

An Achilles tendon allograft is used with a minimum graft length of at least 23 cm to allow for

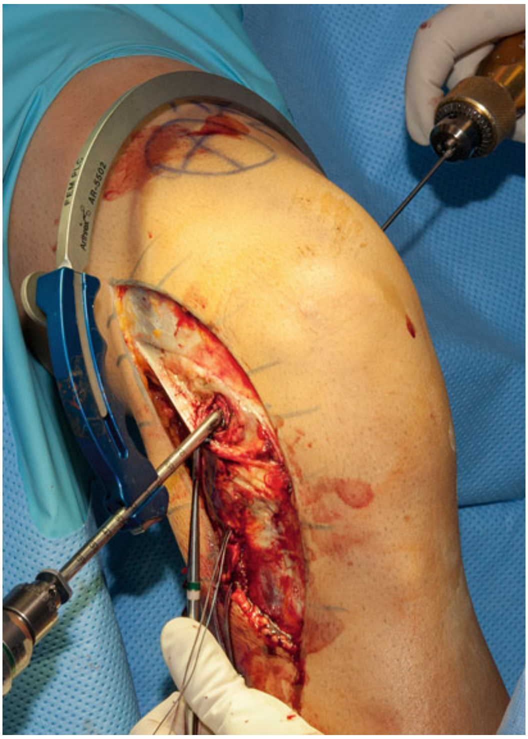

Fig. 8 Photo showing entrance and exit of guide pin for FCL femoral tunnel

adequate length of the reconstruction grafts. The calcaneal bone plug is split lengthwise to create two separate 9 mm diameter and 20 mm long bone plugs. The distal aspects of the grafts are then tubularized with nonabsorbable sutures so that they can fit through the reconstruction tunnels. It is important to ensure that the FCL/PFL graft is tubularized sufficiently enough so that it will fit through the fibular tunnel without bunching up.

Concurrent Intraarticular Procedures

At this point, any intra-articular arthroscopic work can be performed. Meniscal tears are repaired if possible. Cruciate ligament reconstruction tunnels are reamed and the cruciate reconstruction grafts are passed into their femoral tunnels and fixed with interference screws, but without fixation in the tibial tunnels.

Passing and Fixation of Reconstruction Grafts

The previously placed passing sutures are utilized to facilitate passage of the bone plugs into their femoral tunnels. The grafts are then secured in place with nonabsorbable interference screws. The grafts should be manually stressed laterally to ensure secure fixation. In addition, one should palpate over the screws to ensure that they are adequately positioned within the tunnel because proud screws can lead to iliotibial band irritation postoperatively.

The popliteus tendon graft is first passed down the popliteal hiatus along its anatomical path and then pulled out laterally between the lateral gastrocnemius tendon and soleus muscles, awaiting placement in the tibial tunnel until later in the procedure (LaPrade et al. 2004a). The fibular collateral ligament graft is then passed along its anatomical path deep to the superficial layer of the iliotibial band and the lateral aponeurosis of the long head of the biceps femoris. The graft is then placed into the previous reamed fibular head tunnel.

At this point in time, the fixation order of the reconstruction grafts is important to follow correctly. For a concurrent PCL reconstruction, the PCL graft should be fixed prior to fixation of the posterolateral reconstruction grafts. However, for a concurrent ACL reconstruction, fixation of the ACL graft should occur following fixation of the posterolateral grafts to avoid an external rotation deformity of the tibia (Wentorf et al. 2002).

For fixation of the posterolateral grafts, first traction is applied to the FCL graft, the knee is flexed to 20° with a slight valgus reduction force, the foot is held in neutral rotation, and the graft is secured with a bioabsorbable screw. Once this graft has been secured, an exam under anesthesia should verify that all varus instability has been eliminated prior to moving on to further graft fixation. Then, both the popliteus tendon graft and the remainder of the FCL graft are passed anteriorly through the tibial tunnel, thus recreating the PFL with the remainder of the FCL graft (Fig. 3). Tension is applied to each graft, the knee is held at 60° of flexion, the foot is held in neutral rotation, and the grafts are fixed with a

9 mm bioabsorbable screw into the anterior aspect of the tibial tunnel. Subsequently, it is important to validate that posterolateral drawer instability has been completely eliminated. Backup fixation of the grafts in the tibia with a staple may be utilized for patients with osteopenic bone.

A standard layered closure with a subcuticular stitch for the skin is performed with loosely applied Steri-Strips to assist with skin approximation. Then, a standard long leg knee immobilizer is placed, and the patient may be transferred to the recovery room.

Postoperative Rehabilitation

Postoperative rehabilitation is a crucial component in the treatment of posterolateral corner injuries (Lunden et al. 2010). A key principle in the rehabilitation of anatomical posterolateral corner reconstruction is that the reconstruction should not have any significant stress placed on it. For isolated posterolateral corner reconstructions, patients are kept non-weight-bearing in a knee immobilizer for the first 6 weeks. Physical therapy is initiated on postoperative day one with focus on quadriceps strengthening, edema control, and range of motion exercises, with the goal of a minimum of 0–90° of knee flexion within the first few days postoperatively. Patients are instructed to avoid isolated hamstring exercises for the first 4 months postoperatively as well as tibial external rotation to avoid placing extra stress on the reconstruction grafts (Lunden et al. 2010).

Further progression of the rehabilitation program involves initiation of weight-bearing at 6 weeks postoperatively, slowly weaning off crutches once the patient can ambulate without a limp, and the use of a stationary bike with no resistance. Leg presses may also be initiated at this point in time at one-quarter body weight with a maximum of 70° of knee flexion. Side-to-side and Bosu-ball or other types of balance exercises are avoided until 4–5 months postoperatively when varus stress radiographs have verified that there is sufficient healing of the posterolateral corner reconstruction grafts to initiate this program. Patients will then progress to agility and running exercises and will be allowed back to competition upon demonstration of sufficient agility, endurance, and strength at approximately 7–9 months postoperatively.

In the setting of concurrent PCL reconstruction, a more specific PCL protocol is utilized. Prone knee flexion exercises are initiated on postoperative day one. Progression to higher-level activities is delayed until between 9 and 12 months postoperatively, pending sufficient healing of the PCL reconstruction and demonstration of sufficient stability on PCL and varus stress radiographs at 6 months postoperatively.

Considerations for Acute Versus Chronic Injuries

There are important distinctions between the treatments for acute versus chronic posterolateral corner injuries. Outcomes for the treatment of chronic posterolateral knee injuries are inferior to those treated acutely. Thus, diagnosis and treatment of these pathologies early after the injury are optimal. In the setting of acute posterolateral corner injury, often defined as surgery within 3–6 weeks, treatment may be limited to specifically address the injured structures, as opposed to the entire anatomical reconstruction as described above. Furthermore, structures may be amenable to repair rather than reconstruction when there is soft tissue or bony avulsion, and the tissue quality remains adequate. Significant tissue retraction, midsubstance tears, or poor tissue quality are indications for reconstruction. For isolated FCL or popliteus tendon ruptures not amenable to repair, individual anatomical reconstructions have been described using an autogenous hamstring graft (Coobs et al. 2007; LaPrade et al. 2010). However, when both tendons are ruptured, a complete anatomical posterolateral corner reconstruction is recommended. Avulsions of the PFL may be treated with direct repair if the popliteus tendon remains intact and the soft tissues are not excessively damaged.

In patients with chronic posterolateral corner injuries, it is well recognized that genu varus malalignment substantially increases the risk for reconstruction failure if the alignment is not corrected preoperatively or concurrently (Arthur et al. 2007). Thus, in the evaluation of all patients with chronic posterolateral corner injuries, long leg standing films are necessary to evaluate alignment. If present, genu varus malalignment should be corrected with a proximal tibial opening wedge osteotomy. Interestingly, it has been reported that some patients experience resolution of their posterolateral instability following the corrective osteotomy, negating the need for second-stage or concomitant posterolateral corner reconstruction (Arthur et al. 2007).

Conclusions

Injuries to the posterolateral corner of the knee present unique challenges to the orthopedic surgeon. In recent years, improved biomechanical-based research has led to an evolution in surgical techniques from nonanatomic sling procedures to anatomically based and biomechanically validated reconstructions. Biomechanical studies demonstrate that the most important posterolateral stabilizing structures are the fibular (lateral) collateral ligament, the popliteus tendon, and the popliteofibular ligament. Physical examination to assess for the posterolateral corner injury should include the external rotation recurvatum test, varus stress at both 0° and 30°, the dial test at both 30° and 90°, the posterolateral drawer test, and the reverse pivot shift test. Posterolateral corner reconstructions in the acute setting may repair or reconstruct injured structures individually. However, in the setting of severe acute or chronic injuries, anatomical posterolateral corner reconstruction should be performed. In chronic injuries, it is imperative to assess for the presence of genu varus malalignment preoperatively due to the increased risk of reconstruction failure.

Cross-References

▶ Anatomy and Biomechanics of the Knee
▶ Combined Anterior and Posterior Cruciate Ligament Injuries
▶ Current Concepts in the Treatment of Posterior Cruciate Ligament Injuries
▶ Rehabilitation of Complex Knee Injuries and Key Points
▶ Role of Osteotomy for Knee Cartilage, Meniscus, and Ligament Injuries

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