53 Knee Ligament Injuries

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Overview
This chapter provides an overview of knee ligament injuries, an understanding of which is crucial for proper evaluation and treatment of both the general public and athletic population.

53.1 Isolated Ligament Injury

53.1.1 Anterior Cruciate Ligament

53.1.1.1 Anatomy

The anterior cruciate ligament (ACL) consists of two bundles, anteromedial (AM) and posterolateral (PL), which originate on the medial surface of the lateral femoral condyle (LFC) and insert on the tibia immediately posterior to the ACL tubercle and ridge. There is significant overlap of the ACL and the anterolateral meniscal root (Fig. 53.1). More specifically, the AM bundle attaches just proximal to the bifurcate ridge and posterior to the lateral intercondylar ridge (LIR), both of which are useful arthroscopic landmarks on the femur. The tibial attachment of the AM bundle constitutes the entire anterior boundary of the ACL, inserting between the retro-eminence and ACL ridge. The PL bundle originates distally beyond the bifurcate ridge and posterior to the LIR of the femur and inserts medial to the anterior and posterior horns of the lateral meniscus.

53.1.1.2 Function and Injury

The ACL prevents anterior translation and internal rotation of the tibia. Noncontact mechanisms of injury (MOI) are most common (70%) and include pivoting with the foot planted or landing from a jump with the knee in an extended position. Intrinsic risk factors for ACL tears include femoral intercondylar notch stenosis, large lateral tibial slope, and large beta angle (angle between the long axis of the femur and Blumensaat line). Poor lower extremity biomechanics also increase the risk of ACL tear, highlighting the importance of quality prophylactic and perioperative ROM and strengthening exercises. The Lachman test assesses the integrity of the ACL (Fig. 53.2).

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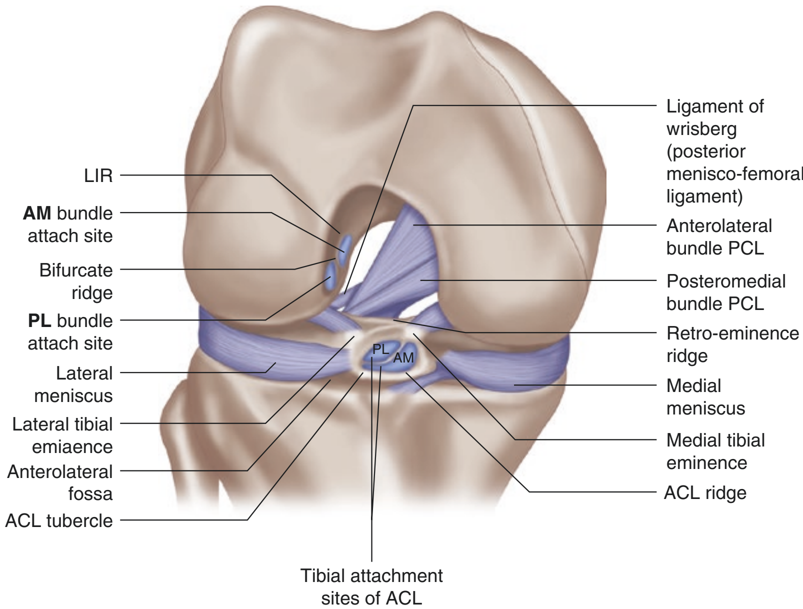

Fig. 53.1 AM and PL bundle attachment of the ACL. *AM* anteromedial, *PL* posterolateral, *ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament, *LIR* lateral intercondylar ridge

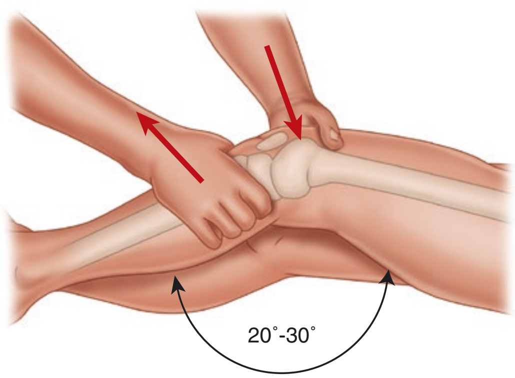

Fig. 53.2 Lachman test for ACL

53.1.1.3 Treatment

Returning to cutting and pivoting sports with a partial ACL tear coincides with a significantly increased risk of a subsequent complete ACL tear. Complete ACL tears warrant a discussion regarding operative treatment, which improves symptomatology and quality of life for those who aim to return to jumping, pivoting, and cutting activities. A delay in surgery can lead to increased cartilage and meniscus damage, resulting in an increased risk of post-traumatic osteoarthritis.

Nonoperative treatment for isolated ACL tear is an option for those planning to return exclusively to straight plane activities; however, current research is lacking in long-term clinical outcomes, and where concurrent meniscus and collateral ligament injuries are involved. There has been increased interest in ACL repairs due to quicker return to previous activity level; however, there is a paucity of reliable data as to its effectiveness.

Bone-patellar tendon-bone (BTB) autograft is the gold standard ACL graft option. Harvesting a portion of patellar tendon can result in increased anterior knee pain, although patients with BTB autografts have significantly improved pivot shift outcomes and increased rates of return to preinjury level. Another option is the hamstring tendon (HT) autograft, which is reserved for carefully selected patients. The quadriceps tendon (QT) autograft is a third option as it supplies ample viable tissue. Soft-tissue allografts are not desired due to high graft failure rates in young and active populations.

Five-year ACL reconstruction (ACLR) survival rates are above 95 percent. ACLR significantly improves the Knee injury and Osteoarthritis Outcome Score (KOOS), with smokers reporting significantly inferior KOOS than nonsmokers. Although ACL grafts have high survival rates, grafts may fail and need to be revised. The following factors are associated with increased revision rates: HT autografts, younger age at surgery, and use of allografts in patients younger than 25 years of age.

53.1.2 Pediatric ACL Injury

53.1.2.1 Diagnosis

Three basics of pediatric ACL assessment include evaluation of hemarthrosis, comparison to the contralateral knee due to increased joint laxity in children, and recognition of pediatric-specific injuries. Plain radiographs are a good starting point, followed by confirmation with magnetic resonance imaging (MRI).

53.1.2.2 Management

Consistent and frequent preventative exercises are important and simple to integrate into training. Proper body position of fundamental movements, such as cutting and landing techniques, is paramount for avoiding ACL injury. A presurgical rehabilitation phase with bracing is acceptable and should be aimed at improving ROM, strength, and inflammation.

Bracing may continue for a short time postoperatively, as gaining early postoperative neuromuscular control of the lower extremity is important. Postponing surgical treatment of pediatric ACL tears can result in an increased risk of meniscus and cartilage damage and is not generally recommended. Indications for surgery include the presence of concomitant knee injury, recurrent instability episodes, and an unacceptable modified activity level. It is important to consider open physes when planning the surgical approach. Autografts are preferable to allografts for pediatric ACLRs due to poor allograft outcomes. Grafts with a diameter of 7 mm or smaller are at greater risk for graft rupture, and HT autografts fail at a significantly greater rate than BTB autografts. Regardless, HT autografts remain the most commonly used graft in pediatric ACLR, since harvesting BTB autografts may disrupt open tibial tubercle growth plates and bone plugs cannot cross open growth plates.

53.1.3 Posterior Cruciate Ligament

53.1.3.1 Anatomy

The posterior cruciate ligament (PCL) consists of two bundles, the anterolateral bundle (ALB) and posteromedial bundle (PMB). The ALB is tightest at 90 degrees of knee flexion, attaching to the femur between the trochlear point, medial arch point, and medial bifurcate prominence. The PMB is most tense at end-range knee flexion and extension and originates on the femur distal to the medial intercondylar ridge and posterior to the femoral attachment of the ALB. The ALB inserts on the tibia below the articular surface, between the posterior portions of the medial and lateral tibial plateaus and anterior to the PMB insertion. Arthroscopically, the distal border of the PMB is marked by the champagne-glass drop-off, where the joint capsule separates the popliteus muscle and intra-articular structures.

53.1.3.2 Function and Injury

As the largest and strongest ligament of the knee, the PCL functions as the primary posterior stabilizer and restricts internal rotation of the tibia. Common mechanisms of injury include motor vehicle accidents, landing directly on the flexed knee, hyperflexion, and dislocations of the tibiofemoral joint. The PCL is commonly injured concomitant to the medial collateral ligament (MCL), ACL, or posterolateral corner. While MRI has high diagnostic accuracy for a suspected acute PCL injury, posterior stress radiographs are fundamental for objective evaluation of PCL tears. Complete PCL tears usually have 8 mm or more of increased posterior tibial translation compared to the normal contralateral knee. Posterior stress radiographs involve kneeling on a horizontal support, leaving the femoral condyles and patella unsupported, and prove to be a reliable and reproducible test.

53.1.3.3 Treatment

Grade I and II PCL injuries can be treated nonoperatively with dynamic force bracing, which alters the applied force based on the knee angle in attempts to match anatomic forces. Grade III PCL tears, a rupture of both bundles, require surgical reconstruction. The goal of the single-bundle PCL reconstruction (SB PCLR) is to reconstruct the ALB fibers. The double-bundle PCLR (DB PCLR) is superior to SB PCLR, resulting in improved objective stability with the goal of restoring the native ligament function.

Outcomes for the DB PCLR technique are comparable to ACLR outcomes. The anatomic double-bundle technique results in significant subjective and objective improvement compared to the preoperative state. Compared to chronic DB PCLRs, acute DB PCLRs result in significantly improved activity and satisfaction scores.

53.2 Multiligament Injury

53.2.1 Knee Dislocations

Some define knee dislocations (KDs) as tearing of both the ACL and PCL, with or without involvement of posteromedial and posterolateral corner structures. Knee dislocations are ranked by the Schenck classification system:

- KD I: Injury to a single cruciate ligament plus collaterals
- KD II: Injury to ACL, PCL, intact collaterals
- KD III M: Injury to ACL, PCL, and MCL
- KD III L: Injury to ACL, PCL, and fibular collateral ligament (FCL)
- KD IV: Injury to ACL, PCL, MCL, and FCL
- KD V: Dislocation plus fracture

Common mechanisms of injury include skiing, motor vehicle accidents, falls from significant heights, and other recreational activities. Meniscus and cartilage injuries are associated with knee dislocations. The risk of cartilage injury increases significantly with meniscus injury and chronic dislocations. The common peroneal nerve and popliteal artery may also be compromised with these injuries.

Limb vascular status should be assessed immediately. If compromised, emergent treatment involves reduction and splinting. Emergent surgery is performed in cases of open injury, vascular compromise, irreducible dislocation, or compartment syndrome.

Knee joint reconstruction/repair is initiated once vascular status has been found to be normal or improved. The optimal surgical treatment window is far enough from the date of injury to allow for decreased inflammation, partial ROM recovery, continued vascular monitoring, and improvement of quadriceps muscle tone (ideally <14 days). Acute treatment is common and results in improved subjective and objective outcomes. Delaying such a procedure greater than 3 weeks may result in increased scarring.

The goal of a multiple-ligament knee surgery is to fix all pathology within a single surgery, allowing for 9–12 months of postoperative rehabilitation before resuming full activity. Long-term outcomes of knee dislocation include significantly increased risk of osteoarthritis, especially for patients who were of increased age at the time of injury. Concurrent cartilage injury results in significantly worse function and symptomatology.

53.2.2 ACL- and PCL-Based Multiligament Reconstruction

These reconstructions treat injuries resulting from grade III tears of at least two out of four major knee ligaments without a knee dislocation (ACL, PCL, FCL, superficial MCL (sMCL), or a complete posterolateral knee injury). Single-stage reconstruction of all injured knee ligaments paired with immediate postoperative rehabilitation significantly improves outcomes and function, achieving low complication rates. Early postoperative rehabilitation improves knee ROM without stretching the fresh grafts.

53.2.3 Posterolateral Corner

53.2.3.1 Anatomy

The posterolateral corner (PLC) of the knee consists of three primary static structures: the FCL, popliteus tendon, and popliteofibular ligament (PFL). The FCL originates on the femur, proximal and posterior to the lateral epicondyle, and inserts on the fibular head, posterior to the anterior margin and distal to the fibular styloid process apex (Fig. 53.3). The popliteus tendon courses laterally from the popliteus muscle and inserts on the lateral femur anterior to the FCL attachment. The PFL originates from the myotendinous junction of the popliteus and runs distolaterally splitting into anterior and posterior divisions, which insert on the anteromedial and posteromedial downslope of the fibular styloid process, respectively.

53.2.3.2 Function and Injury

The FCL, popliteus tendon, and PFL work together to resist varus stress, external rotation, and posterolateral translational joint movement. The FCL is the primary stabilizer against varus forces at low degrees of knee flexion, and the popliteus tendon and PFL are responsible for stabilizing the knee at higher degrees of flexion. Most commonly, PLC injuries are combined with ACL and/or PCL injuries, resulting from a direct blow to the anteromedial knee causing varus stress or hyperextension.

Varus stress radiographs play an essential role in the vital recognition of PLC injuries. This method of evaluation measures gapping between the distal-most portion of the LFC subchondral surface and the lateral tibial plateau. Varus stress radiographs are repeatable and reproducible, and the extent of suspected injured tissue correlates with the amount of lateral joint gapping compared to the healthy knee. Suspected injured tissue and the corresponding increase in gapping compared to the intact state are as follows: isolated FCL tear (2.7 mm), grade III PLC injury (4.0 mm), combined PLC and ACL injury (6.6 mm), and combined PLC, ACL, and PCL injury (7.8 mm).

Bone bruising occurs frequently with PLC injury and is commonly found on the anteromedial femoral condyle and anteromedial tibial plateau. These patterns may fluctuate based on the

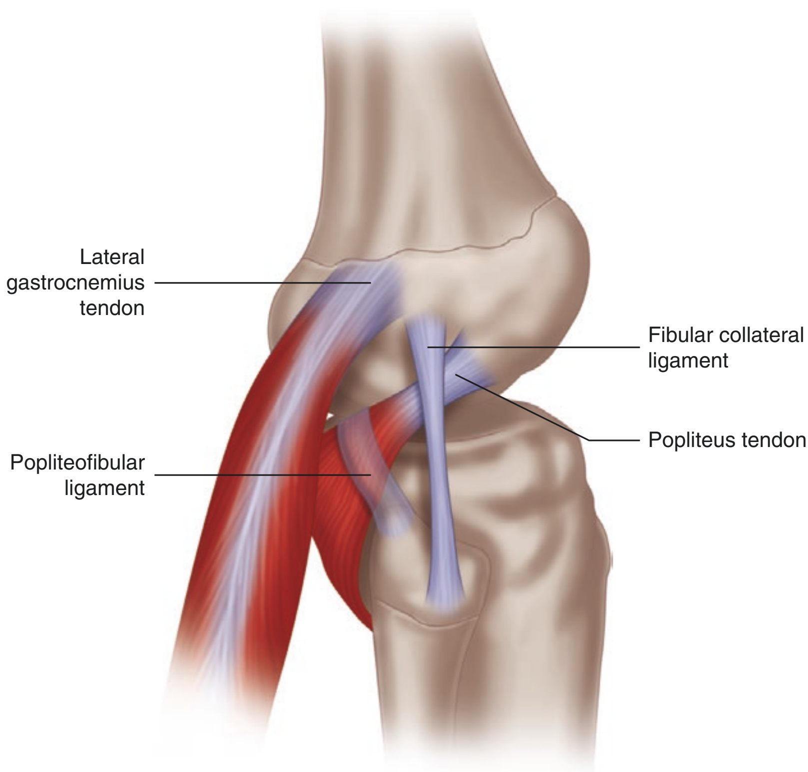

Fig. 53.3 Illustration of the posterolateral corner of the knee

structures injured. If the PLC injury is combined with an ACL tear, a bone bruise may present on the posteromedial tibial plateau.

53.2.3.3 Treatment

Grade III PLC injuries are treated operatively and acutely (<2 weeks) if possible. Lack of surgical correction results in poor biomechanics and outcomes. Structures should be assessed to determine if a repair or reconstruction is most appropriate. A combination of repair and reconstruction of posterolateral avulsed and midsubstance tears, respectively, results in significant objective improvement in stability.

For the first 2 weeks, rehabilitation is guided by a "safe zone" of ROM established intraoperatively (normally 0–90 °). A combination of repair and reconstruction paired with early protected range of motion improves objective outcomes of PLC treatment.

53.2.4 Posteromedial Corner

53.2.4.1 Anatomy

The three main static stabilizers of the medial knee are the sMCL, deep MCL (dMCL), and posterior oblique ligament (POL). The sMCL is the largest and primary medial stabilizing ligament. It attaches proximal and posterior to the medial femoral epicondyle and inserts on the tibia proximally on the anterior arm of the semimembranosus tendon and distally on bone along the floor of the pes anserine bursa. The dMCL is a thickening of the medial joint capsule and has meniscotibial and meniscofemoral components. The dMCL originates distal to the sMCL femoral attachment and inserts distal to the articular surface of the tibia. The POL is a thickening of the posteromedial joint capsule and consists of three arms: superficial, central, and capsular. The central arm is the primary POL structure and should be repaired or reconstructed with a posteromedial corner (PMC) injury.

53.2.4.2 Function and Injury

The sMCL is the primary stabilizer against valgus and external rotation forces, while the POL resists internal rotation near terminal extension. When the PMC is damaged, strain on the ACL and PCL increases due to anteromedial rotatory instability. Common mechanisms of injury include valgus stress of the knee and forced tibial external rotation. Complete medial knee injury is defined as combined sMCL, dMCL, and POL tears. Grade III PMC injuries commonly result in concomitant cruciate ligament injury. Injury to the medial knee structures may present with a lateral compartment bone bruise.

Valgus stress radiographs are a reproducible technique used to detect PMC injury. Increased medial joint gapping is present at 20 degrees of knee flexion with a complete MCL tear (an increase of 3.2 mm or more) and gaps to a greater degree with complete medial knee injuries (9.8 mm increase compared to the intact state) (Table 53.1).

Grading medial knee injuries has been historically based on the amount of subjective joint gapping with valgus force. However, transected structures and their corresponding instability warrant suspicion of medial knee injury at lower degrees of joint gapping, highlighting importance of objective stress radiographs and grading based on the number of structures torn.

Table 53.1 Quantified medial joint line gapping compared to the intact state at 20° knee flexion with clinician-applied valgus stress

Average medial gapping increase compared with intact state	
	Medial joint line gapping
Ligament state	Increase (mm)
Intact	–
Proximal sMCL tear	3.2
Complete medial knee tear	9.8
Complete medial knee and ACL tears	13.8
Complete medial knee, ACL, and PCL tears	20.4

Adapted from LaPrade RF, Bernhardson AS, Griffith CJ, Macalena JA, Wijdicks CA. Correlation of Valgus Stress Radiographs with Medial Knee Ligament Injuries: An in Vitro Biomechanical Study. *Am J Sports Med.* 2010;38(2):330-338

sMCL superficial medial collateral ligament, *PCL* posterior cruciate ligament, *ACL* anterior cruciate ligament

53.2.4.3 Treatment

Isolated PMC injuries are treated nonoperatively with 5–7 weeks of bracing and physical therapy. Surgical repair is indicated for grade III multiligament PMC injuries and sMCL injury with severe rotational instability or valgus gapping in knee extension. Reconstruction of the sMCL and POL is indicated in acute, midsubstance nonrepairable injury, and chronic injury with increased medial gapping, side-to-side instability, and external rotation on both the dial and anteromedial drawer tests. Valgus alignment should be evaluated and corrected in chronic PMC injuries to avoid PMC graft failure. Recreating the anatomic insertion points and the two sMCL functional arms involves use of two separate grafts for the sMCL and POL. Anatomic MCL reconstruction improves side-to-side instability, medial joint gapping, and rotatory instability. Arthrofibrosis and quadricep atrophy are prevented with immediate postoperative ROM guided by a "safe zone" established intraoperatively.

Take-Home Messages

- Reconstruction of the ACL is especially important for those planning to return to pivoting sports. Prevention exercises are important to implement early and often.
- PCL integrity can be reliably assessed with posterior stress radiographs, and DB PCLR successfully restores objective stability.
- It is important to address multiligament knee injuries with acute, single-stage procedures and early postoperative ROM.
- Varus stress radiographs are crucial for objective identification of PLC injuries. A combination of repair and reconstruction of PLC structures leads to improved objective outcomes.
- The PMC can be objectively evaluated with valgus stress radiographs. Surgical correction of high-grade multiligament PMC injuries results in improved objective outcomes.

Summary

Prompt and accurate identification of knee ligament injury is important for the long-term health and well-being of patients. Knowledge of ligament anatomy and function is necessary for proper treatment and rehabilitation.

Questions

Multiple correct answers are possible. Answers available in the book back matter.

1. Which factors put an adult at increased risk for an ACL tear?
   (a) Increased lateral tibial slope
   (b) Wide femoral intercondylar notch
   (c) Poor lower extremity biomechanics
   (d) A and C
   (e) All of the above
2. A patient presents to the clinic after slipping on a dock the past weekend. Patient states that she felt immediate pain on the medial side of her knee. She reports that her knee feels "unstable" and falls in toward her contralateral knee while weight-bearing. Upon examination, there is a contusion present with moderate edema and trace effusion. The patient is point tender to palpation over the proximal medial tibia, medial joint line, and just proximal to the medial femoral epicondyle. Initial set of radiographs are negative for fracture. What should be the clinician's next course of action?
   (a) Obtain a computed tomography (CT) scan
   (b) Obtain valgus stress radiographs
   (c) Obtain magnetic resonance imaging (MRI)
   (d) Put the patient in a long leg splint
3. Which ACL graft type is most commonly used for pediatric ACL reconstruction?
   (a) Soft-tissue allograft
   (b) Hamstring tendon autograft
   (c) Quadriceps tendon autograft
   (d) Patellar tendon autograft
4. In regard to ACL reconstruction, the soft-tissue allograft:
   (a) Is appropriate for use in ACL reconstruction for college-aged soccer players

(b) Is associated with increased postoperative anterior knee pain
(c) Is associated with high graft failure rate in the young and active population
(d) Is the most reliable, gold standard treatment for ACL reconstruction

5. Which of the following should be considered with a multiligament knee reconstruction?
   (a) Aim to repair and reconstruct all structures in a single-stage procedure
   (b) Early controlled postoperative range-of-motion exercises
   (c) Wait at least 4 weeks following the injury to operate to ensure that swelling has decreased
   (d) Both A and B
   (e) All of the above
6. In the posterolateral corner of the knee, which structure(s) is/are most restrictive against varus stress at near-terminal knee extension?
   (a) Popliteus tendon
   (b) Popliteofibular ligament (PFL)
   (c) Fibular collateral ligament (FCL)
   (d) All three (PFL, FCL, and popliteus tendon) provide the same amount of restriction to varus stress at this degree of knee extension
7. Which knee ligament(s) can withstand the greatest force?
   (a) Posterior cruciate ligament (PCL)
   (b) Anterior cruciate ligament (ACL)
   (c) Superficial medial collateral ligament (sMCL)
   (d) The posterolateral bundle of the ACL
   (e) A and B are equally strong

Further Reading

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