Double-Bundle Posterior Cruciate Ligament Reconstruction Technique with Use of Endoscopic Femoral Graft Placement

Robert F. LaPrade MD, PhD, and Casey M. Pierce, MD

Based on an original article: *J Bone Joint Surg Am.* 2011;93:1773-80.

Introduction

As the varied results seen after posterior cruciate ligament (PCL) reconstructions might be due to surgical techniques that fail to reconstruct both functional bundles of the PCL and that injure the vastus medialis obliquus muscle, we developed a technique to address these problems and thus improve patient outcomes.

Typically associated with sports injury or trauma, PCL tears account for a substantial proportion of knee ligament injuries. Whether isolated or combined with other ligamentous injuries, grade-III PCL tears are known to cause functional limitations when a patient does not receive proper treatment¹⁻³.

Patients with a chronic isolated grade-III PCL tear, as well as those with chronic combined grade-III PCL/posterolateral knee injuries, are at a substantial risk of developing long-term problems from these injuries. The two most lasting effects in a PCL-deficient knee are functional limitations and the development of osteoarthritis, especially over the medial compartment and patellofemoral articulation of the knee⁴⁻⁶. At the time of long-term follow-up, patients who had been managed nonoperatively often complain of recurrent pain, instability, and loss of function^{5,7,8}. In addition, patients with a prolonged period between the initial injury and surgical reconstruction have worse outcomes^{9,10}. For these reasons, the literature supports early surgical reconstruction of most symptomatic isolated grade-III and combined knee ligament injuries^{3,11}.

The PCL is composed of two functional bundles, the larger anterolateral bundle and the smaller posteromedial bundle^{9,12}. Both bundles act to restrain posterior translation of the tibia under the femur, but the anterolateral bundle contributes mainly when the knee flexed is 90° while the posteromedial bundle contributes primarily at full extension¹³⁻²⁰. The poster-

omedial bundle also acts as a secondary stabilizer to external rotation¹⁸⁻²⁰.

Several techniques have been adopted to reconstruct a torn PCL. The single-bundle PCL reconstruction technique addresses only the anterolateral bundle and does not fully restore the normal anatomy of the knee^{11,18}. A major shortcoming of this technique is persistent posterior knee laxity postoperatively, especially with chronic PCL tears, which can predispose patients to early-onset osteoarthritis²¹.

As the name implies, the double-bundle PCL technique reconstructs both functional bundles of the PCL and more closely replicates the normal anatomy of the PCL. Theoretically, this technique should more adequately restore normal PCL function and prevent postoperative laxity, but the results of several biomechanical studies comparing the two PCL reconstruction techniques have been inconclusive²²⁻²⁵.

Regardless of the technique used, the quadriceps muscle aids in dynamic stabilization of the knee, and its proper function is essential to the recovery of patients with PCL injuries. Building the strength of the quadriceps is a key principle in operative and nonoperative PCL rehabilitation protocols^{3,11}. Surgical procedures that protect the vastus medialis obliquus muscle should allow an earlier return of quadriceps strength and function during rehabilitation and should improve patient outcomes.

Our technique, which reconstructs both functional bundles of the PCL and avoids injury to the vastus medialis obliquus muscle, is done in seven steps:

1. Examine under anesthesia
2. Perform arthroscopy
3. Drill tibial guidepin
4. Prepare grafts
5. Drill tunnels
6. Place and secure grafts in femur and tibia
7. Postoperative care

The following discussion reviews the surgical technique for an endoscopic double-bundle PCL reconstruction. The technique will be described as if it was performed in an isolated state, without injury to the posterolateral corner soft tissues.

Step 1: Examine Under Anesthesia

Assess range of motion and patellofemoral stability; perform stress tests, Lachman and pseudo-Lachman tests, pivot shift test, drawer tests, reverse pivot shift test, and dial test.

- After the patient is appropriately anesthetized in the operating room, examine both the affected knee and the contralateral, normal knee. This initial examination under anesthesia is especially important for a posterior cruciate ligament reconstruction, to determine the normal tibial step-off compared with the femur at 90° of knee flexion. This is essential because it is the angle at which the PCL anterolateral bundle is fixed. Determine the anatomic position of the normal, contralateral knee to avoid overconstraining or underconstraining the normal relationship of the tibia on the femur at 90° of knee flexion with the PCL reconstruction.
- A complete examination under anesthesia of both the injured and the contralateral, normal knee should include assessment of range of motion, patellofemoral stability, varus and valgus stress tests at 20° of knee flexion, a Lachman test, a pivot shift test, a posterior drawer test, a pseudo-Lachman test (to assess for posterior translation of the knee near extension), posterolateral and anteromedial drawer tests, a reverse pivot shift test, and a dial test (Video 1). Check for any potential, concurrent secondary restraint injuries, with a special emphasis on the posterolateral and posteromedial aspects of the knee.
- The surgical set-up includes 30° and 70° arthroscopes, PCL guides, acorn reamers, a large curet to prevent overpenetration while the tibial tunnel is reamed, a Gore Smoother (Smith & Nephew, Andover, Massachusetts) or looped-suture passing device, surgical bone staples, and power equipment to ream the tunnels.

Step 2: Perform Arthroscopy

Preserve any remnants of PCL at anterolateral and posteromedial bundle attachment sites to promote vascular healing.

- Place a well-padded tourniquet around the proximal part of the thigh of the injured lower extremity and place the involved leg in a leg-holder with the foot of the bed flexed 90°. - Place the contralateral, normal leg into a padded abduction holder to prevent any pressure areas from developing during the procedure. After the patient is given prophylactic antibiotics, prepare the leg and drape it freely in the usual sterile manner. Prior to the surgical incision, call a “time out” to verify the patient’s name, procedure, and correct operative extremity.
- Start with the knee arthroscopy. Create vertical arthroscopic portals adjacent to the patellar tendon on both the medial and the lateral side. Make these portals approximately twice the size of normal arthroscopic portals to allow for placement of the grafts and equipment. Perform a diagnostic arthroscopy to assess for any concurrent injury to the articular cartilage, menisci, and other ligaments. Careful arthroscopic evaluation is particularly important in the face of a PCL tear and includes assessment of the anterior cruciate ligament (ACL) “slack sign” (Fig. 1), the integrity of the posterior horn of the medial meniscus root attachment, and any arthroscopic gapping of the medial or lateral compartments.
- Identify the attachment sites of the anterolateral and posteromedial bundles of the PCL on the femur and use an arthroscopic coagulator to outline the center of each (Fig. 2). It is important to preserve any remnants of the PCL at these attachment sites to promote vascular healing as the patient recovers.
- Place a posteromedial arthroscopic portal. In certain circumstances, placement of the arthroscope into the posterior aspect of the medial part of the joint might be difficult. If it is, place a blunt obturator or shaver through the medial portal while the camera “looks” through the lateral portal. Use the blunt obturator or shaver to define the space between the posterior aspect of the medial femoral condyle at the intercondylar notch and the PCL remnants. When using a shaver, be careful to avoid the posterior horn of the medial meniscus root attachment and the ligament of Wrisberg (posterior meniscofemoral ligament). While visualizing through the interval between the PCL and the medial femoral condyle, place a spinal needle to localize the position of the posteromedial portal. Proper placement of the spinal needle is necessary to verify that the arthroscopic instruments will not impinge against the posterior aspect of the medial femoral

condyle with the knee flexed 90°. This is also essential to ensure that the surgical instruments will be able to approach the normal attachment sites of the PCL on the tibia. Make a small incision and place an arthroscopic cannula through this portal and into the posteromedial aspect of the knee. Use the arthroscopic light source to transilluminate the saphenous nerve and vessels to verify that they are posterior to the portal to prevent iatrogenic injury.

- Debride the tibial attachment of the PCL with a shaver. Point the shaver anteriorly and away from the posterior aspect of the knee to avoid damage to the neurovascular bundle. Identify the “shiny white fibers” of the posterior horn of the medial meniscus where they course laterally from the posterior horn root attachment of the medial meniscus (Fig. 3). These fibers serve as an important arthroscopic landmark and must be protected during the arthroscopic debridement. The PCL tibial attachment can be found 1 cm distal to these fibers.
- After identifying the PCL, locate the small horizontal osseous ridge that separates the anterolateral and posteromedial bundles. Debride the tissues around the PCL attachments on the tibia until the popliteus muscle becomes visible (Video 2). Debridement of the PCL tibial attachment allows for optimal visualization of a transtibial guidepin. Typically, a 70° arthroscope provides optimal visualization for this portion of the surgery.

Step 3: Drill Tibial Guidepin

Guidepin enters tibia at, roughly, 45° angle and 6 cm distal to joint line, midway between anterior tibial crest and posteromedial tibial border.

- Drill the tibial guidepin using a PCL aiming device (Fig. 4). Place the guidepin so that it exits the posterior part of the tibia directly at the horizontal ridge of bone, just proximal to the “champagne-glass drop-off” area on the tibia and approximately midway between the articular cartilage of the posterior aspect of the lateral tibial plateau and the far lateral margin of the medial tibial plateau.
- Remove the arthroscopic cannula from the posteromedial arthroscopic portal and replace it with a large curet to protect the soft tissues against posterior overpenetration of the guidepin. Position the entry point of the guidepin on the anteromedial aspect of the tibia such that the guidepin enters the tibia at approximately a 45° angle (Fig. 5-A). In almost

all circumstances, the guidepin should enter the tibia roughly 6 cm distal to the joint line. The entry point will be midway between the anterior crest of the tibia and the posteromedial tibial border.

- Drill the guidepin directly through skin utilizing the 70° arthroscope to visualize the tip of the guidepin as it exits at the tibial PCL attachment site (Fig. 5-B). Qualitatively determine that the guidepin appears to be in the proper position and then obtain intraoperative anteroposterior and lateral radiographs to objectively confirm the position (Fig. 6). Alternatively, use a mini-fluoroscopy unit for this purpose.

Step 4: Prepare Grafts

Use Achilles tendon allograft for anterolateral bundle and semitendinosus or tibialis anterior allograft for posteromedial bundle.

- While the surgeon is performing the intra-articular portion of the procedure, an assistant can prepare the reconstruction grafts (Video 3). Prepare the anterolateral bundle graft using an Achilles tendon allograft with an 11-mm-diameter, 25-mm-long calcaneal bone plug with passing sutures placed into the bone plug. Trim the distal soft-tissue portion off of the graft so that it fits through an 11-mm sizer and tubularize its end with a number-5 nonabsorbable suture to facilitate intra-articular graft passage.
- Similarly prepare the posteromedial bundle graft from a 7-mm-diameter semitendinosus or tibialis anterior allograft by tubularizing each end with number-2 nonabsorbable sutures. Mark the edges of the bone-tendon interface for the Achilles bone plug and the posteromedial bundle graft with a surgical pen at a distance of 25 mm to allow for arthroscopic visualization as they pass through the joint (Video 3).
- Take care to prepare the grafts properly so that they will fit through the reconstruction tunnels.

Step 5: Drill Tunnels

Guidepin position should be slightly lateral to midline between apices of medial and lateral tibial eminences on anteroposterior radiograph and approximately 7 mm proximal to “champagne-glass drop-off” on lateral radiograph.

- While waiting for the radiographs, or if fluoroscopy confirmed that the guidepin is in the correct position, begin reaming the closed-socket

femoral tunnels. Ream the femoral sockets before the tibial tunnel because arthroscopic fluid leaking out of the tibial tunnel after reaming can make intra-articular visualization more difficult.

- Place an 11-mm acorn reamer on a reaming chuck through the slightly enlarged anterolateral arthroscopic portal to serve as a guide. Position the reamer against the outline of the anterolateral bundle of the PCL with the anterior margins of the reamer abutting the edges of the articular cartilage on the roof of the intercondylar notch and the medial femoral condyle articular cartilage. Drill an islet pin anteromedially through the knee, penetrating the subchondral bone of the opposite cortex of the medial femoral condyle, while avoiding penetration of the skin.
- After placing the islet pin, switch the acorn reamer to power and ream an 11-mm-diameter closed-socket anterolateral bundle reconstruction tunnel to a depth of 25 mm. Before reaming the full depth of the socket, ream 1 to 2 mm of total depth to confirm that the tunnel is accurately reproducing the anatomic position of the anterolateral bundle of the PCL and is 1 to 2 mm posterior to the margin of the articular cartilage at this location.
- After finishing the first tunnel, construct the posteromedial bundle reconstruction tunnel in a likewise fashion. Place a 7-mm acorn reamer on a power chuck through the anterolateral arthroscopic portal against the outline of the posteromedial bundle of the posterior cruciate ligament. Approximately 2 to 3 mm of bone bridge should remain between the two reconstruction tunnels, and the anterior edge of the tunnel should be positioned approximately 6 mm posterior to the articular cartilage margins. Drill an islet pin through the knee in a similar manner to the position of the anterolateral bundle islet pin. Once the islet pin is in place, ream a closed-socket 7-mm tunnel to a depth of 25 mm.
- Use an arthroscopic shaver to remove any osseous debris left by reaming within the joint or tunnels. Confirm tunnel position and removal of bone debris from the femoral tunnel apertures by visualizing them through the anterolateral portal (Fig. 7).
- Verify the correct guidepin location for the tibial tunnel on the radiographs, which should now be ready, and reposition the guidepin if necessary. On the anteroposterior radiograph, the appropriate position for the guidepin is slightly lateral to the midline between the apices of the medial and lateral tibial eminences (Fig. 6-A).

On the lateral radiograph, the proper guidepin position is approximately 7 mm proximal to the “champagne-glass drop-off” of the posterior aspect of the tibia (Fig. 6-B)²⁶.

- Once the guidepin is deemed to be in the appropriate anatomic position, make a small anteromedial skin incision vertically over the guidepin, slightly more distal than proximal, to allow for future fixation of the PCL grafts on the tibia. Using a 12-mm acorn reamer, over-ream the guidepin while viewing the tip of the guidepin arthroscopically. Place a large curet over the anticipated tibial exit point to prevent overpenetration of the guidepin into the posterior soft tissues. During this step, it is important to be able to view the guidepin at all times. If the guidepin retracts proximally within the tibia, immediately cease reaming, disconnect the power from the reamer, and tap the guidepin back into its original position in the tibia to regain visualization. This step is important to avoid reaming over a guidepin that is retracted retrograde into the tibia, which can place the entry point of the tibial tunnel in a nonanatomic position. Use of an acorn reamer is preferred to that of a full-bore reamer because the acorn reamer allows the operator to feel the posterior cortex of the tibia and to drop the trajectory of his or her hand to avoid penetration into this area while following the course of the posterior aspect of the tibia. Published reports have shown that osseous penetration through this area can risk damage to the popliteal artery^{27,28}.
- Carefully complete the reaming of the tibial tunnel posteriorly so that neither the guidepin nor the reamer protrude into the posterior soft tissues (Video 4). After you have finished reaming the tibial tunnel, it is important to hand turn the reamer several times at the tibial tunnel aperture to confirm that the exit site is of appropriate diameter. Again, use the arthroscopic shaver through the posteromedial portal to remove any osseous debris or soft tissues present at the aperture of the tunnel and confirm proper placement.

Step 6: Place and Secure Grafts in Femur and Tibia

Tug hard on grafts through anterolateral arthroscopic portal to verify that they are secured within the femoral tunnel.

- Pass a large Gore Smoother, or other graft-passing device, proximally up through the tibial tunnel and position it outside the anteromedial

portal using a grasper. If necessary, the smoother can be used to even out any irregularities on the aperture on the tibia. Pull the closed loop tip of the smoother or passing device back into the joint and then pass it out of the anterolateral portal of the tibia. Secure the Gore Smoother in place using a hemostat or Kocher clamp to prevent it from being pulled out of the joint inadvertently.

- Next, focus on placement of the PCL bundle reconstruction grafts in their femoral tunnels. First, position the soft-tissue posteromedial bundle graft for the PCL. Place a 7-mm acorn reamer through the anterolateral portal and feed the islet pin through the previously reamed tunnel and out through the skin on the anteromedial portion of the thigh. Pass the islet pin through the reamer to avoid creating soft-tissue bridges, which could potentially prevent proper graft placement, as it passes through the retropatellar fat pad. Remove the reamer and place the sutures originating from the end of the posteromedial bundle graft into the islet pin. Use the islet pin to pull the sutures and graft into the tunnel to the edge of the previously marked 25-mm depth.
- Once the graft is in an appropriate position, place a guidepin for a bioabsorbable screw and insert the screw on the distal and anteromedial portion of the tunnel to secure the graft in place. If the graft is spinning around the screw during placement, have an assistant hold the graft tightly on both ends to prevent movement. (Inserting the screw 2 to 3 mm deep into the tunnel and immediately backing it out to the tunnel aperture can also unwind any rotation of this graft.) Once the screw is in the appropriate position, tug hard on the graft through the anterolateral portal to confirm that it is appropriately secured in the femoral tunnel.
- Secure the anterolateral bundle graft into its femoral tunnel in a similar fashion. Start by placing a 7-mm acorn reamer through the anterolateral portal and into the anterolateral bundle tunnel. Pass an islet pin over the reamer in the anterolateral portal and out through the skin on the anteromedial aspect of the distal part of the thigh. Remove the reamer and place the sutures from the bone plug for the Achilles graft, which reconstructs the anterolateral bundle, into the islet pin. Use the islet pin to pull the sutures and bone plug into its femoral tunnel. Position the bone plug so that the graft fibers are anterior within the tunnel (Fig. 8). Once the graft is in position, confirm that the posteromedial graft has not been pulled into the joint and place a guidepin for a titanium screw through the anterolateral portal and along the anterior aspect of the bone plug of the Achilles graft. Secure a 7-mm titanium screw directly over the guidepin while utilizing a graft protector to ensure that the graft is not damaged during screw placement (Video 5). Again, tug hard on this graft laterally through the anterolateral arthroscopic portal to verify that it is secured within the femoral tunnel (Video 6).
- Both grafts should now be in position within the femoral tunnels and outside the anterolateral arthroscopic portal. Thread the sutures on the ends of both grafts through the Gore Smoother end piece or through the passing device. Pull the passing device or smoother distally through the tibia so that both graft ends pass through the tibial tunnel in a retrograde fashion (Video 7, Fig. 9). Cycle each graft individually to remove any remaining slack. View both reconstruction grafts using the arthroscope to verify their appropriate location, and apply distal tension on the grafts to verify that they restore the normal position of the ACL (Video 8).
- Fix the two PCL bundles on the anterolateral aspect of the tibia. Cycle the grafts to remove any slack by applying distal traction to the grafts through a full range of knee motion. First, fix the anterolateral bundle reconstruction graft using an anterior translation force to the knee flexed at 90°. This is done in an attempt to restore the tibiofemoral step-off to match that in the contralateral, normal knee while applying distal traction to the anterolateral bundle. Make certain that the foot is kept in a neutral rotation position to avoid fixation of the knee in a malrotated position, which could overconstrain and overload the graft. Secure the anterolateral bundle graft to the tibia using a small surgical staple (Fig. 10-A). Once the graft is secured, verify that the positive posterior drawer test has been completely eliminated. Confirm normal positioning of the tibia on the femur as well as restoration of normal ACL positioning using the arthroscope. Place the knee into full extension and fix the posteromedial bundle reconstruction graft to the tibia. Use a medium bone staple to provide fixation for this graft and backup fixation for the anterolateral bundle graft to the tibia (Fig. 10-B).
- After fixing the graft in place, again check the posterior drawer test and concurrently perform the pseudo-Lachman test to verify restoration of this portion of the PCL function. Finally, use

the arthroscope to verify that both grafts appear properly secured and are in the appropriate position.

- Remove any excess portion of the graft, close the deep tissues with absorbable sutures, and close the skin with a subcuticular stitch. Apply a sterile dressing and a knee immobilizer before the patient is transferred to the recovery room.

Step 7: Postoperative Care

Manage knee motion for first six weeks by prone knee flexion to counteract deleterious effects of gravity on reconstruction.

- The rehabilitation program is very important for PCL reconstructions and must start immediately after surgery. On postoperative day one, the patient begins outpatient physical therapy after attaining appropriate analgesic control. Restoring quadriceps function, decreasing edema from the surgery, and increasing knee motion are the immediate goals of therapy.
- Manage knee motion for the first six weeks postoperatively by prone knee flexion to counteract the deleterious effects of gravity on the PCL reconstruction. For the first two weeks, limit prone knee flexion to 0° to 90° with the assistance of a physical therapist or a trained family member. After this time, prone knee flexion can be increased as tolerated.
- Apply a PCL Jack brace (Albrecht, Stephanskirchen, Germany) at three to four days postoperatively, depending on patient tolerance and the removal of the original surgical bandages. Adjust the tensioning and spring-loaded-device portion of the PCL Jack brace to reflect the patient's comfort level; however, the brace is designed to apply appropriate tension to allow the knee to move through a range of motion with no substantial posterior stress on the reconstruction graft.

Results

In a cohort of thirty-nine total patients, thirty-three males and six females, with an average age of thirty-three years, seven isolated PCL reconstructions and thirty-two combined knee reconstructions were performed²⁶. Eight patients were lost to follow-up, leaving a cohort of thirty-one patients. Preoperative Cincinnati and International Knee Documentation Committee (IKDC) subjective scores averaged 34.5 and 39.3, respectively. The scores improved significantly to 73.2 and 74.3, respectively, after an average duration of follow-up of 2.5 years postoperatively (Table I). Pre-

operative posterior knee stress radiographs demonstrated an average of 15 mm of posterior tibial translation; this improved significantly to 0.9 mm postoperatively. Comparison of patients with combined injuries and those with an isolated injury revealed that the two groups had similar improvements in subjective IKDC and Cincinnati scores as well as findings on objective posterior stress radiographs. All patients reportedly complied with wearing of the PCL Jack brace according to the protocol. No intraoperative neurovascular injuries, postoperative deep venous thrombosis, or infections occurred during the study and follow-up periods.

What to Watch For

Indications

- Acute grade-III PCL tears, either isolated or combined (most commonly PCL/posterolateral, but often ACL and/or MCL/medial too)
- Symptomatic chronic isolated and combined grade-III PCL tears

Contraindications

- Extensive injury to the subcutaneous tissues or skin, which would make a safe incision difficult
- Malalignment in the face of a concurrent medial (valgus) or posterolateral (varus) knee injury
- Active infection
- Severe knee osteoarthritis
- Severe arthrofibrosis
- Use of systemic corticosteroids

Pitfalls & Challenges

- Make sure to rule out any combined ligamentous injury when treating a patient with a PCL tear to avoid poor outcomes and postoperative laxity or graft failure.
- Initially treat patients with combined posterolateral knee instability and coexisting genu varus alignment with a proximal tibial biplanar osteotomy prior to simultaneous posterolateral corner reconstruction and double-bundle PCL reconstruction to decrease the risk of the grafts stretching out and failing.
- Properly examine the patient under anesthesia to determine the normal tibial step-off and normal position of the unaffected knee to avoid overconstraining or underconstraining the graft during positioning of the tibia on the femur.
- Take care to preserve any remnants of the PCL at the anterolateral and posteromedial bundle attachment sites because removal could potentially hinder postoperative healing.

- Verify the position of the saphenous nerve and vessels intraoperatively, making certain that they are posterior to the posteromedial portal to avoid damaging them.
- Ream the femoral tunnels prior to the tibial tunnels to prevent arthroscopic fluid leaking into the tibial tunnel, which can make visualization difficult.
- When reaming over the tibial guidepin, be certain to view the guidepin at all times to avoid the guidepin retracting retrograde into the tibia, which can result in placement of the entry point of the tibial tunnel in a nonanatomic position.
- Make certain to use an acorn reamer instead of a full-bore reamer over the guidepin to avoid penetrating the posterior tibial cortex and damaging the popliteal artery.
- Tug hard on the grafts through the anterolateral portal after fixation to ensure that they are secured in the tunnels and decrease the

likelihood of the grafts loosening postoperatively.

- View both bundle grafts arthroscopically while applying distal traction to verify proper position; verify that the ACL is restored back to its normal position.

Clinical Comments

- What refinements in surgical technique or rehabilitation positively affect patient outcomes or objective stability with PCL reconstruction?
- What prophylactic measures are effective in preventing PCL graft loosening/failure postoperatively after PCL reconstruction?
- What prophylactic measures are effective in decreasing the risk of damage to the popliteal artery and/or tibial nerve?
- What postoperative measures or implementations aid in the prevention of osteoarthritis after PCL injury?

Robert F. LaPrade, MD, PhD

Casey M. Pierce, MD

The Steadman Clinic, 181 West Meadow Drive, Suite 400, Vail, CO 81657. E-mail address for R.F. LaPrade: rlaprade@sprivail.org. E-mail address for C.M. Pierce: casey.pierce@sprivail.org

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

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Figures

Fig. 1

Arthroscopic image showing the “slack” ACL (yellow arrow) due to the loss of support from the torn PCL.

Fig. 2

Arthroscopic image showing a coagulator marking the PCL bundle attachment sites on the femur. The anterolateral bundle is indicated by the red arrow, and the posteromedial bundle is indicated by the black arrow.

Fig. 3

Arthroscopic image showing the “shiny white fibers” of the posterior horn of the medial meniscus (yellow arrow).

Fig. 4

Intraoperative photograph showing proper placement of the tibial guide prior to drilling of the guidepin.

Fig. 5

Fig. 5-A Intraoperative photograph showing proper placement of the tibial guidepin at approximately a 45° angle to the tibial shaft or diaphysis. **Fig. 5-B** Arthroscopic image showing the guidepin piercing the tibial plateau while a large curet protects the soft tissues from posterior overpenetration.

Fig. 6

Intraoperative anteroposterior fluoroscopic view (**Fig. 6-A**) and lateral fluoroscopic view (**Fig. 6-B**) demonstrating the proper position for the tibial tunnel guidepin and the “champagne-glass drop-off” (yellow line).

Fig. 7

Arthroscopic image showing the proper location of the femoral tunnels viewed through the anterolateral portal. The anterolateral bundle tunnel is indicated by the red arrow, and the posteromedial bundle tunnel is indicated by the black arrow.

Fig. 8

Intraoperative photograph showing the femoral bundle grafts. The posteromedial bundle graft is fixed in place into the femur, and the anterolateral bundle graft is in place with the bone plug at the edge of the anterolateral portal.

Fig. 9

Intraoperative photographs showing the PCL reconstruction grafts before they are passed through the tibial tunnel (**Fig. 9-A**) and the proper position after they are passed through the tibial tunnel (**Fig. 9-B**).

Fig. 10

Intraoperative photographs showing fixation of the reconstruction bundle grafts to the tibia with use of surgical staples. The anterolateral bundle graft is fixed in flexion (**Fig. 10-A**) and the posterolateral bundle graft, in extension (**Fig. 10-B**).

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

TABLE I Preoperative and Postoperative IKDC Objective Subscores for Patients Treated with Double-Bundle PCL Reconstructions with Endoscopic Femoral Graft Placement

	Preoperative Grade*				Postoperative Grade*			
	A	B	C	D	A	B	C	D
Posterior translation at 90°	0	1	2	36	26	5	0	0
Single-leg hop test	0	3	7	29	15	14	2	0
Lachman test	23	2	4	10	31	0	0	0
Varus stress testing at 20°	0	0	6	13	18	1	0	0
Valgus stress testing at 20°	24	0	6	9	31	0	0	0

*The values represent the numbers of patients with each grade.