Technical Note

Anatomic Double Bundle Posterior Cruciate Ligament Reconstruction Using an Internal Splint

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Abstract: Techniques for reconstruction of posterior cruciate ligament (PCL) tears are rapidly evolving. One problem with current techniques is that laxity may develop early in the postoperative period, leading to relapsed posterior translation of the tibia. Therefore, maintaining tibial reduction during graft incorporation is a target for improvement. We describe using an internal splint to optimize the 4-tunnel, double-bundle allograft PCL reconstruction.

The posterior cruciate ligament (PCL) is the primary restraint to posterior tibial translation and the secondary restraint to internal and external rotation, especially in deep flexion.[1] Although nonoperative management may be sufficient for many low-grade isolated PCL injuries, it may prove to be inadequate over time and in high-demand patients. For instance, the need for our active duty military population to engage in physically rigorous occupational demands, where Service Members are unable to self-limit their activities, makes nonoperative management of PCL injuries a poor option.

PCL reconstruction strategies have continued to evolve.[2-6] Although these techniques can achieve minimal posterior translation intraoperatively, joint laxity may recur insidiously after surgery. In a cohort of 46 patients, Gwinner et al.[7] showed that, although laxity was improved at 3 months after PCL reconstruction, posterior tibial translation significantly recurred at a final follow-up of ≥5 years. Loss of stability is thought to be due to sagging of the tibia disturbing the graft during incorporation and possible disruption of the graft at the "killer turn."[8,9] The former has been historically addressed by locking the knee in extension postoperatively and bolstering the tibia with a support pad.[8] The latter has been addressed by a variety of surgical techniques, including tibial inlay, aperture fixation, and beveling of the tibial tunnel outlet.[9] Furthermore, double-bundle reconstruction has been shown to decrease laxity compared with single-bundle reconstruction.[10] Although outcomes have improved with these techniques, there is still concern for recurrent laxity after fixation.

The purpose of this study is to describe our current PCL reconstruction technique, which is a modification of our previously described, double-bundle PCL reconstruction using a medial femoral cortical bridge.[11] We currently use a 4-tunnel technique using a contiguous posterior tibialis tendon allograft and an internal splint of a high-strength suture tape (Video). This serves to augment the allograft's tensile strength, thus maintaining tibial reduction and preventing allograft failure during the postoperative integration phase. Although suture tape augmentation has recently been described in the setting of PCL repair,[6] it has not been previously applied to femoral reconstruction.

Surgical Technique

Positioning

The patient is placed supine on the operating table. The contralateral limb is placed into a padded leg holder with the hip and knee flexed to allow optimal access to the medial aspect of the operative knee. A hinged post is placed lateral to the operative extremity to facilitate a standard arthroscopic assessment before PCL reconstruction. The end of the table is dropped down, placing the operative knee in flexion, and padding is placed

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The authors report that they have no conflicts of interest in the authorship and publication of this article. The authors report the following potential conflicts of interest or sources of funding: Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received September 22, 2019; accepted February 4, 2020.

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2212-6287/191158

https://doi.org/10.1016/j.eats.2020.02.005

posterior to the thigh to prevent pressure injury. Intraoperative fluoroscopy may be used to assist in drilling the tibial tunnels, the part of the procedure that poses the greatest risk of neurovascular injury. If this is desired, adequate positioning and access of the fluoroscope is confirmed at this time.

Graft Preparation

An aseptically processed, fresh-frozen posterior tibialis tendon allograft is our graft of choice. This technique requires an exceptionally long and wide allograft, which may require special ordering, as these graft dimensions are not widely used. After being thawed in warm saline, the graft is prepared with locking looped sutures on both ends (Fiberloop, Arthrex, Naples, FL). The midpoint is marked, and the diameters of both ends are measured with cylindrical guide blocks. The graft will form both limbs of the double-bundle reconstruction, and the larger half of the graft is specifically marked for reconstruction of the anterolateral bundle.

A 2-mm polyethylene-core tape (FiberTape, Arthrex) is laid over the graft and held in place with 3 simple 2-0 nylon sutures at the midpoint and both ends of the graft (Figure 1). This facilitates passage of both the tape and the graft. The graft is tensioned at 15 to 20 lb until insertion.

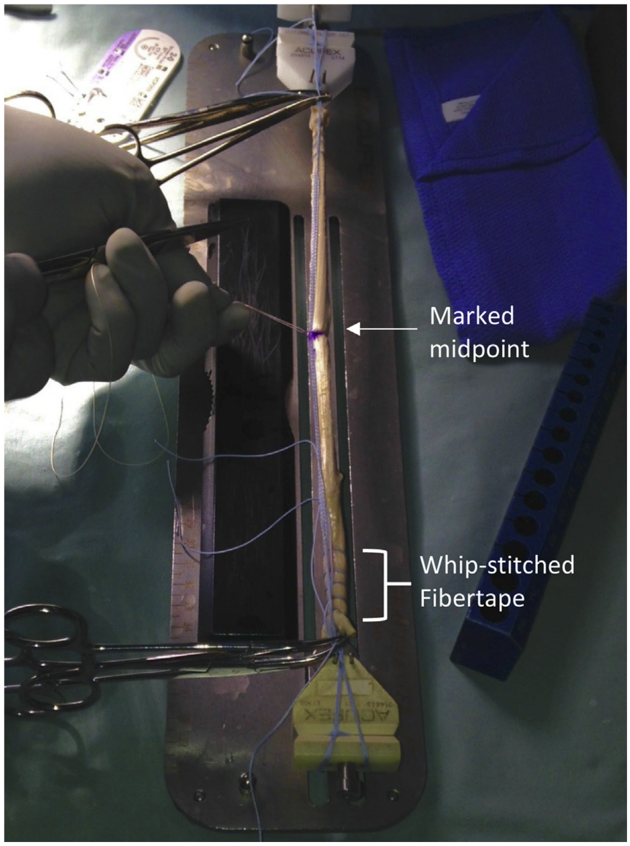

Fig 1. Our construct comprises a long posterior tibialis tendon allograft whipstitched at both ends with a single 2-mm FiberTape, which is laid over the graft with a few absorbable sutures to hold it in place. The absorbable sutures facilitate passing the graft and internal splint simultaneously through the bone tunnels. The marked midpoint of the graft is used to ensure appropriate distribution of the graft's length to either limb. The anterolateral tunnel is longer than the posteromedial; therefore, more graft is preferentially passed down the anterolateral femoral tunnel.

Arthroscopy

After examination under anesthesia, the limb is sterilized and exsanguinated with gravity, and the tourniquet is inflated. Standard anteromedial and anterolateral arthroscopy portals are used as well as a superolateral outflow portal. Diagnostic arthroscopy is performed, and any meniscal or chondral pathology is addressed. Pseudolaxity of the anterior cruciate ligament (ACL) due to tibiofemoral posterior subluxation may be noted at this time (Figure 2). The PCL is often in continuity but shows laxity from interstitial injury. The PCL is resected from its femoral insertion with electrocautery and a mechanical shaver (Figure 3). After a posteromedial portal is established, a 70° arthroscope is inserted through the anterolateral portal to better visualize the tibial insertion (Figure 4A). The PCL remnant is debrided carefully to avoid injury to the posterior horns of the medial and lateral menisci (Figure 4B). The most posterior portion of the tibial PCL insertion is preserved to act as a landmark, mitigating risk of neurovascular injury.

Tibial Tunnels

Using the right-angle arthroscopic guide, guide pins are passed for the drilling of 2 tibial tunnels (Figure 5A). The tunnels are drilled a half-size larger than the graft diameter to facilitate smooth graft passage. The tunnels are started on the anteromedial aspect of the tibia and emerge at the anterolateral and posteromedial aspects of the native PCL footprint on the posterior tibia. A 1- to 2-cm cortical bridge is maintained between the tunnel openings. The starting point for the anterolateral bundle tunnel is more central on the tibia, and the posteromedial one is started more proximal and medial. Care is taken to initiate these tunnels distal enough to allow space for an ACL tibial tunnel if an ACL reconstruction is performed concomitantly. A right-angle PCL tibial guide is used, the tip of which is constantly visualized during drilling (Figure 5B). A right-angle curette is passed through the posteromedial cannula

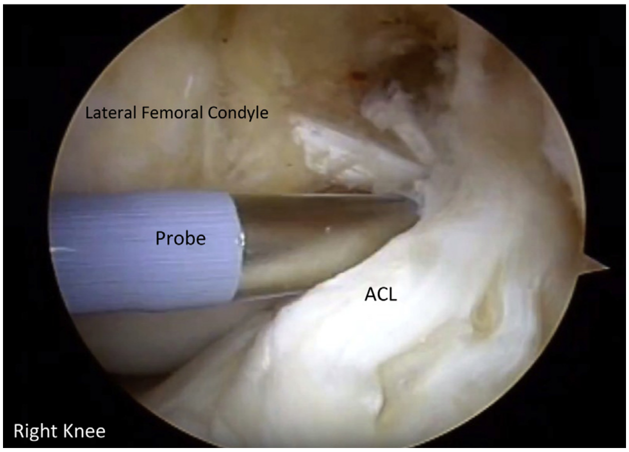

Fig 2. Anterior cruciate ligament (ACL) pseudolaxity, as viewed in the intercondylar notch of a left knee through the anterolateral viewing portal with a 30° scope, is often encountered on standard diagnostic arthroscopy of the posterior cruciate ligament–deficient knee. This resolves with anterior drawer and should not be confused for an ACL injury.

and used to cover the guide pin emergence site to protect the neurovascular bundle during tunnel drilling (Figure 5C). Care is taken to not overpenetrate the posterior cortex. Once both pins are placed, fluoroscopy may be used to ensure that the pins are placed at the downslope of the tibial footprint of the PCL. A Cobb elevator is used to clear out the periosteum between the 2 pin sites, and a motorized chondrotome is used to clear out any remaining soft tissue and smooth the

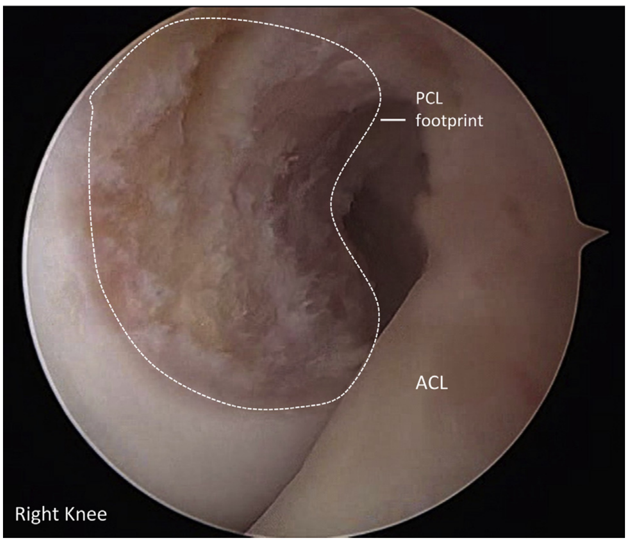

Fig 3. As viewed from the intercondylar notch of a right knee, the posterior cruciate ligament (PCL) is taken down at its femoral origin with mechanical shaver and electrocautery, leaving a debrided PCL footprint. Special care is taken to avoid iatrogenic damage to the femoral origin of the anterior cruciate ligament, which is in close proximity.

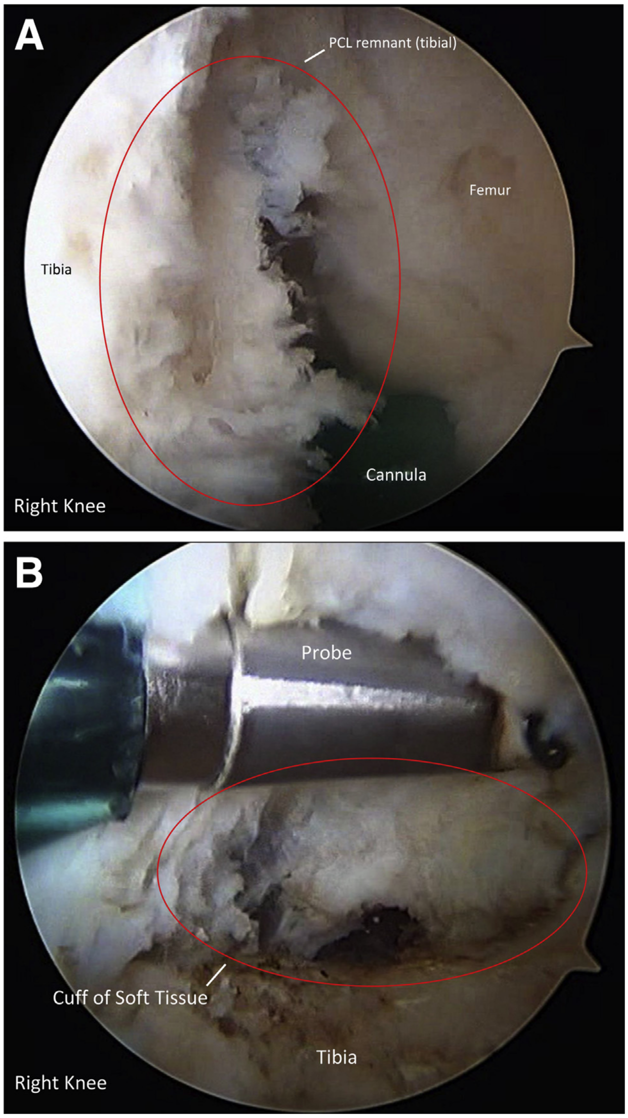

Fig 4. A, Establishment of the posteromedial working portal in the posteromedial compartment in a right knee, as visualized through the anterolateral portal using a 70° scope. The anterolateral portal is ideal for posteromedial compartment visualization. A posteromedial working portal is best suited for accessing the tibial remnant of the posterior cruciate ligament (PCL), which can be visualized. We prefer a cannula to aid in establishment of the working portal. B, Use of the posteromedial working portal to take down the tibial PCL remnant in the posteromedial compartment with electrocautery and the mechanical shaver, as viewed in the right knee with a 70° scope. It is important to pay close attention to avoid damaging the meniscal roots. We also prefer to leave a small cuff of soft tissue (circled in red) on the posterior aspect of the tibia to serve as a landmark in the prevention of damage to the neurovascular structures of the posterior knee.

edges of the tunnel aperture. Two passing sutures of different colors are passed through the tibial tunnels and retrieved from the posteromedial cannula, then

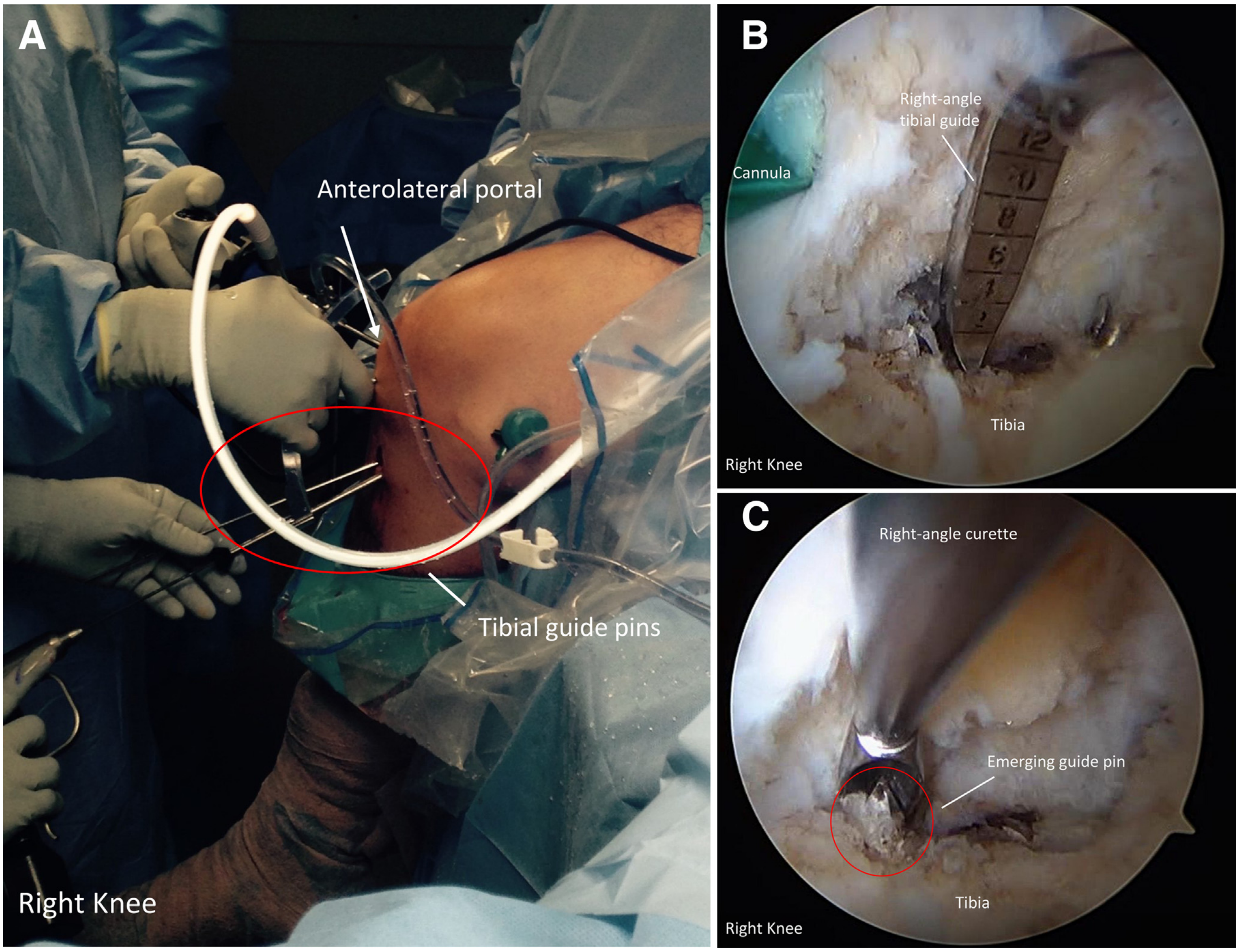

Fig 5. A, Using the right-angle arthroscopic guide, guide pins are passed for the drilling of 2 tibial tunnels in a right knee. B, As viewed inside a right knee with a 70° scope, a right-angle posterior cruciate ligament (PCL) tibial guide (red arrows) is used to pass the guide pins. The tip of the right-angle PCL tibial guide is constantly visualized as the guide pins are passed. The tunnels are started on the anteromedial aspect of the tibia and emerge at the anterolateral and posteromedial aspects of the native PCL footprint on the posterior tibia. The starting point for the anterolateral bundle is more central on the tibia, and the posteromedial one is started more proximal and medial. Care is taken to initiate these tunnels distal enough to allow space for an anterior cruciate ligament (ACL) tibial tunnel if an ACL reconstruction is performed concomitantly. A 1- to 2-cm cortical bridge is maintained between the 2 tunnel openings. C, As viewed inside a right knee with a 70° scope, a right-angle curette is passed through the posteromedial cannula and used to cover the guide pin emergence site to protect the neurovascular bundle during tunnel drilling. Care is taken to not overpenetrate the posterior cortex. Once both pins are placed, fluoroscopy may be used to ensure that the pins are placed at the downslope of the tibial footprint of the PCL. A Cobb elevator is used to clear out the periosteum between the 2 pin sites, and the motorized chondrotome is used to clear out any remaining soft tissue and smooth the edges of the tunnel aperture.

clamped, in preparation for graft passage after femoral tunnel preparation (Figure 6).

Femoral Tunnels

The 2 femoral tunnels are created in a similar technique using 2 guide pins. The guide is placed through the anteromedial portal and placed at the 1:30 position for the anterolateral bundle and the 3:00 position for the posteromedial bundle (Figure 7A). The 2 pins are passed percutaneously, maintaining a cortical bridge of $\geq$2 cm between the 2 pins on the medial femoral cortex (Figure 7B). The skin is incised in line with the pins, the vastus medialis is split in line with its fibers, and the periosteum is cleared

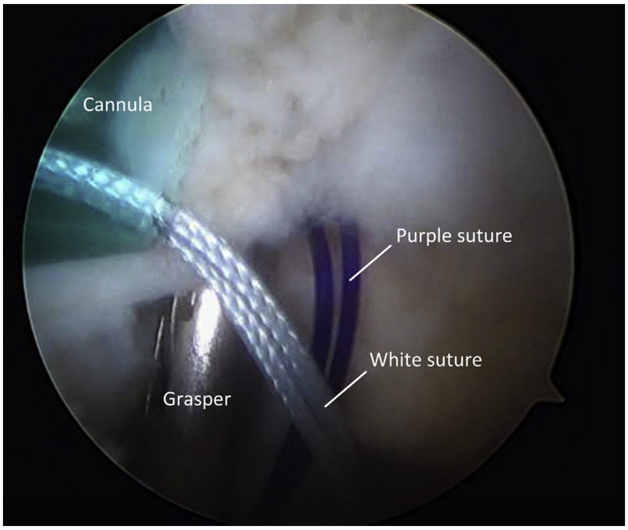

Fig 6. The posteromedial compartment, as viewed with a 70° scope. Two sutures of different colors (one purple and the other white) are passed through the tibial tunnels and retrieved from the posteromedial cannula. The sutures are then clamped on the outside in preparation for graft passage once the femoral tunnels are drilled. We use purple for the posteromedial limb to avoid confusion later. We also plug the tunnels on the tibial surface to preserve our visualization.

with a Cobb elevator. The tunnels are then drilled to 1 size larger than the graft being used. Any remaining soft tissue at the femoral PCL insertion is removed with a motorized chondrotome and electrocautery.

Graft Passage and Internal Splinting

The 2 shuttle sutures are retrieved through the femoral tunnels using a pair of ring graspers in the tunnel and anteromedial portals (Figure 8A). It is imperative that no twists or overlaps exist at this point. These sutures are then used to pass the graft's whip-stitches and internal splint down the femoral tunnel (Figure 8B) and then into the tibial tunnels, exiting from the proximal tibia. The internal splint is oriented so that it lies flush with the bone, thereby not incarcerating the graft. The 2 limbs of the graft are pulled through simultaneously, and the marked midpoint of the graft is used to ensure appropriate distribution of the graft's length to either limb. The anterolateral tunnel is longer than the posteromedial; therefore, more graft is preferentially passed down the anterolateral femoral tunnel. This is facilitated by holding countertension on the graft with a smooth trocar as it is passed (Figure 9). Once the graft and the internal splint are through, the knee is cycled. The 2 limbs are secured first at the femoral side with bioabsorbable interference screws, typically of the same diameter as the tunnel sizes. These are placed over nitinol wires using an outside-in technique. This provides aperture fixation of the grafts and allows differential tightening of both limbs.

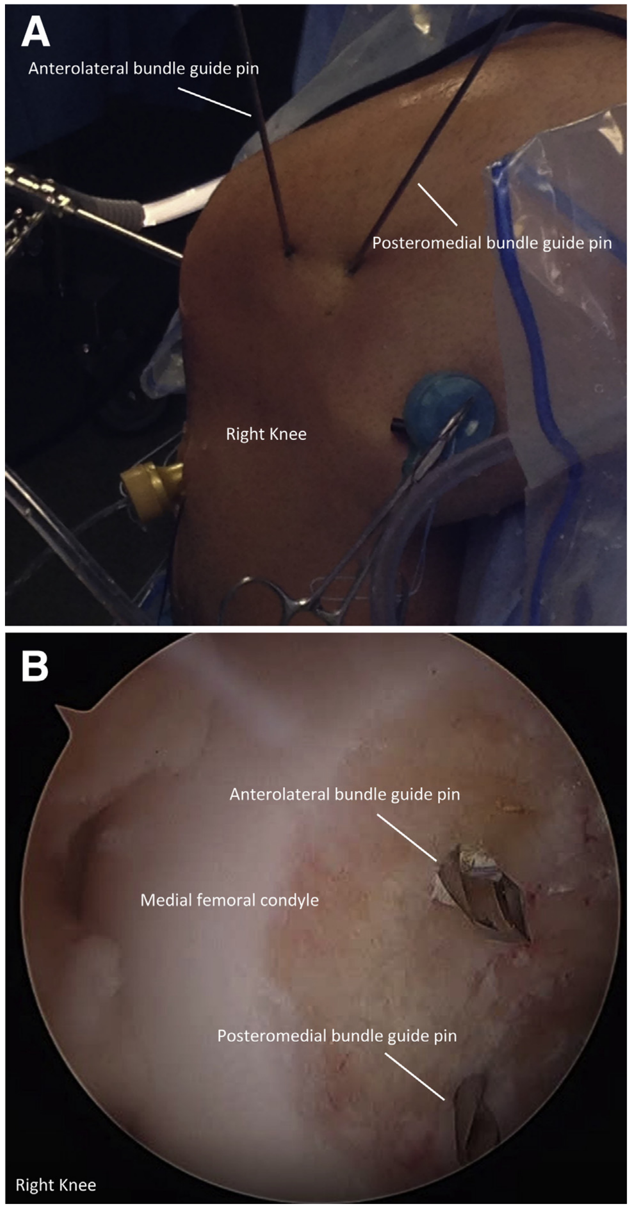

Fig 7. A, Femoral guide pin placement as seen on the outside of a right knee. B, Femoral guide pin placement as seen on the lateral aspect of the medial condyle of a right knee using a 30° scope. A guide placed in the anteromedial portal is used to place the pins at the 1:30 position for the anterolateral bundle and the 3:00 position for the posteromedial bundle. Placement of the bundles at these positions best approximates native biokinematics of the posterior cruciate ligament—intact knee. The pins are placed so as to maintain a 1-to 2-cm bone bridge.

Graft Fixation

An anterior drawer is applied with the knee at 70° to 90° of flexion, and the suture tape is tied over the tibial cortical bridge. This secures the tibial position before

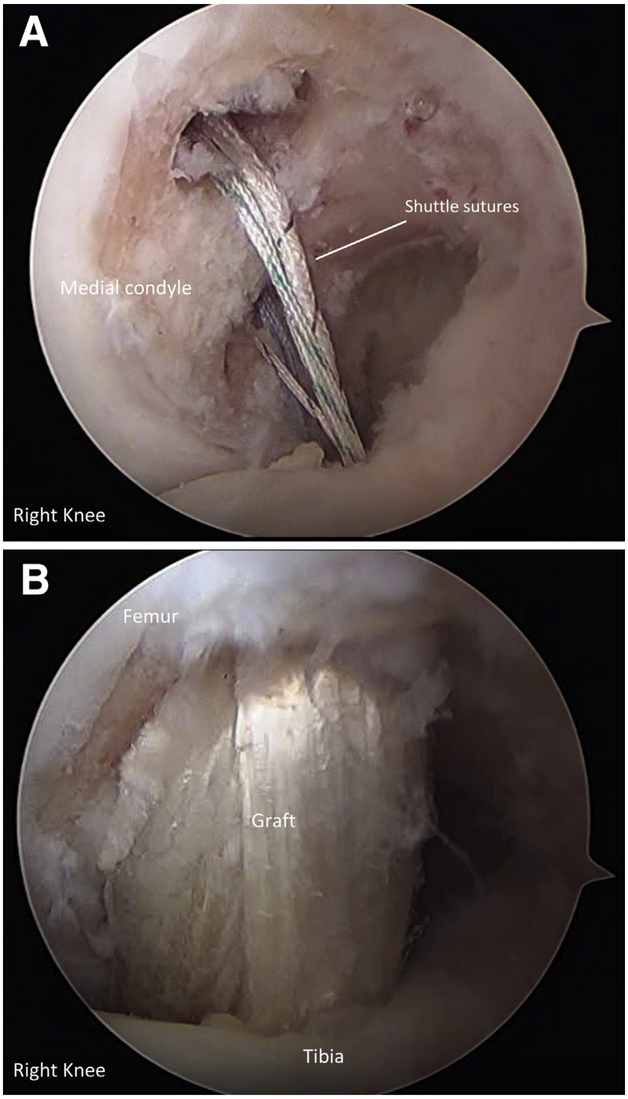

Fig 8. A, Femoral tunnels as seen on the lateral aspect of the medial condyle of a right knee using a 30° scope. Two shuttle sutures are retrieved through the femoral tunnels using a pair of ring graspers through the anteromedial portals. B, Femoral tunnels as seen on the lateral aspect of the medial condyle of a right knee using a 30° scope. Here, the graft-internal strut composite has been pulled through the femoral tunnels via shuttle sutures. The internal splint is oriented so that it lies flush with the bone, thereby not incarcerating the graft. Therefore, it is imperative that no twisting or overlapping of the shuttle sutures occurs.

graft fixation. The knee is reduced, and the posterior drawer is eliminated.

Tibial fixation is performed using bioabsorbable interference screws. We differentially tension the 2 limbs: the anterolateral limb at 70° to 90° and the posteromedial limb at 0° to 30° of flexion. Back-up fixation is provided by tightly tying the sutures from the graft over the cortical bridge. This technique allows us to avoid using additional hardware for back-up fixation. The incisions are closed and dressed in standard fashion, a cooling cuff is applied, and the knee is locked in extension in a hinged brace.

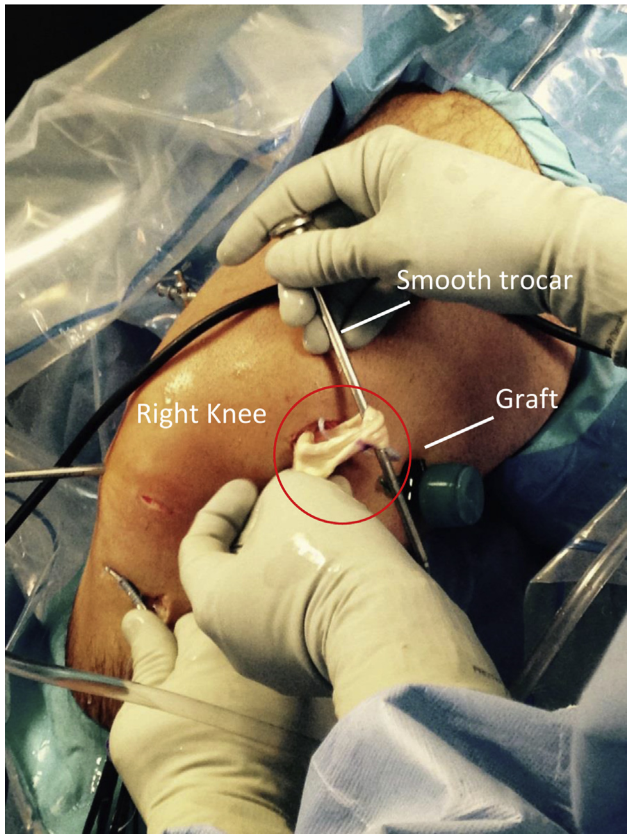

Fig 9. Passing the graft-internal splint construct through the anterolateral and posteromedial femoral tunnels of a right knee. A smooth trocar may be used for countertension to facilitate graft passage. The 2 limbs of the graft are pulled through simultaneously, and the marked midpoint of the graft is used to ensure proper distribution of the graft's length to either limb. More graft is preferentially passed down the anterolateral femoral, since it is longer than the posteromedial tunnel.

Postoperative Regimen

The knee is maintained in extension for the first 2 to 3 weeks. Physical therapy, focusing on regaining quadriceps strength, knee extension, passive flexion, and toe-touch weightbearing, is then initiated. At 4 to

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
A well leg holder on the contralateral leg allows for easy access to the medial knee.	Carefully pad both legs to avoid pressure injuries.
Graft may be prepared and diagnostic arthroscopy performed simultaneously to save time.	Ensure the internal splint is not wrapped around the graft, thus incarcerating it.
The femoral bone bridge is an excellent surface for applying tension.	Be sure to clear any soft tissue overlying the bone bridge so that it is not caught beneath the graft.
The internal splint will hold the knee reduced as the graft is tensioned.	The anterolateral limb is longer. Avoid short-changing it.

6 weeks, the knee brace is discontinued, and progressive weightbearing as tolerated is permitted. The patient is released for full sporting activities at 8 to 9 months.

Discussion

Multiple surgical techniques for posterior cruciate ligament reconstruction have been described[2-5,10,11]; however, reducing postoperative laxity remains a challenging goal with all of them. This technique provides protection for the graft as it undergoes incorporation, while allowing posterior tibial translation to be set before graft tensioning, facilitating differential tensioning of an anatomic double-bundle reconstruction.

It is important to note the limited aims of using an internal splint: it is not intended to replace the function of biological graft in PCL reconstruction. In recent years, there has been resurgence in interest surrounding ligament augmentation devices (LADs) for cruciate ligament reconstruction.[5] The early generations of these devices showed poor results, with many complications, especially synovitis, effusions, and graft failures.[4] Early studies examining the latest generation of LADs have shown encouraging results, notably a decreased report rate of the aforementioned complications and faster return to activities. However, long-term follow-up is required before biological graft can be replaced in PCL reconstruction.[12-14]

We use a double-bundle technique to better reproduce the anatomic relationship between the anterolateral and posteromedial bundles.[15,16] Wijdicks et al.[16] reported that the double-bundle technique was associated with a decrease in posterior tibial translation at 90-degrees from 4.8 mm to 0.6 mm, when compared to single-bundle technique. In practice, our femoral tunnels are similar to those reported by Zhao et al.,[17] and our posteromedial tunnel is pushed distally to a lesser extent than that described by Sheps et al.[18]

The literature has yet to come to a firm consensus regarding optimal tibial tunnel placement.[19] The center of the tibial footprint of the native PCL is 1 to 1.5 mm distal to the articular surface of the tibia, with the anterolateral bundle originating somewhere at this point and the posteromedial bundle originating 4 to 6 mm distal to the articular surface.[20] Single tibial tunnel techniques tend to place the tunnel at the insertion of the anterolateral bundle.[19] Cadaveric biomechanical studies have shown that lateral placement of the tibial tunnel decreases laxity during midrange flexion, but at the expense of increased stress on the joint and on the graft with medial displacement.[8-23] Clinical outcomes of tibial tunnel placement strategies represent an area for further study.

We describe using suture tape as an internal splint for the anatomic double-bundle PCL reconstruction. The suture tape internally augments the posterior tibial tendon allograft, thereby helping to maintain tibiofemoral reduction during the postoperative incorporation period, when the allograft is most at risk for failure.

Pearls and pitfalls are described in Table 1. Advantages and disadvantages are described in Table 2. Risks of this technique include excessive damage to the meniscal roots, damaging the posterior neurovascular structures, and more specifically, incarceration of the graft by the suture tape internal augmentation. A limitation is that clinical outcomes conclusions have yet to be reached regarding this technique, as data have yet to be collected and studied.

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
Provides reduction during differential graft tensioning.	Added cost of suture tape.
Maintains reduction during the postoperative period.	Risk of graft incarceration if the construct twists on itself.

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