## Technical Note

# Anatomic Double-Bundle Posterior Cruciate Ligament Reconstruction

Jorge Chahla, M.D., Marco Nitri, M.D., David Civitarese, B.A., Chase S. Dean, M.D., Samuel G. Moulton, B.A., and Robert F. LaPrade, M.D., Ph.D.

**Abstract:** The posterior cruciate ligament (PCL) is known to be the main posterior stabilizer of the knee. Anatomic single-bundle PCL reconstruction, focusing on reconstruction of the larger anterolateral bundle, is the most commonly performed procedure. Because of the residual posterior and rotational tibial instability after the single-bundle procedure and the inability to restore the normal knee kinematics, an anatomic double-bundle PCL reconstruction has been proposed in an effort to re-create the native PCL footprint more closely and to restore normal knee kinematics. We detail our technique for an anatomic double-bundle PCL reconstruction using Achilles and anterior tibialis tendon allografts.

The posterior cruciate ligament (PCL) is an intra-articular, extrasynovial structure that provides the primary restraint to posterior tibial translation. Recent studies have also identified the PCL as a secondary restraint to internal rotation, particularly between 90° and 120° of flexion.[1] The PCL is composed of two bundles that were historically believed to function independently, with the anterolateral bundle (ALB) predominantly being an important stabilizer in flexion and the posteromedial bundle (PMB) mainly in extension.[2,3] However, recent biomechanical studies have found a co-dominant relation between these two bundles.[4,5]

Although advances in the objective and biomechanical outcomes of single-bundle PCL reconstruction (PCLR) have been achieved regarding tunnel placement, type of fixation, and optimal graft fixation angles, biomechanical reports have suggested a residual laxity after a single-bundle procedure.[6] Traditionally, it has been reported that outcomes of surgical reconstruction for the treatment of symptomatic PCL tears have varied compared with that for anterior cruciate ligament tears and need to be improved.[7,8] We believe that this may be because of a lack of anatomic reconstruction of both functional PCL bundles, as well as the use of techniques that violate the vastus medialis obliquus. The purpose of this study was to describe our technique for endoscopic anatomic double-bundle PCLR.

*From the Steadman Philippon Research Institute (J.C., M.N., D.C., C.S.D., S.G.M., R.F.L.); and The Steadman Clinic (R.F.L.), Vail, Colorado, U.S.A.*

*The authors report the following potential conflict of interest or source of funding: Steadman Philippon Research Institute receives support from Arthrex, Ossur, Siemens, and Smith & Nephew. R.F.L. receives support from Arthrex; Smith & Nephew; Ossur; Health East, Norway; and National Institutes of Health R13 grant for biologics.*

*Received August 3, 2015; accepted October 28, 2015.*

*Address correspondence to Robert F. LaPrade, M.D., Ph.D., The Steadman Clinic, 181 W Meadow Dr, Ste 400, Vail, CO 81657, U.S.A. E-mail: drlaprade@sprivail.org*



*2212-6287/15729/$36.00*

*http://dx.doi.org/10.1016/j.eats.2015.10.014*

## Technique

### Objective Diagnosis

PCL injury rarely occurs in isolation,[9] and therefore diagnosis of isolated versus combined PCL injury should be determined through an accurate physical examination and imaging methods (standard radiographs, PCL stress radiographs, and magnetic resonance imaging). The kneeling technique for PCL stress radiography is a reproducible, accessible, and cost-effective method to quantify posterior knee instability and diagnose isolated versus combined PCL injuries by comparing the difference in posterior tibial translation in the injured knee with that in the contralateral knee.[10] The diagnostic algorithm used at our institution is as follows: A side-to-side difference in posterior displacement of 0 to 7 mm constitutes a partial PCL tear, a difference of 8 to 11 mm indicates an isolated PCL tear, and posterior translation of 12 mm or greater indicates a combined PCL and posterolateral or posteromedial corner tear (Fig 1).

### PCLR Indications

PCLR is indicated for isolated symptomatic acute grade III PCL tears and for combined reconstructions for

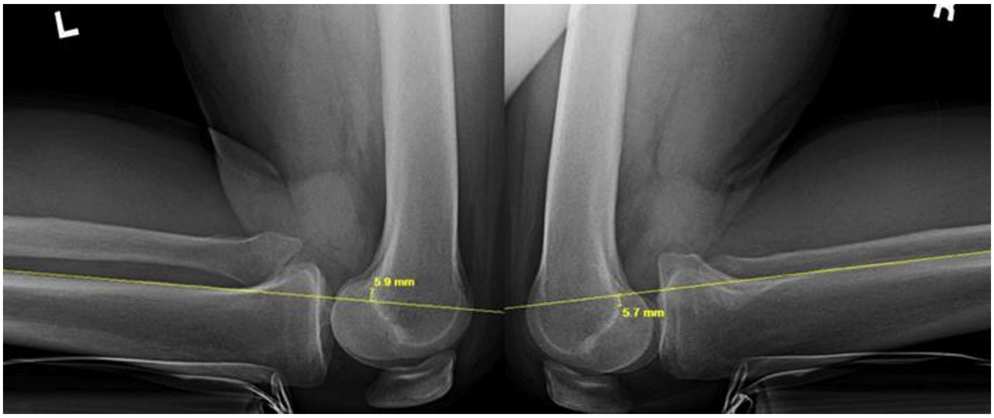


**Fig 1.** Comparative knee posterior stress radiographs. One should note the 11.6-mm difference between the left (L) and right (R) sides signifying a complete posterior cruciate ligament tear.

multiligament lesions or when combined with repairable meniscal body or root tears in the acute setting. Regarding chronic PCL injury, indications include functional limitations due to the PCL tear (e.g., difficulty with deceleration, incline descent, or stairs) and PCL stress radiographic laxity greater than 8 mm in a symptomatic patient.[11]

## Patient Positioning and Anesthesia

The patient is placed in the supine position on the operating table (Appendix Video 1). After the induction of general anesthesia, a bilateral examination is performed to confirm the diagnosis of posterior instability, to evaluate for any concurrent ligament instability, and to assess for range of motion. A well-padded high-thigh tourniquet is subsequently placed around the operative leg, and the leg is placed in a leg holder (Mizuho OSI, Union City, CA); the contralateral knee is placed in an abduction stirrup (Birkova Products, Gothenburg, NE).

## Graft Preparation

For the double-bundle PCLR technique, Achilles tendon and anterior tibialis allografts are used. The ALB graft is prepared from an Achilles tendon allograft with an 11-mm-diameter and 20-mm-long calcaneal bone plug, and the distal soft-tissue aspect of the graft is trimmed and undergoes tubularization at its end with a No. 5 nonabsorbable suture. The PMB graft is similarly prepared from a 7-mm-diameter semitendinosus tendon allograft by tubularization of each end of the allograft with nonabsorbable sutures.

## Surgical Technique

Routine arthroscopy is performed through standard anterolateral and anteromedial portals. Arthroscopic landmarks within the intercondylar notch are key to help identify the anatomic attachment sites of the PCL bundles. The more anterior aspect of the ALB is noted by the trochlear point, whereas its more inferoposterior aspect is delineated by the medial arch point. Likewise, the PMB is located along the wall of the notch and distal to the medial arch point[12] (Fig 2).

The femoral attachments of the ALB and PMB are then marked with an arthroscopic coagulator (Smith & Nephew, Andover, MA). The ALB attachment is first outlined between the trochlear point and medial arch point and adjoining the edge of the articular cartilage. This tunnel needs to be as distal as possible. The PMB attachment is next marked approximately 8 to 9 mm posterior to the edge of the articular cartilage of the medial femoral condyle and slightly posterior to the ALB tunnel.

An 11-mm-diameter acorn reamer (Arthrex, Naples, FL) placed through the anterolateral arthroscopic portal is used to outline and ultimately ream the ALB femoral tunnel. The reamer is positioned at the previously marked center of the ALB so that the reamer edges are against the margins of the articular cartilage at the top of the intercondylar roof and centered between the trochlear point and the medial arch point. An eyelet pin is then drilled through the reamer anteromedially out of the knee (Fig 3). A closed-socket tunnel is reamed over the eyelet pin to a depth of 25 mm. A passing suture is pulled through the tunnel to facilitate later graft passage. With use of the same technique, a 7-mm reamer is placed against the outline of the PMB, and an eyelet pin is also drilled through this reamer, exiting through the anteromedial aspect of the knee. A 25-mm-deep closed socket is likewise reamed. A 2-mm bone bridge distance is maintained between the two femoral PCL bundle tunnels (Fig 4).

A 70° arthroscope (Smith & Nephew) is then used to visualize an arthroscopic shaver (Smith & Nephew) placed through a posteromedial portal to debride the PCL tibial attachment. The PCL tibial attachment site is identified distally along the PCL facet until the proximal aspect of the popliteus muscle fibers is visualized. Next, a guide pin is drilled, entering the anteromedial aspect of the tibia approximately 6 cm distal to the joint line,

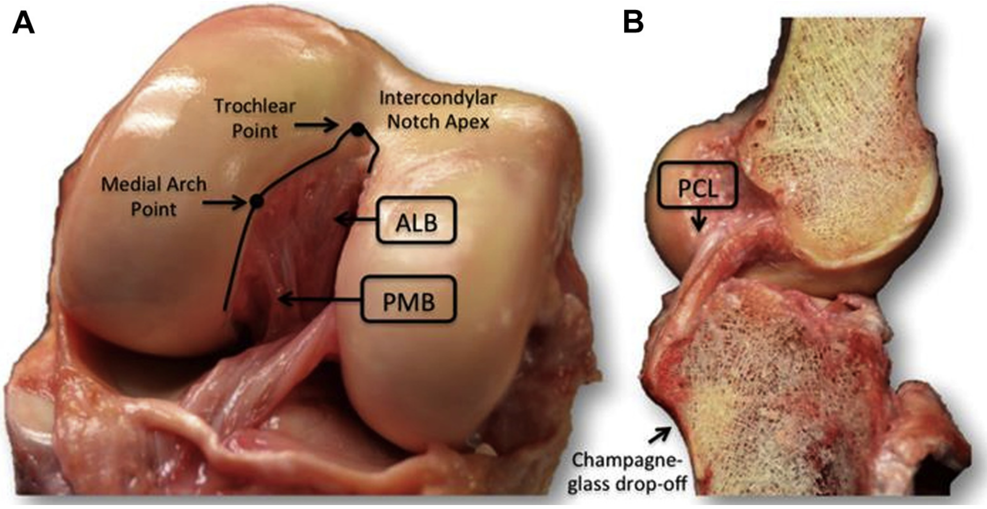


**Fig 2.** (A) Left knee showing both bundles: anterolateral bundle (ALB) and posteromedial bundle (PMB). The trochlear point is easily identifiable on the distal aspect of the trochlea. The more anterior aspect of the ALB is noted by the trochlear point, whereas its more inferoposterior aspect is delineated by the medial arch point. Likewise, the PMB is located along the wall of the notch and distal to the medial arch point. (B) Profile view of a hemi-sectioned left knee showing the tibial and femoral insertion of the posterior cruciate ligament (PCL).

centered between the anterior tibial crest and the medial tibial border, and exiting posteriorly at the center of the PCL tibial attachment along the previously described PCL bundle ridge, which has been reported to be located between the ALB and PMB on the tibia.[12] Intraoperative anteroposterior and lateral radiographs or fluoroscopy is used to verify tibial pin placement, which on the lateral radiograph should be approximately 6 to 7 mm proximal to the champagne-glass drop-off at the PCL facet on the posterior part of the tibia (Fig 5). On anteroposterior radiographs, this point is identified at the medial aspect of the lateral tibial eminence and 1 to 2 mm distal to the joint line.

Once radiographic confirmation of the desired tibial guide pin location is made, a large curette is passed through the posteromedial arthroscopic portal both to retract the posterior tissues away from the reamer and to protect against guide pin protrusion. Then, a 12-mm acorn reamer (Arthrex) over-reams the tibial guide pin under direct posterior arthroscopic visualization. Using a smooth-bore reamer is not recommended when reaming the tibial tunnel because of the increased risk of unknown penetration out of the posterior tibial cortex, which could lead to iatrogenic popliteal artery injury.[14] If bone chatter is encountered as the surgeon approaches the posterior cortex of the tibia, the surgeon's hand can be lowered to allow the acorn reamer to "walk over" the posterior tibial cortex and not over-penetrate it. If necessary, the exit of the reamer out of the posterior tibial cortex can be performed by hand.

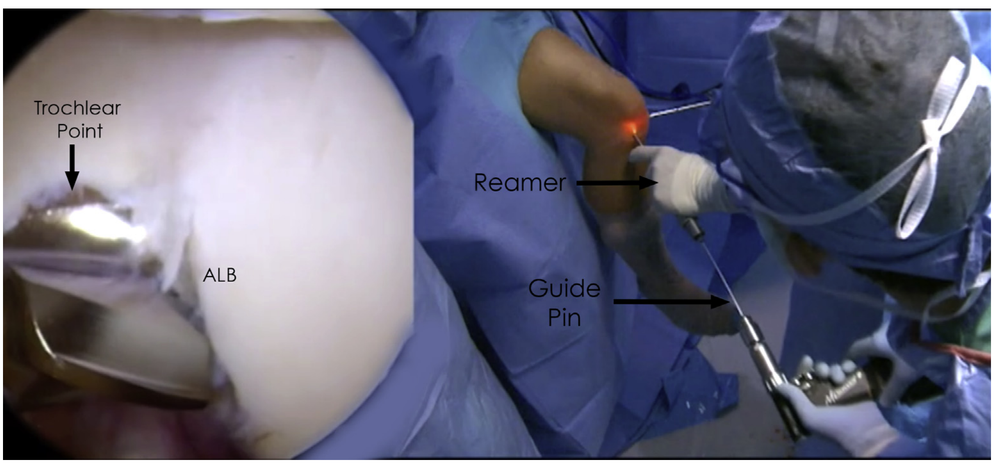


**Fig 3.** Arthroscopic view through anteromedial portal and extra-articular view of a right knee. An 11-mm-diameter reamer is used to outline (against the cartilage) and ream the anterolateral bundle (ALB) femoral tunnel. It should be centered between the trochlear point and the medial arch point. An eyelet pin is then drilled through the reamer.

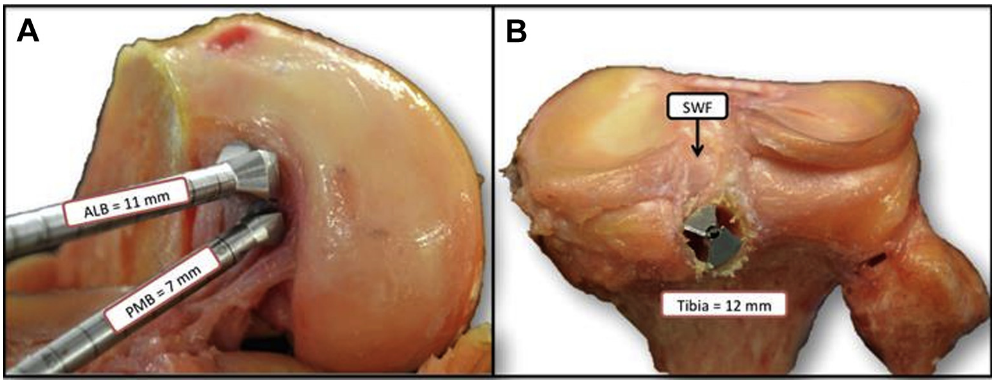


**Fig 4.** Anatomic posterior cruciate ligament attachment sites. (A) Hemi-sectioned image of right knee showing anterolateral bundle (ALB) reamer positioning (11-mm reamer) and posteromedial bundle (PMB) reamer positioning (7-mm reamer) on the femur. Of note, there must exist a 2-mm space between both femoral tunnels. (B) Tibial posterior view of a right knee showing the desired reamer position exit site, with the shiny white fibers (SWF) taken as an anatomic landmark (12-mm reamer).

Passing sutures are placed in the femoral and tibial tunnels to help pass each graft.

Next, a large smoother (Gore Smoother Crucial Tool; Smith & Nephew) is passed proximally up the tibial tunnel and pulled out the anteromedial arthroscopic portal with a grasper. The smoother is gently cycled several times to smooth the intra-articular tibial tunnel aperture to remove any bony spicules, which could interfere with graft passage. It is important to ensure that the smoother does not injure the posterior horn of the medial meniscus root attachment. The closed-loop tip of the smoother is then pulled back into the joint and passed out of the anterolateral arthroscopic portal. A small clamp can secure the end of the smoother in place. Graft passage can now be performed. The PMB graft is passed into its femoral tunnel with the passing suture directed through the anterolateral portal. The PMB graft is then fixed with a 7 × 23—mm bioabsorbable interference screw (Arthrex) (with positioning of the screw at the posteroinferior aspect of the tunnel). The bone plug for the ALB graft is similarly passed into its femoral tunnel with the cortical side of the bone plug placed into the

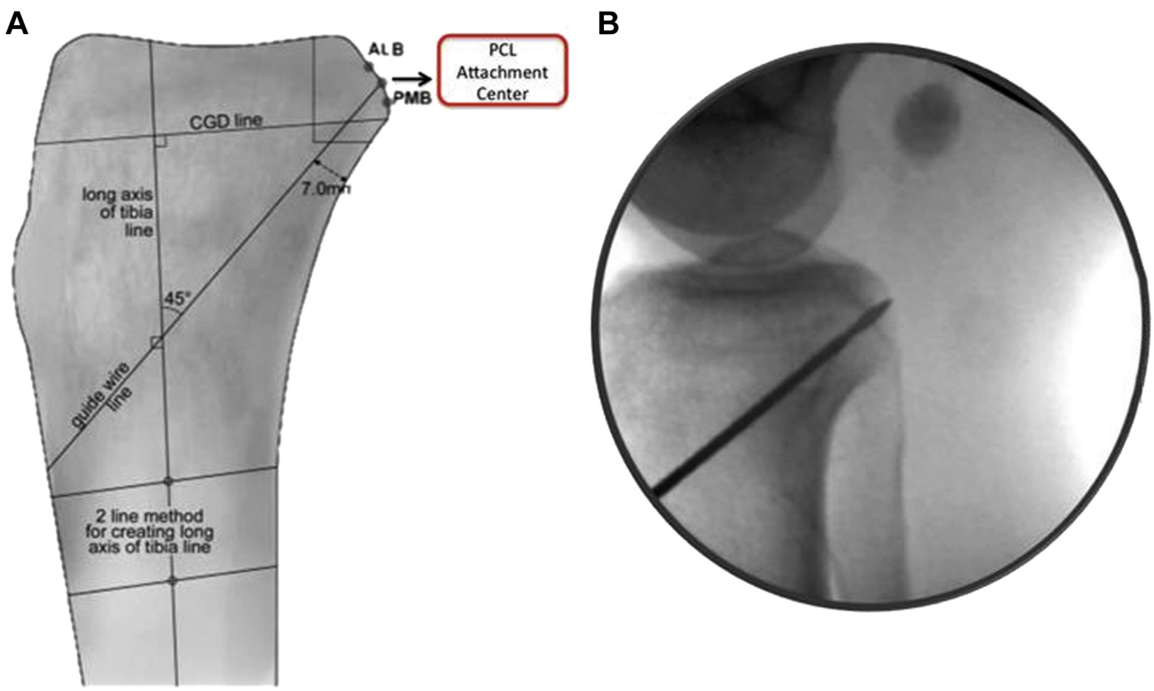


**Fig 5.** (A) Illustration of radiographic lateral tibia view of the right knee. The measurement axis was generated from an estimated long axis of the tibia line. Reprinted with permission.[13] (B) Fluoroscopic lateral image of transtibial tunnel guide pin placement at posterior aspect of tibia in the right knee. Reprinted with permission.[11] (ALB, anterolateral bundle; CGD, position depicting champagneglass drop-off on tibia; PCL, posterior cruciate ligament; PMB, posteromedial bundle.)

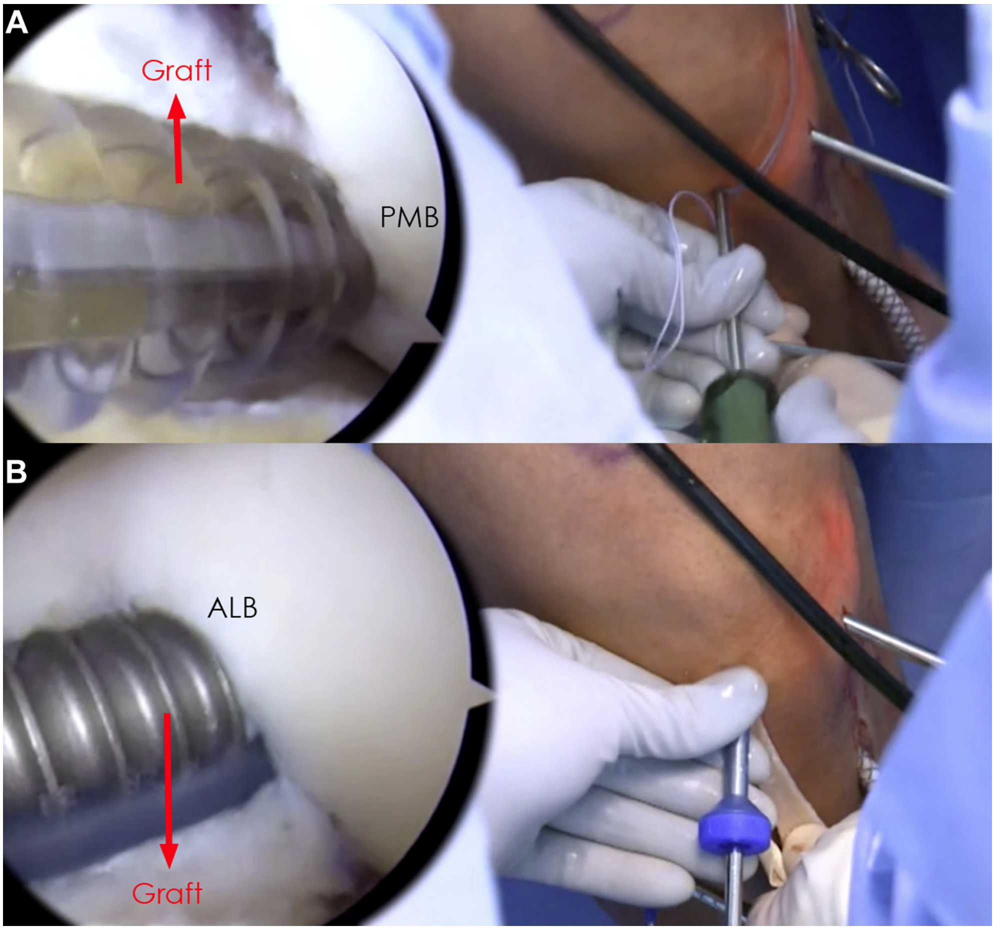


**Fig 6.** Arthroscopic view through anteromedial portal and extra-articular view of a right knee showing (A) posteromedial bundle (PMB) fixation and (B) anterolateral bundle (ALB) fixation. For the PMB graft, the bioabsorbable screw should be positioned at the posteroinferior aspect of the tunnel. For the ALB graft, the titanium interference screw should be positioned at the anterosuperior aspect of the tunnel.

posterior portion of the tunnel adjacent to the articular cartilage and secured with a 7 × 20−mm titanium interference screw (Arthrex) (with positioning of the screw at the anterosuperior aspect of the tunnel) (Fig 6). If necessary, the end of the bone plug can be directed into the femoral tunnel by use of a small elevator.

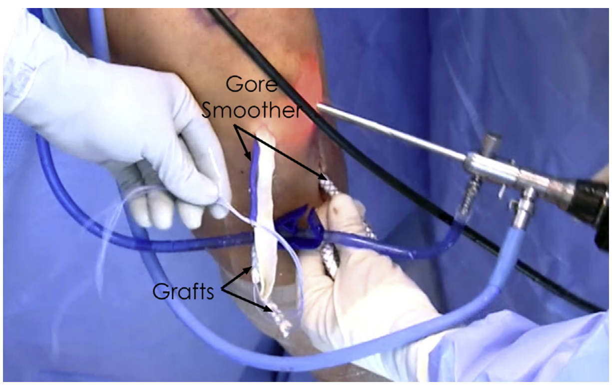


**Fig 7.** Extra-articular view of graft passage in a right knee. The closed-loop tip of the smoother is exiting the anterolateral arthroscopic portal. The sutures are passed through the loop and then pulled through the tibial tunnel.

After the PCL grafts are fixed in the femoral tunnels, the sutures in the ends of both grafts are passed through the loop tip of the smoother (Fig 7). The smoother, with the graft sutures in its eyelet tip, is pulled distally down the tibial tunnel and out of the anteromedial aspect of the tibia and individually cycled several times to remove any potential slack in the grafts. Arthroscopic verification should confirm that the anterior cruciate ligament is reduced to its normal position with traction concurrently placed on the grafts.

In addition, the normal tibiofemoral step-off is verified to be restored while traction is applied to the grafts. With the knee flexed to 90° and in neutral rotation, the ALB is secured to the tibia with a fully threaded, bicortical 6.5 × 40−mm cannulated cancellous screw (Arthrex) and an 18-mm spiked washer (Arthrex) (Fig 8).[15] The PMB is then secured to the tibia with the knee in full extension with the same sized screw and washer that were used for ALB fixation while distal traction is placed on the graft[15] (Fig 9). During tibial graft fixation, an anterior reduction force is applied to the tibia and distal traction is applied to the graft. Verification of posterior stability is confirmed with elimination of the posterior drawer test at 90° of knee

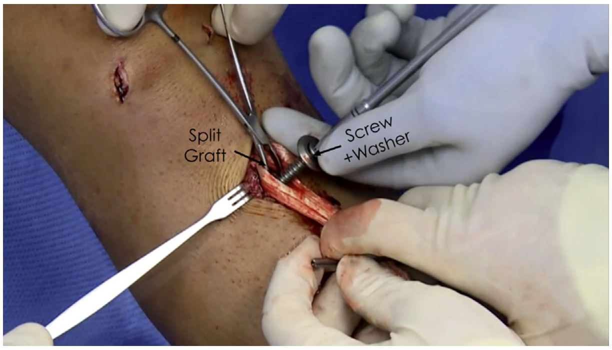


**Fig 8.** Fixation of grafts in a right knee. The grafts are secured to the tibia with a fully threaded, bicortical 6.5 × 40–mm cannulated cancellous screw (through the split tendon graft) and an 18-mm spiked washer.

flexion.[15] The excess portion of the grafts is excised, and the skin and subcutaneous tissues are closed with a subcuticular suture.

## Postoperative Rehabilitation

Rehabilitation should be focused on progressive weight bearing, prevention of posterior subluxation, and strengthening of the quadriceps muscle. Postoperatively, all patients remain non–weight bearing for 6 weeks with a PCL brace (Jake brace [Albrecht, Stephanskirchen, Germany] or Rebound brace [Ossur, Reykjavik, Iceland]). Physical therapy emphasizes early quadriceps muscle activation and prone knee flexion from 0° to 90° of flexion. Knee motion increases past 90° as tolerated starting 2 weeks postoperatively, with prone knee flexion exercises. Six weeks postoperatively, patients begin weight-bearing exercises. The use of a stationary bike with low resistance settings and leg presses to a maximum of 70° of knee flexion is initiated. Additional increases in low-impact knee exercises are permitted as tolerated, starting 12 weeks postoperatively.

Six months postoperatively, patients are evaluated clinically and with kneeling posterior stress radiographs. If there is objective evidence of adequate healing of the double-bundle PCLR (<2 mm of increased posterior translation compared with the contralateral knee), patients are allowed to discontinue the permanent use of the PCL brace and to initiate a slowly progressive impact and agility exercise program. Patients with greater than 2 mm of increased posterior translation, a revision PCLR, or a body mass

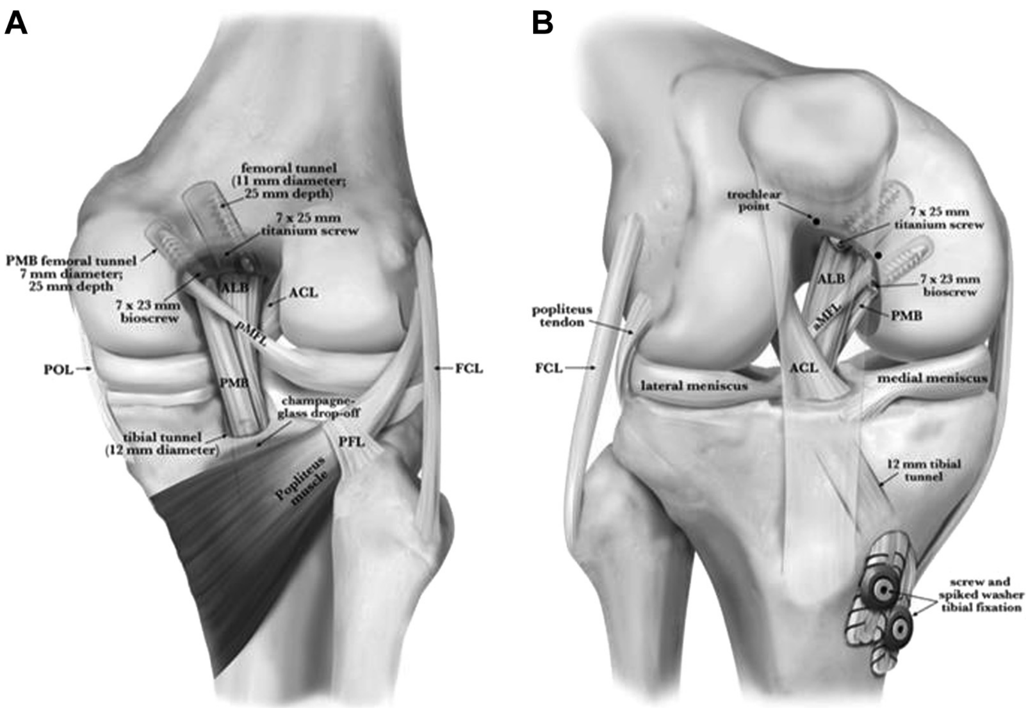


**Fig 9.** (A) Posterior and (B) anterior views of anatomic double-bundle posterior cruciate ligament reconstruction. The reconstructed anterolateral bundle (ALB) and posteromedial bundle (PMB) are shown, as well as the size, shape, and location of their femoral and tibial tunnels. The PMB enters the tibial tunnel posteromedial to the ALB. The PMB is posterior in the transtibial tunnel and exits deep to the ALB and then is fixed medially and distally to the ALB. Femoral fixations of both bundles and the champagne-glass drop-off, the anatomic landmark for transtibial tunnel drilling, are also displayed. Reprinted with permission.[16] (ACL, anterior cruciate ligament; aMFL, anterior meniscofemoral ligament [ligament of Humphrey]; FCL, fibular collateral ligament; PFL, popliteofibular ligament; pMFL, posterior meniscofemoral ligament [ligament of Wrisberg]; POL, posterior oblique ligament.)

**Table 1.** Pearls and Pitfalls

| Pearls | Pitfalls |
|---|---|
| Kneeling stress radiographs are an effective tool to evaluate the degree of PCL injury: 0-7 mm, partial tear; 8-11 mm, complete isolated PCL tear; and $\geq$12 mm, combined PCL and PLC or posteromedial knee tear. | The patient must ideally place his or her entire body weight on the tubercle of the injured knee to elicit the diagnostically appropriate posterior drawer force. This may be a painful experience, and physician support and coaching may be required. |
| During patient positioning, no distal leg fixation is required, and it is important to remember to allow for the ability to flex and extend the knee at various stages of the surgical procedure. | |
| During graft preparation, while the surgeon is whipstitching the soft-tissue graft ends, tightly spacing the sutures protects the grafts from laceration when securing with an interference screw. | Care must be taken not to violate the suture fibers with the needle while the surgeon is tightly stitching the graft. |
| Anatomic identification of each bundle is imperative. Use of an arthroscopic coagulator to mark the location of each bundle allows for more accurate tunnel placement. | |
| Slight divergence of the femoral tunnels ensures that the tunnels will not collapse during fixation. | The interference screws should be placed within the tunnel opposite the bone bridge so as to reduce the potential for fracture. |
| Acorn reamers are recommended so that the surgeon may add fine adjustments to the tunnel path as he or she drills. Particularly, the surgeon may drop his or her hand to lengthen the femoral tunnels as he or she travels proximally. This allows for accommodation of slightly longer bone blocks. | |
| Use of intraoperative fluoroscopy and a large protective curette is encouraged while the surgeon is drilling the posteriorly aimed tibial tunnel. This provides protection to the neurovascular bundle. | |
| A tunnel smoother should be used to reduce friction between the graft and the aperture of the tibial tunnel at the "killer turn"; this reduces the chance of graft laceration as it is drawn into the tunnel. | |
| The ALB should be fixed with the knee in 90° of flexion, whereas the PMB should be fixed with the knee in full extension. | Given the co-dominant nature of the bundles, incorrect knee flexion angles during fixation may result in graft laxity during motion. |
| The senior author (R.F.L.) has found that use of a screw and washer graft fixation system on the anterior tibia minimizes postoperative pain while providing optimal fixation strength. | The use of ligament staples for tibial graft fixation has resulted in prolonged anterior knee pain for past patients and should be avoided. |
| Postoperative rehabilitation should focus on progressive weight bearing and quadriceps activation. | |

ALB, anterolateral bundle; PCL, posterior cruciate ligament; PLC, posterolateral corner; PMB, posteromedial bundle.

index of greater than 35 kg/m$^2$ are instructed to continue to use the PCL brace at night until 1 year postoperatively.

Patients who are allowed to discontinue using the brace can initiate a jogging program, as well as side-to-side and proprioceptive exercises. Functional testing is performed between 9 and 12 months postoperatively to determine the ability of the patients to return to full activities. The functional PCL Rebound brace is worn for the first year of a patient's return to athletic competition. Pearls and pitfalls for our surgical procedure are presented in Table 1.

## Discussion

Anatomic double-bundle PCLR has emerged as an alternative to single-bundle reconstruction to better restore the anatomy and the native kinematics of the knee compared with the single-bundle technique.[15] The anatomic double-bundle PCLR technique has shown improved subjective and objective patient outcomes.[17] We believe this technique has a faster quadriceps recovery time because there is no injury to the vastus medialis muscle.[11]

A 2009 systematic review failed to show superiority when comparing single-bundle PCLR and double-bundle PCLR.[18] However, two recent prospective randomized studies have suggested that although clinical outcomes are similar between both isolated transtibial reconstruction techniques, the objective measures of postoperative side-to-side posterior translation and objective International Knee Documentation Committee scores were significantly improved with double-bundle PCLR compared with single-bundle PCLR.[19,20] Another procedure reported in the literature is the tibial-inlay technique. Two studies retrospectively compared single-bundle versus double-bundle tibial-inlay PCLR.[21,22] Both of these studies failed to prove a significant difference between the two groups.

Regarding graft selection, a systematic review noted satisfactory clinical and functional results for both allograft and autograft but could not identify a clear difference in outcomes between the two.[23] Wang et al.[24] reported no significant difference between allograft tissues (Achilles and anterior tibialis tendon grafts) and autograft tissues (semitendinosus, gracilis, and quadriceps tendon grafts). However, complications were more prevalent with autogenous grafts. Ahn et al.[25] reported a slightly better Lysholm score in their autograft group (Achilles tendon graft) in comparison to their allograft group (semitendinosus/gracilis tendon) ($P < .01$). International Knee Documentation Committee scores and stress radiography findings were not significantly different between the two groups. We recommend our approach for double-bundle PCLR. We encourage further studies by other groups to evaluate our surgical technique and the long-term subjective and objective patient outcomes.

## References

1. Sekiya JK, Whiddon DR, Zehms CT, Miller MD. A clinically relevant assessment of posterior cruciate ligament and posterolateral corner injuries. Evaluation of isolated and combined deficiency. *J Bone Joint Surg Am* 2008;90:1621-1627.
2. Girgis FG, Marshall JL, Monajem A. The cruciate ligaments of the knee joint. Anatomical, functional and experimental analysis. *Clin Orthop Relat Res* 1975;(106):216-231.
3. Van Dommelen BA, Fowler PJ. Anatomy of the posterior cruciate ligament. A review. *Am J Sports Med* 1989;17:24-29.
4. Papannagari R, DeFrate LE, Nha KW, et al. Function of posterior cruciate ligament bundles during in vivo knee flexion. *Am J Sports Med* 2007;35:1507-1512.
5. Harner CD, Janaushek MA, Kanamori A, Yagi M, Vogrin TM, Woo SL. Biomechanical analysis of a double-bundle posterior cruciate ligament reconstruction. *Am J Sports Med* 2000;28:144-151.
6. Kennedy NI, LaPrade RF, Goldsmith MT, et al. Posterior cruciate ligament graft fixation angles, part 1: Biomechanical evaluation for anatomic single-bundle reconstruction. *Am J Sports Med* 2014;42:2338-2345.
7. Lenschow S, Zantop T, Weimann A, et al. Joint kinematics and in situ forces after single bundle PCL reconstruction: A graft placed at the center of the femoral attachment does not restore normal posterior laxity. *Arch Orthop Trauma Surg* 2006;126:253-259.
8. Matava MJ, Ellis E, Gruber B. Surgical treatment of posterior cruciate ligament tears: An evolving technique. *J Am Acad Orthop Surg* 2009;17:435-446.
9. Fanelli GC. Posterior cruciate ligament injuries in trauma patients. *Arthroscopy* 1993;9:291-294.
10. Jackman T, LaPrade RF, Pontinen T, Lender PA. Intraobserver and interobserver reliability of the kneeling technique of stress radiography for the evaluation of posterior knee laxity. *Am J Sports Med* 2008;36:1571-1576.
11. LaPrade CM, Civitarese DM, Rasmussen MT, LaPrade RF. Emerging updates on the posterior cruciate ligament: A review of the current literature. *Am J Sports Med* 2015;43:3077-3092.
12. Anderson CJ, Ziegler CG, Wijdicks CA, Engebretsen L, LaPrade RF. Arthroscopically pertinent anatomy of the anterolateral and posteromedial bundles of the posterior cruciate ligament. *J Bone Joint Surg Am* 2012;94:1936-1945.
13. Johannsen AM, Anderson CJ, Wijdicks CA, Engebretsen L, LaPrade RF. Radiographic landmarks for tunnel positioning in posterior cruciate ligament reconstructions. *Am J Sports Med* 2013;41:35-42.
14. Zawodny SR, Miller MD. Complications of posterior cruciate ligament surgery. *Sports Med Arthrosc* 2010;18:269-274.
15. Kennedy NI, LaPrade RF, Goldsmith MT, et al. Posterior cruciate ligament graft fixation angles, part 2: Biomechanical evaluation for anatomic double-bundle reconstruction. *Am J Sports Med* 2014;42:2346-2355.
16. Wijdicks CA, Kennedy NI, Goldsmith MT, et al. Kinematic analysis of the posterior cruciate ligament, part 2: A comparison of anatomic single- versus double-bundle reconstruction. *Am J Sports Med* 2013;41:2839-2848.
17. Spiridonov SI, Slinkard NJ, LaPrade RF. Isolated and combined grade-III posterior cruciate ligament tears treated with double-bundle reconstruction with use of endoscopically placed femoral tunnels and grafts: Operative technique and clinical outcomes. *J Bone Joint Surg Am* 2011;93:1773-1780.
18. Kohen RB, Sekiya JK. Single-bundle versus double-bundle posterior cruciate ligament reconstruction. *Arthroscopy* 2009;25:1470-1477.
19. Li Y, Li J, Wang J, Gao S, Zhang Y. Comparison of single-bundle and double-bundle isolated posterior cruciate ligament reconstruction with allograft: A prospective, randomized study. *Arthroscopy* 2014;30:695-700.
20. Yoon KH, Bae DK, Song SJ, Cho HJ, Lee JH. A prospective randomized study comparing arthroscopic single-bundle and double-bundle posterior cruciate ligament reconstructions preserving remnant fibers. *Am J Sports Med* 2011;39:474-480.
21. Shon OJ, Lee DC, Park CH, Kim WH, Jung KA. A comparison of arthroscopically assisted single and double bundle tibial inlay reconstruction for isolated posterior cruciate ligament injury. *Clin Orthop Surg* 2010;2:76-84.
22. Kim SJ, Kim TE, Jo SB, Kung YP. Comparison of the clinical results of three posterior cruciate ligament reconstruction techniques. *J Bone Joint Surg Am* 2009;91:2543-2549.
23. Hudgens JL, Gillette BP, Krych AJ, Stuart MJ, May JH, Levy BA. Allograft versus autograft in posterior cruciate ligament reconstruction: An evidence-based systematic review. *J Knee Surg* 2013;26:109-115.
24. Wang CJ, Chan YS, Weng LH, Yuan LJ, Chen HS. Comparison of autogenous and allogenous posterior cruciate ligament reconstructions of the knee. *Injury* 2004;35:1279-1285.
25. Ahn JH, Yoo JC, Wang JH. Posterior cruciate ligament reconstruction: Double-loop hamstring tendon autograft versus Achilles tendon allograft—Clinical results of a minimum 2-year follow-up. *Arthroscopy* 2005;21:965-969.