

Posterior cruciate ligament injury

Anatomy & Pathophysiology

BONY ANATOMY & LIGAMENT STRUCTURE

- The PCL is stronger than the ACL [6].
- The PCL has a broader femoral attachment than the ACL [6].
- The PCL is an intrasynovial but extraarticular structure [7].
- The PCL has an extrasynovial location, which provides better healing potential [6].
- The PCL is composed of two major parts: a large anterolateral bundle (ALB) and a smaller posteromedial bundle (PMB) [7].
- The ALB forms the bulk of the ligament [7].
- The PMB runs obliquely to the back of the tibia [7].
- The PCL cross-sectional area increases from tibia to femur [7].
- The PCL is approximately 50% larger than the ACL at the femur [7].
- The PCL is approximately 20% larger than the ACL at the tibia [7].
- The meniscomfemoral ligaments average approximately 22% of the entire cross-sectional area of the PCL [7].
- The PCL insertion sites are 300% to 500% larger than the cross section of the midsubstance [7].
- The femoral insertion of the PCL extends more than 20 mm from anterior to posterior [6].
- The ALB is more vertical than the PMB and inserts on the anterior roof of the intercondylar notch [6].
- The PMB is more oblique and inserts posteriorly on the lateral wall of the medial femoral condyle [6].
- The PCL and meniscomfemoral ligaments cover almost all of the medial aspect of the intercondylar notch anterior to the medial intercondylar ridge [6].
- The anterior margin of the PCL is 2 mm from the articular cartilage [6].
- The bundle centers of the PCL are an average of 12 mm apart on the femur [6].
- The tibial insertion of the PCL is narrower than the femoral insertion [6].
- The tibial insertion is located in the posterior intercondylar fossa of the proximal tibia [6].

- The PCL tibial footprint extends from the medial meniscus root and the edge of the lateral plateau articular cartilage to a point 1 to 1.5 cm below the joint line [6].
- The most posterior distal fibers of the PCL consist of the thicker PMB [6].
- The PMB blends with the periosteum and posterior capsule to insert distal to the osseous ridge cradling the anterior proximal fibers of the ALB [6].
- The centers of the PCL bundles on the tibia are an average of 9 mm apart [6].
- The tibial attachment is in a depression 1.0 to 1.5 cm behind and below the intraarticular portion of the tibia [7].
- The tibial attachment slips usually blend with the posterior horn of the lateral meniscus, the meniscomfemoral ligaments of Humphrey and Wrisberg [7].
- The center of the femoral insertion of the ALB is 7.4 mm from the trochlear point [7].
- The center of the femoral insertion of the ALB is 11.0 mm from the medial arch point [7].
- The center of the femoral insertion of the ALB is 7.9 mm from the distal articular cartilage [7].
- The center of the tibial attachment site is 6.1 mm from the shiny white fibers of the posterior medial meniscus root [7].
- The center of the tibial attachment site is 4.9 mm from the bundle ridge [7].
- The center of the tibial attachment site is 10.7 mm from the “champagne glass” drop-off [7].
- The bundle ridge is horizontal and separates the ALB from the PMB [7].
- The ALB is bordered medially and posteriorly by the PMB [7].
- At its femoral insertion, the PMB is bordered by the medial intercondylar ridge proximally, the ALB anteriorly, and the anterior meniscomfemoral ligament distally [7].
- The center of the PMB femoral attachment is 11.1 mm from the medial arch point [7].
- The center of the PMB femoral attachment is 10.8 mm from the posterior point of the articular cartilage margin [7].
- The tibial attachment of the PMB is more compact than the ALB [7].
- The PMB fans out in its attachment border along the posteromedial aspect of the ALB [7].
- The thickest portion of the PMB, including the functional center of the bundle, is located posteromedial to the ALB [7].
- The functional center of the PMB is 3.1 mm lateral from the medial groove of the medial tibial plateau articular surface [7].
- The functional center of the PMB is 4.4 mm anterior to the champagne glass drop-off [7].
- The PCL originates on the posteromedial aspect of the intercondylar notch and inserts into the posterior sulcus of the tibia between the medial and lateral joint surfaces [9].

BIOMECHANICS & FUNCTION

- The primary function of the PCL is to resist posterior displacement of the tibia in all knee flexion angles [6].
- The PCL is a secondary varus, valgus, and rotational stabilizer [6].
- The PCL facilitates internal rotation of the tibia at higher flexion angles [6].
- The ALB carries more load in flexion [6].
- The PMB carries more load in extension [6].
- The anterolateral fibers are taut in flexion [9].
- The posteromedial fibers are taut in extension [9].
- With flexion, there is tightening of the bulk of the ligament (ALB) but less tension on the small band (PMB) [7].
- The PCL is associated with the meniscomfemoral ligaments of Humphrey (anterior) and Wrisberg (posterior) [6].
- The PCL is the primary restraint to posterior tibial translation in the intact knee [1].

MECHANISM OF INJURY

- A direct blow to the proximal aspect of the tibia is the most common cause of PCL injury [1].
- In athletes, the mechanism of injury is usually a fall onto the flexed knee with the foot plantarflexed [1].
- This athletic mechanism places a posterior force on the tibia and subsequently causes rupture of the PCL [1].
- In high-energy trauma such as motor vehicle accidents, the PCL is often injured with other capsuloligamentous structures [1].
- The most common mechanisms of injury are a direct blow to the anterior tibia with the knee flexed or a fall into the ground with the foot plantar flexed [3].
- The “dashboard” injury involves the anterior tibia sustaining a posteriorly directed force from the dashboard with the knee in 90 degrees of flexion [3].
- Sports injuries to the PCL result from an outside force or blow, in contrast to the typical deceleration twisting mechanism of ACL injuries [3].
- The most common mechanism for isolated PCL injury in the athlete is a partial tear associated with hyperflexion of the knee [3].
- Significant multiligamentous knee injuries with PCL tears can occur after a varus or valgus stress is applied to the hyperextended knee [3].
- PCL injury usually occurs from a motor vehicle accident (dashboard injury) or during athletic activities [9].
- In athletic injuries, the typical mechanism is a fall onto a flexed knee while the foot is in a plantar flexed position [9].
- A direct blow to the anterior aspect of the tibia while the knee is flexed may result in a tear of the PCL [9].

- PCL injuries are associated with more severe traumas that cause a knee dislocation or a multi-ligamentous injury including a posterolateral corner injury [9].

ASSOCIATED INJURIES & PATHOLOGY

- Injuries to the PCL may be isolated or combined with other capsuloligamentous injuries in the knee [1].
- When three or more ligamentous structures are injured, the injury should be viewed as a dislocated knee and the vascular status of the injured limb should be assessed [1].
- Injury to the posterolateral structures has been reported to occur in up to 60% of PCL injuries [3].
- Concomitant injuries are common with PCL injury, including posterolateral corner and meniscus injuries [3].
- The natural history of certain PCL injuries, especially combined ones, will progress to instability, pain, and osteoarthritis of the knee [1].
- This progression to osteoarthritis is especially noted in the patellofemoral and medial tibiofemoral compartments [1].
- Patients with significant varus alignment or injury to the lateral structures of the knee will often complain of feelings of instability and giving way [3].
- In contrast to an ACL tear, it is rare for patients with PCL injuries to report hearing a “pop” or report any feelings of subjective instability [3].
- Patients with PCL injuries more commonly complain of knee pain, swelling, and stiffness [3].
- The presentation of a subacute or chronically injured PCL can range from asymptomatic to significant instability and pain [3].
- Specific cues to PCL injury on initial inspection include abrasions or ecchymosis around the proximal anterior tibia and ecchymosis in the popliteal fossa [3].
- Subtle posterior subluxation on the lateral radiograph may indicate PCL injury [3].
- In the chronic setting of PCL injury, radiographs are useful to assess for patellofemoral and medial compartment degenerative changes [3].

Classification

- PCL injuries occur in isolation or in combination with other injuries [1].
- The grades of PCL injuries are based on physical examination and MRI findings [1].
- A partial PCL injury is characterized by posterior tibial translation of less than 10 mm on the posterior drawer test with the knee in neutral rotation [1].
- A partial PCL injury is characterized by the presence of an end point on the posterior drawer test [1].
- A complete isolated PCL injury is characterized by posterior tibial translation of 8–10 mm on the posterior drawer test with the knee in neutral rotation [1].

- In a complete isolated PCL injury, posterior tibial translation is diminished with the knee in internal rotation [1].
- A combined PCL and capsuloligamentous injury is characterized by posterior tibial translation greater than 10 mm on the posterior drawer test with the knee in neutral rotation [1].
- In a combined PCL and capsuloligamentous injury, the PCL is injured in conjunction with other structures such as the ACL, posterolateral corner, or medial side [1].
- A grade I PCL injury is defined by a step-off of less than 1 cm between the tibial plateau and femoral condyle at 90° of flexion, with the tibial plateau remaining anterior to the femoral condyle [1].
- A grade II PCL injury is defined by the tibial plateau being flush with the femoral condyle at 90° of flexion [1].
- A grade III PCL injury is defined by the tibial plateau being posterior to the femoral condyle at 90° of flexion [1].
- A grade I PCL injury on the posterior drawer test is defined by 3 to 5 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- A grade II PCL injury on the posterior drawer test is defined by 6 to 10 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- A grade III PCL injury on the posterior drawer test is defined by greater than 10 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- The degree of posterior tibial translation may decrease with internal tibial rotation in partial tears [1].
- A combined PCL and capsuloligamentous injury is indicated by more than 15 mm of posterior translation with the knee at 90° and in neutral rotation [1].
- A combined PCL and capsuloligamentous injury is indicated by more than 10 mm of posterior translation with the knee in internal rotation [1].

Clinical Presentation

HISTORY AND MECHANISM OF INJURY

- In athletes, the mechanism of injury is usually a fall onto the flexed knee with the foot plantarflexed, which places a posterior force on the tibia [1].
- The “dashboard” injury involves a posteriorly directed force to the anterior tibia with the knee in 90 degrees of flexion [3].
- Sports injuries to the PCL result from an outside force or blow, contrasting with the typical deceleration twisting mechanism of ACL injuries [3].
- Significant multiligamentous knee injuries with PCL tears can occur after varus or valgus stress is applied to the hyperextended knee [3].
- It is rare for patients with PCL injuries to report hearing a “pop” or report feelings of subjective instability [3].

- Patients with PCL injuries commonly complain of knee pain, swelling, and stiffness [3].
- Patients with significant varus alignment or injury to the lateral structures of the knee often complain of feelings of instability and giving way [3].
- An isolated PCL injury may be less obvious than a combined injury because instability is often subtle or even asymptomatic [1].

PHYSICAL EXAMINATION

- The posterior drawer test is the primary dynamic test to diagnose a PCL injury [1].
- The posterior drawer test is performed with the knee flexed to 90 degrees and a posteriorly directed force applied to the anterior tibia [3].
- In a grade I PCL injury, the step-off between the tibial plateau and femoral condyle is < 1 cm but the tibial plateau remains anterior to the femoral condyle [1].
- In a grade II PCL injury, the tibial plateau is flush with the femoral condyle [1].
- In a grade III PCL injury, the tibial plateau is posterior to the femoral condyle [1].
- A grade I injury on posterior drawer test is defined as 3 to 5 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- A grade II injury on posterior drawer test is defined as 6 to 10 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- A grade III injury on posterior drawer test is defined as >10 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- The quadriceps-active test is positive when the tibia translates anteriorly at 90° of flexion with resisted knee extension [1].
- The posterior sag or Godfrey test involves flexing the knee and hip and noting the posterior pull of gravity creating posterior “sag” of the tibia on the femur [3].
- An adjunct to the posterior sag test involves watching for a reduction of subluxation with active quadriceps contraction [3].
- The reverse pivot shift test is performed by placing a valgus stress on the knee with the foot externally rotated and extending from 90 degrees of flexion [3].
- A palpable reduction of the posterolateral tibial plateau is noted between 20 and 30 degrees of flexion during the reverse pivot shift test [3].
- Evaluation of ACL laxity in the presence of an acute PCL injury is challenging due to the lack of a stable reference point for Lachman or anterior drawer tests [3].

IMAGING

- Plain radiographs are important initially to rule out fractures and avulsions [1].
- Plain radiographs are essential to evaluate for bony injuries, dislocation, or evidence of other associated injuries given the magnitude of forces required to injure the PCL [3].

- Stress posterior drawer radiographs and contralateral comparisons may increase the sensitivity for detecting PCL injuries with plain radiographs [3].
- MRI has been shown to have a very high sensitivity and specificity in diagnosing a PCL injury [1].
- MRI has been reported to be 96–100% sensitive at diagnosing PCL tears [3].
- MRI helps determine the site and degree of injury by assessing the continuity of the PCL [1].
- MRI may indicate the presence of other meniscal, chondral, or ligamentous injuries which may influence treatment strategies [1].
- MRI is valuable in detecting associated injuries, particularly posterolateral corner injuries that can be missed on initial clinical examination [3].
- In multiligamentous knee injuries, MRI can be used to assess the ACL as clinical examination of the ACL is challenging in the setting of a complete PCL tear [3].

Investigations

HISTORY AND MECHANISM

- The history of injury helps differentiate between high- and low-energy traumas [1].
- Concurrent injuries such as knee dislocation, neurovascular injury, and additional ligamentous or skeletal injuries assist in the evaluation [1].
- Patients with PCL injuries rarely report hearing a “pop” or feelings of subjective instability, unlike ACL tears [3].
- Sports injuries to the PCL result from an outside force or blow, contrasting with the deceleration twisting mechanism of ACL injuries [3].

PHYSICAL EXAMINATION

- The physical examination is specific for PCL injury and is classified based on the degree of injury [1].
- At 90° of flexion, there is normally a 1-cm step-off between the tibial plateau and femoral condyle [1].
- In a grade I injury, the step-off is < 1 cm but the tibial plateau remains anterior to the femoral condyle [1].
- In a grade II injury, the tibial plateau is flush with the femoral condyle [1].
- In a grade III injury, the tibial plateau is posterior to the femoral condyle [1].
- The posterior drawer test is the primary dynamic test to diagnose PCL injury [1].
- Grade I PCL injury on posterior drawer test is defined as 3 to 5 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- Grade II PCL injury on posterior drawer test is defined as 6 to 10 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].
- Grade III PCL injury on posterior drawer test is defined as >10 mm of increased posterior tibial translation compared with the uninvolved knee at 90° of flexion [1].

- The Lachman test for ACL injury, varus and valgus laxity testing, and assessment of external and internal tibial rotation differences are critical in differentiating between isolated and combined injuries [1].
- An adjunct to the posterior sag test involves watching for a reduction of this subluxation with active quadriceps contraction [3].
- The reverse pivot shift is performed by placing a valgus stress on the knee with the foot externally rotated and extending from 90 degrees of flexion, noting a palpable reduction of the posterolateral tibial plateau between 20 and 30 degrees of flexion [3].
- The accuracy, sensitivity, and specificity of clinical examination findings for PCL injury are greater than 90% [14].
- In a simplified grading system, a grade A injury presents with a slight loss of anterior tibial offset at 90° of flexion [14].
- In a simplified grading system, a grade B injury presents with the tibia flush with the femoral condyles at 90° of flexion [14].
- In a simplified grading system, a grade C injury presents with tibial displacement posterior to the femoral condyles at 90° of flexion [14].
- Grades A, B, and C injuries correlate with grades I, II, and III injuries when considering treatment options and outcomes [14].

IMAGING

- Radiographs can reveal PCL tibial avulsion injury, capsular avulsion, or associated fracture as well as posterior resting position and subluxation of the tibia [14].
- Stress radiographs can be used to assess PCL disruption [14].
- MRI complements the history and physical examination and helps determine the site and degree of injury by assessing the continuity of the PCL [1].
- MRI is extremely valuable in its ability to detect associated injuries, particularly posterolateral corner injuries which can often be missed on initial clinical examination [3].
- MRI is used to determine the location and severity of PCL disruption and shows concomitant meniscal, osteochondral, chondral, and ligament injuries [14].
- If grade III posterior tibial laxity is present and radiographs show more than 10 mm of posterior subluxation, a combined PCL and posterolateral corner injury should be suspected [14].

Treatment

NONSURGICAL

- Nonsurgical treatment is reserved for isolated partial PCL injuries with <10 mm of increased posterior tibial translation [1].

- Conservative management for PCL injuries focuses on quadriceps strengthening to prevent posterior tibial sag [17].
- Return to sports is usually achieved in 2 to 4 weeks for grade I–II PCL injuries [17].
- Treatment for grade III PCL injuries includes relative immobilization in extension for 4 weeks [17].
- Special braces have been designed to prevent posterior sag in PCL injuries [17].
- Chronic PCL deficiency can lead to increased contact pressures in the patellofemoral and medial compartment of the knee [17].
- Nonsurgical treatment is recommended for patients with an isolated grade I or II PCL injury [19].
- The nonsurgical program for isolated grade I or II PCL injuries includes extension bracing treatment, protected weight bearing, and quadriceps strengthening rehabilitation [19].
- Two natural history studies of nonsurgically treated isolated grade I or II PCL injuries found good subjective and objective outcomes with no functional deterioration [19].
- Two natural history studies of nonsurgically treated isolated grade I or II PCL injuries found 97% quadriceps and 93% hamstring strength [19].
- A 7-year follow-up study reported that 92% of patients with grade I or II PCL injuries had a good to excellent result after nonsurgical management based on the Tegner Activity Level Scale and Lysholm-II Knee Questionnaire scores [19].
- Shelbourne and Muthukaruppan reported good clinical outcomes when partial PCL injuries with 1+ to 2+ posterior laxity were treated conservatively initially [18].
- Conservative treatment for partial PCL injuries consists of knee extension and a protective rehabilitation program with no active hamstring strengthening [18].
- Long-term results for conservatively treated isolated PCL injuries did not correlate with the initial degree of instability [18].
- Subjective scores for conservatively treated isolated PCL injuries did not deteriorate with time [18].

SURGICAL INDICATIONS

- Surgical treatment is indicated in patients with symptomatic isolated PCL tears [17].
- Surgical treatment is indicated in patients with PCL avulsion fractures [17].
- Surgical treatment is indicated in the setting of a multiligament injured knee [17].
- Surgical treatment is recommended for a chronic grade III PCL lesion if the patient is symptomatic [19].
- PCL injuries with 3+ laxity (≥ 8 mm on stress radiographs) are reconstructed [18].
- Symptomatic PCL injuries are reconstructed [18].

SURGICAL TECHNIQUES

- Primary repair or open reduction and internal fixation is performed for PCL avulsion injuries [17].
- Reconstruction is performed for PCL injuries other than avulsion injuries [17].

- Options for PCL reconstruction include tibial inlay versus transtibial, single-bundle versus double-bundle, and autograft versus allograft [17].
- The tibial inlay technique theoretically reduces the “killer turn” between the posterior border of the tibial plateau and the graft [17].
- The reduction of the “killer turn” by the tibial inlay technique may decrease failure rates [17].
- Double-bundle PCL reconstruction is theoretically stronger than single-bundle reconstruction [17].
- Double-bundle PCL reconstruction may be beneficial in the revision setting or with multiple ligament reconstruction [17].
- There has been no evidence to suggest one PCL reconstruction technique is superior over another [17].
- The results of PCL reconstruction are less favorable than primary repair of avulsion fractures as residual posterior laxity often exists [17].
- An osteotomy should be considered in the setting of malalignment for PCL injuries [17].
- A high tibial osteotomy can treat varus malalignment as well as increase tibial slope to help reduce posterior tibial sag [17].
- Avulsion of the PCL usually occurs at the femoral attachment and can be repaired using suture anchors or femoral bone tunnels [19].
- Large osseous avulsion fragments from the tibial attachment can be repaired with open reduction and screw-and-washer fixation [19].
- The tibial inlay technique is usually performed through an open posterior approach [19].
- In the tibial inlay technique, the bone block is recessed and fixed with an interference screw at the posterior tibia, ensuring to avoid graft protrusion [19].
- Advantages of the tibial inlay technique include osseous graft healing, avoidance of so-called killer turn stresses, decreased graft wear, and improved graft biomechanics [19].
- An arthroscopic inlay technique using suture button fixation over the tibial-side bone block has been described as combining the advantages of arthroscopic and inlay techniques [19].
- In the transtibial technique, the tibial tunnel is reamed from anterior to posterior through the tibia under direct arthroscopic and fluoroscopic visualization [19].
- The tibial footprint for the transtibial technique is approximately 7 mm anterior to the posterior tibial cortex as seen on a perfect lateral image [19].
- Cadaver biomechanical data revealed no difference between transtibial and tibial inlay techniques when grafts were appropriately pretensioned before insertion [19].
- Multiple studies report no difference in functional, radiographic, or clinical outcomes between transtibial and tibial inlay techniques [19].
- Multiple studies report no difference in functional, radiographic, or clinical outcomes between arthroscopic and open PCL reconstruction techniques [19].
- Biomechanical comparison studies concluded that double-bundle PCL reconstruction is preferable for decreasing posterior tibial translation and improving rotational restraint [19].

- Biomechanical advantages of double-bundle PCL reconstruction were not correlated with superior clinical outcomes [19].
- Isolated single-bundle PCL reconstruction yields good long-term results without functional differences in comparison with double-bundle reconstruction [19].
- Double-bundle reconstructions have gained favor with many surgeons, but anatomic single-bundle techniques have good results similar to those for transtibial and inlay techniques [18].
- The two-tunnel technique has been shown in clinical studies to have increased stability and to better fill the large PCL footprint [18].
- The single-tunnel technique is used mostly for reconstruction of multiple knee ligaments in knee dislocations [18].
- The two-tunnel technique is used primarily in isolated PCL reconstruction [18].
- An Achilles tendon allograft is the preferred graft source for PCL reconstruction in the described protocol [18].
- Comparable results have been reported with allografts and autografts for PCL reconstruction [18].
- An all-arthroscopic inlay procedure using a retrocutting reamer and a closed-ended tibial tunnel with suture fixation anteriorly produces a shorter, stiffer graft construct [18].
- The all-arthroscopic inlay procedure removes the “killer curve” that sometimes occurs in the transtibial technique, although a killer curve still remains on the femoral side [18].
- Comparative studies show that anatomic single-tunnel and inlay procedures produce equal function and stability [18].
- Double-bundle PCL techniques have been shown to be slightly better than single-bundle techniques with 2.5 mm of posterior displacement compared with 3.2 mm [18].
- Double-bundle PCL techniques have been shown to have better IKDC scores in most studies [18].
- The most important factors for long-term success in PCL reconstruction are correction of associated instabilities and meniscal preservation [18].
- Slow, protected rehabilitation increases the likelihood of knee stability and should emphasize early maintenance of knee extension, delayed weight bearing, and delayed return to sports [18].
- LaPrade et al. showed that a decreased posterior tibial slope puts athletes at some increased risk of PCL injuries [18].
- With double-bundle PCL reconstruction, there is no increased failure rate based on tibial slope [18].

POSTOPERATIVE REHABILITATION

- Postoperative rehabilitation for PCL surgery consists of early immobilization in extension and protection against gravity [17].
- Early range of motion should be performed in the prone position [17].
- The focus of postoperative rehabilitation is on quadriceps strengthening [17].

- Resisted hamstring strengthening should be avoided early in rehabilitation because the posterior pull increases stress on the graft [17].

Complications

- Posterior laxity increases over time after PCL reconstruction [2].
- Tibial slope strongly influences knee stability after posterior cruciate ligament reconstruction [2].
- Consequences of tibial tunnel reaming on the meniscal roots during cruciate ligament reconstruction were evaluated in a cadaveric model for the posterior cruciate ligament [2].
- Septic arthritis after arthroscopic posterior cruciate ligament and multi-ligament reconstructions is rare [4].
- Septic arthritis after arthroscopic posterior cruciate ligament and multi-ligament reconstructions can be successfully treated with arthroscopic irrigation and debridement [4].

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