Transmedial All-inside TriLink Posterior Cruciate Ligament Reconstruction

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Abstract: Posterior cruciate ligament (PCL) injuries usually constitute part of a multiligament injury. Isolated PCL injuries account for only approximately 3% of all ligament injuries. No consensus on optimal surgical reconstruction exists. The PCL is a double-bundle structure that functions in an anisometric manner. Biomechanical studies have shown that recreating the PCL femoral double-bundle configuration provides greater stability. We present a 3-socket approach for an anatomic "all-inside" double-bundle PCL reconstruction using our preferred option of a FiberTape (Arthrex, Naples, FL)–reinforced peroneus longus allograft fashioned to create a trifurcate graft: the TriLink technique. Cortical suspensory fixation devices are used, allowing differential tensioning of the anterolateral and posteromedial bundles. This enables more accurate replication of the native PCL and its biomechanical properties.

Posterior cruciate ligament (PCL) injuries are uncommon and usually form part of a multiligament injury, with isolated injuries accounting for only approximately 3% of all knee ligament injuries.[1] PCL reconstruction is a technically challenging surgical procedure, and the optimal surgical technique is debated. Numerous single- and double-bundle techniques have been described.[2,3] A better understanding of PCL anatomy and biomechanics has led to questioning of the ideal tibial and femoral graft positioning and graft configuration.

The PCL is an anisometric double-bundle structure.[4] Several anatomic studies have shown the PCL tibial footprint to be compact, whereas the femoral footprint fans out over the lateral wall of the medial femoral condyle and onto the roof of the intercondylar notch.[4,5] Biomechanical studies have shown double-bundle femoral graft positioning is a key factor in controlling posterior tibial laxity and improving rotational stability.[6,7] We present a transmedial all-inside PCL reconstruction technique using a double-bundle configuration on the femur and a single tibial socket. Our preferred graft is a peroneus longus allograft reinforced with FiberTape (Arthrex, Naples, FL). The graft is fashioned into a Y-shaped "TriLink" construct to recreate the anterolateral (AL) and posteromedial (PM) femoral bundles. This best replicates PCL anatomy and function while minimizing the surgical complexities of PCL surgery—particularly those of double-bundle reconstruction.

Surgical Technique

The indication for surgery is a rupture of the PCL in patients with functional demands justifying surgical repair. This is a technically challenging arthroscopic technique that requires the specific equipment outlined in Table 1. The key steps are summarized in Table 2 and

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Table 1. Equipment Required for Transmedial All-inside TriLink PCL Reconstruction

Instrument or Implant	Reason
Standard 30° arthroscope	• Used throughout except for tibial tunnel preparation
70° arthroscope	• Used to visualize posterior aspect of tibia and allow tibial tunnel preparation
Curved calibrated radiofrequency device (CoolCut CaliBlator)	• Allows better preservation of bony landmarks compared with shaver • Contoured so that while the probe tip is debriding the tibial footprint, the arm is in an optimal position to retract the posterior capsule, thus protecting the neurovascular bundle • The arm is calibrated, enabling direct measurement of the medial wall of the intercondylar notch to facilitate accurate femoral tunnel placement
PCL RetroConstruction Drill Guide Set (Arthrex), tibial PCL aiming guide with marking hook, and femoral PCL aiming guide with marking hook	• Specifically contoured instruments enabling accurate placement without impingement on bony landmarks • Enables protection of posterior capsule while tibial tunnel is drilled
Combined guide pin and retrograde drill (second-generation FlipCutter)	• Popularized by all-inside ACL reconstruction • Creates bone-preserving tibial and femoral sockets
Arthroscopic shoulder cannula	• Used to maintain patency of posteromedial portal
Arthroscopic portal cannula	• Used for anteromedial portal • Enables clear passage of snare sutures without soft-tissue bridges • Allows easier passage of graft into knee without skin contact
Image intensifier	• Required during tibial tunnel placement
FiberTape	• High-strength composite polymer tape used to reinforce peroneus tendon autograft
Fixation devices	
2 reverse-tension ACL TightRope devices	• For femoral fixation of anterolateral and posteromedial limbs of TriLink construct
TightRope ABS implant with ABS button	• For primary tibial fixation
4.75-mm SwiveLock anchor	• For backup fixation of FiberTape in proximal tibia

ABS, attachable button system; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

shown in Video 1. The patient is positioned supine on a radiolucent table with the operative knee flexed to 90°. A padded side support and footrest are used, and a thigh tourniquet is inflated throughout. We advocate a thorough examination with the patient under anesthesia before the procedure because PCL injuries frequently occur in combination with injuries to the other supporting structures of the knee.

The following description assumes the use of a peroneus longus allograft. This reliably gives a graft of suitable diameter and length while shortening operative duration (by negating the need for hamstring harvest) or preserving the semitendinosus for use elsewhere (e.g., in the multiligament-injured knee). However, Video 1 depicts the use of a semitendinosus autograft, which is a suitable alternative graft choice. The steps involved in creating the trifurcate TriLink graft are identical.

Graft Preparation

Two reverse-tension TightRope devices (adjustable suspensory fixation devices; Arthrex) are placed along the tendon to be used in the reconstruction. The 2 ends of the tendon are sutured together with a nonabsorbable high−tensile strength suture (e.g., No. 2-0 FiberWire [Arthrex]) to form a continuous loop (Fig 1A). The resulting double-stranded graft is then positioned with the knot centrally, with a loaded TightRope at each end (Fig 1B). The graft is ideally manipulated such that the knot is turned inward. A third TightRope is then placed at the midpoint of the looped graft and secured at 1 end of the preparation table. The initial 2 TightRope devices are both secured at the other end of the table to form a Y-shaped trifurcate graft: the TriLink construct. The configuration is then secured at the desired limb lengths using further nonabsorbable sutures (Fig 1C). The single, 4-stranded limb of the graft is marked at 20 mm, which will facilitate insertion into the tibial socket to the correct depth. The graft is then tensioned and compressed. If any concerns over graft diameter or strength exist, a loop of high-strength composite polymer tape (FiberTape) is used to reinforce the graft. This has become the default technique in our unit.

Arthroscopy Portals

A high AL portal is first created adjacent to the patellar tendon. A low anteromedial (AM) portal, also adjacent to the patellar tendon, is then established. This portal is formed under direct vision in line with the anterior cruciate ligament and just above the intermeniscal ligament and facilitates access to the tibial PCL footprint. A standard PM portal is created under direct vision using a 70° arthroscope through the AL portal. Arthroscopic portal cannulas are inserted to maintain the patency of the portals during instrument changes.

Table 2. Summary of Key Steps in TriLink Transmedial PCL Reconstruction

1. Preparation of TriLink trifurcate graft with or without FiberTape reinforcement using peroneus longus allograft or semitendinosus autograft
Graft sutured into loop with TightRope at either end
Knot inverted
Third TightRope positioned close to midpoint
Four-strand tibial limb sutured to retain shape of construct
2. Tibial footprint preparation with neurovascular protection. Single retrograde socket drilled to 30-mm depth under fluoroscopic guidance, using the following aids:
RF device
PM portal with 70° arthroscope
PCL aiming guide
FlipCutter
3. Direct measurement and marking of AL and PM femoral socket positions
4. Retrograde drilling of 20-mm femoral sockets with PCL aiming guide
5. Graft deployment through AM portal
Tibial limb docked to 20 mm
AL bundle docked next, followed by PM bundle
6. Graft fixation and tensioning
AL bundle tensioned first; tensioned at 90° of flexion
PM bundle tensioned at 30° of flexion
SwiveLock backup fixation in tibia if required

NOTE. The operative procedure is further shown in Video 1.
AL, anterolateral; AM, anteromedial; PCL, posterior cruciate ligament; PM, posteromedial; RF, radiofrequency.

Tibial Socket Preparation

The 70° arthroscope is inserted through the PM portal, and the posterior aspect of the tibia is visualized. A calibrated radiofrequency ablation probe (CoolCut CaliBlator; Arthrex) is used through the AM portal to clear the tibial footprint. The use of radiofrequency allows soft-tissue clearance without debridement of the osseous anatomy, which facilitates socket placement. The calibrated markings on the probe are used to ascertain the position of the tibial socket, which is marked. We aim to position our socket at 40% of the mediolateral distance from the posterodistal margin of the posterior horn of the medial meniscus and the lateral margin of the cartilage of the posterior tibial plateau; this position is 2 mm proximal to the posteroinferior bony ridge separating the AL and PM bundles. These measurements have recently been validated arthroscopically in cadaveric knees.[6]

The tibial aiming guide (Arthrex) is inserted through the AM portal and positioned over the marked area in the PCL footprint. The guide handle is typically set between 70° and 80° to ensure an adequate socket depth. Correct placement is confirmed with intraoperative fluoroscopy, which also enables the surgeon to ensure the guide pin exits perpendicularly to the posterior tibial facet. The FlipCutter retrograde drill (Arthrex) is sized according to the graft diameter, and a 30-mm "retrosocket" is drilled. This can be accurately measured during drilling through use of the calibrated markings on the drill bit and is facilitated by the use of a large-bore suction shaver through the PM portal to remove debris and keep the visual field clear. We typically drill a 30-mm socket to accept approximately 20 mm of graft; the additional 10 mm accommodates for any graft laxity during final tensioning, thus preventing the graft from "bottoming out" before adequate tension is reached.

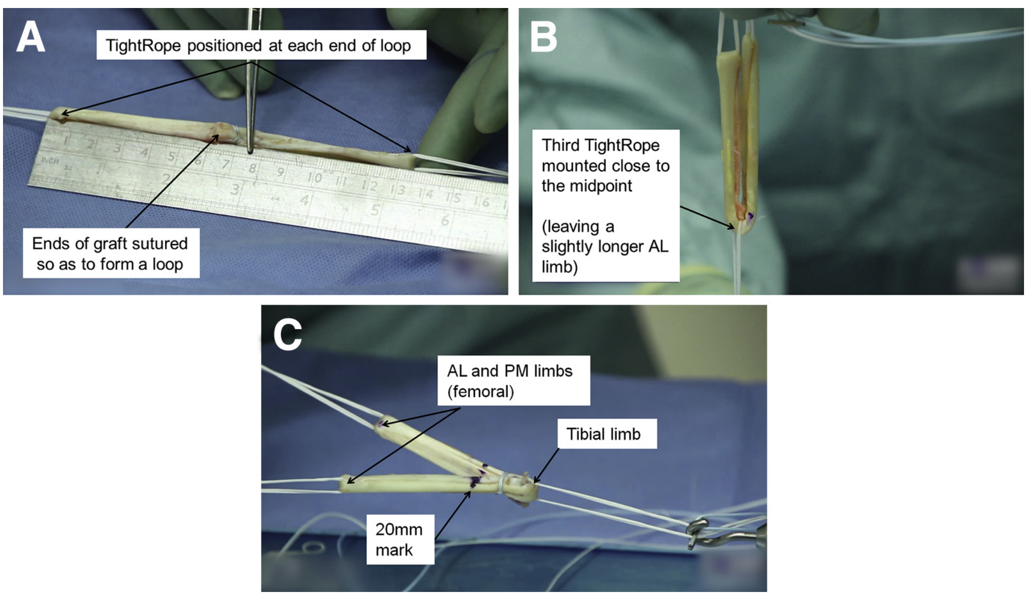

Fig 1. Key steps in formation of TriLink construct for use in posterior cruciate ligament reconstruction. (A) The ends of the graft are sutured together with a TightRope positioned at either end. (B) A third TightRope is passed to the center of the loop, and the 2 resultant limbs are adjusted in size. (AL, anterolateral.) (C) The position of the TriLink graft is fixed with nonabsorbable sutures. Our preferred graft is quadrupled semitendinosus or FiberTape-reinforced peroneus longus allograft. (AL, anterolateral; PM, posteromedial.)

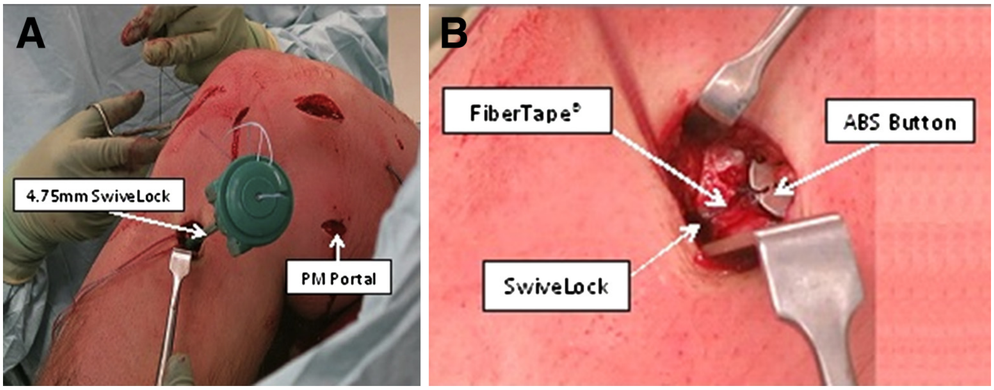

Fig 2. SwiveLock fixation device used if backup fixation at tibia is required. (A) The Application and tensioning of SwiveLock. (PM, posteromedial.) (B) In situ SwiveLock with components labeled. (ABS, attachable button system.)

After reaming, a stiffened plastic sleeve containing a striped looped suture (TigerStick; Arthrex) is passed through the drill sleeve and into the joint. The suture loop is retrieved with a suture grasper and delivered through the AM portal.

Femoral Socket Preparation

The transmedial technique allows for femoral socket preparation through the AM portal, using a 30° arthroscope inserted through the AL portal. This enables excellent visualization of the lateral wall of the medial femoral condyle. Again, a radiofrequency device is used to prepare, measure, and mark the intended socket positions using the references described as follows: The preferred position for the AL bundle is centered at a point triangulated by 3 arthroscopic landmarks: proximal to the medial bifurcate prominence, 7 mm posterior to the margin of the cartilage at the apex of the intercondylar notch, and 8 mm proximal to the distal articular cartilage margin in a line

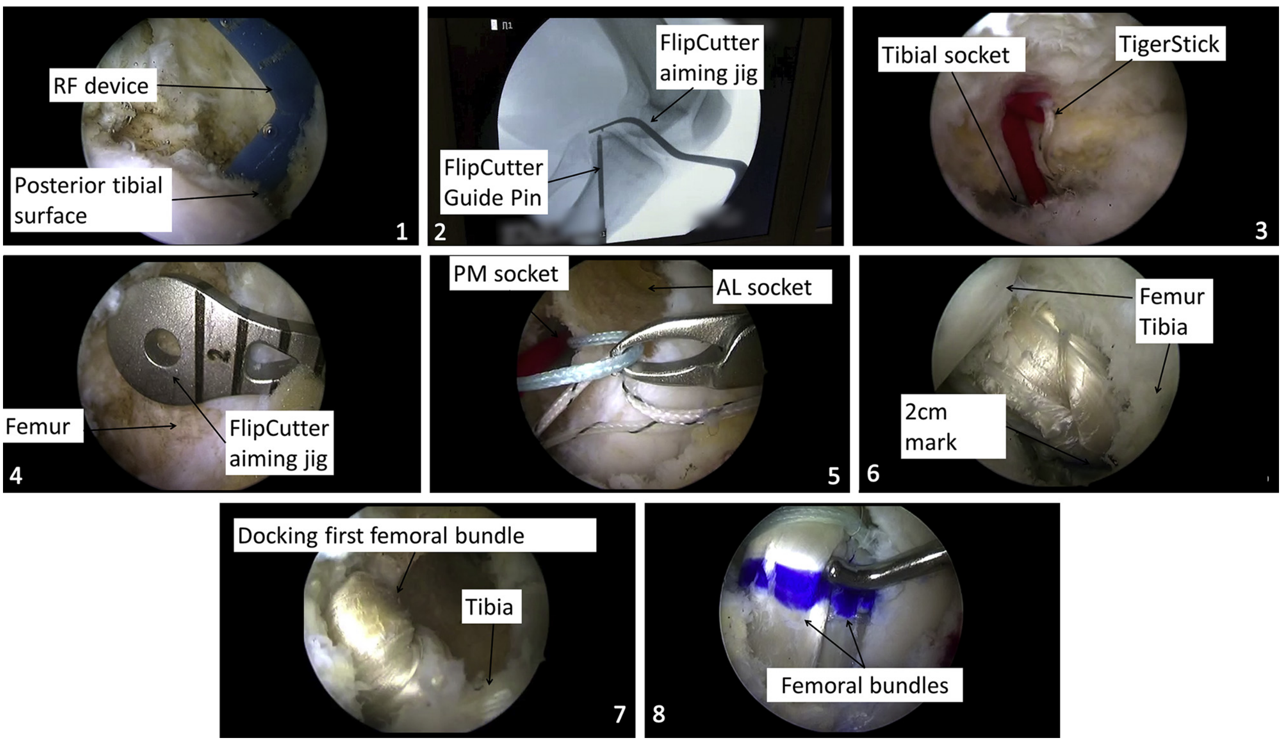

Fig 3. Key steps in transmedial all-inside posterior cruciate ligament reconstruction (depicted in a right knee): (1) Radiofrequency (RF) ablation is used to clear the tibial footprint. (2) The FlipCutter guide is placed and a guidewire drilled into the knee under fluoroscopic guidance. (3) A TigerStick is used to pass a shuttling suture through the resultant retrosocket. (4) The FlipCutter is centered over the sites for the 2 femoral bundles, and 2 further retrosockets are created. (5) Shuttling sutures are passed and retrieved simultaneously. (AL, anterolateral; PM, posteromedial.) (6) The tibial limb is docked to the premarked 2-cm mark. (7, 8) The 2 femoral bundles are docked and tensioned individually.

Table 3. Principal Advantages and Disadvantages, Along With Pertinent Pearls and Pitfalls, of Transmedial TriLink PCL Reconstruction

	Explanation
Advantages	
Double bundle on femur	• Replicates femoral anatomy • Improved femoral footprint fill • Improved biomechanical stability
Anatomic positioning of femoral bundles	• No need for intraoperative hyperflexion • Matches functional PCL anisometry • Better replicates PCL biomechanics
Single tibial bundle	• Matches compact tibial PCL footprint • Avoids technical difficulty with 2 tibial sockets • No risk of socket confluence
Bone preserving	• Sockets created, not tunnels
Cortical suspensory fixation	• Robust and reliable fixation method • Allows in situ adjustment of tension
Easy graft passage	• Graft introduced into knee and drawn into sockets; therefore, no requirement for graft to be dragged around "killer turn" of tibia
Disadvantages	
Technically challenging	• More challenging than single-bundle reconstruction but easier than traditional double-bundle techniques
Pearls	
Use of arthroscopic cannulas	• This not only is advantageous by maintaining the patency of the port during instrument changes but also facilitates withdrawal of the sutures without entrapment of the soft tissues.
Tensioning second limb by femoral TR alone	• The AL bundle is tensioned first, and having done so, the tibial TR cannot be adjusted (when tensioning the PM bundle) without compromising the AL tension.
Use of a 70° arthroscope	• Direct visualization of the tibial footprint is allowed.
Pitfalls	
Graft and suture entanglement	• Meticulous suture management is required, which can be facilitated by use of a PassPort cannula (Arthrex) through the AM portal.
Potential graft bottoming out	• Retrosockets must have sufficient depth to accommodate any slack in the graft. • Insufficient socket depth will result in bottoming out of the graft and graft laxity.
Overconstrained knee	• Pulling too much graft into the sockets by over-tensioning will reduce intra-articular graft length and overconstrain the knee.

AL, anterolateral; AM, anteromedial; PCL, posterior cruciate ligament; PM, posteromedial; TR, TightRope.

parallel to the long axis of the femur. The PM bundle is similarly triangulated using the following 3 landmarks: distal to the medial bifurcate prominence, 11 mm above the posterior cartilage margin, and 8 mm proximal to the distal articular cartilage margin in a line parallel to the long axis of the femur.

These measurements are similar to those recommended by LaPrade and colleagues,[6] among other authors.[8-10] These arthroscopic reference points are marked and subsequently used to center the femoral PCL aiming guide (Arthrex). The FlipCutter is then used to create retrosockets to a depth of 20 mm. The diameter of the FlipCutter used is determined by the width of the individual femoral bundles of the trifurcate graft, which may differ. We aim to leave a minimum of 3 mm between the 2 tunnels to avoid socket confluence and improve footprint fill.[10]

After each socket is created, a stiffened plastic sleeve containing a plain looped suture (FiberStick; Arthrex) is passed down the drill sleeve into the joint. The suture loops from both sockets are retrieved from the knee through the AM portal, preferably simultaneously to avoid a soft-tissue bridge.

Graft Deployment

The looped sutures are adjusted so that a single end of each suture is withdrawn through the AM portal, ensuring no soft-tissue entrapment. The retrieved ends of these sutures are individually linked to the TightRope devices of the TriLink graft and used as lead sutures to draw the graft into the knee.

Under arthroscopic visualization, the tibial end of the graft is docked to a depth of 20 mm into the tibial retrosocket. The adjustable button of the TightRope is seated onto the anterior tibial cortex for cortical fixation and subsequent final tensioning. The femoral ends are then drawn into their respective sockets and partially seated, starting with the PM bundle. This is achieved by advancing the TightRope devices through the guide pin tunnels on their lead sutures. Once beyond the femoral cortices, the buttons are flipped. Care is taken to ensure that there is no soft-tissue interposition affecting the quality of graft tensioning and fixation.

Graft Fixation and Tensioning

With the femoral TightRope devices flipped and docked firmly against the medial femoral cortex, tensioning can commence. This is achieved by pulling the free ends of the TightRope back and forth to advance the TriLink graft into the retrograde sockets. The tensioning regimen reflects the tension profile of each bundle of the PCL during knee flexion. The AL bundle is tensioned at 90° of flexion (the position of greatest tension in the AL bundle physiologically) with concomitant anterior tibial translation applied by the surgical assistant. If insufficient tension in the AL bundle occurs because of the graft bottoming out within its femoral socket, this can be overcome by further tensioning of the tibial TightRope. It is imperative that no subsequent alterations to the tibial TightRope are made once the AL bundle is satisfactorily tensioned because this would either loosen or overconstrain the AL limb of the graft. After cycling of the knee, the PM bundle is tensioned at 30° of flexion (the position of maximum physiological tension).

The knee is cycled several times through full range of movement before the TightRope button fixation is finalized. Before the tensioning sutures are cut, the posterior drawer test and arthroscopic visualization are used to verify satisfactory fixation and restoration of normal anteroposterior laxity. For TriLink constructs reinforced with FiberTape, as in our unit, the free ends of the FiberTape polymer loop are anchored distally in the tibia with a 4.75-mm anchor device (SwiveLock; Arthrex) (Fig 2).

Postoperative Rehabilitation

Our unit uses a standardized rehabilitation protocol. Initially, a hinged knee brace is worn continuously for 12 weeks. For the first 6 weeks, patients are restricted to partial weight bearing with the brace locked in extension. The focus is on quadriceps activation, prone passive knee flexion from 0° to 90°, and active extension exercises. From 6 to 12 weeks, patients are allowed to fully bear weight with the brace in situ and range of movement is increased incrementally. Patients are restricted from squatting or sudden deceleration for 6 months. At 6 months, patients may begin straight-line jogging if quadriceps and hamstring deficits are less than 20%. Once patients can run straight ahead at full speed, they are allowed to progress to lateral running, crossovers, and cutting exercises before returning to sport at 9 to 12 months.

Discussion

Restoration of normal knee stability and kinematics is the goal in all ligament reconstructions. This is especially challenging in PCL reconstruction because of the awkward position of the tibial footprint and the broad femoral PCL attachment, as well as its anisometric characteristics. Anatomic replication of the femoral PCL insertion with double-bundle grafts has been shown in several biomechanical studies to be key in controlling posterior tibial laxity and rotational stability.[6,7] Double-bundle grafts have been tentatively shown to be clinically superior to single-bundle constructs, although concern about data quality exists.[11]

It is hoped that the progression of steps in the described technique (summarized in Figs 1 and 3) together with specialized instruments, which provide access to the posterior aspect of the tibia while protecting the neurovascular bundle, will provide surgeons reassurance when tackling these challenging cases. The technique uses anatomic positioning of the tibial tunnel, which has been shown biomechanically to minimize posterior laxity and thus lead to a more stable construct.[12] The use of a single tibial bundle eliminates the risk of tunnel convergence at the tibia and simplifies the technique, while still allowing good "footprint fill" of the compact tibial footprint. Simultaneously, the TriLink construct allows the double-bundle femoral anatomy to be replicated, with subsequent benefits on biomechanics. Although the technique remains technically challenging, it remains less so than double-bundle PCL reconstructions while retaining many of their kinematic advantages over single-bundle reconstructions. These advantages and disadvantages are summarized in Table 3.

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