Technical Note

Single-Bundle Anatomical Posterior Cruciate Ligament Reconstruction With Remnant Preservation

Jinzhong Zhao, M.D.

Abstract: Remnant always exists following injuries of the posterior cruciate ligament (PCL). To improve the clinical outcomes of PCL reconstruction, preservation of the remnant has long been a consideration. However, how to make the remnant-preservation technique simple and more effective is of concern. We describe a single-bundle anatomical PCL reconstruction technique with remnant preservation in which the posteromedial and posterolateral portals are used, the graft is placed at the lateral side of the remnant, and pulleys are used to facilitate graft passage at the 2 killer turns of the grafting routes. We consider introduction of this technique will provide reasonable choices in PCL reconstruction.

Unlike anterior cruciate ligament injury, posterior cruciate ligament (PCL) injuries always leave nonabsorbed remnant fiber that connect the femur and the tibia. As the clinical results of PCL reconstruction still leave great room for improvement, PCL reconstruction with remnant preservation has long been considered, and various related techniques have been reported.[1-4] However, PCL reconstruction with remnant preservation is not so popular because a simple, safe, and effective method to manipulate in the posterior compartments and to avoid the hindrance of the remnant fibers to observation and manipulation is still needed. Thus, we describe a single-bundle anatomical PCL reconstruction technique, in which each step is made simple and reproducible. This procedure is suitable for PCL injury with remnant attached to the femur.

From the Department of Sports Medicine, Shanghai Sixth People's Hospital, Shanghai Jiao Tong University, Shanghai, China.

The author reports the following potential conflicts of interest or sources of funding: funded by National Key Research and Development Program of China (Grant Nos. 2018YFC1106200 and 2018YFC1106202), and the project of Shenkang Hospital Development Center of Shanghai (Grant No. 16CR3108B). Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received April 12, 2021; accepted July 1, 2021.

Address correspondence to Jinzhong Zhao, M.D., Department of Sports Medicine, Shanghai Sixth People's Hospital, Shanghai Jiao Tong University, 600 Yishan Rd., Shanghai 200233, China. E-mail: zhaojinzhong@vip.163 or jzzhao@sjtu.edu.cn

2212-6287/21600

https://doi.org/10.1016/j.eats.2021.07.006

Surgical Technique (With Video Illustration)

The patient is supine and receiving regional or general anesthesia. A lateral supporting plate is fitted on the proximal side of the thigh to provide support when the knee is flexed (Table 1).

Tendon Harvesting and Preparation

For single-bundle PCL reconstruction with remnant preservation, a tendon graft that is at least 9 mm large and 8 cm long is needed to ensure the strength of the graft and the into-tunnel length. The semitendinosus tendon, the gracilis tendon, and the anterior half of the peroneus longus tendon[5] are harvested. A 9-stranded graft is made from these 3 tendons to obtain a graft with a length of over 8 cm and a size of over 9 mm (Fig 1). After measuring the total diameter of the graft, the graft is pretensioned with 80-N to 100-N force until it is needed to implant the graft into the tunnel. A mark is made by suture the graft with an absorbable suture at a site 25 mm to the end of the graft.

Establishing the Surgical Portals

The operation is performed using high anterolateral (AL), high anteromedial (AM), posteromedial (PM), and posterolateral (PL) portals. The AL and AM portals are first created. Concomitant lesions are treated. The arthroscope is placed into the PM compartment through the AL portal and the femoral notch (Video 1). The PM portal is created, and a cannula is placed in. The arthroscope is placed into the PM compartment through the PM portal. The center of the posterior septum is found and pressed against with the arthroscope. Keeping the trocar in place, an obturator is used to replace the arthroscope. The trocar with the obturator is pushed

Table 1. Step-by-Step Procedure of Single Bundle PCL Reconstruction With Remnant Preservation

1. The semitendinosus tendon, the gracilis tendon, and the anterior half of the peroneus longus tendon are harvested. A 9-stranded graft is made from these three tendons.
2. The anterolateral and anteromedial portal are first created. Concomitant lesions are treated.
3. The arthroscope is placed into the posteromedial compartment through the anterolateral portal. The posteromedial portal is created.
4. The arthroscope is placed into the posteromedial compartment through the posteromedial portal, across the posterior septum to the posterolateral compartment. The posterolateral portal is created.
5. A shaver is placed into the posterolateral compartment through the posterolateral portal and into the posterior septum. Part of the posterior septum is removed to expose the PCL remnant and its tibial insertion.
6. The arthroscope is placed into the anterior compartment through the anterolateral portal. A tibial tunnel locator is placed into the femoral notch from the anteromedial portal, through the lateral side of the PCL remnant, to the posterior compartment.
7. The arthroscope is placed into the posteromedial compartment. The tibial tunnel locator is placed along the PCL tibial insertion down to against the posterior capsule attachment, just lateral to the midline of the PCL insertion. A K-wire is drilled in.
8. The arthroscope is placed in through the anteromedial portal. The femoral tunnel is created sequentially with a K-wire and a drill to expected size and depth.
9. The arthroscope is placed into the posterior compartments through the posteromedial portal. The switching stick is placed in through the posterolateral portal to lever the posterior capsule posteriorly. The K-wire is overdrilled to create the tibial tunnel to expected size.
10. The arthroscope is placed in through the anteromedial portal. A guide suture is placed in through the anterolateral portal, passed through the lateral side of PCL to the posterior compartment.
11. The arthroscope is placed in through the posteromedial portal. The guide suture is retrieved through the tibial tunnel.
12. A medial incision is made over the medial femoral epicondyle.
13. The arthroscope is placed in through the anteromedial portal. A guide pin tailed with a suture loop is placed in through the anterolateral portal and passed through the femoral tunnel.
14. The guide suture is passed through the femoral tunnel with the suture loop tailing the guide pin and out of the medial incision.
15. The arthroscope is placed in through the posteromedial portal. A switch stick is placed in through the posterolateral portal to the anterior inferior side of the guide suture and used as a pulley and a lever.
16. With the guide suture, the fixing sutures at the proximal end of the graft is pulled in through the tibial tunnel and out through the femoral tunnel.
17. With constant pulling of the fixing sutures, the graft is pried into the joint through the tibial tunnel with repeated maneuver of the switching stick.
18. The arthroscope is placed in through the anterolateral portal. An obturator is placed at the turning point of the fixing sutures at the inner orifice of the femoral tunnel as a pulley. The graft is pulled into the femoral tunnel.
19. The proximal fixing sutures are tied on a cortical fixation button over the outer orifice of the femoral tunnel.
20. With constant pulling of the distal end of the graft, the knee is flexed several times to pull back and tension the graft.
21. At full extension of the knee, an interference screw is place into the tibial tunnel for primary fixation.
22. A trans-tibial ridge tunnel is created. A set of mini plate with an adjustable loop is pulled through this tunnel from the medial to the lateral side.
23. The sutures from the distal end of the graft are fixed at the adjustable loop.

PCL, posterior cruciate ligament.

across the posterior septum to the PL compartment. The arthroscope is placed into the PL compartment to replace the obturator. The PL portal is created under observation, and a cannula is placed in (Fig 2).

Exposing the Tibial Insertion of the PCL

A shaver is placed into the PL compartment through the PL portal. The arthroscope is retrieved back into the PM compartment. The shaver is placed into the posterior septum along with the retrieving of the arthroscope. Part of the posterior septum is removed to expose the PCL remnant and its tibial insertion in the posterior compartments. The capsule insertion at the distal edge of the PCL tibial insertion is exposed (Fig 3).

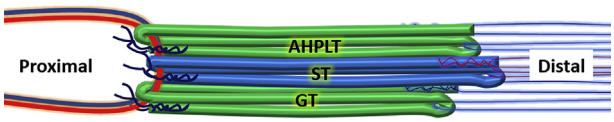

Fig 1. Illustration of the fabrication of a 9-stranded graft with the semitendinosus tendon, the gracilis tendon, and the anterior half of the peroneus longus tendon. (AHPLT, the anterior half of the peroneus longus tendon; GT, the gracilis tendon; ST, the semitendinosus tendon.)

Placing the Guidewire for the Creation of the Tibial Tunnel

The arthroscope is placed in through the AL portal. A tibial tunnel locator for PCL reconstruction (Smith-Nephew, Andover, MA) is placed in through the AM portal, passed through the lateral side of the PCL remnant, to the posterior compartments (Fig 4A).

The arthroscope is placed into the PM compartment. The tibial tunnel locator is placed along the PCL tibial insertion down to against the posterior capsule attachment to position the inner orifice 7 mm in front of the attachment line of the posterior capsule, just lateral to the midline of the PCL insertion (Fig 4B). The tibial tunnel aiming pin is amounted to set the angulation of the tibial tunnel at about 45° to the tibial axis in the sagittal plane. A K-wire is drilled in (Fig 4C).

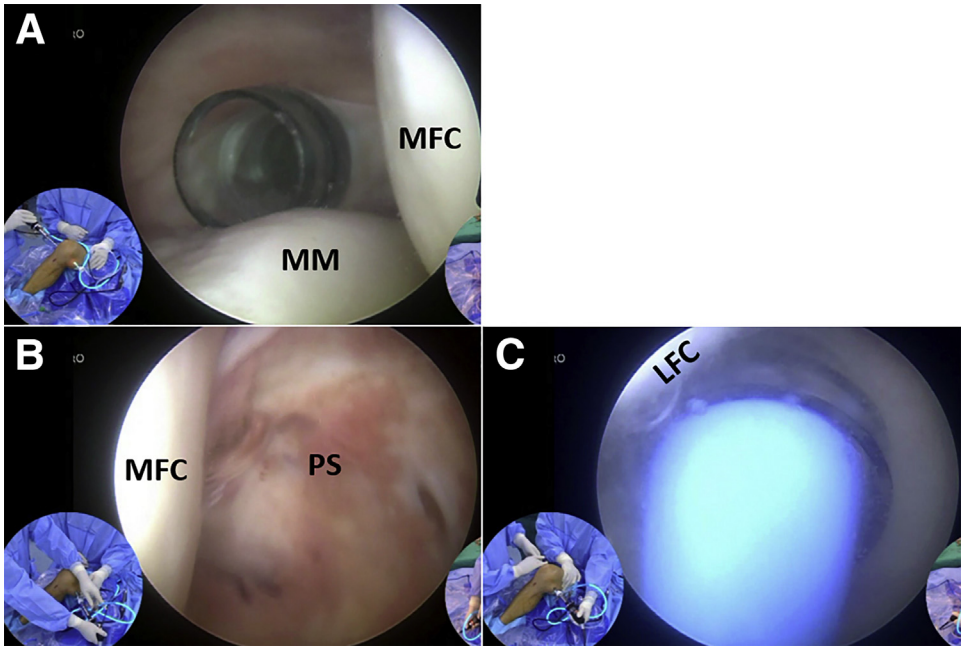

Fig 2. Creation of the posteromedial portal (A) (arthroscopic view of the posteromedial compartment of the right knee through the anterolateral portal) and creation of the posterolateral portal with the arthroscope placed into the posterolateral compartment (C) through the posterior septum (B) (arthroscopic view of the posteromedial compartment of the right knee through the posteromedial portal). (LFC, lateral femoral condyle; MFC, medial femoral condyle; MM, medial meniscus; PS, posterior septum.)

Creating the Femoral Tunnel

With the arthroscope placed in through the high AM portal, the femoral tunnel is drilled through the AL portal. The inner orifice of the femoral tunnel is located 12 mm from the most anterior edge of the PCL femoral footprint, and 7 to 8 mm from the distal cartilage margin. The femoral tunnel is created sequentially with a K-wire and a drill to expected size and depth (Fig 5).

Creating the Tibial Tunnel

The arthroscope is placed in through the PM portal. The switching stick is placed in through the PL portal to lever the posterior capsule posteriorly to increase the buffer space for the drilling of the tibial tunnel. The K-wire is over drilled to create the tibial tunnel to expected size, which is equal to the distal end of the graft (Fig 6).

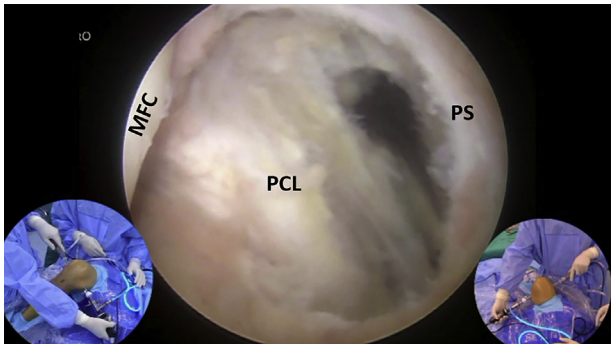

Fig 3. Connecting the posteromedial and posterolateral compartments by removing part of the posterior septum. (MFC, medial femoral condyle [arthroscopic view of the posterior compartments of the right knee through the posteromedial portal]; PCL, posterior cruciate ligament; PS, posterior septum.)

Placing the Guide Suture

The arthroscope is placed in through the AM portal. A guide suture loop is placed in through the AL portal, passed through the lateral side of PCL and the inferior side of the meniscofemoral ligament to the posterior compartments (Fig 7A). The arthroscope is placed in through the PM portal. A suture retriever is placed in through the PL portal to adjust the position of the guide suture. The guide suture loop is retrieved through the tibial tunnel (Fig 7B).

A 2 cm-long incision is made over the medial femoral epicondyle. The arthroscope is placed in through the AM portal. A guide pin tailed with a suture loop is placed in through the AL portal and passed through the femoral tunnel inside-out (Fig 8A). The guide suture loop is passed through the femoral tunnel with the suture loop tailing the guide pin and out of the medial incision (Fig 8B).

Graft Implantation

The arthroscope is placed in through the PM portal. A switching stick is placed in through the PL portal to the anterior inferior side of the guide suture and used as a pulley and a lever (Fig 9A). Along with the proximal pulling of the guide suture, the fixing sutures at the proximal end of the graft is pulled in through the tibial tunnel and out through the femoral tunnel (Fig 9B). With constant pulling of the fixing sutures, the graft is pried into the joint through the tibial tunnel with repeated maneuver of the switching stick.

The arthroscope is placed in through the AL portal. An obturator is placed at the turning point of the

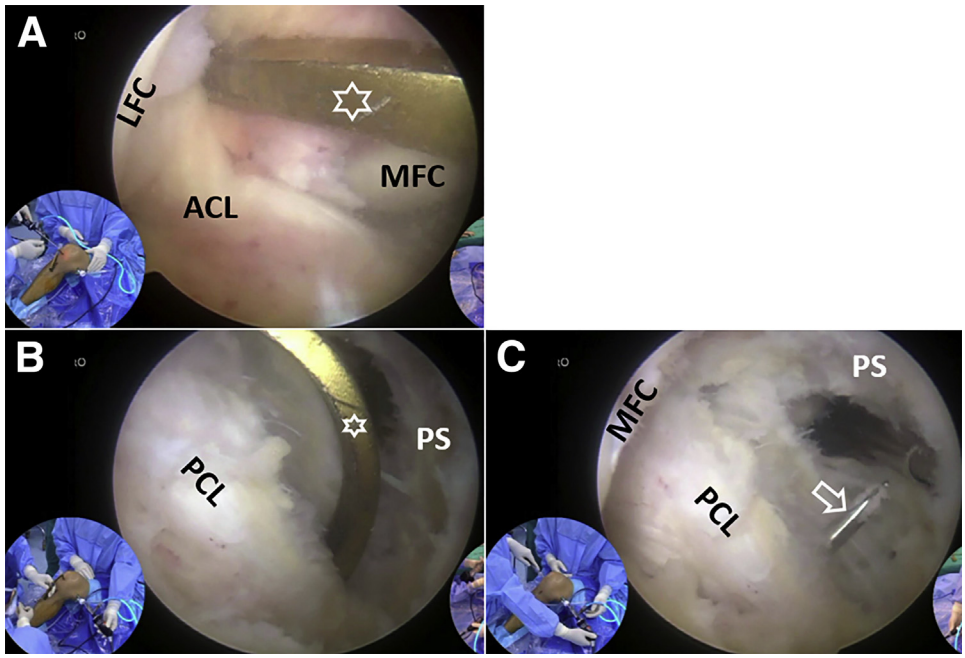

Fig 4. Placing the guidewire for the creation of the tibial tunnel. (A) The tibial tunnel locator is placed in through the anteromedial portal and the lateral side of the posterior side of the posterior cruciate ligament to the posterior compartments (arthroscopic view of the femoral notch of the right knee through the anterolateral portal). (B) The tibial tunnel locator is set at the desired place in the tibial insertion of the posterior cruciate ligament (arthroscopic view of the posterior compartments of the right knee through the posteromedial portal). (C) The guidewire for tibial tunnel creation is drilled in (arthroscopic view of the posterior compartments of the right knee through the posteromedial portal). (ACL, anterior cruciate ligament; MFC, medial femoral condyle; PCL, posterior cruciate ligament; PS, posterior septum.)

fixing sutures at the inner orifice of the femoral tunnel as a pulley. The graft is pulled into the femoral tunnel (Fig 10A).

Graft Fixation

The proximal fixing sutures from the graft are passed through the middle 2 holes of a cortical fixation button

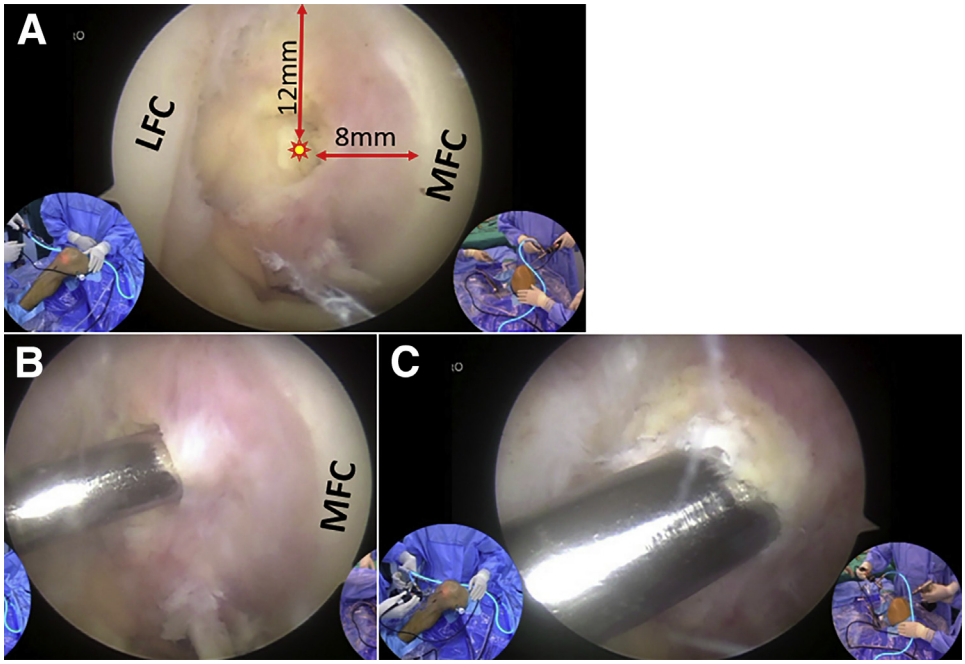

Fig 5. Creation of the femoral tunnel (arthroscopic view of the femoral notch of the right knee through the anteromedial portal). (A) The location of the femoral tunnel is marked with a radiofrequency probe. (B) A K-wire is first drilled in. (C) The tunnel is finally created to expected length with a drill. (LFC, lateral femoral condyle; MFC, medial femoral condyle.)

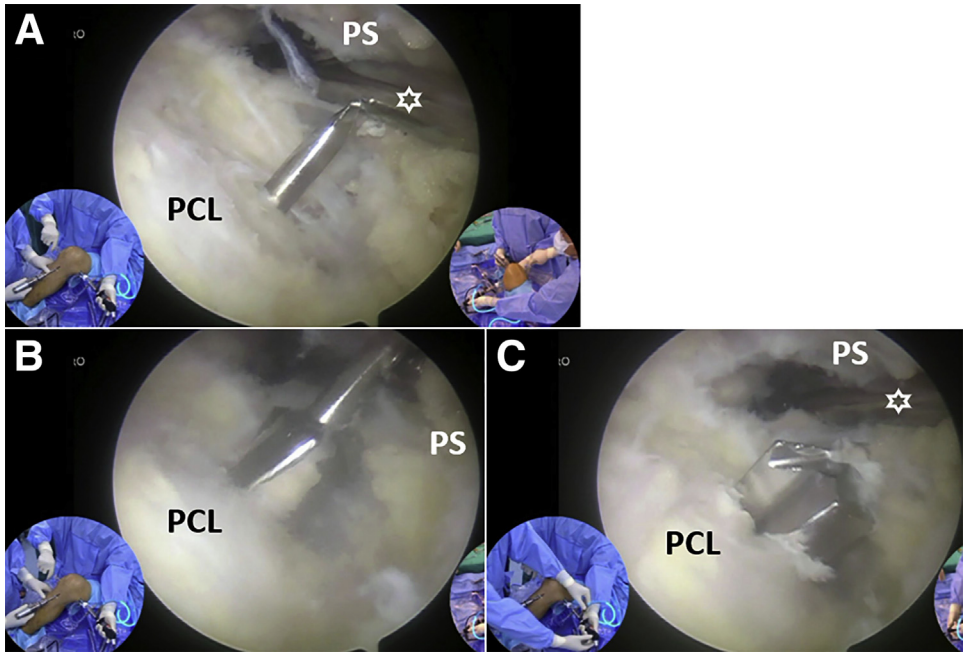

Fig 6. Creation of the tibial tunnel (arthroscopic view of the posterior compartments of the right knee through the posteromedial portal). (A) A switching stick (star) is placed into the posterior compartments through the posterolateral portal to lever the posterior capsule away from the tibial insertion of the posterior cruciate ligament. (B) The guidewire is first overdrilled with a 6-mm cannulated drill. (C) The tibial tunnel is created to expected size. (PCL, posterior cruciate ligament; PS, posterior septum.)

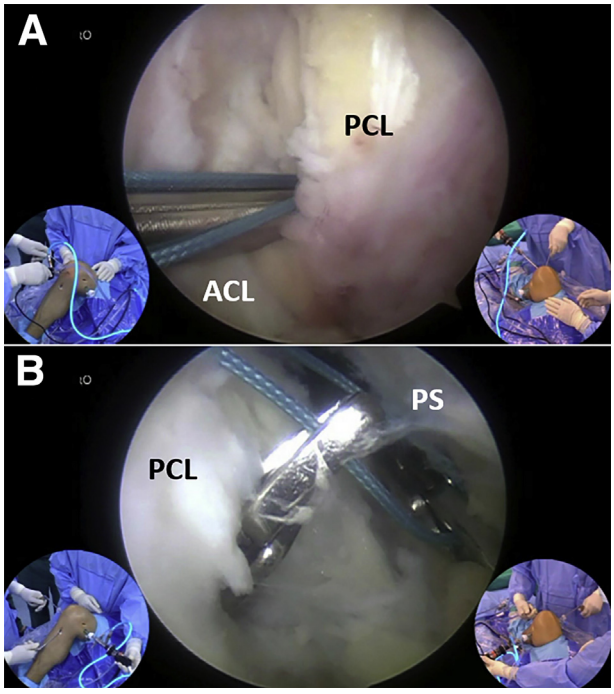

Fig 7. A guide suture loop is placed in through the anterolateral portal, passed through the lateral side of the posterior cruciate ligament to the posterior compartments (arthroscopic view of the femoral notch of the right knee through the anteromedial portal). (B) The guide suture loop is retrieved out through the tibial tunnel (Arthroscopic view of the posterior compartment of the right knee through the posteromedial portal). (ACL, anterior cruciate ligament; PCL, posterior cruciate ligament; PS, posterior septum.)

(Smith & Nephew, Andover, MA), which lies over the outer orifice of the femoral tunnel and tied on the button for proximal fixation.

With constant pulling of the distal end of the graft, the knee is flexed several times to pull back and tension the graft (Fig 10B). At full extension of the knee, an interference screw is placed into the tibial tunnel for primary fixation.

A 4.0-mm transtibial ridge tunnel is created with a Steinman pin at a transverse plane distal to the orifice of the tibial tunnel. A set of cortical suspensory fixation device with an adjustable loop (Arthrex, Naples, FL) is pulled through this tunnel from the medial to the lateral side. Half of the fixing sutures from the distal end of the graft are passed through the adjustable loop. The mini plate is pulled through the transverse tibial tunnel and flipped over the lateral orifice. The sutures passing through the adjustable loop are tied to their counterparts to connect the fixing sutures to the adjustable loop. The adjustable loop is reduced to tension the graft finally (Figs 11 and 12).

Discussion

The purpose of PCL reconstruction with remnant preservation is to make full use of the remnant to improve the surgical results. Because there is no study to directly compare PCL reconstruction with remnant preservation and that with remnant removal, evidence that supports the preservation of the remnant is still lacking.[6] However, efforts have kept been made to

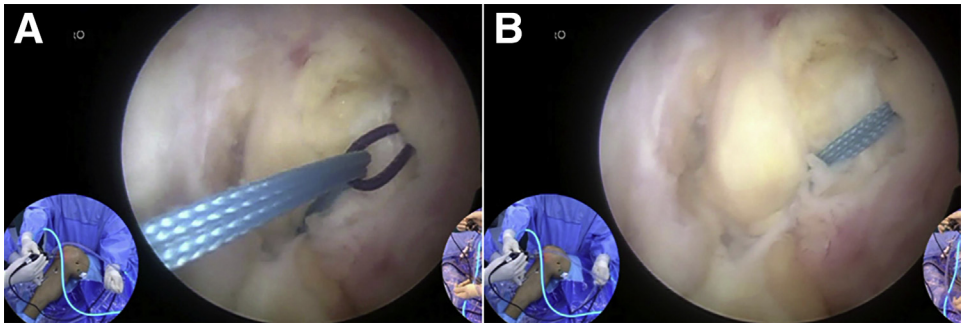

Fig 8. The proximal end of the guide suture loop is passed through the tailed suture loop of a pin passing through the femoral tunnel (A) and pulled out through the femoral tunnel (B) (arthroscopic view of the femoral notch of the right knee through the anteromedial portal).

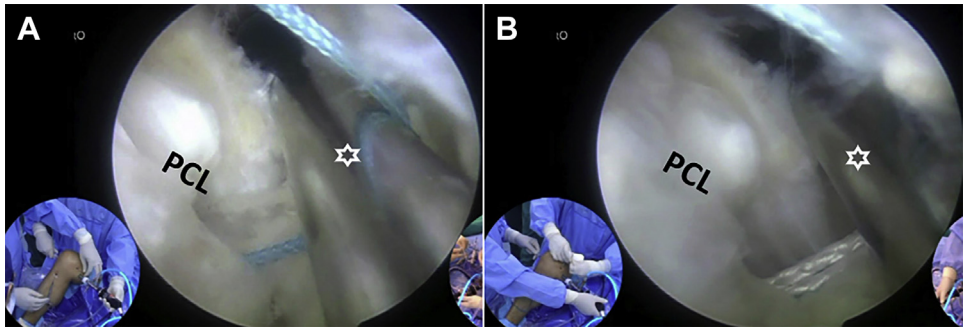

Fig 9. A switching stick (star) is placed at the anterior inferior side of the guide suture and used as a pulley (A), and the fixing sutures at the proximal end of the graft are pulled into the joint through the tibial tunnel (B) and out of the femoral tunnel (arthroscopic view of the posterior compartments of the right knee through the posteromedial portal). (PCL, posterior cruciate ligament.)

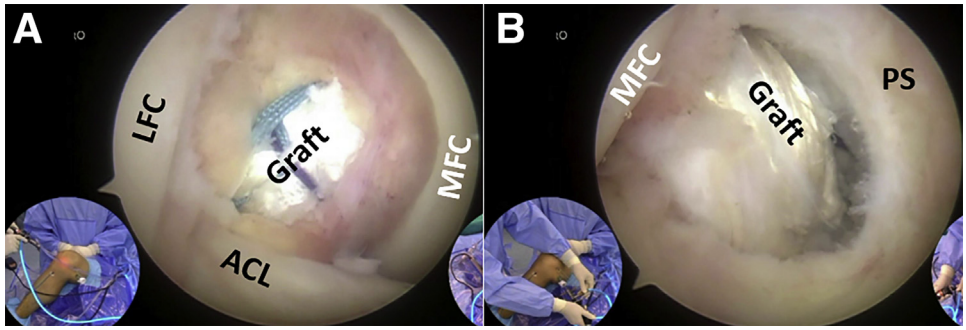

Fig 10. The graft is pulled into the femoral tunnel (A) (arthroscopic view of the femoral notch of the right knee through the anterolateral portal), fixed on the femoral side, and pulled back into the tibial tunnel (B) (arthroscopic view of the posterior compartments of the right knee through the posteromedial portal). (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; MFC, medial femoral condyle; PS, posterior septum.)

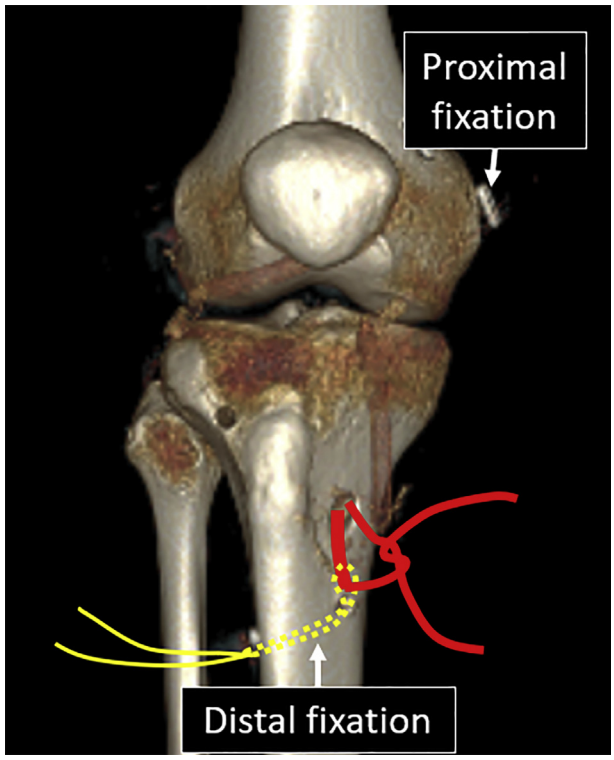

Fig 11. Illustration of the proximal fixation of the graft on a mini plate and distal fixation of the graft at an adjustable suture loop (right knee).

preserve the remnant during PCL reconstruction with the expectation of better surgical results.[7-11]

There are some important features in the current technique. First, although we believe remnant preservation will be beneficial to the restoration of stability following PCL reconstruction, we still rely on a strong graft to provide mechanical support instead of on the remnant. Thus, a 9-stranded graft made from the semitendinosus tendon, the gracilis tendon, and the anterior half of the peroneus longus tendon is usually used. Second, the PM and PL compartments are connected by removing part of the posterior septum, to facilitate observation and manipulation in the posterior compartments. Third, pulleys are used at the 2 killer-turns of the grafting route to facilitate graft implantation. Fourth, double fixation is used on the tibial side.

The pearls and pitfalls of the current technique are listed in Table 2. The most critical point of the current technique is preventing neurovascular injury during creation of the tibial tunnel.

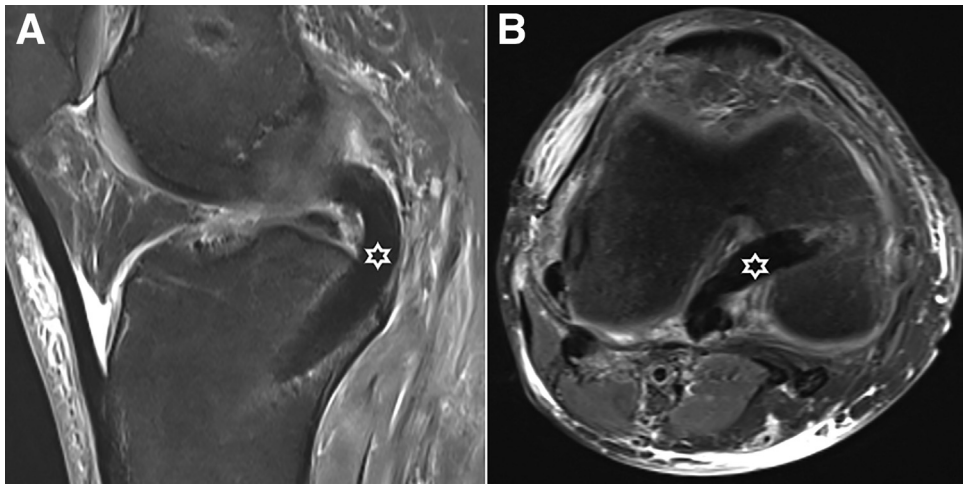

Fig 12. Postoperative images indicating the graft (star) (right knee). (A) Sagittal view. (B) Cross-section view.

Table 2. Pearls and Pitfalls of Single Bundle Posterior Cruciate Ligament Reconstruction With Remnant Preservation

1. Though the remnant is preserved in the current technique, a strong graft is needed. We prefer a graft with a size of at least 9 mm.
2. Placing the arthroscope across the posterior septum is technically demanding. In the posteromedial compartment, finding and pressing the center of the posterior septum with the arthroscope, replacing the arthroscope with obturator, pushing the trocar and obturator across the posterior septum, and replacing the obturator with the arthroscope are the simplest methods.
3. Connecting the posterior compartments by removing part of the posterior septum facilitates later manipulation in the posterior compartments.
4. Exposing the capsule attachment at the proximal tibial recess is critical for proper location of the tibial tunnel.
5. Placing the graft at the superior lateral side of the remnant results in better synovial coverage of the graft than placing it at the inferior medial side of the remnant.
6. During creation of the femoral tunnel, try to avoid cartilage injury of the medial femoral condyle.
7. During creation of the tibial tunnel, increase the bumper space for the drill is critical to avoid posterior neurovascular injuries. Lever the posterior tissue away from the tibial insertion of the posterior cruciate ligament is a simple way.
8. Overdrilling of the K-wire with a smaller drill first and a drill with equal size to the graft sequentially is favorable to avoid sudden protrusion of the drill.
9. Before placing the guide suture, enlarge the space between the remnant and the meniscofemoral ligament facilitates graft passage.
10. During Implantation of the graft, placing a lever at the posterior killer-turn of the graft facilitates graft placement.
11. In case of severe regional osteoporosis, the fixation and traction suture at the proximal end of the graft may cut into the bone at the proximal killer-turn, the inner orifice of the femoral tunnel. Creating a pulley at this site is critical.
12. On the tibial side, interference screw fixation is not enough because of osteoporosis of the proximal tibia. Backup fixation to a suture loop is important.

References

1. Zhao JZ, Huang-Fu XQ, He YH, Yang XG. Single-bundle posterior cruciate ligament reconstruction with remnant preservation: Lateral versus medial-sided augmentation technique. *Orthop Surg* 2009;1:66-73.
2. Ahn JH, Lee SH. Anatomic graft passage in remnant-preserving posterior cruciate ligament reconstruction. *Arthrosc Tech* 2014;3:e579-e582.
3. Lee DW, Choi HW, Kim JG. Arthroscopic posterior cruciate ligament reconstruction with remnant preservation using a posterior trans-septal portal. *Arthrosc Tech* 2017;6:e1465-e1469.
4. Chernchujit B, Samart S, Na Nakorn P. Remnant-preserving posterior cruciate ligament reconstruction: Arthroscopic transseptal, rod and pulley technique. *Arthrosc Tech* 2017;6:e15-e20.
5. Zhao J, Huangfu X. The biomechanical and clinical application of using the anterior half of the peroneus longus tendon as an autograft source. *Am J Sports Med* 2012;40:662-671.
6. Song JG, Kim HJ, Han JH, et al. Clinical outcome of posterior cruciate ligament reconstruction with and without remnant preservation. *Arthroscopy* 2015;31:1796-1806.
7. Eguchi A, Adachi N, Nakamae A, Usman MA, Deie M, Ochi M. Proprioceptive function after isolated single-bundle posterior cruciate ligament reconstruction with remnant preservation for chronic posterior cruciate ligament injuries. *Orthop Traumatol Surg Res* 2014;100:303-308.
8. Lee DW, Jang HW, Lee YS, et al. Clinical, functional, and morphological evaluations of posterior cruciate ligament reconstruction with remnant preservation: Minimum 2-year follow-up. *Am J Sports Med* 2014;42:1822-1831.
9. Lee DW, Kim JG, Yang SJ, Cho SI. Return to sports and clinical outcomes after arthroscopic anatomic posterior cruciate ligament reconstruction with remnant preservation. *Arthroscopy* 2019;35:2658-2668.e1.
10. Chun KC, Shin CH, Kang HT, Kwon HY, Jo HJ, Chun CH. Mechanoreceptors in remnant posterior cruciate ligament and Achilles tendon allografts after remnant-preserving posterior cruciate ligament reconstruction: Hematoxylin-eosin and immunohistochemical assessments. *Am J Sports Med* 2020;48:3013-3020.
11. Yoon KH, Kim JS, Park JY, Park SY, Kiat RYD, Kim SG. Comparable clinical and radiologic outcomes between an anatomic tunnel and a low tibial tunnel in remnant-preserving posterior cruciate ligament reconstruction. *Orthop J Sports Med* 2021 23;9(2):2325967120985153.