Injuries to the posterolateral corner (PLC) of the knee are most commonly associated with athletic traumas, motor vehicle accidents, and falls. PLC injuries account for 16% of knee ligament injuries and often occur in combination with other ligament injuries. Overlooking this injury can lead to residual instability, which may lead to chronic pain or surgical failure in the presence of cruciate ligament reconstruction. The most common mechanisms leading to PLC injuries include a blow to the anteromedial aspect of the knee with the knee at or near full extension, contact and noncontact knee hyperextension injuries, and valgus contact force applied to a flexed knee. Another mechanism of injury consists of a severe tibial external rotation torque applied with the knee in flexion or in hyperextension. The PLC is comprised of various muscles and ligaments, with the exact structures varying, depending on the source of the description. Given the multitude of structures involved and the inherent and distinct biomechanics of each structure, the PLC is inherently complex both anatomically and functionally. A thorough understanding of the anatomy, biomechanics, and healing physiology is essential for the successful treatment and rehabilitation of PLC injuries for patients to return to the highest level of function. The aim of this manuscript is the anatomy and biomechanics of the PLC, and to review the evaluation, surgical treatment, and rehabilitation of PLC injuries.

THE DESCRIPTION OF THE ANATOMY of the PLC varies depending on the source and nomenclature that is used. The PLC provides both static and dynamic stability to the knee to prevent excessive hyperextension, varus angulation, and tibial external rotation. The PLC is especially important for providing stability at lower angles of knee flexion (<45°) in weight-bearing activities. Furthermore, the PLC has been shown to augment the contribution of the posterior cruciate ligament (PCL) to tibiofemoral posterior stability, especially at 30° of knee flexion. There are numerous structures that compose the PLC. The

**SYNOPSIS:** Injuries to the posterolateral corner of the knee pose a significant challenge to sports medicine team members due to their complex nature. Identifying posterolateral corner injuries is paramount to determining proper surgical management of the injured athlete, with the goal of preventing chronic pain, instability, and/or surgical failure. Postoperative rehabilitation is based on the specific structural involvement and surgical procedures. A firm understanding of the anatomy and biomechanics of the structures of the posterolateral corner is essential for successful rehabilitation outcomes. Emphasis is placed on protection of the healing surgical repair/reconstruction, with gradual restoration of range of motion, strength, proprioception, and dynamic function of the knee. The purpose of this paper is to provide an overview of the anatomy, biomechanics, and mechanism of injury for posterolateral corner injuries, with a review of clinical examination techniques for identifying these injuries. Furthermore, a review of current surgical management and postoperative guidelines is provided.


**KEY WORDS:** fibular collateral ligament, multiligamentous knee injuries, rehabilitation
following anatomic structures and their contribution to stability of the knee will be reviewed: iliotibial band (ITB), biceps femoris muscle, fibular collateral ligament (FCL), popliteus muscle, popliteofibular ligament, lateral gastrocnemius muscle, lateral joint capsule, coronary ligament, oblique popliteal ligament, and the fabellofibular ligament.

**Static Structures**

The 3 most important stabilizing structures providing static (passive) and dynamic (active) posterolateral knee stability are the popliteus tendon, popliteofibular ligament, and FCL ligament (FIGURE 1).9

The FCL serves as the primary static stabilizer to varus opening at the knee from 0° to 30° of knee flexion,65 and it also provides a checkrein to external rotation of the tibia.65 This extracapsular structure originates just proximal and posterior to the lateral femoral epicondyle and spans roughly 7 cm to its insertion on the fibular head.29,65 The popliteus muscle originates from the posteromedial aspect of the proximal tibia,27,61 and its proximal tendon has multiple points of insertion collectively called the popliteus complex. One such attachment to the posteromedial aspect of the fibula is known as the popliteofibular ligament. This ligament is a static stabilizer resisting varus, external rotation, and posterolateral tibial rotation.46,54 Along with the popliteus muscle, this ligament is considered a crucial stabilizer to the posterolateral knee and, therefore, typically is surgically reconstructed when torn. The popliteus complex also has a tibial attachment and 3 connections, or popliteomeniscal fascicles, to the lateral meniscus. Together, these structures stabilize the lateral meniscus and prevent medial entrapment of the meniscus when varus forces are applied at the knee.49 The main tendinous attachment of the popliteus tendon is to the femur at the anterior aspect of the popliteus sulcus, just posterior to the lateral femoral condyle articular cartilage surface.49 The popliteus tendon provides dynamic internal tibial rotation and serves as both a dynamic and static stabilizer to the knee against external tibial rotation.55

Other static contributors to posterolateral knee stability include the popliteus tendon, the coronary ligament, oblique popliteal ligament, and fabellofibular ligament. The posterolateral joint capsule includes portions of the posterior and the lateral joint capsule, and spans from the anterior border of the popliteus tendon’s insertion on the femur to the lateral gastrocnemius attachment.56 The posterior capsule attaches to around the lateral femoral condyle. The mid-third lateral capsular ligament is a thickening of the lateral capsule and provides an important secondary stabilizer role to varus stability.65 The coronary ligament of the lateral meniscus extends from the popliteal hiatus to the popliteomeniscal fascicle. This is also referred to as the meniscotibial portion of the posterolateral capsule. This structure is important to provide resistance to hyperextension and tibial posterolateral rotation.74 It also secures the posterior horn of the meniscus to the tibia.65 The oblique popliteal ligament is formed from a combination of an expansion of the semimembranosus complex and a portion of the posterior oblique ligament.65 Muscular contraction of the semimembranosus muscle assists in the tightening of this ligament. Anatomically, it forms part of the floor of the popliteal fossa and attaches to the posterolateral capsule at the fabella region. The fabellofibular ligament spans from the lateral aspect of the fabella and attaches to the fibular head.65 If there is no fabella, it originates from the tendon of the lateral gastrocnemius.65 Clinically, it is thought to be an important lateral knee stabilizer in extension.55

**Dynamic Structures**

The dynamic structures of the knee that assist with posterolateral stability include the popliteus muscle, the ITB, biceps femoris, and the lateral gastrocnemius tendon. The contribution of the popliteus complex to posterolateral knee stability is described above, as it provides static and dynamic contributions to knee stability. The ITB is a dense fibrous extension of the fascia covering the gluteus maximus and tensor fascia latae muscle. The ITB originates from the anterior superior iliac spine, anterior border of the ilium, and the external lip of the iliac crest.65 The insertion is located on the lateral intermuscular septum, lateral aspect of the patella, and the anterolateral aspect of the lateral tibial plateau at Gerdy’s tubercle.61 During knee motion, the ITB moves anterior in extension and posterior in flexion. Along with the lateral ligaments and lateral capsular structures, the ITB aids in lateral knee stability to prevent excessive
varus in positions of knee extension.

The biceps femoris muscle is composed of a long and short head. The long head originates from the ischial tuberosity. The short head originates from the middle third of the linea aspera and the lateral supracondylar ridge of the femur. The long head has 5 major insertions at the knee, divided into 2 tendinous and 3 fascial components. The condylar component connects the long and short heads of the biceps femoris to the posterolateral aspect of the FCL. The short head of the biceps femoris has multiple insertions, including a muscular attachment onto the long head tendon, FCL, and the ITB. Both heads assist the knee with flexion and lateral rotation and aid in dynamic stability in preventing varus angulation, controlling tibial internal rotation, and working synergistically with the medial hamstrings to prevent excessive tibiofemoral anterior translation. Surgical repair of the biceps femoris is needed with avulsions from the fibula. If intact, a portion of the biceps femoris tendon can be used as a tenodesis to the lateral femoral epicondyle to reconstruct the FCL. It is worth noting that the common peroneal nerve lies deep to the biceps femoris tendon and can be involved with PLC injuries. The lateral gastrocnemius tendon originates around the supracondylar process of the distal femur. At the knee, this structure blends with the posterior capsule and popliteofibular ligament to assist with posterolateral stability.

**EVALUATION**

It is important for clinicians to accurately evaluate and assess posterolateral knee injuries. Failure to diagnose and treat a PLC injury in a patient who has a PCL or anterior cruciate ligament (ACL) tear requiring reconstruction can result in failure of the cruciate ligament graft. Examination of injuries to the PLC may reveal diffuse tenderness over the posterolateral region of the knee and localized pain at the fibular head or joint line upon palpation.

**Mechanism of Injury**

Mechanisms resulting in PLC injuries include a posterolateral-directed force to the anteromedial tibia, knee hyperextension, and/or severe tibial external rotation while the knee is partially flexed. The forces involved during the injury and the patient’s anatomic makeup will dictate which specific structures are injured. In knee hyperextension injuries the posterior capsule is often strained or torn, followed by injury to the PLC and finally the PCL. In a cadaveric biomechanical model, Csintalan et al demonstrated that external rotation injuries with the knee partially flexed may result in tears of the popliteus tendon, popliteofibular ligament, FCL, and the ACL. Following PLC injury, pain may be reported at the medial and/or lateral joint line, or the posterolateral aspect of the knee. Often described is functional instability which may include a feeling of the knee giving way into hyperextension with stairs or graded ambulation. Perception of instability can also result with cutting or pivoting movements.

**Gait**

Due to the knee instability resulting from an injury to the PLC, the gait pattern is often altered to an extent that the patient cannot employ a muscular compensation strategy to effectively stabilize the knee. A varus thrust of the knee is often seen during the loading-response phase of gait in individuals with a chronic posterolateral knee injury, especially those with underlying varus osseous alignment. The varus thrust gait pattern is likely associated with a lift-off of the lateral compartment of the knee, which has been shown to significantly increase medial compartment joint stresses and ultimately hasten medial compartment cartilage wear if left untreated. Currently, there are no studies specifically addressing the effects of acutely induced high adduction moments, as seen in patients with traumatic acute PLC injuries. However, studies looking at varus knee alignment established a good foundation for the importance of critically observing and correcting abnormal gait patterns as a means to protect the long-term health of the medial compartment cartilage of the knee.

In addition to the increased adduction moment found in the gait pattern of patients with PLC injuries, patients also often demonstrate a knee hyperextension thrust during the loading response into the early stance phase of gait. This hyperextension thrust gait pattern observed in individuals with an ACL-deficient knee or those who are post-ACL reconstructive surgery is often referred to as a “quadriceps avoidance pattern.” With this abnormal gait pattern, a decrease in knee flexion moment and increase in hip flexion moment have been observed during loading response. It has been postulated that the hyperextension thrust is used as a strategy to stabilize the ACL-deficient knee; however, the lack of a proper deceleration moment achieved through knee flexion and eccentric quadriceps activation during loading response may result in increased compressive forces at the tibiofemoral joint.

In the individual with a PLC injury, the hyperextension thrust gait pattern may be the result of significant genu recurvatum instability rather than quadriceps weakness, due to injury to multiple static and dynamic posterior lateral stabilizing structures. Further complicating the gait pattern of a patient with a PLC injury is the fact that these patients may also present with a footdrop gait pattern due to an injury to the common peroneal nerve. With the known deleterious effects of faulty gait mechanics on the health of the knee’s articular cartilage, it is critical to address the muscular control and recruitment deficits to normalize lower extremity kinematics and minimize medial compartment knee joint stresses.

**Associated Injuries**

Because of the risk for vascular injuries with knee trauma, it is important to
Special Tests

There are several special tests for PLC injuries that can and should be used to help confirm a diagnosis. We will review the posterolateral drawer, Dial, external rotation recurvatum, varus stress, reverse pivot-shift, and standing apprehension tests.

The posterolateral drawer test is performed with the patient in supine, with the knee flexed to 80° to 90° and the foot externally rotated 15°. While the clinician stabilizes the patient’s foot, a posterolateral drawer force is applied (FIGURE 2). A positive posterolateral drawer test, indicated by increased posterolateral rotation compared to the contralateral knee, may implicate injury to the popliteus tendon, popliteofibular ligament, and FCL. This should not be confused with testing the knee in neutral rotation or internal rotation at 90°, which would be utilized to assess a PCL injury. Sensitivity and specificity values have not been reported for the posterolateral drawer test in diagnosing PLC injuries. The Dial test may be performed with the patient positioned either supine or prone and has been shown to have substantial agreement within and between testers. If a PCL-PLC combined injury is suspected, performing the Dial test with the patient in prone or adding an anteriorly directed force to the tibia while testing in the supine position can increase the amount of tibial external rotation observed and would presumably increase the sensitivity of the test. However, sensitivity and specificity values have not been reported for the Dial test. With the patient supine, the knee is flexed off the edge of the examining table to 30° and then 90° with the thigh stabilized against the table. The foot is externally rotated, while the examiner records the amount of external rotation of the tibial tubercle compared to the uninjured limb (FIGURE 3). An increase of greater than or equal to 15°, as compared to the contralateral side, is considered positive. A Dial test that is positive at 30° of knee flexion but normal at 90° of knee flexion is indicative of a potential injury to the PLC, or more specifically, the popliteus complex. A positive test at both 30° and 90° of knee flexion indicates both a PCL and PLC injury.

The external rotation recurvatum test may be used to detect a concomitant PLC-ACL injury. The external rotation recurvatum test is performed by lifting a supine patient’s great toe with 1 hand and lifting the patient’s great toe with the other hand, to observe the amount of genu recurvatum. If a diminished foot pulse is detected in comparison to the contralateral limb or the ABI is less than 0.9, an arteriogram or vascular ultrasound study may be warranted.
than the contralateral knee. The postero-lateral structures potentially involved with a positive test include the coronary ligament to the lateral meniscus, popliteus tendon, and the structures which attach to the fibular head: fabellofibular ligament, biceps femoris, popliteofibular ligament, and FCL. Caution is warranted in interpreting the external rotational recurvatum test, as it has been shown to have a high incidence of false negative results for ACL-PLC injuries, and it is rarely positive in patients with PCL-PLC or isolated PLC injuries. Specifically, the sensitivity of the external rotation recurvatum test for ACL-PLC injuries has been reported as 30%, while the specificity was 100%.

The varus stress test is performed with the patient supine, with the proximal femur stabilized on the examination table. The examiner stabilizes the tibia from unwanted rotation and applies a varus stress to the knee through the foot/ankle, first with the knee at 30° of flexion and repeated with the knee extended to 0°. The test is considered positive if the examiner feels an increased amount of translation as compared to the contralateral knee. The injury is graded according to the amount of subjective translation (or joint opening) and the perceived quality of resistance at the endpoint. A grade I FCL sprain shows mild gapping with a firm endpoint, grade II shows moderate gapping with an endpoint, and a grade III shows gapping without an endpoint. A positive varus stress test at 30° is indicative of a complete tear of the FCL (Figure 5). A positive varus stress test at 0° of knee extension indicates a more severe injury, which may include the PCL, FCL, meniscotibial ligament, popliteus tendon, and the superficial layer of the ITB. However, data on the sensitivity and specificity of the varus stress test have not been reported.

A positive reverse pivot shift may indicate an injury to the PLC. Specifically, the reverse pivot shift test is positive with injuries to the following anatomic structures of the PLC: FCL, popliteus complex, and the mid-third lateral capsular liga-ment. In this test, the knee is flexed to 45° and the foot is externally rotated with a valgus stress applied (Figure 6). A positive test is indicated by a subluxation felt with extension at around 25° flexion. It is important to compare with the contralateral normal knee because this test has been reported to have a false positive rate of up to 35%.

A standing apprehension test has also been reported to assess injury to the PLC. The patient stands with his/her weight on the injured (tested) knee and slightly flexes it, while the clinician applies a medially directed force on the anterolateral portion of the lateral femoral condyle. Rotation of the condyle relative to the tibia, in addition to the patient feeling a giving-way sensation, indicates a positive test. The standing apprehension test was reported to have 100% sensitivity for reproducing posterolateral instability in patients with a history of an ACL reconstruction or other arthroscopic knee surgery. Specificity for the standing apprehension test has not been reported. It should be noted that injury to the anatomical structures of the PLC was not confirmed either by imaging studies or operative examination, thus the standing apprehension test should only be considered useful to reproduce a patient’s symptoms of knee instability.

**Imaging**

In cases where there is significant edema present, a clinical exam may be equivocal and diagnostic imaging will assist in making a diagnosis. Furthermore, diagnostic imaging is a useful tool to assist with identification of specific anatomical structures involved. Plain radiographs may reveal a fibular head fracture, lateral joint space widening, or avulsions of the lateral capsule. Magnetic resonance imaging that includes a coronal oblique image plane in all sequences of the entire fibular head and styloid process can be a helpful diagnostic tool in assessing structural integrity of the PLC, as it has been found to accurately assess the integrity.
of most of its components (Figure 7). Imaging can also be very useful in determining avulsion versus midsubstance injuries. Stress radiographs are very helpful to assess for chronic PLC injuries. LaPrade et al evaluated the use of varus stress radiographs with the knee at 20° of flexion to provide objective and reproducible measures of lateral compartment gapping, and reported a grade III PLC injury should be suspected if an increased opening of approximately 4 mm is found (Figure 8).

**Classification**

Injuries to the PLC can be graded using 2 different classifications proposed by Hughston and Fanelli that are based on the amount of excessive laxity or structures involved (Table).

Hughston reported 3 grades to classify collateral ligament injuries of the knee. Grade 1+ instability is indicated by opening of the affected joint by an amount of 0 to 5 mm with varus stress; grade 2+ is indicated by opening of 6 to 10 mm; and grade 3+ with an opening of greater than 10 mm. Our own sectioning studies have revealed a fault in the old subjective grading scales that were not based on actual science (Table). It is important to point out that the Hughston classification (old American Medical Association) is a subjective clinical-based test and that the actual numbers quoted for the amount of instability are inaccurate. While we recognize that this grading scale is very important for making clinical decisions, it is also important that the amount of instability is much less than that which was subjectively proposed by both the American Medical Association and Dr Hughston in their grading scales. If one reads an article on a surgical procedure that does not return the knee to less than 2 mm, the procedure would be regarded as a failure under stress radiograph grading, while subjectively it may be felt to be acceptable.

The Fanelli scale classifies injuries into type A, B, or C. Type A injuries include the popliteofibular ligament and popliteus tendon, and only an increase in knee (tibial) external rotation is observed upon clinical testing. Type B injuries include the popliteofibular ligament, popliteus tendon, and ACL and/or PCL disruption. With type C PLC injuries, the clinical exam reveals increased tibial external rotation and marked varus instability at 30° of knee flexion. Once the grade of injury is established, the clinician can determine the course of management. Grade 1+ and

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<th>Table</th>
<th>Grading Scales for PLC Injuries of the Knee</th>
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<tr>
<td>Fanelli Scale for PLC Injury (location based)</td>
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<tr>
<td>A: injury to popliteofibular ligament, popliteus tendon</td>
<td></td>
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<tr>
<td>B: injury to popliteofibular ligament, popliteus tendon, and FCL</td>
<td></td>
</tr>
<tr>
<td>C: injury to popliteofibular ligament, popliteus tendon, and FCL, lateral capsular avulsion, and cruciate ligament disruption</td>
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<tr>
<td>Hughston Scale for Collateral Ligament Injury (instability based)</td>
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<tr>
<td>1+: varus opening, 0-5 mm*</td>
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<tr>
<td>2+: varus opening, 5-10 mm*</td>
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<tr>
<td>3+: varus opening, &gt;10 mm*</td>
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<tr>
<td>Varus stress radiographs (sectioning based)</td>
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<tr>
<td>FCL: varus opening, 2.7 mm*</td>
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<td>FCL, popliteus tendon: varus opening, 3.5 mm*</td>
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<td>FCL, popliteus tendon, popliteofibular ligament: varus opening, 4 mm*</td>
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* Increased opening compared to contralateral knee.
NONSURGICAL MANAGEMENT

Conservative management of PLC injuries is not well documented in the literature. This is most likely due to the fact that PLC injuries are typically combined with an injury to one of the cruciate ligaments, for which surgical management is indicated. In addition, patients with isolated grade 1+ and 2+ PLC injuries, for which conservative treatment may also be appropriate, often may not present for treatment. DeLeo et al. presented a case study of an 18-year-old female who sustained a noncontact grade II FCL sprain with concomitant posterolateral instability. The patient was able to return to her previous level of activity, which included reserve officer training, 23 weeks following her injury, with 9 weeks of intensive physical therapy (23 visits) that included fibular head mobilization followed by taping of the fibular head and perturbation training, in addition to transcutaneous electrical nerve stimulation and range-of-motion and strengthening exercises.

Our approach to conservative management of PLC injuries is to initiate an accelerated form of the postsurgical rehabilitation outlined in detail below. The program is accelerated compared to the postsurgical PLC program, as progression for the conservative management of PLC injuries is not dependent on allograft healing timelines but is based on anthropometric measures, functional progression, and symptom and impairment resolution. Briefly, the rehabilitation of the isolated PLC is based on the patient’s presentation. For patients who have increased gapping on stress radiographs but who don’t have a complete FCL tear, the use of a medial compartment unload-er brace for high-level athletic activities may be indicated. As with all knee injuries, the goals for phase 1 are edema manage-ment, restoration of range of motion, and quadriceps muscle activation. Patients are progressed to the second phase of rehabilitation once knee extension is restored to within normal limits of the contralateral knee, knee flexion is greater than 120°, and they are able to perform a supine straight leg raise (SLR) without a knee extension lag. The second phase of rehabilitation is devoted to normalizing of gait mechanics and increasing muscle strength. Lower extremity strengthening exercises are particularly focused on the quadriceps, hamstrings, gastrocnemius, and popliteus. During later phases of rehabilitation, emphasis is placed on the lateral hamstrings and lateral gastrocnemius to control varus moments at the knee. Emphasis is also placed on control of tibial external rotation with the medial hamstrings by having the patient perform traditional strengthening exercises modified with the tibia positioned in internal rotation. Furthermore, a program of hip and lumbopelvic stabilization exercises is included. Patients are typically advanced from the second phase, when normal gait pattern has been restored. Phase 3 of PLC rehabilitation is devoted to neuromuscular control and strengthening with functional movement patterns. Particular emphasis is placed on control of knee varus and tibial external rotation at lower angles (<45°) of knee flexion in weight bearing. Verbal, manual, and visual cueing with the use of a mirror or video feedback are all utilized to increase the patient’s control with weight-bearing activities. Functional testing and training, including timed balance and single-limb squat for depth, and hop testing (single- and triple-crossover hops for distance and timed hop for speed), are performed. Once patients achieve a limb symmetry index of greater than 85% on functional testing, they are progressed to phase 4 rehabilitation. Finally, phase 4 of PLC rehabilitation is devoted to sport-specific drills, with a gradual return-to-play program. Due to the rarity of reported treatment of isolated grade 1+ and 2+ PLC injuries and superior surgical outcomes for acute versus chronic PLC injuries, we treat patients with grade 3+ PLC injuries surgically.

SURGICAL TREATMENT

Surgical treatment of the PLC can vary, depending on the structural involvement and the time frame of the procedure from the date of injury. However, the goals of the reconstruction are the same for all the procedures: to have a stable, well-aligned knee and to restore the preinjury kinematics of the knee joint. Surgical management of isolated acute PLC injuries has been reported to result in more successful outcomes than chronic injuries. Acute injuries include grade 3+ PLC injuries reconstructed within 3 weeks of the injury. All major structures of the PLC should be evaluated, including the ITB, biceps tendon, popliteus, FCL, popliteofibular ligament, and the peroneal nerve. Surgical approaches can vary, and an extensive report is beyond the scope of this paper.

In general, it is recommended that anatomic repairs or reconstructions of the PLC structures be performed. Similar to the outcomes following reconstructions of the cruciate ligaments, it has been found that the outcomes of delayed primary repairs and sling procedures of the PLC structures also have less than optimal outcomes as compared to anatomic reconstructions. Primary repairs of the FCL may be performed within the first 2 to 3 weeks after injury. After this time, the avulsed structures retract so that the tissue cannot be restored to its native anatomic location. Furthermore, the torn structure becomes necrotic after 3 weeks and does not hold sutures well. Therefore, primary repairs of the FCL are not recommended at greater than 3 weeks following injury and require a reconstruction. But, regardless of when the surgery is performed, midsubstance tears of the FCL cannot be repaired and require a reconstruction. Our recommended technique for a FCL reconstruction follows the description by Coobs.
et al., in which an autogenous semitendinosus graft is harvested and sized to fit into reconstruction tunnels reamed at the anatomic attachment sites of the FCL. For complete nonrepairable acute tears or chronic attenuation of the main posterolateral knee structures, multiple repair and reconstructive procedures have been reported, including FCL reconstruction, FCL reinforcement with the use of an allograft, femoral bone-block advancement, proximal tibial osteotomy, biceps femoris tenodesis, popliteus tendon and popliteofibular ligament reconstruction, popliteofibular ligament, and ITB or biceps femoris graft. However, an anatomic reconstruction of the FCL, popliteus tendon, and popliteofibular ligament are recommended (FIGURE 9).

At the University of Minnesota Sports Medicine Institute, we advocate the surgical procedure developed in our biomechanics lab, for which clinical outcomes have been published by LaPrade et al. A brief overview of a procedure is summarized below. The initial incision to expose the PLC begins as an 8- to 10-cm hockey stick-shaped incision, originating over Gerdy’s tubercle. Multiple fascial incisions can then be used to access the specific components of the PLC. The surgical approach to repair of posterolateral injuries should take a deep to superficial approach. The superficial fascial layer of the ITB is split in line with its fibers and retracted to expose the proximal attachments of the FCL and popliteus tendon. A second fascial incision is made parallel to the long head of the biceps femoris. Dissection occurs to reveal the popliteofibular ligament’s attachment site. Two grafts from a split Achilles tendon allograft are used for reconstruction. The first is used to reconstruct the popliteus tendon and the second to reconstruct both the popliteofibular ligament and the FCL. These structures have been found to be the most important stabilizing structures and act in concert with the cruciate ligaments to provide overall knee stability.

Chronic PLC injuries tend to be a more complex problem than acute injuries. This can be due to extensive scarring, secondary changes to surrounding structures, and potential limb malalignment. A multistep procedure with a correction of a genu varum deformity initially needs to be considered. This can be addressed through a proximal tibial osteotomy and should be done prior to soft tissue reconstruction. The goal is to prevent excessive loads on the lateral capsular structures that are to be potentially reconstructed after the osteotomy heals. Some, but not all, of the other techniques to reconstruct/approximate the FCL are Achilles tendon allograft, bone patellar bone autograft, and tenodesis of the biceps femoris tendon. Surgical repair of the FCL may be performed if it is avulsed off of its femoral or fibular attachments. Midsubstance tears of the FCL can be augmented with a portion of the biceps femoris or reconstructed. If the ligament is absent or if chronic PLC injury is present, a reconstruction may be indicated.

The popliteus complex may be reconstructed with hamstring autograft, Achilles tendon autograft, or ITB autograft. Sutures can be used to repair tears to the coronary ligament of the posterior horn of the lateral meniscus, the popliteomeniscal fascicles, portions of the ITB, and portions of the long and short heads of the biceps femoris. Reconstruction of a coexisting cruciate ligament tear should be concurrently addressed with a combined injury. It is important for therapists to consult the physician and/or review the operative notes due to variation and complexity among surgical procedures. Therapists should also have understanding and appreciation of the postoperative precautions and restrictions. This will lead to a better understanding of this region of the knee and assist with optimal outcomes.

**POSTSURGICAL REHABILITATION**

**POSTSURGICAL REHABILITATION**

Rehabilitation in advance of the surgery or “prehabilitation” is an optimal course of care and should be considered, when possible, to allow for better surgical outcomes by preventing contractures that may affect postsurgical range-of-motion or intraoperative difficulty in obtaining native graft placement. Patients are seen prior to surgery to regain range of motion, to increase quadriceps control, to review and provide patients with a postoperative rehabilitation protocol and restrictions, and to discuss any questions patients might have entering the procedure. Patients can utilize aquatic centers to increase range of motion and mobility prior to surgery, by being able to stress...
their knees more effectively, without the associated pain from full weight bearing.

This paper will follow the guidelines of Robert F. LaPrade, MD, PhD for a posterolateral reconstruction involving the popliteus tendon, popliteofibular ligament, and the FCL (Appendix). These guidelines may be modified with a concurrent knee ligament injury. Postoperative restrictions for the first 6 weeks postoperatively include being non-weight bearing and remaining in the knee immobilizer at all times other than for range-of-motion exercises. For the first 4 months postoperatively, closed kinetic chain (squatting) exercises are limited to 70° or less knee flexion, tibial external rotation is avoided, and resistive or repetitive hamstring exercises with the knee in flexion are avoided. Patients are kept non-weight bearing for 6 weeks to allow for healing of the reconstruction and to prevent stretching of the graft during ambulation. The rationale for hamstring avoidance is primarily based on surgeons’ anecdotal information. Markolf et al have demonstrated that activation of the hamstrings significantly increased mean forces applied to the PCL, when the knee was in more than 30° of flexion. Patients should be educated in the avoidance of tibial external rotation to prevent over-stretching of the surgical reconstruction. This includes avoidance of sitting with the legs crossed, sitting with an excessive toe-out posturing, or pivoting away from the fixed weight-bearing surgical lower extremity. Patients often inquire as to a timeline for driving. If the left knee is reconstructed, driving can occur after the first week. If the right knee is reconstructed, patients can begin driving around 7 to 8 weeks postoperatively, when specified impairments have resolved enough to allow them to exhibit a normal gait pattern. The patient should be comfortable with brief, rapid, lower extremity movements to negotiate braking.

After reviewing the initial restrictions with the patient, the rehabilitation focus should center on edema control, gentle range of motion, and quadriceps activation. Edema control can be addressed through cryotherapy, compression, elevation, and skeletal muscular pumping, repetitive ankle dorsiflexion, and plantar flexion. The patient remains with the knee in full extension for the initial 1 to 2 weeks. This is to allow for the proliferation of fibroblasts and the formation of collagen and ground substance (fibroplasia), which will result in the formation of granulation tissue. Patients can then progress with protective motion to stimulate collagen formation and alignment. Range of motion begins with the patient passively or actively assisting the motion of flexion and extension at the knee. Patellofemoral mobilizations in all directions are important for prevention of arthrofibrosis and to maximize range-of-motion gains in the initial phases of rehabilitation. Excessive hyperextension should be avoided to prevent excessive posterior stress at the knee. Consulting with the treating physician as to optimal extension goals to be achieved is recommended. After 105° of knee flexion is achieved, stationary cycling can be used. Initially, the bicycle is to be used to obtain fluid motion using a low constant resistance. Cycling cleats are not allowed. Patients begin with 5-minute sessions and slowly work up to 20 minutes a day. Significant soreness or effusion is an indicator to reduce the duration and/or frequency.

Early quadriceps activation can be achieved with isometric exercises. Electromyographic biofeedback, neuro-muscular electrical stimulation, taping, or other techniques may be utilized to increase quadriceps recruitment. Our clinic has found the best success in facilitating quadriceps activation through the use of electromyographic biofeedback. Patients should strive to perform up to 30 repetitions of quadriceps sets, 5 to 6 times a day, as symptoms allow. To ensure quality of exercise, not quantity of exercise, patients should be encouraged to work to the point of muscle fatigue by holding the quadriceps contraction for 8 to 10 seconds with each repetition, with full relaxation of the limb for 2 to 3 seconds between repetitions. SLRs may also be performed with a goal to achieve similar values of repetitions and frequency as the quadriceps-setting exercise. SLRs are to be completed in the knee immobilizer until a SLR can be performed with the absence of knee extension lag. It is crucial to regain quadriceps function early in the rehabilitation process. Core (lumbopelvic and hip) strengthening, such as abdominal and gluteal setting exercises, can begin immediately and progress as strength allows and should be performed while wearing the extension splint. SLR exercises in sidelying and prone can begin initially at patient tolerance and are performed while in the knee immobilizer.

Patients should wear a knee immobilizer at all times during the initial 6 weeks. Exceptions include when performing range-of-motion exercises and quadriceps isometrics with the knee in extension. The patient can typically begin gentle active, active-assisted, and/or passive range-of-motion exercises at the end of the first or second postoperative week. Goals should be set at achieving 0° to 90° of flexion by 2 weeks and full range of motion by 6 weeks. Full extension on a mat/floor is permitted, but stretching into hyperextension should be avoided.

At the completion of the sixth week postoperatively, the patient will typically follow up with the physician. Reevaluation of the knee’s structural integrity will occur via clinical examination, and the weight-bearing restriction will be lifted if appropriate. Criteria for progression to phase 2 or the weight-bearing phase are based on allograft healing timelines. The early phase of graft healing is from 0 to 4 weeks postoperatively and is marked by increasing necrosis, with decreasing mechanical strength of the graft, until the sixth week postoperatively. Therefore, weight bearing is restricted during this time. The proliferative phase of graft healing is from week 4 to week 12, when cell numbers increase and revascularization occurs. Therefore, in function, of
the strength deficits present in most patients following PLC surgery, full-bodyweight squats are typically instituted at the 12-week mark. Resisted hamstring activity and closed kinetic chain exercises at depths greater than 70° of knee flexion are restricted until the fourth month postoperatively, because of the possible continued graft vulnerability to stretching with these activities. The ligamentization phase of graft healing occurs from approximately 12 weeks to 12+ months postoperatively and involves graft remodeling toward restoration of the physiological and mechanical properties of the native graft. However, at this point, the later phases are guided more by objective strength and proprioceptive measures than graft healing timelines.

At 6 weeks postoperatively, patients may progress to phase 2 of rehabilitation, if they have no signs of effusion, can demonstrate a supine SLR without a knee extension lag, exhibit 0° of knee extension, and have greater than 120° of knee flexion. Therapists will assist the patient with a weight-bearing progression and crutch weaning. Weight-shifting exercises in sitting or standing with upper extremity support are advisable in the early stages of weight bearing. Dependence on upper extremity support is reduced until the patient is ultimately able to balance independently on the surgical limb and ambulate with an even stride length and symmetrical stance time. Crutch weaning is best performed over a 2-week time frame for a gradual return to full weight bearing. A scale may be used as a biofeedback tool to monitor actual weight-bearing forces through the surgical extremity as the patient progresses toward full-bodyweight acceptance. This will allow time for the patient to build confidence and stability on the surgical limb. The patient should be able to ambulate without a limp prior to discontinuing crutch use. A fluid gait pattern is first established using 2 crutches and subsequently reduced to 1 crutch. This will further progress to utilization of crutches solely for community mobility. By the end of the second week of allowed weight bearing (eighth week postoperatively), the patient should be able to discontinue crutch usage. Normalization of gait and confidence on the lower extremity should be the focus. Particular focus should be placed on the loading and midstance phase of gait to ensure a return to normal kinematics and kinetics of the lower extremity. A primary goal is to abolish the varus thrust pattern often observed presurgically. Quadriceps activation for deceleration of body mass during the loading phase of gait and control of limb position throughout the stance phase are critical. Electromyographic biofeedback of the quadriceps muscle group during gait simulation drills or actual gait training can be a useful tool for restoring a normal pattern of muscle activation. Video-based gait analysis is also a useful tool for restoring normal gait mechanics. Eccentric hamstring control during midstance and terminal stance is important to avoid an uncontrolled thrust into hyperextension. Thus, it is important that hamstring strengthening with the knee extended (to protect the allografts from unwanted posteriorly directed forces) be initiated in the early phases of rehabilitation with mat-based exercises (FIGURE 10) and progressed to weight-bearing exercises and varying angles of knee flexion in the later phases of rehabilitation (FIGURE 11).

Balance exercises should start during week 7. Higher-level balance activities should include patients demonstrating an ability to control for varus and valgus forces of the lower extremity. This might involve manual perturbation or simply maintaining balance on varying surfaces with a taught resistive band placed medially or laterally above the knee. Also during this time, weight-bearing and low-impact closed kinetic chain exercises with the knee in less than 70° of flexion can be added. This includes using a leg press with up to 25% of the patient’s body weight, with emphasis on eccentric quadriceps strengthening for muscular endurance initially, with progression to concentric strengthening for muscular strength and power. Repetitions should be performed until fatigue and terminated if symptoms arise. Closed kinetic chain exercises should be progressed from double-limb support to single-limb support per the patient’s strength and alignment control. Static holds in a squat or lunge position may be useful if the patient exhibits symptoms or a lack of control with dynamic exercises. As with any phase of the rehabilitation following PLC reconstruction, progression should not only be based on strength and control but also symptom tolerance, as evident through pain and effusion.

It is important to keep the leg press from exceeding a maximum of 70° of knee flexion. Flexion beyond this depth is thought to increase the stress on the posterior healing repair or reconstruction procedure. This stress is a result of the cam effect of the posterior aspect of the femoral condyles on the posterior aspect...
of the knee. Swimming can begin at 8 weeks. Although a flutter kick is technically an open kinetic chain hamstring activity, the majority of the motion is at the hip, with very little knee flexion. Therefore, theoretically, the hamstrings do not apply much force on the graft, so there is little concern of stretching out the graft with this activity at this time point. Patients are to avoid breast and side stroke techniques, along with any whip kick motions in the pool. Finally, isolated open chain hamstring exercises should be avoided over the initial 4 months postoperatively. The rationale here is to avoid potential deleterious effects of hamstring contraction on the PLC reconstruction.

Closed kinetic chain hamstring strengthening is allowed due to cocontraction of the quadriceps muscles to counteract the posterior translation of the tibia by the hamstrings. A clear understanding of the expectations and restrictions by both the physical therapist and patient will establish the foundation to a successful surgical outcome.

At 3 months postoperatively, patients will typically follow up with the physician for further clinical examination and clearance for further activities, if the patient has evidence of adequate joint stability per the clinical examination, exhibits a normal gait pattern, and has minimal to no effusion at rest and following activity. For therapy, patients can begin using a squat rack with 50% body weight, while continuing to maintain depth above 70° of knee flexion. Patients can progress to full body weight over the course of the next 3 weeks. Clearance is typically provided at 4 months for patients to squat with increased depth (>70° of knee flexion).

At the 4-month period, patients can begin a daily walking program at a brisk pace. Criteria for progressing to a daily walking program include adequate lower extremity knee range for normal gait kinematics, being able to demonstrate a normal gait pattern, and the absence of increased joint effusion with prolonged walking. Walking should start at no more than 20 minutes and increase 5 minutes per week. The surgeon may give clearance for jogging/running and initiation of plyometric exercises after that point as strength allows. One of the criteria for clearance to initiate plyometric exercises and jogging is that patients need to be able to ambulate pain free 3 to 5 km, with bouts of brisk walking and navigating uneven terrain. Patients also need to demonstrate proper mechanics and control with single-limb squattting to at least 60° of knee flexion for 20 repetitions.

Also at 4 months, stationary cycling can be performed with increased resistance. The goal is to feel fatigue in the thighs following 20 minutes of bicycling. This can be done up to 3 to 5 times per week. Forward, lateral, and retro step-ups at greater than 70° of knee flexion can be initiated at 4 months. Here, the patient begins with the surgical lower extremity on the step and, using the surgical limb, extends the lower extremity to ascend the step. Step height and repetitions are increased in 5-cm increments as tolerated. A lunge progression at greater than 70° of knee flexion can begin after 4 months. Depth and plane of movement can vary, based on exercise control and symptomology. Lunging repetitions will move from stationary to walking and can be done while performing diagonal (chopping) movements. Lightweight or medicine balls can be held to increase difficulty. This chopping motion should occur both towards and away from the lead lower extremity. Emphasis will be on controlling varus stresses due to the nature of the injured structures. A chopping pattern directed medially away from the lead limb will promote varus control (FIGURE 12).

Functional Testing/Return to Play

The patient will follow up with the physician at 5 to 6 months postoperatively for further evaluation and varus stress radiographs. Functional testing is performed between 5 and 7 months postoperatively. This consists of KT-1000 arthrometer testing (with concomitant ACL injury), isokinetic testing, and sports simulation activities. With the patient positioned supine and the knee flexed from 20° to 35°, KT-1000 arthrometer values are taken at 10, 20, and 30 lb of force, directed anteriorly, and a manual maximum value. Testing with a posterior force of 20 lb is also performed. Isokinetic testing is performed using 3 different speeds: 120°/s, 180°/s, and 240°/s. The concentric/concentric setting is used. Sports simulation testing consists of squat and anterolateral and anteromedial reaches, single-limb stance with eyes closed, single-limb squat for depth, retro step-up for height, single-limb hop for distance, timed hop, and crossover triple hop for distance. The objective test values along with clinical observation during the testing aid to assist with return-to-play and -sport decisions. Athletes are allowed to return to an interval sport program if limb symmetry indices of greater than
85% for both isokinetic and sport simulation/functional testing are achieved. The athlete’s jumping and landing techniques during functional testing should be closely monitored. If the athlete exhibits tendencies to land on an extended knee with either a varus or valgus angulation, the athlete should go through training sessions to correct this technique.\textsuperscript{14,27,51,52,63} In addition, the athlete’s lumbopelvic and lower extremity strength should be retested with manual muscle testing to determine if the faulty jump/landing mechanics observed are more a result of muscular weakness or motor planning/neuromuscular control. Varus and posterior (for concurrent PCL reconstruction) knee stress radiographs will confirm reconstruction stability and confirm if it is safe to proceed with advanced activities.\textsuperscript{31} Physician clearance is required before cutting, pivoting, or hopping activities are performed both in and out of clinic. Before resumption of practice or return to play, we recommend supervised training of cutting and pivoting drills with verbal\textsuperscript{52} and video\textsuperscript{63} feedback from the physical therapist or athletic trainer. Observations made during in-clinic visits and functional testing regarding the patient’s return to normal anthropometric measurements and physical performance factors will help guide the therapist regarding the timing of patient discharge from formal physical therapy to a self-directed exercise program. Patients should be aware that it may take up to 2 years to recover from an injury and surgical reconstruction of the PLC, especially with a concurrent cruciate ligament reconstruction, or for patients who required a staged reconstruction after an osteotomy. Therefore, it is important to instruct patients on the importance of continued compliance with their home exercise program and/or independent strengthening program after formal physical therapy has ceased. Athletes receiving clearance for participation in sport and competition should continue to maintain a home exercise program established by a physical therapist. This program will vary with the individual’s activities and goals. This is in addition to any practice and team weight-training session. Finally, use of a medial unloader brace/varus-valgus-producing brace may be warranted during sport for proprioceptive input and to decrease varus stresses to facilitate normal mechanics with running, cutting, and pivoting activities, especially in patients with a revision PLC reconstruction and/or a high body mass index.

**CONCLUSION**

Clinically, injuries to the PLC or “dark side” of the knee are becoming more recognized. Undiagnosed PLC injuries may lead to poor outcomes or failures of cruciate reconstructions, chronic instability with resulting early onset osteoarthritis, and chronic pain. More recently, our understanding of the anatomy, biomechanics, diagnosis, and management of PLC injuries has increased. The intent of this paper is to provide therapists with a better understanding of the injury, the components of the PLC, surgical reconstruction, and a suggested treatment approach.*

### REFERENCES


CLINICAL COMMENTARY


46. LaPrade RF, Wentorf F. Diagnosis and treatment of posterolateral knee injuries. Clin Orth Relat Res. 2002;210-211.


APPENDIX

PROTOCOL FOR REHABILITATION OF A POSTEROLATERAL KNEE RECONSTRUCTION

Procedure

The popliteus tendon, the popliteofibular ligament, and fibular collateral ligament are reconstructed.

This protocol can be combined with cruciate reconstruction protocols adhering to all restrictions for each protocol.

Postoperative Restrictions

1. Patient remains in the knee immobilizer in full-knee extension at all times during the first 6 weeks postoperatively other than when working on knee range of motion (ROM) or performing quadriceps exercises.
2. Patient remains non-weight bearing for 6 weeks.
3. Patient to avoid tibial external rotation, and external rotation of the foot/ankle, especially in sitting for the first 4 months postoperatively.
4. Patient avoids open-chain hamstring exercises until 4 months postoperatively.

Postoperative Red Flags

Signs and symptoms of infection (excessive swelling, body temperature [fever] greater than 101°, increasing redness around the surgical incisions) calf swelling or tenderness, lack of full knee extension, complaints of knee instability, complaints of catching or locking, and increased effusion following activity/therapy.

Phase 1

Weeks 1-2
1. Edema management: ice, compression, elevation.
2. Quadriceps sets and straight leg raises (SLRs) performed in the knee immobilizer. Quadriceps sets can be performed hourly up to 30 repetitions and SLR up to 30 repetitions 4 to 5 times per day.
3. Four times a day gentle passive and active assisted ROM exercises. Goal is 90° of knee flexion by the end of 2 weeks, and 0° of knee extension.
4. Core (lumbo pelvic and hip) stabilization exercises in knee immobilizer that do not increase knee forces in varus, hyperextension, or tibial external rotation.

Weeks 3-6
1. Continue with passive and active assisted ROM exercises 4 to 6 times per day. Patient should achieve full extension at this time, and 120° of flexion.
2. Continue with quadriceps sets and SLRs.

Phase 2

Weeks 7-12
1. Start partial weight bearing using crutches. Goal is to ambulate full weight bearing without crutches within 2 weeks. Patient must be walking without a limp to discharge crutches. Discontinue knee immobilizer if able to perform SLR without a knee extension lag.
2. Initiate use of stationary exercise bike if 105° of knee flexion ROM is achieved. Working on motion, beginning with 5 minutes every other day and increasing to 20 minutes daily, based on the knee's response to increased activity. If soreness or effusion is evident reduce time or days utilizing the bike.

Weeks 13-16

At this time the patient should have a normal gait pattern, without the presence of a limp or Trendelenburg sign.

1. Leg press up to 25% of the patient’s body weight to fatigue. Knee flexion allowed to a maximum of 70°.
3. Closed kinetic chain exercise progression: double-limb squating, lunges, single-limb squatting, etc. All exercises performed with less than 70° of knee flexion.
4. Daily biking or swimming, if swimming, no whipkicks or flip turns.

Phase 3

Months 4-6 (Weeks 16-24)

Physical therapy goals: improve quadriceps strength and function, increase endurance, improve coordination, improve proprioception.
1. Walking program: 20 to 30 minutes daily with a medium to brisk pace. Add 5 minutes per week.
2. Resistance can be added to bicycling as tolerated. Biking done 3 to 5 times per week for 20 minutes, and the lower extremities should feel fatigued post biking.
3. Advanced closed kinetic chain exercise progression: addition of unstable surface, movement patterns, resistance, etc.
4. Return to run program once patient is able to perform 20 repetitions of involved lower extremity single-limb squatting to greater than 60° of knee flexion with good control.
5. Plyometric progression: supported jumping, jumping, leaping, hopping, etc.

Month 7 and Beyond (Week 28)

Goals: achieve maximum strength of operative extremity.
1. Maintenance of home exercise program 3 to 5 times per week.
2. Return to sport simulation activities as appropriate. Physician clearance is based on favorable outcomes with imaging studies, clinical exam findings, and functional progression with therapy. The coordination of care between the surgeon and physical therapy staff is critical for a complete assessment of patient function and a complete recovery from the surgery.
3. Functional testing often performed at this time. A progressive return-to-play program is initiated if the limb symmetry index is greater than 85% with functional testing and satisfactory varus stress radiographs.

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516 | AUGUST 2010 | VOLUME 40 | NUMBER 8 | JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY
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