17 Surgical Treatment of Combined PCL Medial and Lateral Side Injuries: Acute and Chronic

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17.1 Classification

The Schenk anatomic classification (Table 17.1) [1] is widely accepted and is based on the ligaments and structures injured rather than the direction of the dislocation. For example, a KD I injury describes a knee dislocation in which one or both of the cruciate ligaments are intact, and where collateral ligament injuries have variable degrees of injury. A knee dislocation that has an intact ACL with injury to the PCL, medial, and lateral corners can be classified as a KD I injury, but in our experience, these types of dislocations are quite rare compared to KD III injuries.

17.2 Mechanism of Injury

Multiple knee ligament injuries can result from various types of injuries, but the vast majority result from high-energy trauma such as motor vehicle accidents (52%) [2]. Other high energy causes include motorcycle collisions (17%) and motor vehicle versus pedestrian accidents (16%). However, low energy sports injuries can also result in knee dislocations, with mechanisms typically involving hyperextension of the knee. Football and equestrian injuries are the two most common causes of low energy knee dislocations [2].

17.3 Initial Evaluation

Since the majority of knee dislocations are the result of high-energy trauma, patients often present with multiple injuries that may be life-threatening and frequently involve the ipsilateral extremity. Because of the possibility of other distracting injuries, the diagnosis of a spontaneously reduced knee dislocation in the emergency room is difficult. If the knee remains dislocated, a closed reduction under complete sedation should be performed as soon as the patient's condition allows. Typically, gentle longitudinal traction is sufficient for reduction. However, occasionally, soft tissue interposition can prevent complete reduction. If this is the case, the patient should be taken to the operating room and an open reduction must be performed. Following reduction, a complete neurovascular examination is the single most important step to perform. Postreduction, the knee should be immobilized in slight flexion in a knee immobilizer, splint, or hinged knee brace. If the knee will not stay reduced, is an open KD, or has a significant vascular injury, a spanning external fixator should be applied.

An open knee dislocation should be suspected when there is an open wound around the knee. The most common location of the open wound is in the popliteal fossa. Open knee dislocations should undergo a debridement and irrigation in the operating room as soon as the patient's condition permits. In most cases, a spanning external fixator should be used to stabilize, temporize, and stage the knee, until soft tissues allow for definitive repair.

It is important to document the pulses of both the involved and uninvolved extremities to evaluate for any arterial injury. Pedal pulses at both the dorsalis pedis and posterior tibial arteries are examined and must be compared to the contralateral side. Subtle signs such as skin temperature, color, and capillary refill are also noted but not nearly as important as the pulses. Following reduction, the neurovascular structures should be reassessed and documented thoroughly. All patients with a knee dislocation should be admitted for careful observation and have serial neurovascular examinations for at least 48 h. The pedal pulse should be checked and compared to the contralateral side before and after reduction, between 4 and 6 h, at 24 h, and at 48 h following reduction [2, 3]. If there is any decrease in the pulse, or if the pulse is absent, emergent angiography should

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Table 17.1 Schenk anatomic knee dislocation classification

KD I	One cruciate ligament torn with one or both collaterals torn
KD II	Both ACL and PCL torn; collateral ligaments intact (rare)
KD III-M	ACL, PCL, and MCL torn
KD III-L	ACL, PCL, and LCL torn
KD IV	ACL, PCL, MCL and LCL torn
KD V	Fracture—dislocation
C (added to above)	Associated arterial injury
N (added to above	Associate nerve injury

This is a widely accepted classification based on the ligaments and structures injured rather than the direction of the dislocation

be performed, and vascular surgery should be consulted. This "selective arteriography" protocol has been proven reliable and safe for the diagnosis of popliteal artery injuries [2]. A complete neurologic exam is also performed with the focus on the common peroneal nerve due to the high frequency of injury.

A ligament exam is often difficult in the acute setting due to pain, swelling, and distracting ipsilateral extremity injuries. Accurate diagnosis of instability patterns becomes crucial later in order to allow definitive ligament repair or reconstruction, and should be established with a careful examination under anesthesia (Table 17.2). Careful documentation of the ligament examination findings at the end of operative fixation of ipsilateral fractures (e.g., tibial plateau, distal femur, and acetabulum) is also very important for future ligament reconstructions.

17.4 Imaging Studies

Anteroposterior and lateral radiographs of the knee are obtained before and after reduction in order to assess the direction of dislocation, concomitant periarticular fractures,

Table 17.2 Special tests for examination of ligamentous structures of the knee

Ligament	Diagnostic tests	Positive finding: interpretation
MCL and PMC	Valgus stress at 30° and 0° flexion	Medial joint opening Positive only at 30°: isolated MCL injury Positive at both 30° and 0°: MCL + PMC + cruciate injury
	Tibial external rotation at 90° flexion	Anterior subluxation of the medial tibial plateau from under the femoral condyle MCL + PMC injury
FCL and PLC	Varus stress at 30° and 0° flexion	Lateral joint opening Positive only at 30°: isolated FCL injury Positive at both 30° and 0°: FCL + PLC + cruciate injury
	Dial test at 30° and 90° flexion	External rotation increase >10° compared to normal side Positive only at 30°: FCL + PLC injury Positive at both 30° and 90°: FCL + PLC + cruciate injury
	External rotation recurvatum test	Knee recurvatum and varus + tibial external rotation FCL + PLC injury
ACL	Lachman test	Anterior subluxation of tibia at 30° flexion ACL injury
	Anterior drawer	Anterior subluxation of tibia at 90° flexion ACL injury
	Pivot-shift test	Sudden reduction of anteriorly subluxated tibia at 20°–40° flexion Small subluxation: ACL injury Greater subluxation: ACL + PLC injury
PCL	Posterior drawer test	Posterior subluxation of tibia at 90° flexion PCL injury
	Quadriceps active test/posterior sag sign	Anterior movement of posteriorly subluxated tibia with active quadriceps contraction at 90° flexion PCL injury

MCL medial collateral ligament, *PMC* posteromedial corner, *FCL* fibular collateral ligament, *PLC* posterolateral corner, *ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament foreign bodies, avulsion fractures, malalignment of the knee, and joint incongruity. A quick stress view radiograph at the end of an ipsilateral fracture fixation is very helpful in determining future ligament injury management. It is important to obtain an MRI of the knee before the application of any metal hardware when there is high suspicion of a knee dislocation. An MRI is an important roadmap to the assessment of a ligamentous injury pattern, particularly when there are ipsilateral extremity injuries. MRI is also useful for assessing meniscal injuries, osteochondral lesions, and occult tibial plateau fractures. However, examination under anesthesia remains the gold standard for the ultimate diagnosis of the ligament injury pattern, which determines the final treatment strategy.

17.5 Surgical Indications and Timing

The vast majority of patients who have sustained knee dislocations should undergo surgical reconstruction, which allows early mobilization of the knee. With the exception of patients who are extremely sedentary, uncooperative, or critically ill with chronic medical conditions, ligament reconstruction with early mobilization benefits nearly all patients following knee dislocations. The results of nonoperative treatment (e.g., cast, knee brace, and external fixation) in the patients who were poor candidates for reconstructive surgery are invariably poor with residual instability and stiffness. External fixation should be used as a temporary treatment prior to reconstruction in patients with open knee dislocations, severe soft tissue injuries, grossly unstable dislocations, and initial vascular surgery due to a popliteal artery injury. If it is inevitable to use external fixation as a definitive immobilization method, the external fixator is maintained for 6–8 weeks, and manipulation under anesthesia or arthroscopic lysis can be attempted to regain the knee motion afterward.

Definitive surgical treatment is typically performed within 4 weeks following the injury. If there are associated fractures, these are fixed surgically within the first week. Ligament reconstruction is typically performed between 2 and 4 weeks following the initial injury. This is to allow enough soft tissue recovery and to restore the watertight joint capsule for arthroscopic reconstruction procedures. For knee dislocations with posterior cruciate ligament (PCL), posterolateral corner (PLC), and posteromedial corner (PMC) injuries, the injured ligament structures can be reconstructed all at once. If there is an associated tibial plateau fracture, the surgical timing is changed. Fixation of the plateau fracture is performed within the first week, and this is followed by reconstruction of the PCL and PMC along with the application of a Compass Knee Hinge external fixator (Smith & Nephew, Memphis, TN, USA) for 2–4 weeks after the initial trauma. Finally, reconstruction of the PLC is performed 3–4 months later. The reason for delaying the PLC reconstruction in the presence of a tibial plateau fracture is that the tibial bone tunnel for fixation of the PLC graft inevitably passes through the fractured plateau, which was found to be a cause of reconstruction failure. A period of 3–4 months is usually required for fracture healing before drilling the tibial tunnel.

17.6 Surgical Technique

Reconstruction is preferred over repair in the majority of patients with knee dislocation. This is based on our previous study findings that reconstructions have a significantly lower failure rate than repairs of the PLC. The only exception to this would be a dislocation with a large avulsion fracture, which can be repaired with open reduction and internal fixation (ORIF) of the bony fragment. Similar data have been published regarding the reconstruction of the PMC in patients with knee dislocations. For dislocations with combined injuries to the PCL and both corners, the reconstruction procedure should start with the PCL followed by the reconstruction of the PMC and PLC. The final tensioning and fixation of the PCL graft is delayed, until after the grafts of both of the corners are in place.

The PCL is composed of two bundles, the larger anterolateral bundle and the smaller posteromedial bundle. One cause of PCL failure is the “killer turn,” which is the sharp angle that is created by a transtibial approach that exits too proximally near the articular surface. The PCL inlay technique was developed to resolve this, by placing a bone block on the posterior aspect of the tibia which decreases the killer turn. A new technique using a transtibial approach that exits the back of the tibia more distally in the same location as the bone block on the inlay technique also eliminates the killer turn. This technique combines the aspects of both inlay and transtibial PCL reconstruction with a more distal insertion point on the tibia to replicate the anatomy of the PCL (Fig. 17.1).

In the past, I have used screws and washers for graft fixation. I have however converted to the use of suspensory fixation, which allows repetitive tensioning after stressing and ranging the knee intraoperatively. Furthermore, all creep can be removed from the grafts, fixation is not dependent on the quality of the cancellous bone of the patient, and there is less hardware prominence compared to the screws that have required removal in the past. The final benefit is that each graft can be tensioned when it is placed, and then tensioned again as additional grafts are placed completing the reconstruction.

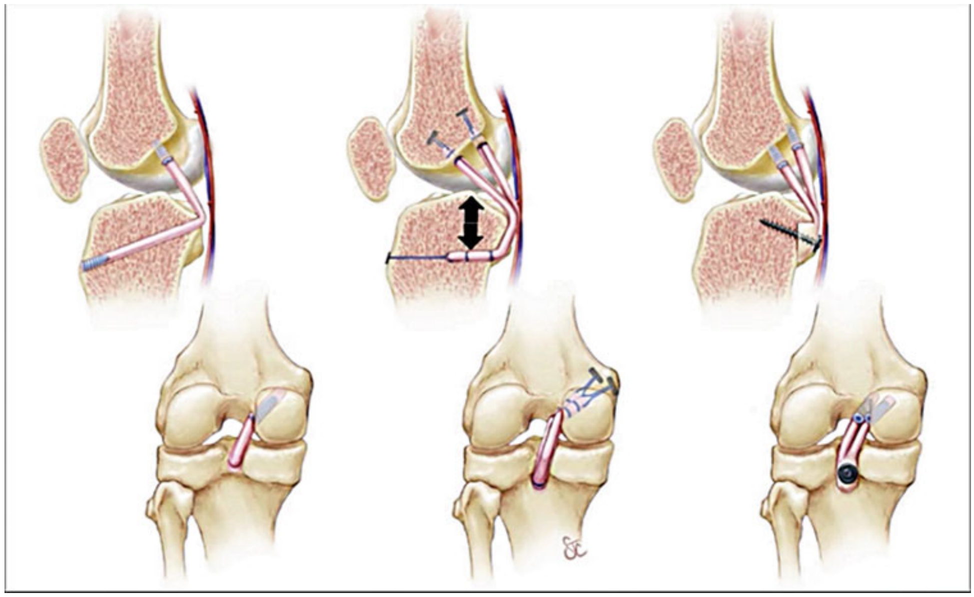


Fig. 17.1 PCL reconstruction techniques. The traditional PCL reconstruction is shown on the left and also demonstrates the "killer turn" and sharp angle associated with PCL reconstruction failure. The center images demonstrate the new PCL reconstruction with suspensory fixation. The images on the right show the PCL inlay technique. ©2018 The Curators of the University of Missouri, reprinted with permission

17.6.1 PCL: Anatomic Posterior Cruciate Ligament Reconstruction with Suspensory Fixation of a Double-Bundle Achilles Tendon Allograft

17.6.1.1 Examination Under Anesthesia and Diagnostic Arthroscopy

The "gold standard" for determining the extent of an injury in a knee dislocation patient is a thorough examination under anesthesia. The instability pattern is reassessed and compared to the preoperative diagnosis. It is important to compare the affected extremity to the contralateral extremity because of the variability of normal laxity among individuals. This is followed by a diagnostic arthroscopy to confirm the diagnosis. The patient is placed supine on the operating table so that the operative leg can hang off the side of the table during the arthroscopic portion of the procedure. A simple lateral post without a circumferential leg holder is positioned at the level of the tourniquet to facilitate intraoperative valgus stress (Fig. 17.2). A #11 blade is used to make an anterolateral portal and an 18-gauge needle is used for localization followed by a #11 blade to make an anteromedial portal under direct visualization. Arthroscopic evaluation of the knee should view the suprapatellar pouch, medial gutter, and lateral gutter, followed by the patellofemoral joint, the medial compartment, notch, and the lateral compartment. The articular surfaces are checked in addition to the menisci, and the ACL and PCL are visualized in the notch. Any meniscal or chondral injuries are addressed. Easy widening of a compartment confirms an injury to the corner on that side. The torn PCL or remnant is debrided in the notch using an aggressive shaver. Care should be taken to note the natural attachment of the PCL on the femur.

17.6.1.2 Preparation of Allograft for PCL Suspensory Technique

A graft is prepared using an Achilles tendon allograft. The tendon portion of the graft is split into two bundles using a #10 blade. One bundle is approximately 60% of the width of the tendon for the lateral side and the other is 40% for the medial side. This normally creates a larger anterolateral bundle and a smaller posteromedial bundle. It must be ensured that the larger AL bundle is made on the lateral

Fig. 17.2 Basic set up for multi-ligament reconstruction knee surgery. The patient is placed in supine position and the operating table is left flat so that the operative leg can hang off the side of the table. A pneumatic tourniquet is applied to the upper thigh but not inflated until the latter part of the procedure. A simple lateral leg post without a circumferential leg holder is positioned at the level of the tourniquet

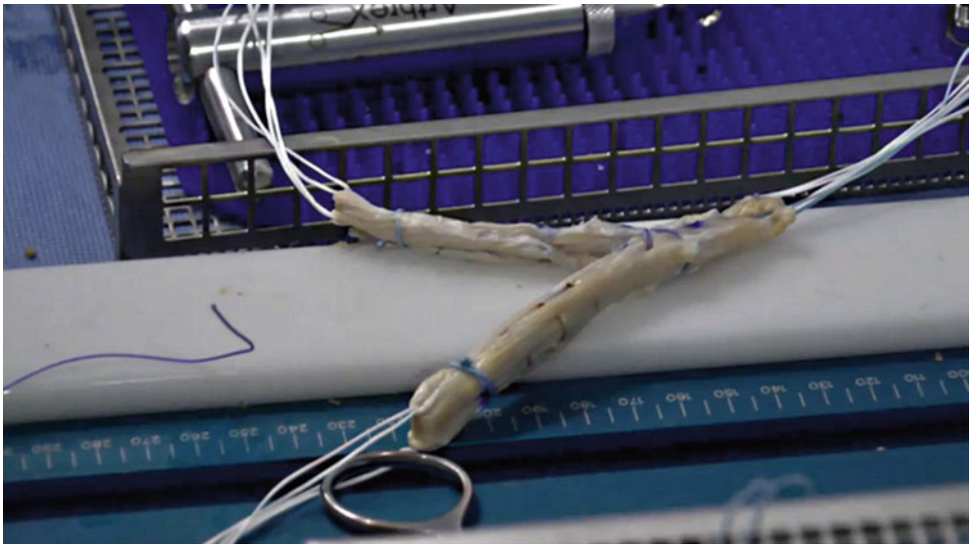


Fig. 17.3 Preparation of the Achilles tendon allograft. The tendon portion of the graft is split into two bundles using a #10 blade. One bundle is approximately 60% of the width of the tendon for the lateral side and the other is 40% for the medial side. The limbs are measured and prepared with locking Krakow stitches with #2 Fiberwire and then attached to Fiberlink buttons. Two different colored sutures are used for accurate and quick identification of the AL and PM bundles. The common bundle that goes into the tibia is usually 12 mm and the sizes for the limbs are a 10.5 mm size for the anterolateral bundle and 7.5 mm size for the posteromedial bundle

aspect of the graft. The graft is trimmed in line with the fibers. The limbs are measured and prepared with locking Krakow stitches with #2 Fiberwire. Two different colored sutures are used for accurate and quick identification of the AL and PM bundles. The common bundle that goes into the tibia is usually 12 mm and the sizes for the limbs are a 10.5 mm size for the anterolateral bundle and 7.5 mm size for the posteromedial bundle (Fig. 17.3).

17.6.1.3 PCL with Suspensory Fixation

A bump is then placed under the knee, and the leg hangs off the side of the table with the knee flexed to approximately 90°. The anterolateral bundle is addressed first. This is created by placing the PCL guide (Arthrex, Inc. Naples, FL, USA) through the anteromedial portal proximally in the notch and 10 mm posterior to the articular cartilage. It is usually located at an 11 o'clock position of a left knee and a 1 o'clock position of a right knee (Fig. 17.4). An incision is made through the skin of the superomedial aspect of the knee, and a Kelly clamp is used to spread the soft tissues. A flip cutter is drilled across the medial femoral condyle in the desired position. The guide is tamped in and the rubber grommet is placed down the guide for measurement. The flip cutter is flipped and a socket is reamed to a depth of

(a) (b)

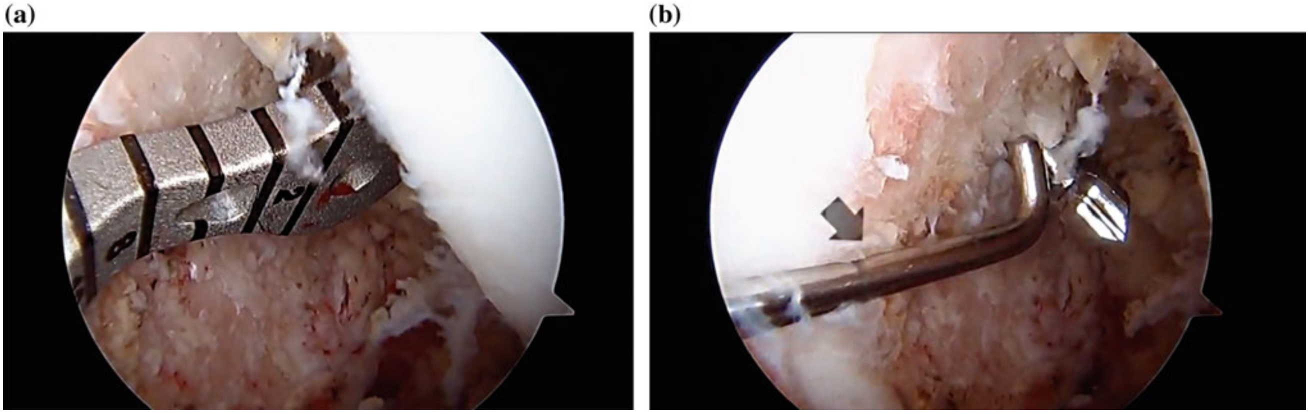


Fig. 17.4 Positioning of the PCL guide for the anterolateral bundle of the PCL. **a** The guide is placed as proximal as possible in the notch and 10 mm posterior to the articular cartilage. It is usually located at an 11 o'clock position of a left knee and 1 o'clock position of a right knee. The flip cutter is drilled into the knee and the position is checked. **b**. If the position is acceptable, the flip cutter is flipped and a socket of about 25 mm is drilled

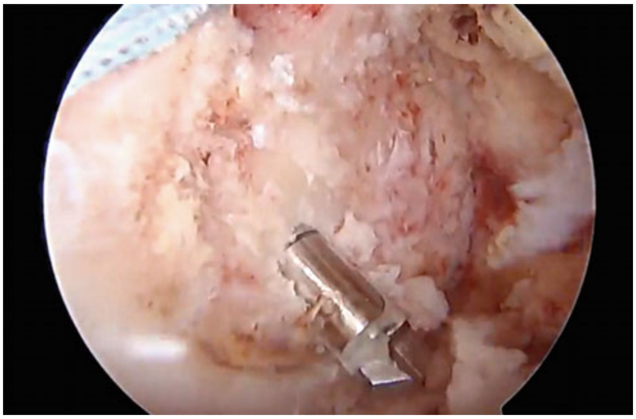


Fig. 17.5 Drilling the posteromedial bundle of the PCL. The posteromedial bundle is drilled just inferior to the tunnel for the anterolateral bundle (above the flip cutter in the picture) and is approximately 8 mm posterior to the articular surface

approximately 25 mm. The flip cutter is then returned to the notch, flipped, and removed. A fiber stick is then placed into the knee and grasped with a looped grasper out the lateral portal and clamped to itself.

The posteromedial bundle is created by placing the guide immediately below the anterolateral bundle, which is usually about 8 mm from the articular cartilage (Fig. 17.5). The tunnels shoulder be slightly divergent. Similarly, the flip cutter is used to create a socket of approximately 25 mm. A fiber stick is then passed and pulled out the medial portal. The socket technique spares bone and allows for a less painful reconstruction (Fig. 17.6).

A posteromedial portal is established by using a spinal needle to localize the position under direct visualization. An incision is made for the portal on the posterior medial skin.

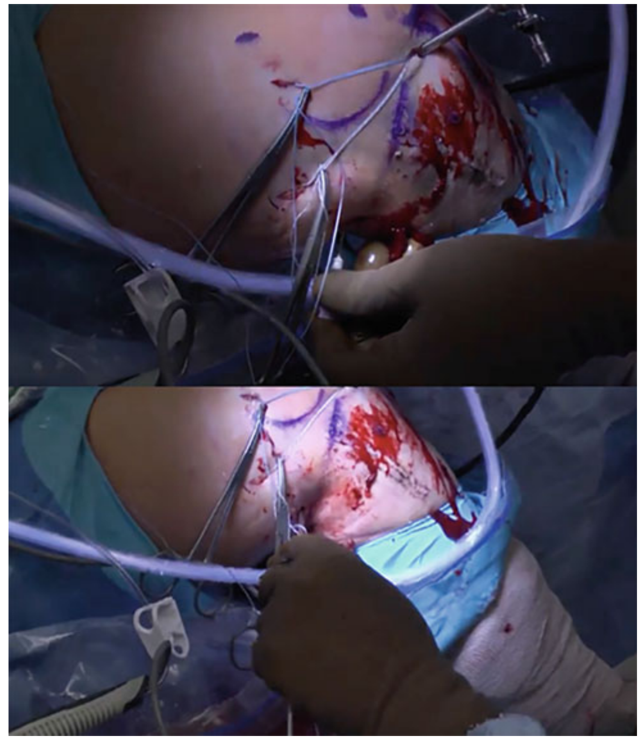


Fig. 17.7 Establishing the posteromedial portal to prepare the posterior aspect of the tibia. A spinal needle is used to find an appropriate position for the posteromedial portal under direct visualization. Once the preferred position is found, a skin incision is made and a switching stick is used to gain access to the joint. A dilator is then used followed by insertion of a cannula. This allows easier access for preparation of the posterior tibia

A switching stick is used to gain access to the posterior aspect of the knee, followed by a dilator and a cannula to use as a working portal for instrument use (Fig. 17.7). After the

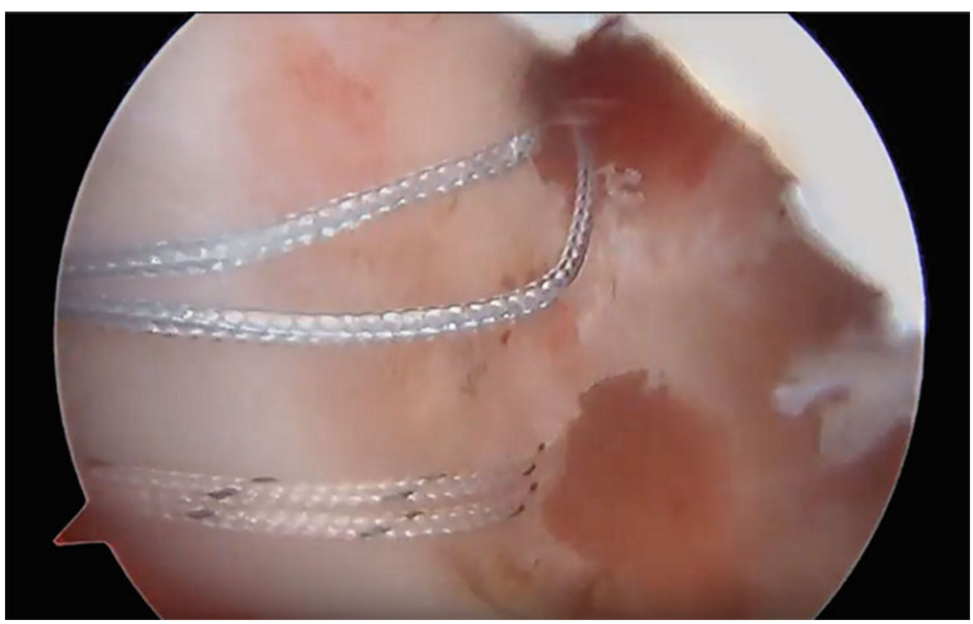


Fig. 17.6 The tunnels for the anterolateral and posteromedial bundles of the PCL in the femur. Once the tunnels are drilled, fiber stick sutures are shuttled through the tunnels and then attention is turned to preparation of the tibia

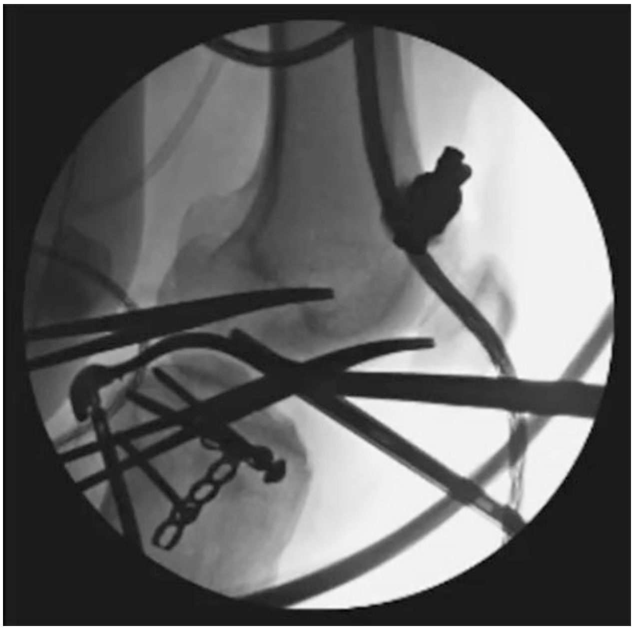


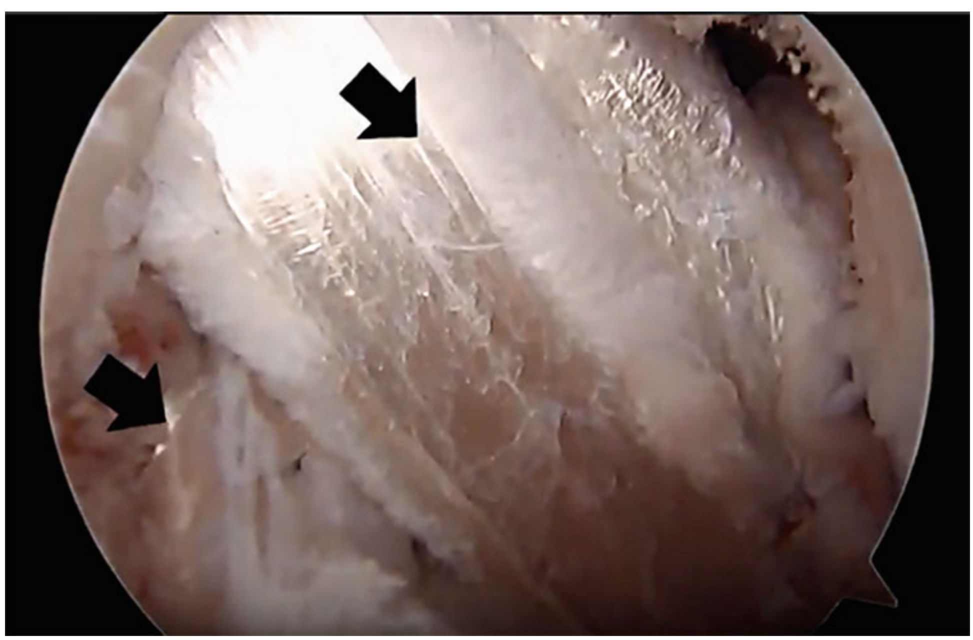
Fig. 17.8 Placing the PCL drill guide for the tibial tunnel. The arthroscopic PCL guide (Arthrex, Inc., Naples, FL) is placed into the knee and should sit in the back of the tibia. Intraoperative fluoroscopic images can be used to confirm this as shown. A 12-mm flip cutter is drilled across the knee, flipped, and a 50-mm deep socket is made. A fiber stick is passed through that socket and out through the medial portal coming through the notch to allow for passage of the graft

portal is established, a combination of a thermal tool and an aggressive shaver are used to debride the remnant of the PCL off the back of the tibia. This is safe as long as one stays on the bone, the blades face anteriorly, and tools do not drift posteriorly. A rasp and curette can also be used to help speed the process of debridement in the posterior aspect of the tibia. Once this is complete, the arthroscopic PCL guide (Arthrex, Inc., Naples, FL, USA) is placed into the anteromedial portal of the knee and should sit in the back of the tibia (Fig. 17.8). A 12-mm flip cutter is drilled across the knee, flipped, and a 50-mm deep socket is made. A shaver is used to debride away the excess bone. A fiber stick is passed through that socket and out through the medial portal coming through the notch. After using a looped grasper to make certain there were no soft tissue bridges, the PCL graft is pulled into the knee and into its tibial socket. The posterior medial bundle is pulled into its socket, the button is flipped, and the graft pulled approximately 15 mm deep. The same process is repeated to pull the anterolateral bundle into its socket. The tibial side is tensioned first in flexion. A removable button is pulled down to the tibia. The anterolateral bundle is tensioned in 90° of flexion. The posteromedial bundle is tensioned in about full extension. The knee is stressed and ranged and the grafts are all retightened again. The grafts are checked with a probe and grafts are again retightened. If the medial or lateral corners are also being reconstructed, these will be performed and the PCL bundles can be retightened again after the completion of those reconstructions (Fig. 17.9).

17.6.2 PCL: Anatomic Posterior Cruciate Ligament Reconstruction with a Double-Bundle Inlay Technique Using Achilles Tendon-Bone Allograft

A PCL inlay technique was developed to avoid the “killer turn” associated with conventional transtibial PCL

Fig. 17.9 Final intraoperative images of the larger anterolateral bundle (right arrow) and posteromedial bundle (left arrow)



reconstructions. Although technique modifications and fixation methods have led us to use a modified transtibial technique for most PCL reconstructions, the inlay technique will still be useful in cases where tunnel crowding is an issue (e.g., cases where the previous fixation of tibial plateau fractures has been performed).

17.6.2.1 Preparation of Allograft for PCL Inlay Technique

The graft is prepared as a double bundle using Achilles tendon allograft. The graft is split using a #10 blade, with about 60% for the lateral side and 40% for the medial side. The graft is trimmed in line with the fibers and tapered at the ends. The limbs are measured and prepared with locking Krakow stitches and with #2 Fiberwire. The sizes for the limbs are approximately 10.5 mm for the anterolateral bundle and 7.5 mm for the posteromedial bundle.

The bone block is then prepared. A proposed block is drawn with the marker on the graft and an oscillating saw is used to cut the excess bone. The graft should be no less than 15 mm long by 10 mm wide and 10 mm thick (Fig. 17.10). Care should be taken to ensure that the graft is 10 mm thick to minimize the risk of fracture of the bone block when the fixation screw is tightened. The edges are beveled with the oscillating saw. The bone block is drilled with a 4.5 mm drill bit in the center, which allows the 4.5 mm screw to function as a lag screw.

17.6.2.2 PCL Inlay Technique

After examination under anesthesia and diagnostic arthroscopy, the anterolateral and posteromedial tunnels are prepared in a manner similar to that described in the previous section for PCL reconstruction with suspensory fixation technique. The drill guide is placed as proximal as possible in the notch and 10 mm posterior to the articular cartilage. An incision is made through the skin and a Kelly clamp is used to spread the soft tissues. A flip cutter is drilled across the medial femoral condyle in the desired position. The guide is tamped in and the rubber grommet is placed down the guide for measurement. The flip cutter is flipped and a socket is reamed to a depth of 25 mm. The flip cutter is then returned to the notch, flipped, and removed. A fiber stick is then placed into the knee and grabbed with a looped grasper out the medial portal and clamped to itself. The posteromedial bundle is created by placing the guide immediately inferior to the anterolateral bundle, which is usually about 8 mm from the articular cartilage. Similarly, the flip cutter is used to create a socket of approximately 25 mm. Again, a fiber stick is then passed and pulled out the medial portal as well.

The patient's leg is placed in a figure-of-four position for the open approach. I normally do not use a tourniquet, but it is an option if visualization is difficult due to bleeding. A straight-line incision approximately 8–10 cm in length is used along the posteromedial edge of the tibia. The knee should be flexed with deeper dissection to avoid the neurovascular structures. Electrocautery dissection is used to dissect down through the superficial tissues and then finger dissection is performed to the posterior edge of the tibia. The inferior border of the approach is the semitendinosus tendon. Right above this tendon and anterior to the medial head of the gastrocnemius, a Cobb elevator is used to release the attachments to the posterior edge of the tibia, taking care to keep the instrument right against bone and elevate up the popliteus muscle. The medial head of the gastrocnemius can be released to aid in exposure. A blunt Hohmann retractor is placed across the back of the tibia to keep the popliteus and gastrocnemius muscles between the surgeon and the neurovascular structures (Fig. 17.11). The foot is externally rotated to facilitate the visualization of the posterior tibial surface.

Once this is exposed, the trough is ready to be prepared. A 1/2-inch-curved osteotome is used to make the superior, then medial, lateral, and inferior edges of the rectangular trough on the back of the tibia. The insertion of the PCL starts approximately 10 mm inferior to the articular surface of the tibia in the midline. The trough is then enlarged using the 1/4 inch osteotome, rongeur, or burr to meet the size of the graft. The graft is then placed within the trough and impacted. The graft should be flush or slightly prominent and should not be countersunk. The bone block should be held in place and a guidewire for a 4.5 mm cannulated screw can be drilled into place. This should be horizontal with the knee joint and should be directed toward the tibial tubercle. This screw is frequently directed slightly from posteromedial

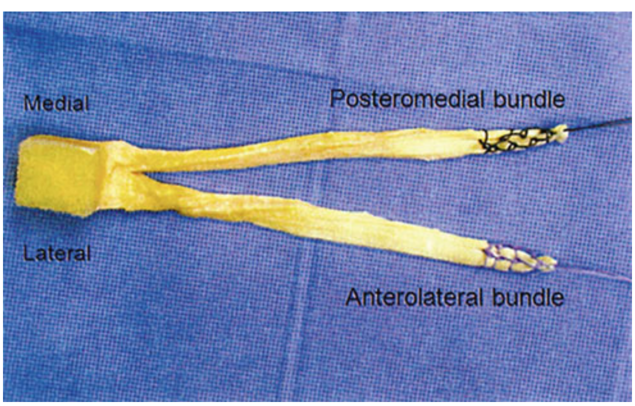


Fig. 17.10 Achilles bone-tendon allograft for anatomic double-bundle inlay PCL reconstruction. The tendon part of the graft is split longitudinally to make the larger anterolateral (AL) bundle and a smaller (PM) bundle. The larger AL bundle must be made at the lateral side of the graft with the cancellous portion of the bone block facing anterior. This graft is prepared for a left knee PCL reconstruction. We use two different colored sutures for accurate and quick identification of the AL and PM bundles during the procedure

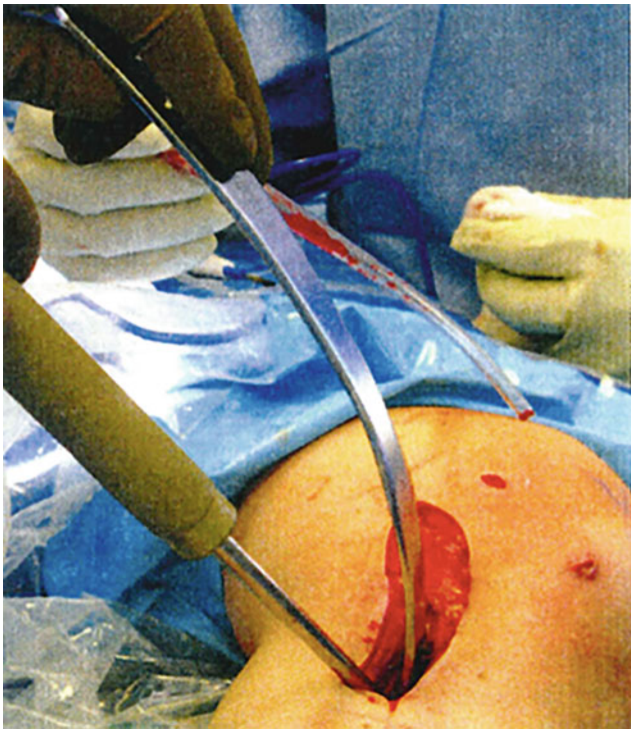


Fig. 17.11 Posteromedial knee approach for PCL reconstruction with inlay technique. The same approach is used for PMC reconstruction. A Cobb elevator is placed to elevate the popliteus muscle off of the entire posterior surface of the tibia, and a blunt Hohmann retractor is placed to keep the popliteus and gastrocnemius muscles between the surgeon and neurovascular structures

to anterolateral. Fluoroscopy is then used to check the position of the guidewire. This is measured for the appropriate length, and a screw and washer can be placed (Fig. 17.12). It may be beneficial to take a 6 mm to 8 mm off of the measured length to avoid soft tissue irritation with the screw anteriorly. The guide wire can be tapped out anteriorly and removed to avoid losing any fixation with the cancellous screw.

A hole then should be made in the posterior capsule using a Kelly clamp, and a suture passer can be inserted through the anteromedial portal and posterior joint capsule opening. Care should be taken to ensure that the suture passer travels between the ACL and medial femoral condyle. The suture of the posterior medial bundle can be pulled into the knee. The arthroscope is then reinserted and that bundle is then pulled into its tunnel with a grasper and with the assistance of a probe. The button is then flipped on the cortex and the graft is pulled to the depth of about 15 mm. The process is then repeated with the anterolateral bundle. It is pulled into the knee with the suture passer on the lateral side of the posterior medial bundle, and then is pulled into its socket. The button is again flipped on the cortex with the knee in flexion. The posteromedial bundle is tensioned in full extension and the anterolateral bundle is tensioned in about 90° of flexion. At the time of final fixation, the PCL grafts are pretensioned by ranging the knee 20 times and then tightening the fixation again.

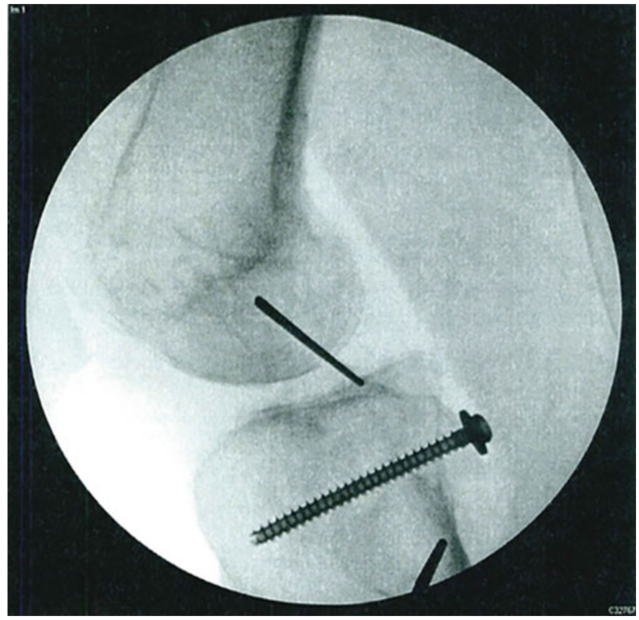


Fig. 17.12 Intraoperative fluoroscopic image showing the placement of a 4.5 mm fully threaded cannulated screw with a washer to secure the PCL allograft bone block. Note that, the bone block is placed in a trough that starts approximately 5–10 mm inferior to the articular surface of the tibia. Care needs to be taken not to have a long screw that is prominent out of the anterior cortex

17.6.3 Posteromedial Corner Reconstruction

A torn PMC is different from a torn medial collateral ligament (MCL) due to rotatory instability from a torn posterior oblique ligament (POL) and/or capsule. This can be differentiated by performing an anterior drawer test with the foot placed in external rotation. A PMC reconstruction addresses both the superficial MCL and the POL.

17.6.3.1 Allograft for PMC Reconstruction

A semitendinosus or split tibialis posterior or anterior tendon allograft is used. The graft is divided into two 5–7 mm diameter grafts. Locking stitches are placed at each end of the graft to facilitate passage. FiberTapes (Arthrex, Inc., Naples, FL, USA) is used to create loops in the graft for the graft-link suspensory fixation. Approximately, 20 mm of graft is marked out at the limbs—this is the length of graft to be pulled into the tunnel. The two arms of the graft are each stabilized to the FiberTape and tied with suture. The limbs are measured to check for size and are usually around 7 mm (Fig. 17.13).

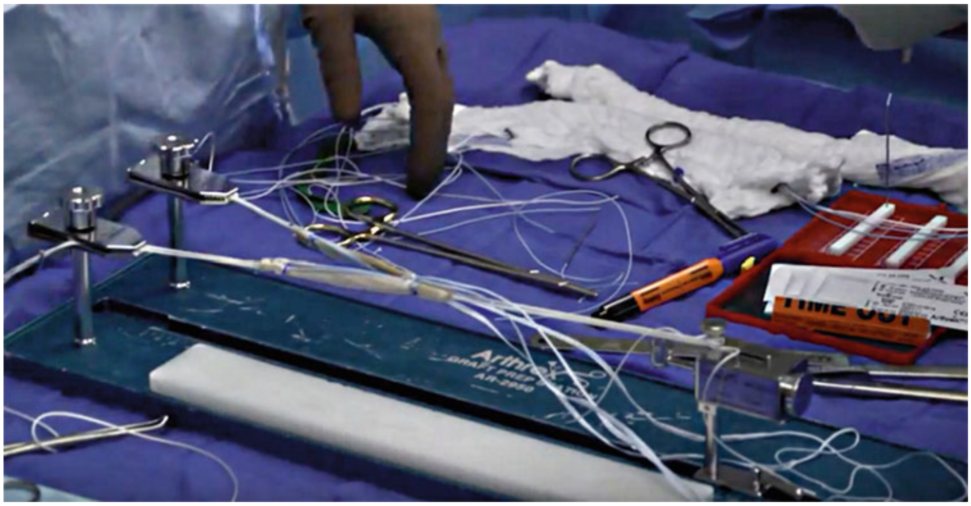


Fig. 17.13 Final graft preparation for the PMC. A semitendinosus or split tibialis posterior or anterior tendon allograft is used. The graft is divided into two 5–7 mm diameter grafts. Locking stitches are placed at each end of the graft to facilitate passage. FiberTapes are used to create loops in the graft for the graft-link suspensory fixation. Approximately, 20 mm of graft is marked out at the limbs—this is the length of graft that is pulled into the tunnel

17.6.3.2 PMC Reconstruction

A straight-line incision with a #10 blade is used to make a skin incision along the posteromedial edge of the tibia. This incision and approach are similar to that used for the superficial portion of the PCL inlay technique described earlier. Sharp dissection is used to dissect down and expose the insertion of semitendinosus and gracilis tendons (Fig. 17.14). One can mark the insertion of the superficial MCL just proximal to the semitendinosus with electrocautery.

The isometric point on the femur is then identified with a perfect lateral fluoroscopic X-ray. This is found at the intersection of the line along the posterior aspect of the posterior femoral cortex with Blumensaat's line (Fig. 17.15). Once that point is identified, a spade-tipped guidewire is drilled across the femur. This should be aimed slightly anterior and proximal to avoid other potential tunnels in a multi-ligament knee reconstruction. A 9-mm reamer is then drilled approximately 60 mm in length to create a socket for the femur based on the size of the graft and a passing suture is passed through the femur.

The distance of the superficial MCL is measured. Another spade-tipped guidewire is drilled across the tibia at that point just proximal to the insertion of the semitendinosus and gracilis, and then reamed with a 70 mm reamer to the far cortex. A suture is pulled through that socket as well for passage of the graft later (Fig. 17.16).

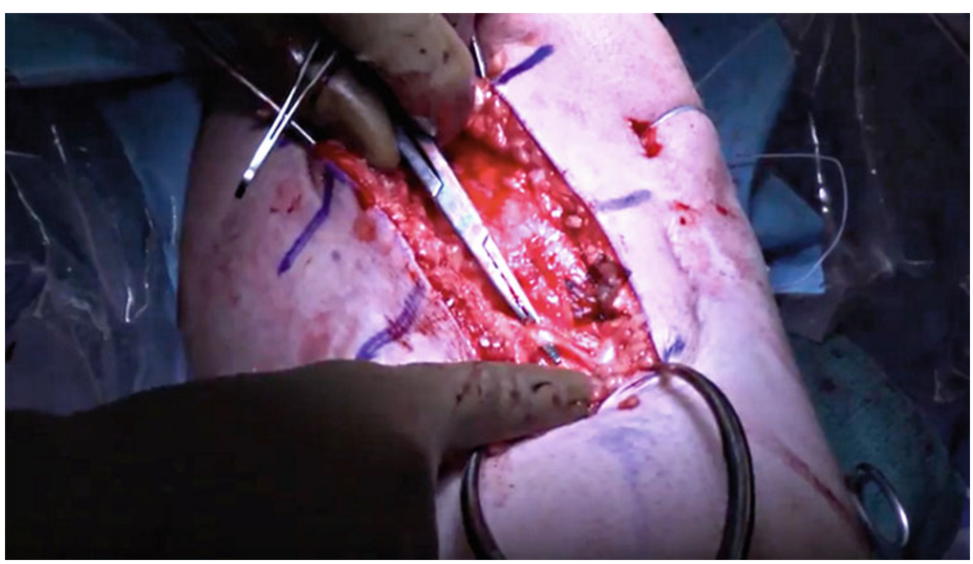


Fig. 17.14 A straight-line incision with a #10 blade is used to make a skin incision along the posteromedial edge of the tibia. Sharp dissection is used to dissect down and expose the insertion of semitendinosus and gracilis tendons as seen isolated by the tonsil clamp in the figure. One can mark the insertion of the superficial MCL just proximal to the distal portion of the semitendinosus tendon with electrocautery

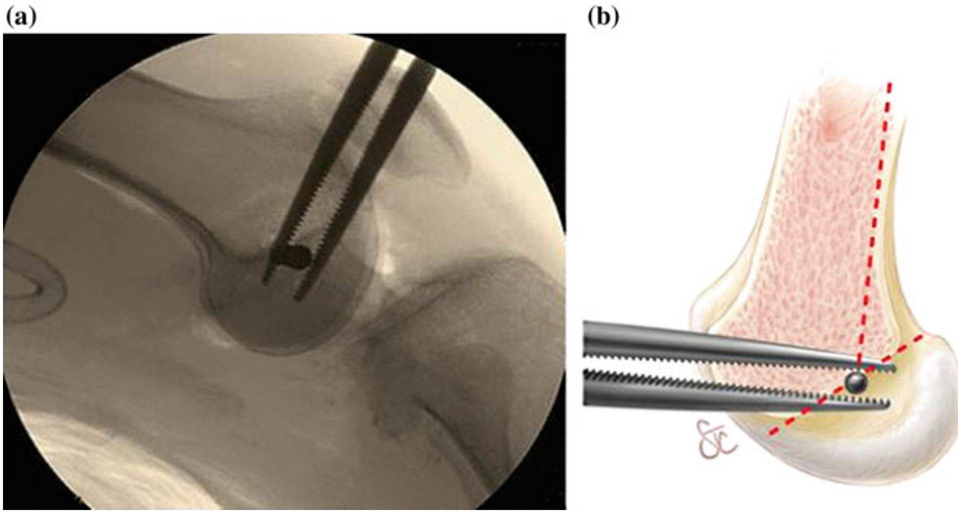


Fig. 17.15 The isometric point on the femur is then identified with a perfect lateral fluoroscopic X-ray. This is found at the intersection of the line along the posterior aspect of the posterior femoral cortex with Blumensaat's line. A spade-tipped guidewire is drilled across the femur, aimed slightly anterior and proximal. **a** An intraoperative photograph and **b** an artist's depiction. **a** From [10]. Reprinted with permission from Thieme New York. **b** ©2018 The Curators of the University of Missouri, reprinted with permission

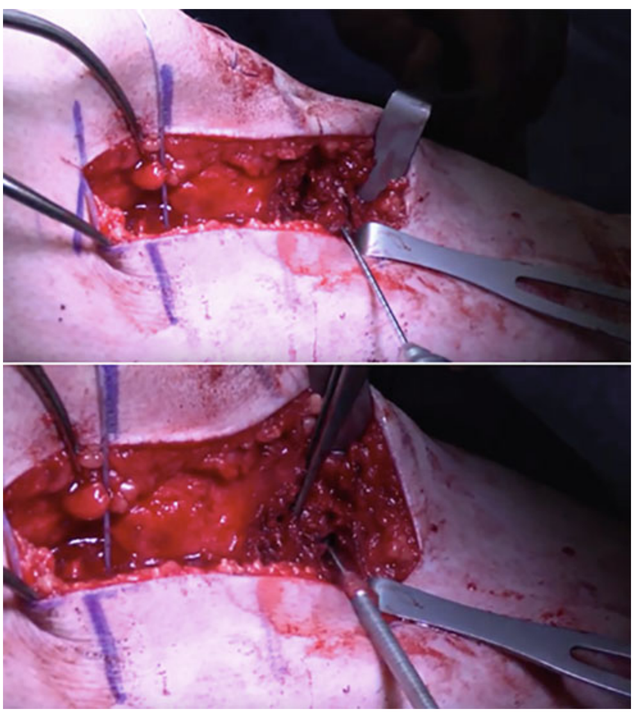


Fig. 17.16 The insertion point of the superficial MCL identified during the approach is again addressed. Another spade-tipped guidewire is drilled across the tibia at that point just proximal to the insertion of the semitendinosus and gracilis, and then reamed with a 70 mm reamer to the far cortex. A suture is pulled through that socket as well for passage of the graft limb for the superficial MCL later in the procedure

Fluoroscopy is used combined with anatomy to find the appropriate insertion point for the POL (Fig. 17.17). A spade-tipped guidewire is drilled to the opposite cortex just posterior to the direct head of the semimembranosus muscle. A 7-mm reamer is then used and checked with fluoroscopy to ensure that the tunnel for the PCL reconstruction is not encountered. Again, another suture is pulled across there for graft passage.

The common bundle of the allograft is then pulled into the femur and the button is flipped on the lateral cortex. After confirming that position with fluoroscopy, the graft is pulled into the socket approximately 20 mm. The limb for the superficial medial collateral ligament is pulled in line with its fibers and then pulled across into the tibial socket. The button is flipped on the lateral cortex and the graft is pulled to a depth of 15 mm. The POL graft is then routed underneath the semimembranosus and pulled into its socket (Fig. 17.18). The button is flipped on the lateral cortex, and the graft is also pulled to a depth of 15 mm. The common bundle is then retightened. With the knee held in 20°–30° of flexion, the limb for the superficial MCL button is then tightened on the tibia. The knee is then placed in full extension and the POL button is tightened. After the knee is ranged and stressed, the buttons are then retightened one last time (Fig. 17.19).

17.6.4 Posterolateral Corner Reconstruction

Many surgeons use a two-tailed approach to PLC reconstruction: one tail is based in the tibia while the other is based in the fibula to address all three components of the PLC. Fanelli supports a fibula-based reconstruction with a capsular shift instead of the tibia-based tail [4]. However, there are deficiencies of the two-tailed techniques that should

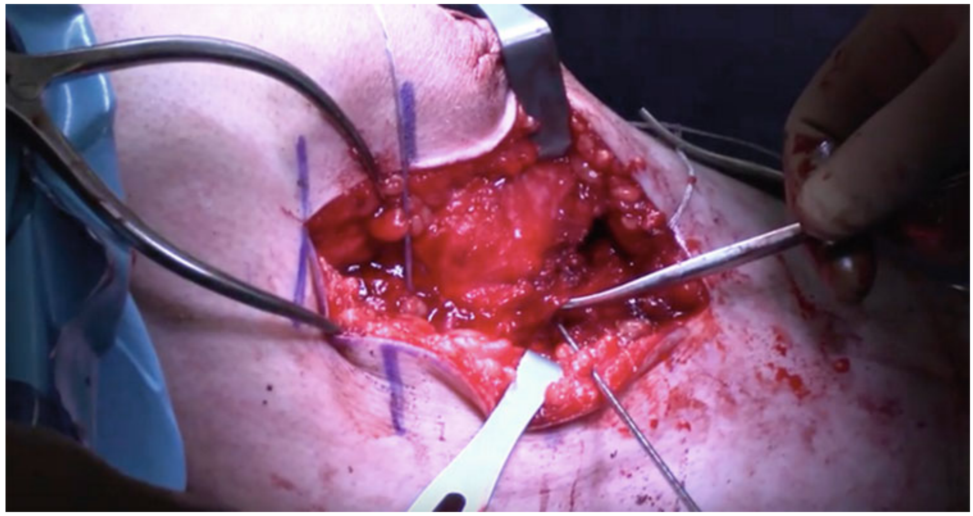


Fig. 17.17 The insertion point for the POL is identified using a combination of anatomy and fluoroscopy. A spade-tipped guidewire is drilled to the opposite cortex just posterior to the semimembranosus muscle, which is retracted in the picture by a tonsil clamp. A 7-mm reamer is then used and checked with fluoroscopy to ensure that the tunnel for the PCL reconstruction is not encountered

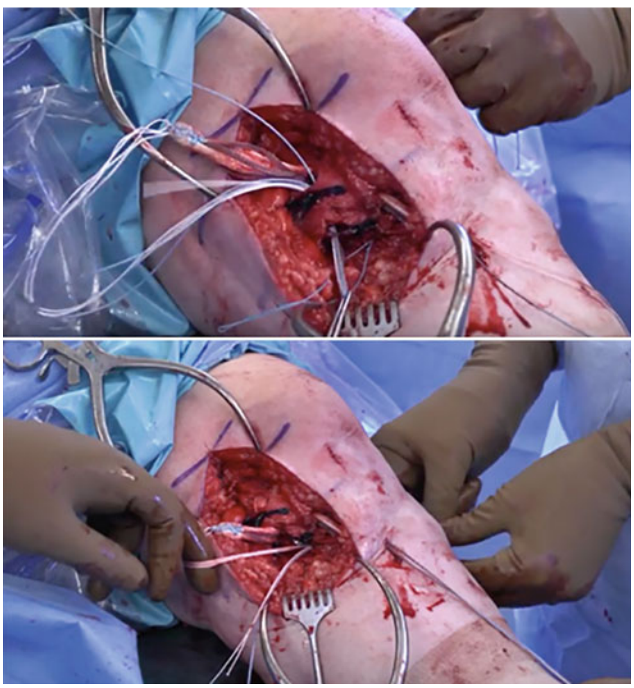


Fig. 17.18 The posterior oblique ligament graft is then routed underneath the semimembranosus (note the graft passing under the muscle marked by the purple pen) and pulled into its socket. The button is flipped on the lateral cortex, and the graft is also pulled to a depth of 15 mm

be addressed. A study by van der Wal et al. demonstrates that varus stability was improved but not restored to match that in the contralateral knee in 5-year follow-ups [5]. As stated previously, the use of a screw and washer in the femoral condyle can lead to complications such as hardware prominence. Helito et al. reported a 66% incidence of radiographic loosening and a 50% incidence of pain and irritation of the iliotibial band caused from the screw and washer [6]. Because of these limitations and improvements in fixation devices, a new two-tailed reconstruction method was devised and tested [7]. This technique uses cortical button suspensory fixation and interference screw fixation of the allografts in their respective sockets, and allows for individualized tensioning of the grafts in order to obtain optimal stability.

Two separate allograft tendons are used to create the FCL/popliteofibular and popliteus grafts. A semitendinosus, anterior tibialis, or gracilis allograft is used to create the FCL/popliteofibular limb. The allograft chosen should be 6.0–7.0 mm in diameter and at least 240 mm long. A piece of 36″ long, 2 mm wide FiberTape is looped over a cortical button suspensory fixation device at the mid portion of the FiberTape. The tendon allograft is then looped over the suspensory fixation device 20 mm from the end of the allograft (Fig. 17.20). A #2 FiberLoop suture (Arthrex, Inc., Naples, FL, USA) is passed through both arms of the allograft and incorporates both strands of the FiberTape, about 5 mm from the doubled-over end. The loop end of the FiberLoop is then passed through the suspensory fixation device and the needle end of the FiberLoop is passed through the loop end and back through both arms of the allograft to lock and secure the FiberLoop over the suspensory fixation. The two limbs of the allograft are then sutured together over the 20 mm overlap with a locking double whipstitch. The diameter of the doubled over part of the FCL graft should be 8–10 mm. The allograft is then cut to 220 mm in length from the doubled-over end. The FiberLoop suture is pulled taut to the free end of the tendon allograft and used to suture the end of the tendon allograft to both strands of the FiberTape using a locking double whipstitch pattern 15 mm from the free end of the graft. The

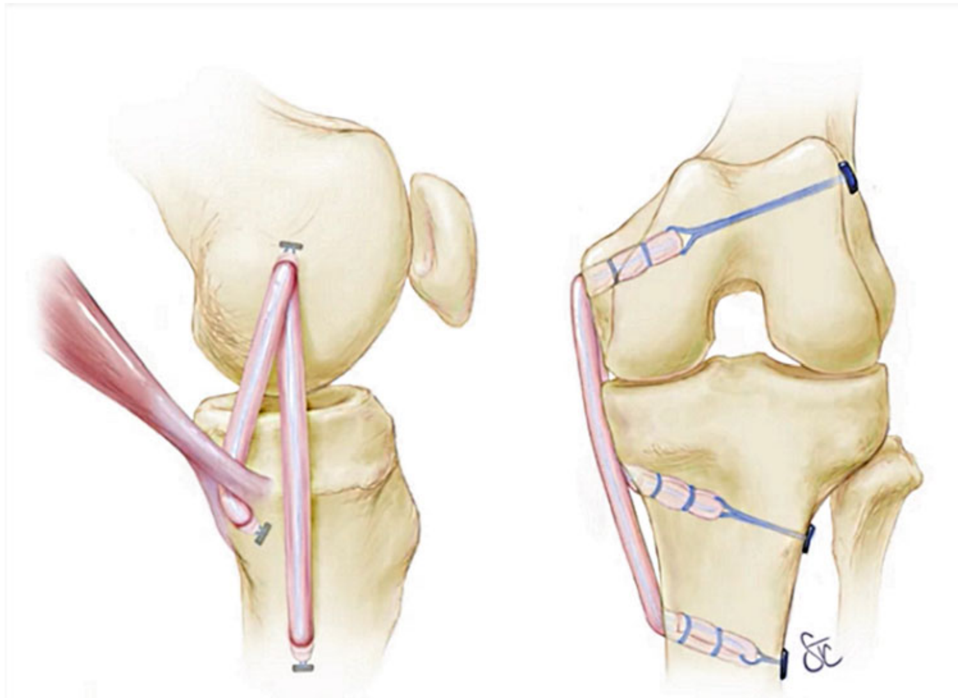


Fig. 17.19 A final schematic of the finished PMC reconstruction with suspensory fixation. ©2018 The Curators of the University of Missouri, reprinted with permission

needle is then removed. The diameter of the FCL portion should be no greater than 7 mm from the end of the doubled-over portion to the free end.

Again, a semitendinosus, anterior tibialis, or gracilis allograft is used to create the popliteal portion of the construct. The tendon allograft should be 5.5–6.5 mm in diameter and at least 130 mm long. A #2 FiberLoop suture is placed at each end of the graft using a locking double whipstitch pattern over 15 mm of the free end of the allograft.

A bump is placed underneath the knee, and the knee is dropped off the side of the table. The PLC is exposed through the posterolateral approach, allowing relaxation and protection of the peroneal nerve. A #10 blade can be used to make an incision in line with the middle of the fibular head. The biceps tendon, iliotibial band, and overlying fascia are identified. Sharp dissection is used to dissect down to the deeper fascia (Fig. 17.21). Using careful dissection, the peroneal nerve is identified. It can usually be palpated just posterior to the hamstrings in the groove below the head of the fibula. A Penrose drain can be placed around it to allow for gentle retraction and easy identification (Fig. 17.22). No clamps or other surgical instruments should be placed on the Penrose drain as permanent traction injuries can result. With sufficient dissection of the nerve, the entire proximal fibula is made readily accessible. Blunt dissection is carried out to define the plane anterior to the lateral head of the gastrocnemius. It is important to never stray posterior to the lateral head of the gastrocnemius as it places the popliteal neurovascular structures at risk. The interval between the biceps femoris tendon and iliotibial band is opened along the direction of their fibers to evaluate the FCL and popliteus tendon (Fig. 17.23). The popliteus runs deep to the FCL to attach to its femoral insertion that is 1–2 cm anterior and distal to the FCL attachment.

The isometric point is located approximately halfway between these two attachment sites and can be found in a similar fashion as in the PMC reconstruction isometric point. A perfect lateral view of the knee is obtained, and the isometric point is identified where a line extends from where the posterior femoral cortex intersects with Blumensaat's line. It is sometimes necessary to release the iliotibial band near the femoral attachment of the FCL to facilitate the graft placement. If the IT band is released, it should be repaired at the end of the procedure. The popliteofibular ligament traverses from the posterior aspect of the head of the fibula to the popliteus tendon. This normal anatomy is frequently disrupted in patients with knee dislocations. The isometric point is drilled with a spade-tipped guide wire and is reamed based on the size of the graft to create a tunnel of at least 50 mm. A suture is passed for future graft passage. The guide wire should be aimed anterior and proximal in order to avoid ACL femoral tunnel placement.

A tunnel is drilled through the head of the fibula from anterolateral to posteromedial, first with a 3.2 mm drill bit. It is followed by a 6-mm cannulated reamer and a manual 7-mm reamer. A 3.2-mm drill bit is then used to make a hole in the lateral tibia in an anterior to posterior direction. The drill enters the tibia directly medial and inferior to the anterolateral arthroscopic portal, at least 2 cm below the

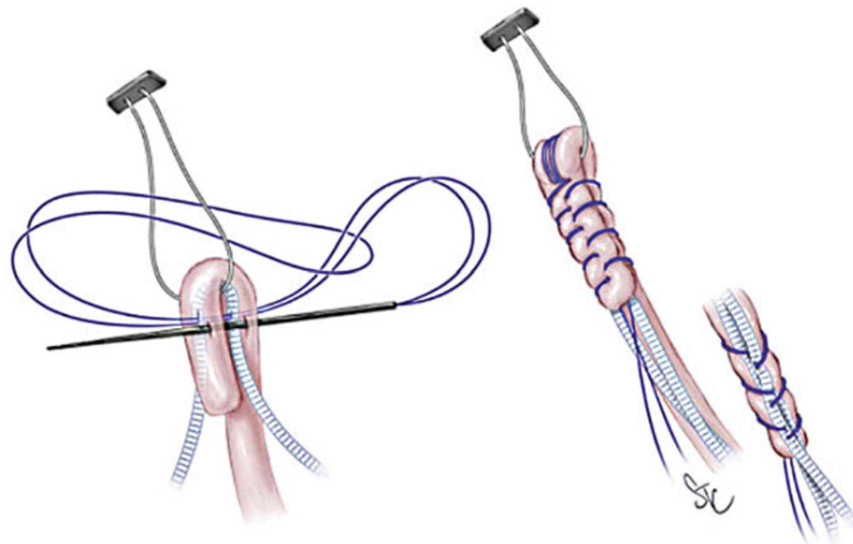


Fig. 17.20 Illustration depicting the preparation of the fibular collateral ligament/popliteofibular graft for the allograft reconstruction of the PLC using cortical button suspensory and interference screw fixation. ©2018 The Curators of the University of Missouri, reprinted with permission

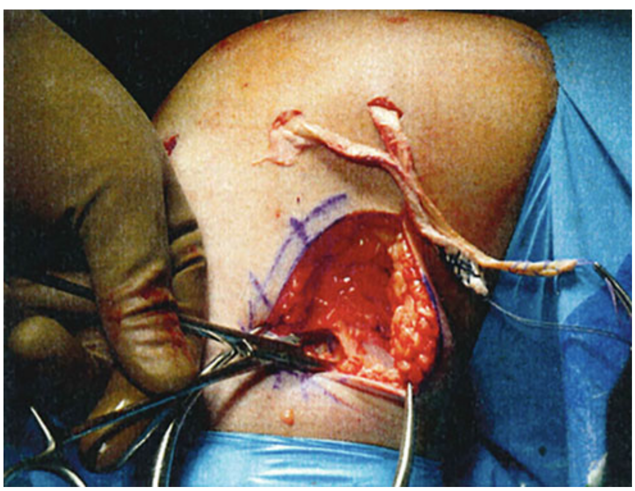


Fig. 17.21 Posterolateral approach of PLC reconstruction in a left knee. The skin incision is placed in line with the fibular head and carried in a straight line proximally and distally. The biceps tendon, iliotibial band, and the overlying fascia are identified. A pair of scissors is placed immediately posterior to the biceps tendon along the direction of the tendon to open the deep fascia, and the peroneal nerve is identified and dissected out from the fibular neck. *Note* The graft materials exiting the lateral femoral condyle in this image were for ACL reconstruction in this case

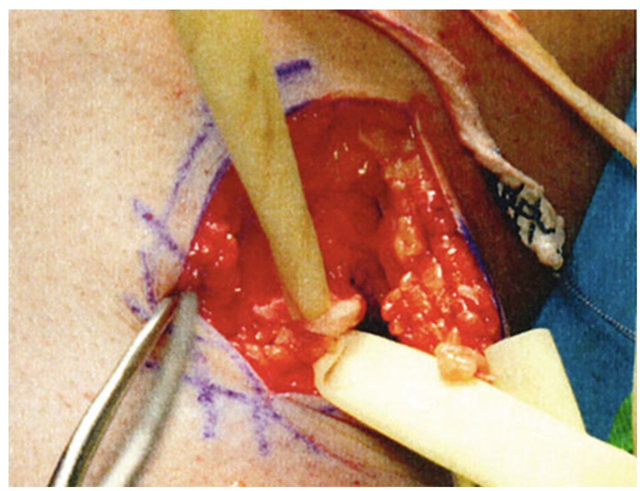


Fig. 17.22 A Penrose drain is placed around the peroneal nerve during the posterolateral approach of the knee

joint line, and exits on the posterolateral tibia just medial to the head of the fibula. A freehand technique is used for the drilling and involves positioning the index finger of the nondominant hand at the posterolateral edge of the tibia through the interval described above. The tibial tunnel is reamed to a diameter of 6 mm and tapped to a diameter of 7 mm. Another suture is passed through this tunnel.

The grafts are then passed and tensioned. The free end of the FCL graft is passed deep to the IT band proximal to distal and pulled through the fibular tunnel from anterior to posterior with the passing suture. The free end of the FCL/popliteofibular is then passed back to the socket at the isometric point and attached to a graftlink or other suspensory fixation device. This is then pulled into the socket and flipped on the medial cortex. The graft is pulled to an initial depth of 15 mm. The popliteal graft is passed together under the biceps tendon, IT band, and FCL graft toward the socket drilled at the proximal part of the popliteal hiatus. It is placed into the popliteal socket and fixed with an interference screw. The tibial end of the popliteal graft is pulled taut and the knee is cycled to take slack out of the graft. The knee is then placed in 30° of flexion and neutral rotation and a 7-mm interference screw are placed in the tibial tunnel in an anterior to posterior direction. Extra popliteal graft is then

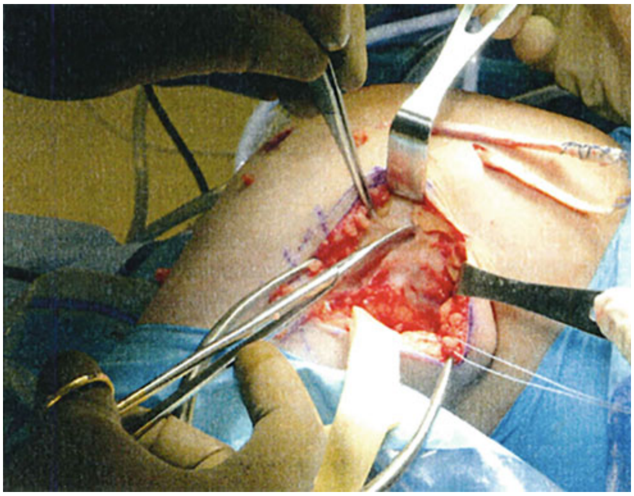


Fig. 17.23 The interval between the biceps femoris tendon and the iliotibial band is opened along the direction of their fibers. This allows for the evaluation of the status of the FCL and popliteus tendon, and facilitates graft passage underneath the biceps tendon and iliotibial band later

excised. The femoral suspensory fixation device is then tightened after cycling the knee to obtain the desired stability (Fig. 17.24).

17.6.5 Posterolateral Corner Reconstruction—Figure of Eight

If there is no rotational instability on examination under anesthesia, the popliteus does not need to be reconstruction and a figure-of-eight reconstruction can be performed. This procedure is identical to what is described above minus the popliteus reconstruction. The reconstruction is based on the isometric point and a tunnel through the head of the fibula from anterolateral to posteromedial. The suspensory fixation device is tightened to reconstruct the FCL and popliteofibular ligament. The knee is ranged and stressed and the buttons are retightened multiple times (Fig. 17.25). Final fluoroscopic images confirm the position of the button.

17.7 Postoperative Care

Most patients with multi-ligament reconstruction require several days of hospitalization following the procedure. Patients are given antibiotic prophylaxis initially, but it is discontinued before 24 h following surgery. For deep vein thrombosis (DVT) prophylaxis, patients are placed on both the mechanical prophylaxis such as thrombo-embolic deterrent (TED) hose compression stockings or sequential compression devices, as well as pharmacological prophylaxis during inpatient hospitalization. On discharge, they

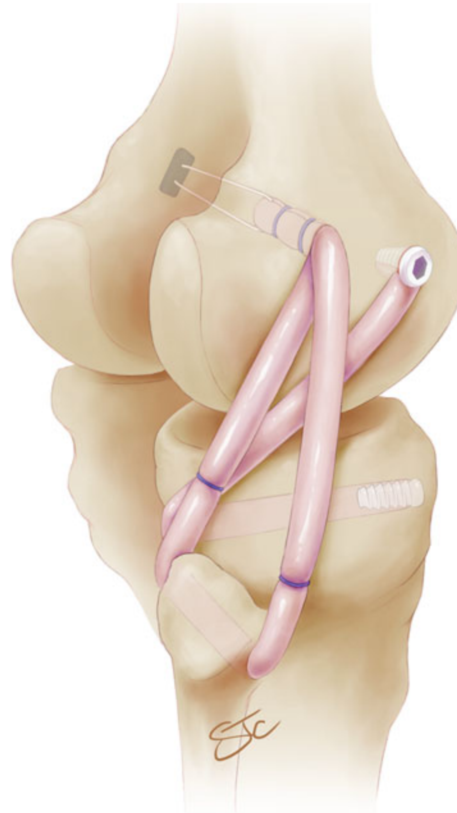


Fig. 17.24 New anatomic reconstruction of the posterolateral corner with suspensory fixation. ©2018 The Curators of the University of Missouri, reprinted with permission

have prescribed one baby aspirin per day as DVT prophylaxis, until the patient resumes full normal weight bearing ambulation. If there is an immediate family history of symptomatic DVT or PE, pharmacologic prophylaxis is maintained for 6 weeks.

Following PCL and corner reconstructions, patients start weight bearing as tolerated with crutches with the knee locked in full extension in a hinged knee brace on the first postoperative day. Patients begin range of motion at 0°–30° on the first postoperative day and progress as tolerated. A continuous passive motion (CPM) machine can assist with this also. Care should be taken not to progress the motion too quickly in order to allow early graft healing into the tunnels and fixation points. At 3–4 weeks, the hinged knee brace is unlocked during weight-bearing activities. Physical therapy starts after the first 2 weeks. The main focus during the initial recovery period is to obtain and maintain knee motion. In this regard, patellar mobilization is another important exercise during this phase because the patella is frequently involved in arthrofibrosis following multi-ligament knee injuries. By 6 weeks, the patient should be expected to have 0°–90° of active and passive knee motion, good patellar mobility, and normal gait without any assistive device. Once

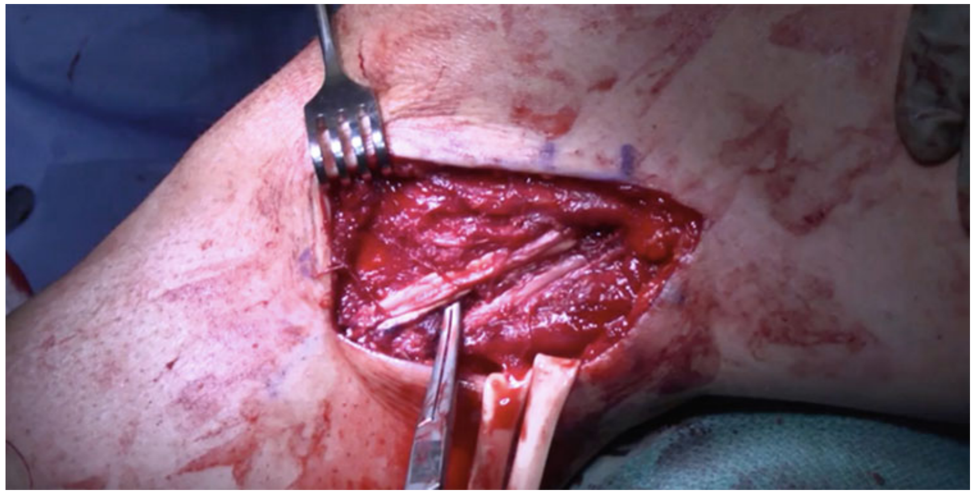


Fig. 17.25 Final figure-of-eight reconstruction. *From* Stannard et al. [7]. Reprinted with permission from Thieme New York

all these goals have been achieved, the patient can start the strengthening phase. The brace is discontinued anytime after 6–8 weeks once patients have achieved 0°–120° of active motion, 30 s of single leg balancing, and normal gait without extensor thrust. A custom-fit knee brace is recommended for therapy and athletic activities for the first 2 years following reconstruction of a knee dislocation.

Return to heavy work and sports are gradually allowed during the period of 9–12 months post-surgery. For patients who have sustained a multi-ligament injury, full recovery frequently involves a 12–18-month process. The criteria for return to heavy work and sports varies depending on the activity level that patients want to perform; but in general, patients return to strenuous activities when they have convincingly regained normal stability, motion, and strength of the knee.

17.8 Clinical Outcomes

The overall incidence of failure of our anatomic PCL reconstruction was 7% (4/54) [8] in a patient population with a mean follow-up of nearly 5 years. All remaining 50 patients had a negative posterior drawer test, with 44 (88%) having a 0 and 6 (12%) having 1+ posterior drawer. Excellent stability was found when knee stability was measured in the anteroposterior direction with KT-2000 arthrometer at 30° and 70°. The injured knee was 0.07 mm tighter at 30° and 1.08 mm looser at 70° than the uninjured knee. PLC failure rates in our published studies have been 7–8%. In our separate published study, the failure rate of PMC reconstruction was found to be 4% compared to 20% failure rate with PMC repair [9]. Following reconstruction of the PCL and other ligaments, 90% of patients were able to return to some type of work [8]. Seventy-six percent of patients returned to full-time work at the same job, while 8% returned to full-time employment at a different job. Six percent of patients returned to light duty only, and 10% were not able to return to work. Fifty percent of patients were able to return to their prior level of recreational activities and 25% returned to a lower level of activity.

17.9 Conclusions

Multiple-ligament-injured knees pose a formidable challenge to the orthopedic surgeon. The neurovascular structures may be injured and result in a limb-threatening situation. Concomitant injuries to the ipsilateral extremity further complicate the diagnosis and treatment. Clinical outcomes have often been discouraging, and complications are frequent. It is not uncommon for patients to have chronic pain, stiffness, residual instability, early post-traumatic arthritis, and so forth. Injuries to the PCL and both the PMC and PLC should be managed surgically with the reconstruction of each ligamentous structure. An anatomic double-bundle inlay technique using Achilles tendon allograft is a reliable and reproducible method for PCL reconstruction. This technique eliminates the killer turn, which has been shown to be associated with graft stretch and failure. The PMC is reconstructed with allograft by reconstruction the MCL and POL. The PLC is reconstructed with a modified two-tail technique which reconstructs all three critical components of the PLC—the FCL, popliteus, and popliteofibular ligament. With experience in patient evaluation and surgical technique, these clinical outcomes have shown a steady improvement in recent years.

References

1. Schenk RC. Knee dislocations. In: Schafer M, editor. Instructional course lecture, vol. 43. Rosemont: American Academy of Orthopaedic Surgeons; 1994. p. 127–36.
2. Stannard JP, Sheils TM, Lopez-Ben RR, McGwin G Jr, Robinson JT, Volgas DA. Vascular injuries in knee dislocations: the role of physical examination in determining the need for arteriogrphy. J Bone Joint Surg Am. 2004;86-A(5):910–5.
3. Hollis JD, Daley BJ. 10-year review of knee dislocations: is arteriography always necessary? J Trauma. 2005;59(3):672–5 Discussion 675–676.
4. Fanelli GC, Fanelli DG. Fibular head-based posterolateral reconstruction of the knee combined with capsular shift procedure. Sports Med Arthrosc Rev. 2015;23(1):33–43.
5. Van der Wal W, Heesterbeek P, van Tienen T, Busch V, van Ochten J, Wymenga A. Anatomical reconstruction of the posterolateral corner and combined injuries of the knee. Knee Surg Sports Traumatol Arthrosc. 2016;24(1):221–8.
6. Helito CP, Bonadio MB, Demange MK, et al. Screw loosening and iliotibial band friction after posterolateral corner reconstruction. Knee. 2014;21(3):769–73.
7. Stannard JP, Stannard JT, Cook JL. Repair or reconstruction in acute posterolateral instability of the knee: decision making and surgical technique introduction. J Knee Surg. 2015;28(6):450–4.
8. Stannard JP, McKean RM. Anatomic PCL reconstruction: the double bundle inlay technique. Oper Tech Sports Med. 2009;17:148–55.
9. Stannard JP, Black BS, Azbell C, Volgas DA. Posteromedial corner injury in knee dislocations. J Knee Surg. 2012;25(5):429–34.
10. Stannard JP, Schenck RC Jr. Knee dislocations and ligamentous injuries. In: Stannard JP, Schmidt AH, Kregor PJ, editors. Surgical treatment in orthopaedic trauma. New York: Thieme; 2007. p. 687–712.
11. Stannard JP, Brown SL, Farris RC, McGwin G Jr, Volgas DA. The posterolateral corner of the knee: repair versus reconstruction. Am J Sports Med. 2005;33(6):881–8.