Technical Note

Autograft Anatomic, Double-Bundle Posterior Cruciate Ligament Reconstruction

Nelson Ponzo, M.D., Juan Del Castillo, M.D., José Fregeiro, M.D., Mitchell I. Kennedy, B.S., and Robert F. LaPrade, M.D., Ph.D.

Abstract: It is well known that the posterior cruciate ligament (PCL) is the main stabilizer to posterior tibial translation in the knee. Anatomic double-bundle reconstruction has recently been proposed to best restore posterior and rotational tibial instability, especially compared with a single-bundle PCL reconstruction (PCLR). Most publications in the peer-reviewed literature on double-bundle PCLR have used allografts. However, in many countries, allografts are not available. This Technical Note describes an all-autograft arthroscopic technique for PCLR using the quadriceps and semitendinosus tendons.

The 2 bundles of the posterior cruciate ligament (PCL) have been documented to be the main static stabilizers of the knee to both posterior tibial translation (PTT) and rotational stability, working in a codominant relation.1,2 More recent robotic work has noted that both the anterolateral bundle (ALB) and posteromedial bundle (PMB) of the PCL function synergistically to provide stability to the knee.3,4 Studies have documented that double-bundle (DB) PCLR has improved kinematic and objective stability in restoring nearly normal PTT to the knee. However, most of these studies have used allograft tissue to reconstruct the 2 bundles. In many countries, the use of autografts is limited because of either cultural issues or significant cost.5 Therefore, we present the technique of anatomic DB PCLR using both quadriceps tendon and semitendinosus autografts. Thus, the purpose of this study was to describe our anatomic DB PCLR using autograft tissues (Video 1).

Technique

Diagnosis

The diagnosis of PCL tears depends on a thorough clinical examination and the use of PCL stress radiographs. The posterior drawer test should be assessed to determine whether there is an increase in PTT compared with the contralateral normal knee, with the knee flexed to 90°.6 Concurrent with this, the patient can perform the quadriceps active test to determine whether he or she has a posterior tibial sag present. It is important to recognize that most PCL tears occur with other concurrent ligament injuries,7 so assessments using the Lachman test, pivot-shift test, varus and valgus stress testing, and anteromedial and posterolateral drawer tests are an essential part of the workup for a PCL tear.

In addition to the clinical examination, radiographs are important to assess for PCL tears. Acute PCL tears may show avulsion injuries, whereas chronic PCL tears may show posterior tibial subluxation on plain radiographs. We strongly recommend the use of bilateral PCL stress radiographs to determine the amount of PTT objectively. An increase in PTT of 8 mm on the posterior stress radiograph compared with the contralateral knee is indicative of a complete PCL tear, whereas an increase in PTT of 12 mm or greater usually is an...
indication of a combined PCL and posterolateral corner or posteromedial corner injury.\textsuperscript{7}

**Indications for PCLR**

It is important to differentiate between acute and chronic PCL tears. In isolated acute tears, a trial of physical therapy, often augmented by a dynamic PCL brace or a brace with a posterior wedge to prevent PTT, allows the PCL to heal in a more anatomic position and reduces the risk of significant functional difficulties.\textsuperscript{8}

For combined PCL tears with other ligament injuries, it is usually recommended to proceed with 1-stage surgery to address the ligament instability by ligament reconstruction. For chronic injuries, it is important to determine whether the injury is isolated or combined. Combined chronic ligament injuries need long-leg alignment radiographs to ensure that a concurrent osteotomy may not be indicated primarily as the first stage when multistage procedures are necessitated.

**Preoperative Setup**

The patient is positioned in the supine position on the operating table. After induction of anesthesia, a bilateral
knee examination is recommended to thoroughly assess for the presence of any concurrent ligament injury. An ipsilateral tourniquet is placed high on the thigh, and the leg is placed in a leg holder (Muzoho OSI, Union City, CA). The contralateral normal leg should be positioned such that it is not in the operative field and undergoes no increase in traction.

Attachment Site Identification and Tunnel Preparation

A comprehensive arthroscopic examination of the knee is performed through standard anterolateral and anteromedial arthroscopic portals. The anterior cruciate ligament will appear slack from the tibia sitting posteriorly, resultant of the missing stabilizing force of the PCL (Fig 1). The tunnel placement is vital to ensure correct anatomic replication of the native PCL attachment sites; these are further detailed in Figure 2. The attachment site of the ALB is outlined between the trochlea point and the medial arch point on the roof of the intercondylar notch with an arthroscopic coagulator (Smith & Nephew, Andover, MA). The attachment site of the PMB is outlined on the wall of the intercondylar notch and distal to the medial arch point (Fig 3). An eyelet pin is drilled from the center of the ALB attachment site out the anteromedial aspect of the medial femoral condyle; the pin should exit near the adductor tubercle. An 11-mm-diameter acorn reamer (Arthrex, Naples, FL) is then reamed to a depth of 25 mm (Fig 4). A similar eyelet pin is drilled anteromedially out the medial femoral condyle, exiting the anteromedial knee more distally than the ALB guide pin. A 7-mm reamer is reamed to a depth of 25 mm, again creating a closed socket tunnel. A 2-mm bone bridge should be maintained between these femoral tunnels.

Once the posteromedial arthroscopic portal is localized, a 30° or 70° arthroscope (Smith & Nephew) is used to visualize the tibial attachment site of the PCL. An arthroscopic shaver (Smith & Nephew) is initially used to debulk any scar tissue and torn ligament. When the surgeon is dissecting directly down on the attachment site of the PCL, it is important to release the more proximal attachment of the PCL to visualize the popliteus tendon musculature; overly proximal placement puts the posterior horn of the medial meniscal root at risk of iatrogenic damage. Identification of bony landmarks,
such as the bundle ridge, midpoint between the ALB and PMB, and the champagne-glass drop-off (i.e., the drop-off of the tibia at the location of the popliteus musculature), is vital to ensure correct anatomic positioning. The bundle ridge is about 6 to 7 mm proximal to the champagne-glass drop-off.

For the tibial tunnel, a guide pin is drilled at a 45° angle from the anteromedial aspect of the tibia 6 cm distal to the joint line, ultimately exiting posterior to the bundle-ridge landmark. While the surgeon is using a 12-mm acorn reamer or FlipCutter (Arthrex), a curette may be placed through the posteromedial portal to prevent overpenetration and damage to the popliteal artery. After the femoral and tibial tunnels are drilled, passing stitches should be placed to facilitate graft passage later in the procedure.

**Graft Harvest and Preparation**

For quadriceps tendon graft harvest, a 12- to 15-cm vertical incision is made over the proximal aspect of the extensor mechanism, centered over the quadriceps and extending distally to about half the length of the patella. A 20 × 11-mm–diameter bone plug is then harvested off the patella, ensuring the graft is at least 10 cm in overall length and nearly full thickness.

For harvesting of the semitendinosus tendon, an incision is made over the proximal anteromedial tibia, approximately 6 cm distal to the joint line. Dissection down through the pes tendons is performed, and a surgical release of the semitendinosus tendon is performed directly off the tibia. The end of the semitendinosus tendon is then whipstitched, and an open hamstring harvester is placed up along the tendon to harvest the tendon at the musculotendinous junction. The quadriceps tendon bone plug is sized to fit through an 11-mm tunnel along with the distal soft-tissue end, which is tubularized with No. 5 nonabsorbable sutures and ultimately used for the ALB graft. The ends of the semitendinosus graft are whipstitched on each end with No. 5 nonabsorbable sutures and are used for the PMB graft. Graft harvesting is further visualized in Figure 5.

**Graft Fixation**

The PMB graft is passed first and secured thoroughly against the edge of the notch with a 7 × 23-mm

| Table 1. Advantages and Disadvantages |
|---------------------------------------|
| Advantages                            | Disadvantages                                             |
| Quantitative radiographic assessment allows for clearly defined parameters of isolated PCL injuries (PTT >8 mm) or concurrent PLC injury (PTT >12 mm). Lower rates of anterior knee pain are reported relative to patellar tendon graft use. Native biomechanics is re-established owing to the restoration of the native anatomic attachment points and double-bundle reconstruction. | No bone-to-bone healing occurs. Extended pain may occur during quadriceps muscle activation during rehabilitation. |

PCL, posterior cruciate ligament; PLC, posterolateral corner; PTT, posterior tibial translation.
bioabsorbable screw (Arthrex). Sutures for the ALB bone plug of the quadriceps autograft are pulled into the respective femoral tunnel and fixed by a 9 × 20-mm titanium screw (Arthrex); screw placement is shown in Figure 6. The graft is passed down the tibial tunnel, and the ALB graft is fixed first with the knee flexed to 90°, with partial-protected weight-bearing programs beginning at 6 wk, allowing low-level activities for the first 6 mo, and full activity participation allowed around the 9- to 12-mo time point.

Postoperative Rehabilitation

Patients are kept non-weight bearing for the first 6 weeks but are allowed to initiate prone knee flexion from 0° to 90° for the first 2 weeks. At 6 weeks, a partial-protected weight-bearing program is begun and patients are weaned off crutches; low-level activities are advocated in the first 6 months to allow the graft to heal. At the 6-month point, if a PCL stress radiograph difference of 2 mm or less to the contralateral side is present, an increase in activity level may be allowed. Full activity participation is typically allowed closer to the 9- to 12-month point. In addition, gravity can have deleterious effects on PCLR; to negate this effect, a dynamic PCL brace (Rebound Brace; Ossur, Reykjavik, Iceland) or a brace with a posterior bolster is recommended.

Discussion

The most important feature of the described technique is that autograft tissue, specifically the quadriceps tendon, can be readily used for anatomic DB PCLR, resulting in an improved method to restore knee stability and kinematics. The main limitation of using the quadriceps tendon for the PCL graft is the potential effect it may have on the quadriceps mechanism. Graft harvesting of the quadriceps tendon has been associated with deficits in the quadriceps mechanism and prolonged pain, but reports are limited to case reports because long-term outcome studies have yet to publish.
data on this occurrence. In addition, a recent biomechanical analysis on DB PCLR graft use during simulated partial weight-bearing protocols found that in combination with a hamstring tendon, less laxity was associated with patellar tendon autografts (1.06 mm) relative to the quadriceps tendon autografts (1.50 mm, $P = .01$). The earlier healing allowed from using autograft tissue may help to overcome these limitations. Last, access to allografts may be limited by countries’ health care policies, and quadriceps graft use provides an autograft option for patients requiring multiple graft harvesting in surgical reconstruction procedures.

Although the overall improvement of subjective outcomes from DB versus single-bundle PCLR needs to be further analyzed, we strongly believe that objectively restoring stability to the knee through anatomic restoration better allows patients to improve their function and decreases the risk of arthritis development in the medial and patellofemoral compartments. To summarize, we recommend our anatomic, autograft DB PCLR technique in those circumstances in which allografts may not be available or in which the cost of allografts may be prohibitive for some patients (Tables 1 and 2).

References
1. Harner CD, Vogrin TM, Hoher J, Ma CB, Woo SL. Biomechanical analysis of a posterior cruciate ligament reconstruction. Deficiency of the posterolateral structures as a cause of graft failure. *Am J Sports Med* 2000;28:32-39.
2. 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.
3. 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.
4. Kennedy NI, Wijdicks CA, Goldsmith MT, et al. Kinematic analysis of the posterior cruciate ligament, part 1: The individual and collective function of the anterolateral and posteromedial bundles. *Am J Sports Med* 2013;41:2828-2838.
5. 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.
6. 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.
7. 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.
8. LaPrade RF, Smith SD, Wilson KJ, Wijdicks CA. Quantification of functional brace forces for posterior cruciate ligament injuries on the knee joint: An in vivo investigation. *Knee Surg Sports Traumatol Arthrosc* 2015;23:3070-3076.
9. 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.
10. Moatshe G, Slette EL, Engebretsen L, LaPrade RF. Intertunnel relationships in the tibia during reconstruction of multiple knee ligaments: How to avoid tunnel convergence. *Am J Sports Med* 2016;44:2864-2869.
11. LaPrade CM, Smith SD, Rasmussen MT, et al. Consequences of tibial tunnel reaming on the meniscal roots during cruciate ligament reconstruction in a cadaveric model, part 1: The anterior cruciate ligament. *Am J Sports Med* 2015;43:200-206.
12. Zawodny SR, Miller MD. Complications of posterior cruciate ligament surgery. *Sports Med Arthrosc Rev* 2010;18:269-274.
13. 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.
14. Mook WR, Civitarese D, Turnbull TL, Kennedy NI, O’Brien L, Schoeberl JB, LaPrade RF. Double-bundle posterior cruciate ligament reconstruction: a biomechanical analysis of simulated early motion and partial and full weightbearing on common reconstruction grafts. *Knee Surg Sports Traumatol Arthrosc* 2017;25(8):2536-2544.