Technical Note

All-Inside PCL Reconstruction, Double Bundle, With Internal Brace Augmentation

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Abstract: PCL reconstructive techniques are constantly evolving, and further clinical studies are needed to definitively understand the potential benefits of internal brace augmentation and anatomic double-bundle PCL reconstruction. This Technical Note reports an arthroscopic all-inside anatomic double-bundle PCL reconstruction with internal brace augmentation that is effective and reproducible.

Introduction

The posterior cruciate ligament (PCL) is a strong intra-articular and extrasynovial ligament of the knee with the predominant function of limiting posterior tibial translation throughout knee range of motion. While isolated PCL injuries are relatively uncommon, these injuries can frequently be encountered in the setting of multiligament knee injuries (MLKI), particularly among athletes involved in contact sports.[1,2] Conservative management is often successful in the management of grade 1 and 2 injuries, but PCL reconstruction is often needed in the treatment of grade 3 and multiligament knee injuries. PCL reconstruction techniques are continuing to evolve, with the goal of improving clinical results. Outcomes after PCL reconstruction have been less predictable compared to anterior cruciate ligament reconstruction, with evidence of increasing laxity over time after PCL reconstruction.

Double-bundle PCL reconstruction has been described to improve knee biomechanics compared to standard single-bundle reconstruction techniques. Double-bundle techniques aim to anatomically reconstruct the anterolateral and posteromedial bundles of the PCL. Anatomic studies have shown that the anterolateral bundle (ALB) is tauter in flexion and laxer in extension, while the posteromedial bundle (PMB) is tauter in extension and more lax in flexion.[3,4] However, more recent studies have shown a synergistic relationship throughout range of motion in restraining posterior tibial translation rather than a purely reciprocal relationship between the two bundles. Internal bracing has been recently shown to decrease graft elongation and improve ultimate load to failure in PCL grafts in a biomechanical study.[5] The purpose of this study was to describe our technique of an all-inside anatomic double-bundle PCL reconstruction with internal brace augmentation.

Patient Positioning and Anesthesia

The patient is placed in the supine position on the operating table. After general anesthesia is induced, fluoroscopic evaluation under anesthesia is performed on both knees to confirm PCL insufficiency of the operative extremity, as well as evaluate for any concomitant ligament instability and for assessing range

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of motion. A thigh tourniquet is applied to the operative leg. A 10-lb. sandbag footrest is taped down to the end of the table to allow for the knee to be easily held in 85° of flexion. The contralateral leg is appropriately padded and secured. After standard sterile prepping and draping, a large fluoroscopy unit is used, along with a removable wedge between the side post and the leg, which allows the operative leg to remain positioned in flexion to allow for easy concomitant fluoroscopy and arthroscopy (Figs 1 and 2).

Graft/Implant Preparation and Planning

For this double-bundle PCL reconstruction technique, two individual semitendinosus allografts are used for the ALB and PMB (Fig 3). The ALB graft is prepared to a 9-mm diameter × 80 mm graft length, and the PMB is prepared to a 6.5-mm diameter × 80-mm graft length. Both grafts are placed in 20 pounds of longitudinal traction to remove creep. A TightRope (Arthrex, Naples, FL) fixation device is used on the ends of both grafts. A doubled-over 2-mm FiberTape (Arthrex) is used as the internal brace paired with the PMB. A TightRope-to-TightRope construct composed of two free TightRopes (Arthrex) joined together is used as the internal brace paired with the ALB. The ends of each TightRope loop are attached to a FiberLink (Arthrex) closed loop suture in a luggage tag fashion, which is used as a shuttling stitch, which is removed at the end of the case. The FiberTape internal brace has a FiberLink (Arthrex) attached at the doubled-over end. The ALB and PMB are fixed with separate Dog Bone or Attachable Button System (ABS) suture buttons (Arthrex) on the femur and are fixed together on a single ABS suture button (Arthrex) on the tibial side (Fig 4). Backup fixation may be added on the tibial side, as desired.

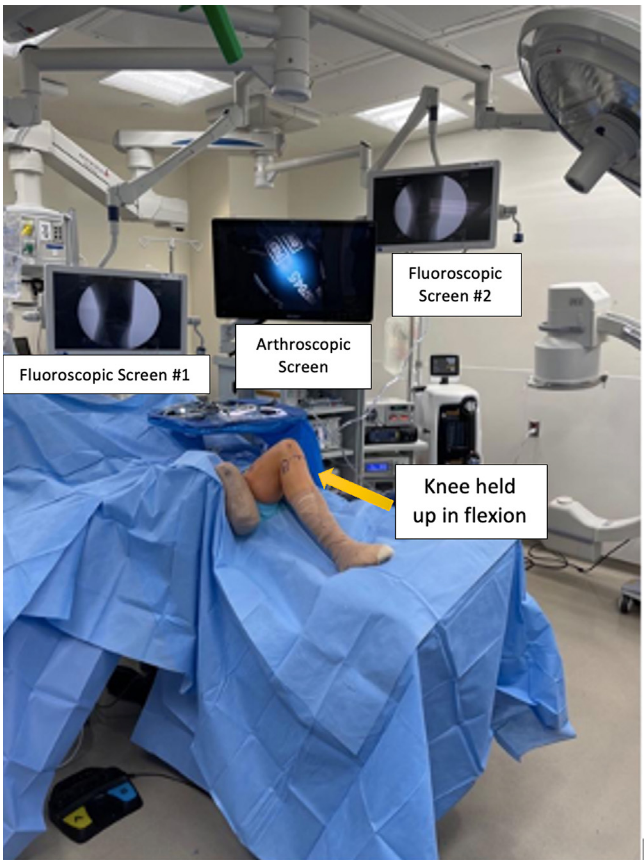

Fig 1. Patient is positioned supine on the operating table with a removable wedge between leg and side post to allow for the knee to be held upright in flexion, while allowing unencumbered concomitant fluoroscopy and arthroscopy.

Surgical Technique

Initial Arthroscopy

The limb is exsanguinated, and the tourniquet is inflated. Standard anterolateral and anteromedial arthroscopic portals are made. Both portals are made close to the patellar tendon to facilitate access to the posterior compartment as well as for placement of the tibial and femoral drill guides. Routine diagnostic arthroscopy is performed. The intraarticular portion of the PCL is debrided, leaving intact fibers of the femoral origins of the ALB and PMB for later anatomic positioning of the tunnels.

Tibial Tunnel

A modified Gilquist maneuver is then performed through the intercondylar notch with the knee flexed to 85° of flexion. A posteromedial portal is placed under direct arthroscopic visualization using an outside-in technique, being cautious to avoid injuring the saphenous neurovascular bundle. The 30° scope is exchanged for a 70° scope. The tibial facet at the insertion site of the native PCL is debrided. Several landmarks to identify the correct and safe positioning of the tibial tunnel are identified, including the medial and lateral mammillary bodies on each respective side of the tibial PCL insertion, the shiny white fibers of the medial meniscus, and the champagne glass drop-off of the posterior tibial facet. The anteromedial portal is the primary viewing portal, and the posteromedial portal is the primary working portal.

The side-specific tibial PCL guide (Arthrex) is set to 60° to minimize the killer-turn. Anteriorly, the bullet sleeve to the guide is placed ~1 cm medial to the tibial crest; while viewing through the posteromedial portal, the guide is placed through the anteromedial portal and the intercondylar notch and seated on the tibial footprint posteriorly. This is confirmed in the coronal plane with direct arthroscopic visualization of the guide placed between the mammillary bodies and confirmed in the sagittal plane under intraoperative C-arm fluoroscopy, just proximal to the champagne glass drop off. We have found that utilization of a large C-arm fluoroscopy unit, as opposed to a

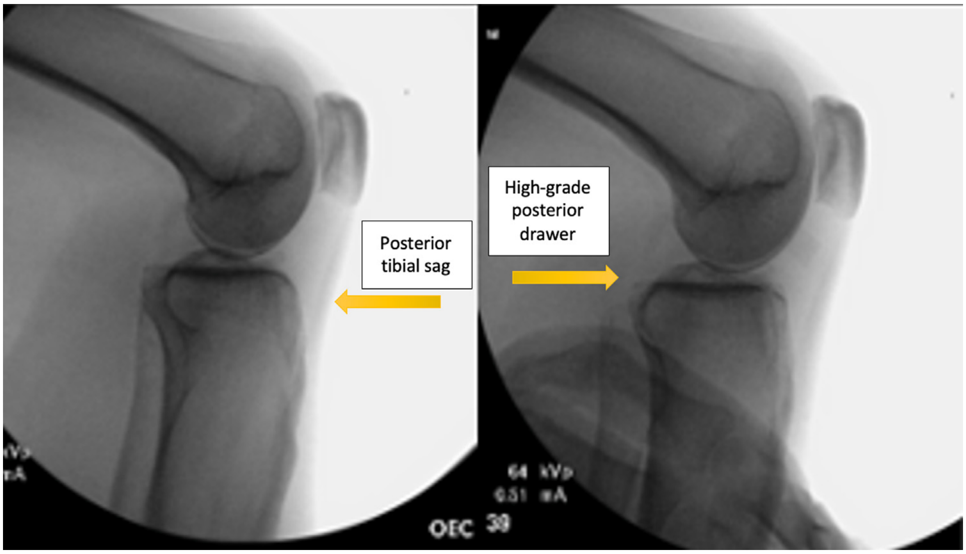

Fig 2. Evaluation under anesthesia performed via fluoroscopy. Lateral radiographs of the knee demonstrating posterior tibial sag (left) and high-grade posterior drawer (right).

mini C-arm, works best as the larger size allows for easy navigation between concomitant arthroscopic and fluoroscopic visualization (Figs 5 and 6).

A guide pin is drilled under fluoroscopic guidance to ensure proper and safe aiming of the guide pin and is drilled into the posterior compartment under direct arthroscopic visualization through the posteromedial portal to prevent injury to the posterior neurovascular structures. A 3.5-mm FlipCutter (Arthrex) is then exchanged for the guide pin and similarly drilled into the posterior compartment under fluoroscopic guidance and direct arthroscopic visualization. The tibial guide is detached from the bullet and is used to retract the posterior capsule and, in turn, shield and protect the neurovascular bundle. The FlipCutter is used to create an 11 mm × 35 mm blind tunnel. A FiberStick (Arthrex) is used to shuttle passing sutures through the tibial tunnel.

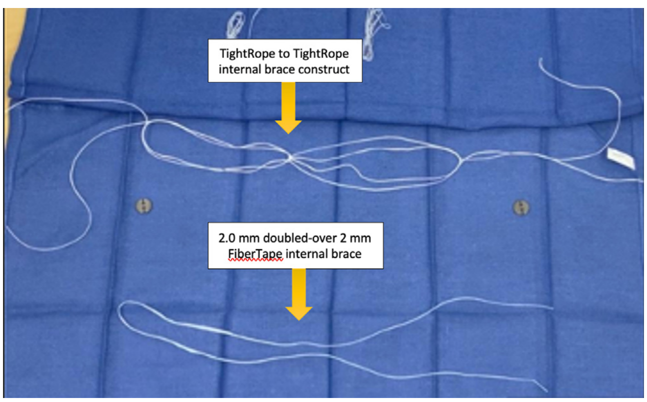

Fig 3. TightRope to TightRope internal brace construct (top), 2.0-mm doubled-over 2-mm FiberTape internal brace (bottom). The internal brace construct is used to reinforce the posterior medial bundle of the reconstruction.

Femoral Tunnels

A 30° scope is used, viewing through the anterolateral portal. The anterolateral bundle is drilled first. An outside-in femoral guide set to 55° is placed in the anatomic origin of the ALB, abutting the cartilage margin. A 55° angulation is chosen as a compromise to minimize the angulation of the critical corner at the

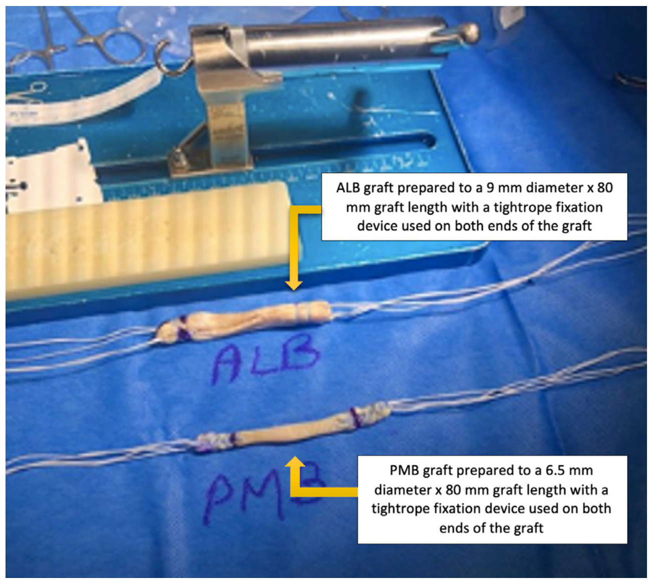

Fig 4. Anterolateral bundle (ALB) and posteromedial bundle (PMB) semitendinosus allografts after preparation and attached TightRopes. The ALB graft is prepared to a 9-mm diameter × 80-mm graft length, and the PMB is prepared to a 6.5 mm diameter × 80 mm graft length, with a tightrope fixation device used on both ends of the graft.

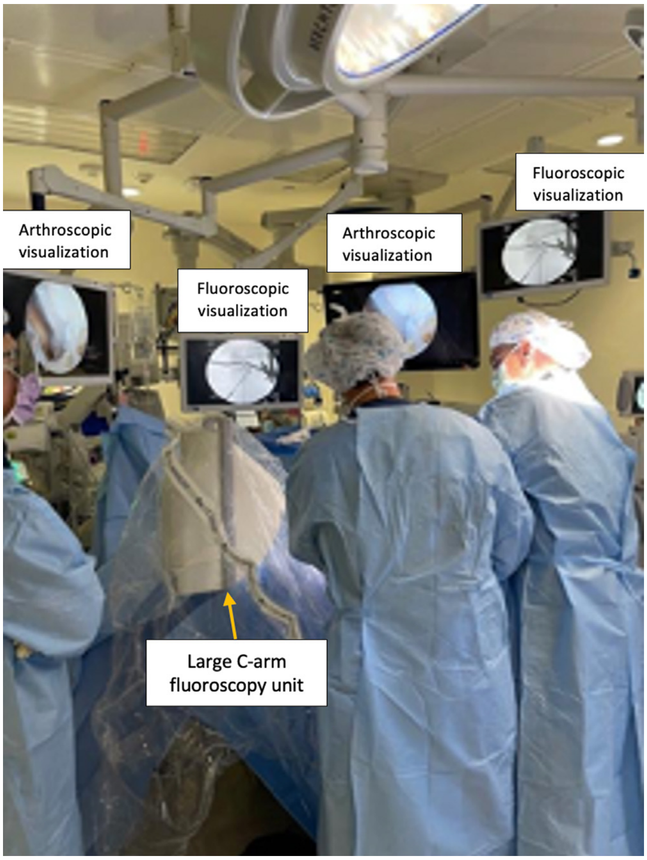

Fig 5. Intraoperative image that depicts fluoroscopic and arthroscopic monitors positioned, so the surgeon can easily view both images while standing on either side of the table. Large C-arm fluoroscopy unit used to allow for ease of concomitant arthroscopy and fluoroscopy.

femoral aperture, as well as ensuring a tunnel with adequate length.[6-9] A small counter incision is made on the distal medial femur. An incision is made through the vastus medialis fascia, and gentle blunt dissection to the medial distal femoral cortex is performed. With an orientation of ∼20° anterior to the transepicondylar axis in the axial plane of the distal femur (Fig 7), the bullet sleeve is brought down to bone, and a guide pin is

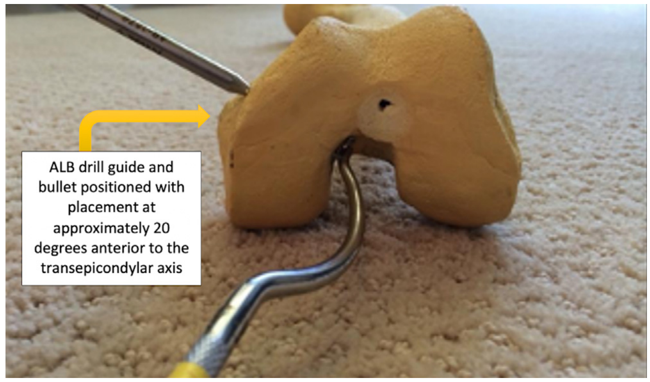

Fig 7. A model demonstrating the position of the anterolateral bundle ALB drill guide and bullet, with placement at approximately 20 degrees anterior to the transepicondylar axis.

drilled, followed by a FlipCutter (Arthrex) to create a 9 mm × 25 mm blind tunnel under direct arthroscopic visualization. Passing sutures are shuttled. The same technique is used to drill the PMB femoral tunnel. With the guide set on 55°, the intra-articular tip of the outside-in femoral guide is placed in the anatomic origin of the PMB taking care to be posterior to the ALB. The bullet sleeve of the guide is oriented ∼10° anterior to the transepicondylar axis in the axial plane of the distal femur. A separate counter incision is made over the medial distal femur and in a similar fashion to the ALB tunnel a 6.5 mm × 20 mm blind tunnel is drilled, and passing sutures are shuttled. Care is taken during the drilling of both tunnels to avoid tunnel convergence.

Graft Passage and Fixation

A PassPort cannula (Arthrex) is placed through the anterolateral portal. All grafts and internal braces are passed in the following order: through the anterolateral portal, into the femoral tunnel, and subsequently into the tibial tunnel. All graft passage is performed under direct arthroscopic visualization from the anteromedial portal. The PMB graft and internal brace is passed first. The FiberTape internal brace doubled-over end is first

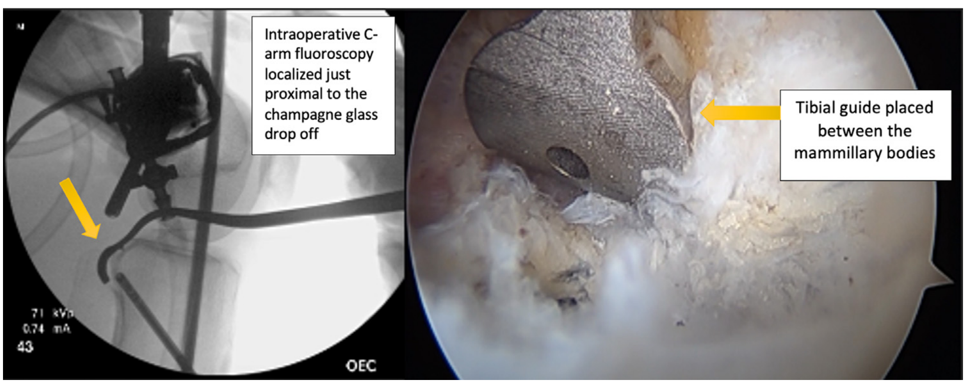

Fig 6. Demonstrating concomitantly performed fluoroscopy and arthroscopy to confirm the positioning of the tibial guide. Positioning is confirmed in the coronal plane with direct arthroscopic visualization of the guide placed between the mammillary bodies (right) and confirmed in the sagittal plane under intraoperative C-arm fluoroscopy to be localized just proximal to the champagne glass drop off (left).

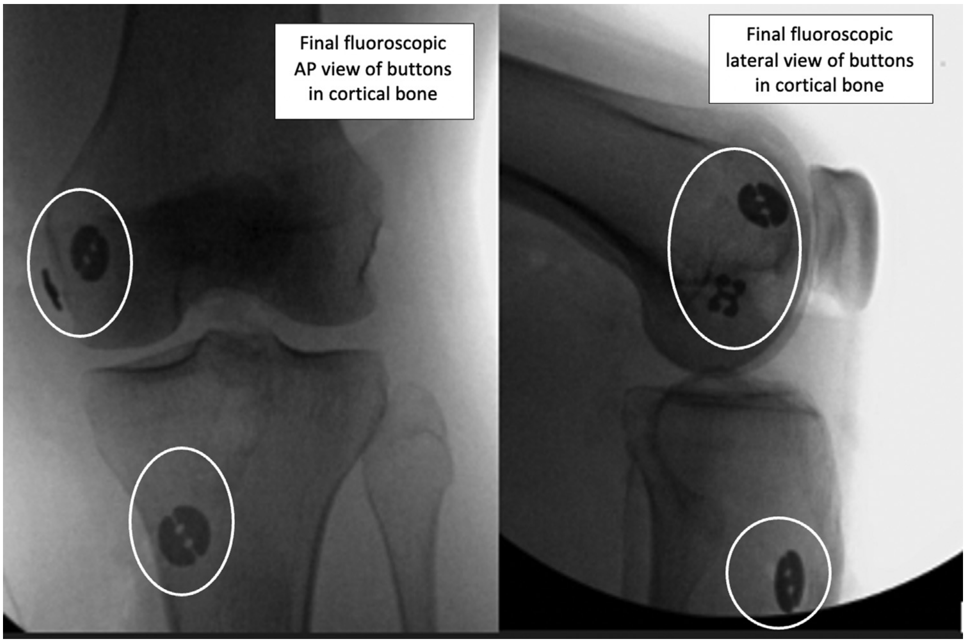

Fig 8. Final fluoroscopic views in both the AP (right) and lateral (left) planes are taken to confirm buttons are fully seated on cortical bone.

passed into the femoral PMB tunnel and then the tibial tunnel. This is followed by the PMB graft. This is then repeated for the ALB and Tightrope-to-Tightrope internal brace. The TightRope-to-TightRope internal brace is first passed into the femoral ALB tunnel, and then the tibial tunnel. This is followed by the ALB graft. Direct arthroscopic visualization of the femoral tunnels and tibial tunnel is performed to ensure that an appropriate length of graft is shuttled into each tunnel. The ALB and TightRope-to-TightRope internal brace are secured over an ABS suture button (Arthrex) on the distal femur. The graft for the PMB and the FiberTape internal brace are secured over a separate ABS suture button (Arthrex) on the distal femur. Of note, the internal brace constructs are placed on the buttons first, and then the TightRopes from the grafts are placed on top. The sequence ensures that the TightRope securing the graft can be easily adjusted and tightened without encountering resistance caused by the internal brace construct. On the tibial side, a single ABS suture button (Arthrex) is used for fixation of the total four constructs: two graft TightRopes and two internal braces. The knee is cycled through several repetitions to remove creep. Full knee flexion and extension is confirmed. Direct arthroscopic visualization is performed to ensure appropriate tension on each graft. With tension on all four constructs, the knee is taken from full extension into 85° of flexion. Then under C-arm fluoroscopy, the tibia is reduced in relationship to the posterior femur and the ALB and Tightrope-to-Tightrope internal brace are sequentially tensioned and fixed. The knee is then brought into 10° of flexion with an anteriorly directed force on the tibia, and the PMB and internal brace are sequentially tensioned and fixed. Subsequently, backup fixation on the tibial side is performed with SwiveLock suture anchors (Arthrex). A complete description of our technique is described in Video 1.

Final Evaluation and Closure

Range of motion is examined and should reveal full flexion and extension. A posterior drawer is checked under fluoroscopic guidance to ensure elimination of the posterior drawer at 85° and 10° of flexion. C-arm fluoroscopy is used to confirm appropriate positioning of the suture buttons on cortical bone without interposed soft tissue (Fig 8). All arthroscopic equipment is removed, the tourniquet is dropped, and Doppler assessment and palpation are used to ensure patent flow through the dorsalis pedis and posterior tibial arteries. Wounds are closed in the surgeon's usual preference.

Postoperative Rehabilitation Protocol

A Continuous Passive Motion machine with range of motion of 0-90° is started immediately postoperatively. Early quadricep activation is emphasized as is passive prone knee motion from 0 to 90°. The patient is nonweight bearing for the first 2 weeks, followed by toe-touch weight bearing for an additional 4 weeks. At the 2-week benchmark once swelling permits, the patient is placed in a custom dynamic PCL unloader brace (PCL Jack brace [Albrecht, Stephanskirchen, Germany] or Rebound brace [Ossur, Reykjavik, Iceland]) to be

Table 1. Advantages and Disadvantages

Advantages
- Internal brace as a check or rein to protect the graft during healing and ligamentization.
- Outside-in creation of femoral tunnel minimizes the critical-corner angle to potentially decrease graft stresses at the femoral aperture.
- Improved biomechanical properties of double-bundle PCL reconstruction over single-bundle reconstruction
Disadvantages
- Suspensory fixation and the risk for bungee cord and windshield wiper effect

worn at all times, except for bathing. The dynamic PCL brace is worn for 6 months postoperatively. The patient is instructed to avoid posterior sag at all times and active hamstring firing for the first 6 weeks postoperatively.

Discussion

Previous biomechanical studies have validated the use of internal brace constructs in PCL reconstruction.[5,10,11] Trasolini et al. demonstrated that internal brace augmentation of the PCL demonstrates decreased posterior translation of the tibia upon posterior drawer loading, a result that held consistent, even at higher loads without an appreciable increase in stiffness of the construct, as compared to PCL reconstruction without internal bracing.[11] These data suggest a checkrein mechanism of action for the internal brace rather than a load-sharing mechanism.[11] A biomechanical study by Levy et al. evaluated the use of internal bracing constructs for two PCL reconstruction techniques, including the use of suspensory adjustable loop devices and tibial interference screw application. The endpoints measured included elongation, stiffness, and ultimate strength, with the authors noting a reduction in total elongation and a significant increase in ultimate strength irrespective of the reconstruction technique used.[5] Adding an internal brace to PCL reconstruction decreases dynamic and total elongation, while increasing ultimate load to failure, regardless of fixation technique.[5]

Outside-in tunnel placement for the femoral PCL tunnels has been shown to lead to decreased acuity of the critical-corner compared to inside-out techniques.[12-15] Handy et al. noted in their biomechanical study that traditional inside-out creation of the femoral tunnels produced a critical-corner angle of nearly 90° in flexion versus 50° with the outside-in technique.[12] Narvy et al. demonstrated in their biomechanical study that outside-in creation of the femoral anterolateral bundle tunnel resulted in decreased mean and peak contact pressures at the femoral aperture compared with inside-out tunnel creation.[14] These biomechanical data support the use of outside-in femoral tunnel creation to decrease the acuity of the critical-corner angle and decrease PCL graft stresses. However, there is a paucity of clinical data to support outside-in over inside-out femoral tunnel creation. Nonetheless, we recommend outside-in tunnel positioning to decrease the angle of the critical-corner and potentially decrease graft stresses at the femoral aperture.

Previous reports of PCL repair with internal bracing have demonstrated comparable patient-reported outcome measures to standard PCL reconstruction in regard to the Knee Injury and Osteoarthritis Outcome Score (KOOS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and visual analog scale for pain (VAS-pain) scores.[16] Additionally, the utility of an internal brace construct for PCL repair has been explored in cases of multi-ligament knee injuries demonstrating correction of posterior tibial translation as well as radiographic evidence of adequate ligament healing.[17]

Anatomic double-bundle PCL reconstruction has previously been described in the literature.[18,19] Chahla et al. described an anatomic double-bundle PCL reconstruction without internal bracing, a methodology validated by prior studies demonstrating good outcomes and noninferiority to single-bundle reconstructions.[20-22] Anatomic double-bundle PCL reconstruction has biomechanical benefits, which has yet to show a significant clinical superiority to single-bundle reconstructive techniques. Several biomechanical studies have demonstrated decreased posterior tibial translation with double-bundle techniques.[23-27] However, these improved biomechanical properties have not demonstrated any significant clinical benefits in terms of functional scores, patient satisfaction, or radiographic examination in clinical studies over single-bundle PCL reconstruction.[28-34] Because of the arthroscopic nature of our technique, use of a large fluoroscopy unit and leg positioners holding the knee

Table 2. Pearls and Pitfalls

Pearls
- Use of a large fluoroscopy unit and leg positioners holding the knee in flexion allow for easy concomitant fluoroscopy and arthroscopy.
- Anterolateral and anterolateral portals placed tight on the patellar tendon allow for easy access into the posterior compartment, as well as during placement of the femoral outside-in drill guide.
- Using the PCL tibial guide as a soft tissue retractor during tibial tunnel drilling aids in visualization and protection of the posterior neurovascular structures.
- Organized suture management plan during graft passage and fixation: graft constructs should be placed on suture buttons after the internal brace constructs to allow for easier tensioning of the grafts.
Pitfalls
- Avoid too much suture traffic in the anterolateral portal, while passing the graft and internal braces.
- Avoid placement of the posteromedial portal too close to the medial femoral condyle/too anterior. Posteromedial portal needs to be around 1 cm posterior to the condyle to improve mobility of instrumentation through the portal.

in flexion allow for easy concomitant fluoroscopy and arthroscopy. Anterolateral portals placed tight on the patellar tendon allow for easy access into the posterior compartment and during placement of the femoral outside-in drill guide. One of the difficulties in this case is to avoid too much suture traffic in the anterolateral portal, while passing the graft and internal braces; therefore, an organized suture management plan during graft passage and fixation is imperative. Graft constructs should be placed on suture buttons after the internal brace constructs to allow for easier tensioning of the grafts. By using the PCL tibial guide as a soft issue retractor during tibial drilling, better visualization and protection of the posterior neurovascular structures will be maintained. A complete list of advantages and disadvantages of our technique is listed in Table 1. Pearls and pitfalls of our surgical technique are highlighted in Table 2. Issues including the heterogeneity in study design and technical differences, including differences in graft tunnel positioning, graft tension, and knee flexion angle of tensioning make it difficult to test for superiority of any one technique. Future high-powered studies are needed to determine whether double-bundle PCL reconstruction has clinical superiority over single-bundle PCL reconstruction.

We recommend this technique for an anatomic PCL reconstruction with internal brace augmentation to better replicate anatomic knee biomechanics, decrease graft elongation, and increase ultimate load to failure. PCL reconstructive techniques are constantly evolving, and further clinical studies will be needed to further understand the potential benefits of internal brace augmentation and anatomic double-bundle PCL reconstruction.

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