Technical Note

Posteromedial Portal Technique With Bone—Patellar Tendon—Bone Graft for Inside-Out Revision of Anterior Cruciate Ligament Reconstruction

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Abstract: Bone—patellar tendon—bone (BTB) is a graft material used in anterior cruciate ligament (ACL) reconstruction. We describe creating a femoral tunnel using an inside-out posteromedial (PM) portal technique during anatomic double-bundle ACL reconstruction with a hamstring graft. We hypothesized that applying this femoral tunnel creation method to the revision ACL reconstruction using BTB would enable reconstruction in 1 stage. In this technique, an anteromedial, an anterolateral, and a PM portal are created to confirm the original ACL footprint and location and direction of the bone tunnel during primary reconstruction. The surgeon then drills from the PM portal, so that the femoral tunnel opening touches the posterior proximal articular cartilage margin in the ACL footprint. Even if the opening partially overlaps with the primary tunnel, it is possible to create a new tunnel with a different direction. Finally, the BTB graft is guided from the tibial tunnel to the femoral tunnel and fixed with interference screws. Intraoperative PM arthroscopic views can confirm that the femoral tunnel has been created, avoiding overlap, and that the revision ACL has been reconstructed. This procedure may be useful for 1-stage revision ACL reconstruction for reinjury after primary ACL reconstruction by other conventional procedures.

Revision anterior cruciate ligament (ACL) reconstruction is associated with problems such as retained grafted tendon material from the primary reconstruction, the number and location of bone tunnels, and bone loss associated with bone tunnel enlargement.[1] In contrast, revision ACL reconstruction using bone—patellar tendon—bone (BTB) is useful in cases where the hamstring was used at the time of primary surgery and in cases with bone defects because the size of the collected bone plugs can be freely adjusted.[2]

There are 2 methods of femoral tunnel creation: the inside-out technique and the outside-in technique. There are individual differences in the width of the intercondylar portion of the femur and the size of the femoral condyle. Therefore, inside-out procedures using an anterior approach from a transtibial tunnel or an anterior medial (AM) portal may cause posterior-wall blowout and damage to the posterior articular cartilage during femoral tunnel creation.[3-5] The outside-in procedure reduces these risks but presents the dilemma of a less accurate tunnel center determination compared to the inside-out procedure.[6] To overcome these procedural problems, we have been using the posteromedial (PM) portal approach since 2003 for the creation of femoral tunnels for primary double-bundle ACL reconstruction using hamstring tendons.[7] This femoral tunnel creation procedure is an inside-out

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Table 1. Surgical Steps, Pearls, and Pitfalls

Surgical Steps	Pearls	Pitfalls
AL and AM portal	It is used for dissection of ACL residual tissue using arthroscopy, shaving of femoral intercondylar area, and dissection of septum posterior to the PCL. The AM portal is also used for device placement during tibial tunnel creation.	If the portal is made far from the patellar tendon, dissection of the ACL around the proximal posterior cartilage margin of the LFC and dissection of the septum behind the PCL becomes difficult. Dissection of the posterior PCL septum with knee extension or knee flexion over the popliteal area carries the risk of popliteal neurovascular injury.
PM portal	Position the patient in a supine position with the knee flexed to 90°, and make a skin incision to avoid injury to the infrapatellar branch of the saphenous nerve. Create a portal that enables safe intra-articular manipulation from the medial posterior joint capsule to the LFC by viewing the PCL posteriorly from the AL portal. Insert a cannula into the PM portal and perform ACL footprint confirmation, femoral tunnel drilling, and graft fixation.	If the septum behind the PCL is not successfully dissected, it is difficult to create a safe portal using only a 30° oblique scope. In this case, it is also possible to use a 70° oblique scope according to the method of making a trans-septal portal.
Femoral tunnel drilling	The cartilage margin and lateral intercondylar ridge on the posterior proximal LFC are identified, the center of the bone tunnel is determined based on the 8-mm outer diameter of the first cannula, and a 2.4-mm K-wire is inserted using the inside-out technique through the PM portal. Using this K-wire as a guide, drill from the PM portal in an antegrade fashion with a diameter of 8 mm.	Since the ACL footprint may be underestimated using only the AL or AM portal arthroscopic view, the PM portal should also be used for confirmation and orientation. Failure to protect the soft tissue behind the PCL and the medial femoral condyle with the cannula during creation of the tunnel will result in injury from drilling.
Tibial tunnel drilling	Identify the anatomic ACL tibial footprint and insert the K-wire using a standard tibial guide at a 45° entry angle. Using this K-wire as a guide, a hollow drill is used to drill antegrade to create a 9-mm tibial tunnel.	If the operator does not fix the limb position during drilling after inserting the K-wire, the K-wire, which serves as a guide during the creation of the bone tunnel, will bend or break.
Graft harvesting and creation	A midline incision is used to harvest the BTB graft. The patellar tendon is harvested so that the bone plugs at both ends are 8 mm wide and 20 mm long.	If the extracted bone plug is thin, it may crack during graft passage or interfere with screw fixation.
Graft passage	A passing pin is passed through the femoral tunnel from the PM portal, and the nylon thread passed through the passing pin is pulled out from the tibia tunnel and used as a guide thread. This guide thread is pulled toward the femur, and the graft is passed antegrade from the tibial tunnel to the femoral tunnel.	If the femoral bone tunnel and the bone plug of the BTB are not aligned and the guide thread is pulled too much, there is a risk of the bone plug breaking.
Graft fixation	The fixation of the femoral graft is performed by inserting a guidewire through the PM portal and using an interference screw anterogradely. Fix the tibial graft with the knee in 20° of flexion and fix it with interference screws while pulling the soft steel wire through the bone plug with maximum manual tension.	Attempting intraosseous fixation with an interference screw without properly inserting the guidewire will result in poor fixation.

ACL, anterior cruciate ligament; AL, anterolateral; AM, anterior medial; BTB, bone–patellar tendon–bone; LFC, lateral femoral condyle; PCL, posterior cruciate ligament; PM, posteromedial.

posterior approach procedure and the tunnel created distally and anteriorly from the intra-articular tunnel opening. On the other hand, the other conventional procedures are different because the femoral tunnel is created in the proximal anterior direction from the intra-articular tunnel opening. For this reason, if this procedure is used for ACL reinjuries, it may be possible to reconstruct them in 1 stage while avoiding overlap with the femoral tunnel. Considering these advantages, we applied the PM portal technique and describe a surgical procedure for anatomic ACL reconstruction using BTB (Video 1, Table 1).

Surgical Techniques (Video 1, Table 1)

Preoperative Setup

The patient is placed in the supine position and the tourniquet is placed around the affected thigh. The

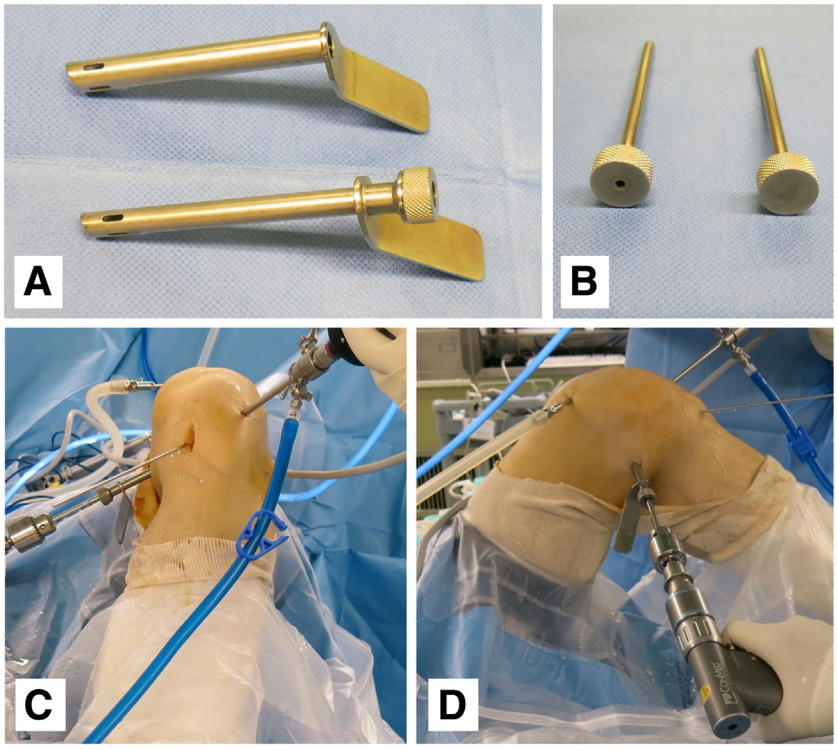

Fig. 1. (A) Cannula for posteromedial (PM) portal. The narrow outer sheath (first cannula) has an inner diameter of 6 mm and an outer diameter of 8 mm, and the wide outer sheath (second cannula) has an inner diameter of 8 mm and an outer diameter of 10 mm. (B) There are 2 types of inner tubes, one with a hole through which a K-wire with a diameter of 2.4 mm passes and the other without a hole. (C, D) Clinical images of a patient in a supine position with the left knee flexed at 90°, and a K-wire is inserted through the PM portal (C: front view, D: medial view).

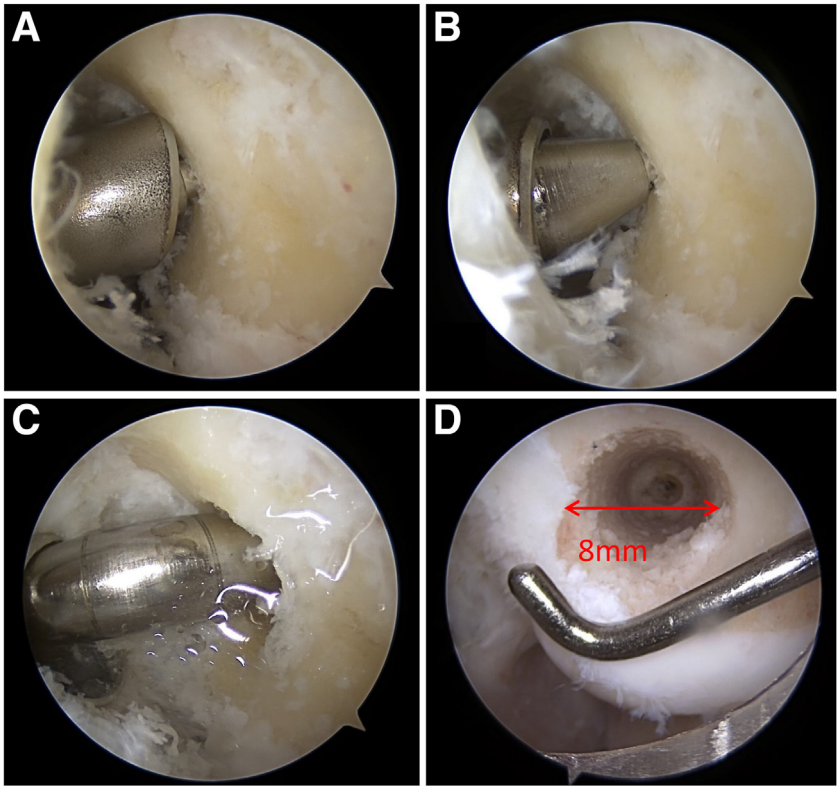

Fig. 2. Arthroscopic views of the left knee through the anterolateral portal (A, B, C) and the posteromedial portal (D) of a patient in a supine position with 90° of knee flexion during femoral tunnel drilling. (A) Confirmation that the first cannula with an outer diameter of 8 mm can be placed in the cartilage margin and lateral intercondylar ridge behind the proximal lateral femoral condyle. (B) K-wire is inserted in the center of the bone tunnel at the optimal position. (C) Drilling with an 8-mm reamer to a depth of 20 mm. (D) Confirming that an 8-mm bone tunnel opening can be made at an anatomic position near the articular cartilage margin when viewed from the posteromedial portal.

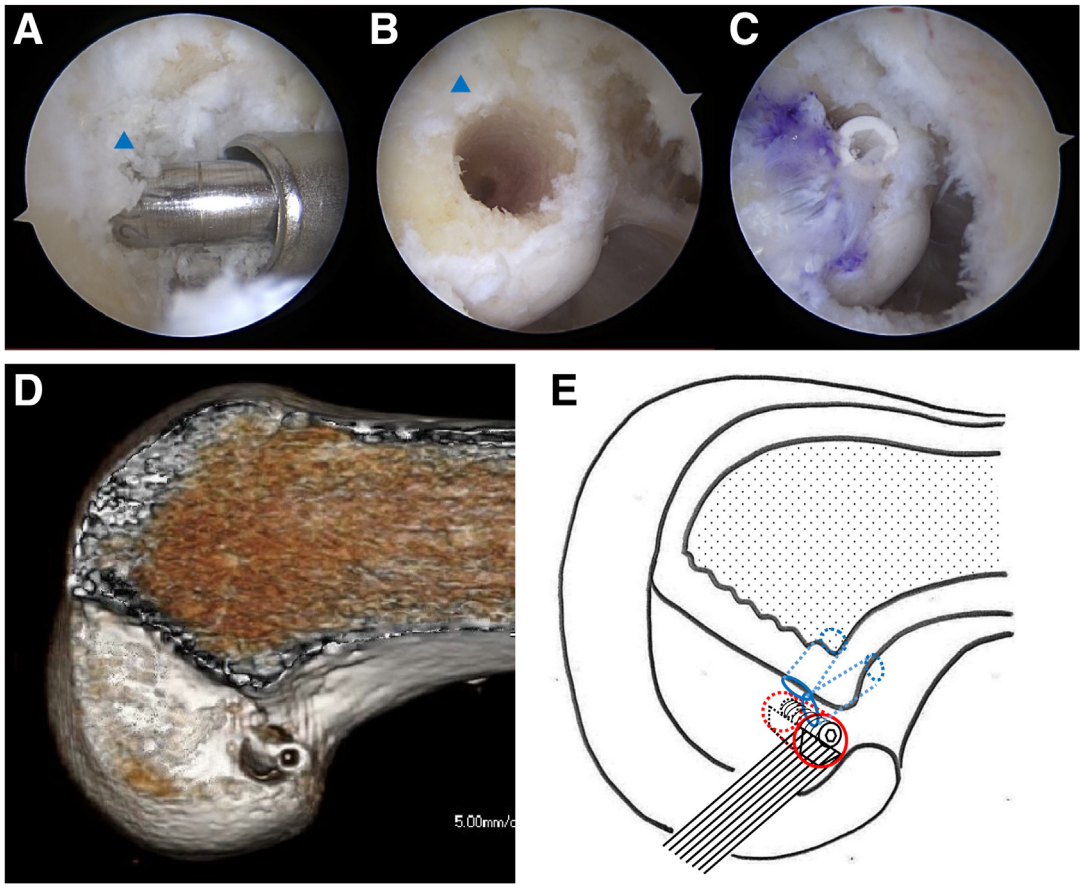

Fig. 3. A representative case in which revision anterior cruciate ligament (ACL) reconstruction of the right knee was performed using this technique in which the primary femoral tunnel was created using an anterior approach. (A) Anterolateral portal arthroscopic view of femoral tunnel creation using this technique with 90° of knee flexion. The newly created bone tunnel partially overlaps the opening in the joint with the primary tunnel (▲). (B) The posteromedial (PM) portal arthroscopic view confirms that the only duplication is the opening and that a new femoral tunnel has been created that allows for graft fixation. (C) PM portal arthroscopic view after fixation of the bone–patellar tendon–bone (BTB) graft with interference screws. (D) Postoperative 3-dimensional computed tomography of the lateral femoral condyle (right knee) also confirms that the fixed position and depth of the graft are appropriate. (E) Schematic representation of the femoral tunnel of the lateral femoral condyle (right knee). The primary ACL reconstruction femoral tunnel (blue) created by the anterior approach and the newly created bone tunnel (red) of this procedure have different directions. Therefore, it is possible to create a bone tunnel that can fix the BTB graft even if there is partial overlap.

knee is then supported in a 90° flexed position using the Alvarado Knee Positioner.

Portal Creation

An anterolateral (AL) portal and an AM portal are created, and a 30° oblique scope is used to perform arthroscopic visualization of the intercondylar area and dissection of the damaged or loosened graft tendon to confirm the bone tunnel used at the time of primary surgery. A PM portal is created, and a dedicated cannula is inserted to the portal (Fig 1).

Femoral Tunnel Drilling

The outer sheath of the dedicated cannula (Fig 1A) has 2 sizes. The narrow-sized outer sheath (first cannula) has an inner diameter of 6 mm and an outer diameter of 8 mm, and the wide-sized outer sheath (second cannula) has an inner diameter of 8 mm and an outer diameter of 10 mm. There are 2 types of inner tubes, one with a tunnel through which a 2.4-mm K-wire passes and the other without a tunnel (Fig 1B). In order to orient the ACL footprint of the lateral femoral condyle (LFC), the cartilage margin and lateral intercondylar ridge should be identified by the AM and PM portal view. Finally, a 2.4-mm K-wire is inserted into the optimal position through the inside-out technique using the first cannula and hollow inner tube from the PM portal while observing from the anterior portal. Considering that the outer diameter of the first cannula is 8 mm, we decided to create a tunnel at the proximal

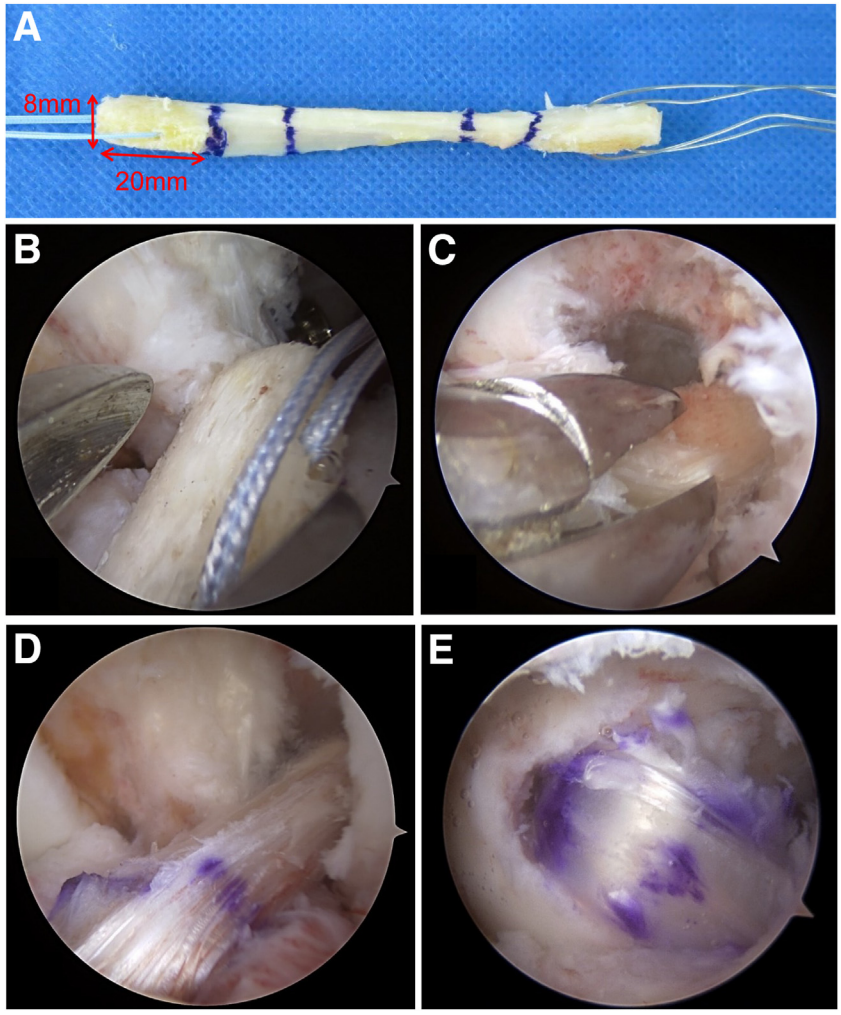

Fig. 4. (A) A photograph of the bone–patellar tendon–bone (BTB) used as a tendon graft. Two Fiberwires are passed through the patella bone plug to be inserted into the femoral tunnel, and 2 soft steel wires are passed through the tibial bone plug to be inserted into the tibia tunnel. (B, C, D) Anterolateral portal arthroscopic views of the BTB graft being guided into the femoral tunnel of left knee with 90° of knee flexion. (E) The posteromedial portal arthroscopic view after guiding the BTB graft into the femoral tunnel. By orienting forward the cancellous bone side of the bone plug, the patellar tendon runs from the vicinity of the proximal articular cartilage rim, mimicking the running of the anterior cruciate ligament.

position of the LFC as much as possible within the footprint (Fig 2A,B). Using a second cannula, the LFC is reamed with an 8-mm-diameter cannulated drill along this K-wire to complete a 20-mm-deep tunnel (Fig 2C). This is followed by confirming with the PM portal view that a tunnel has been created in the anatomical ACL

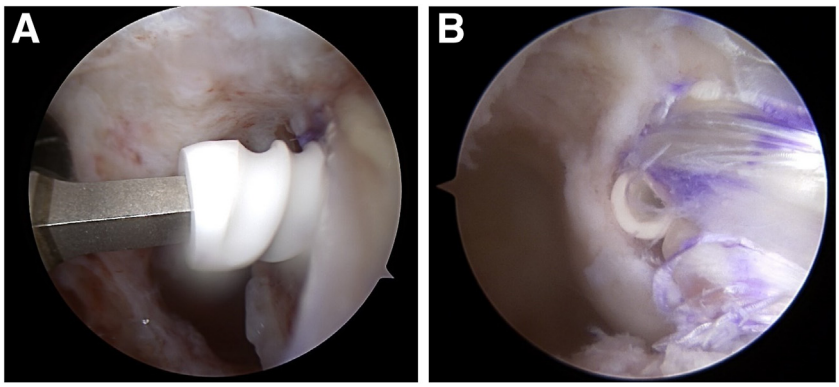

Fig. 5. Arthroscopic views of the left knee with 90° of knee flexion during graft fixation in the femoral tunnel using an interference screw. (A) During viewing through anterolateral portal, a guidewire is inserted into the femoral tunnel from the posteromedial (PM) portal, and an interference screw and a driver are inserted and fixed along the guidewire from the PM portal. (B) An arthroscopic view from the PM portal confirms that the bone plug is fixed in the femoral tunnel with a screw and that there is no proximal posterior articular cartilage damage due to this operation.

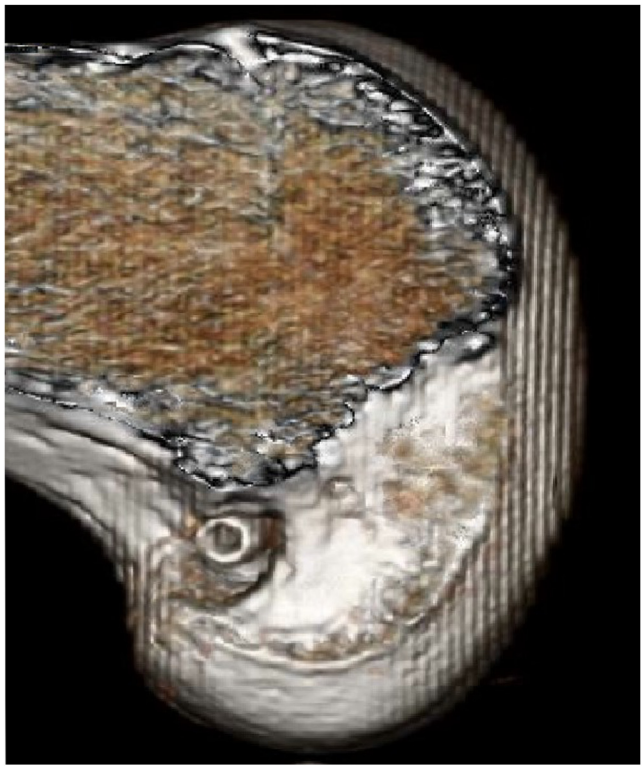

Fig. 6. Postoperative 3-dimensional computed tomography image of the lateral femoral condyle (left knee). A femoral tunnel opening made from the posteromedial portal was made to the anatomic footprint of the anterior cruciate ligament, and there was no posterior-wall blowout of the lateral femoral condyle. The bone–patellar tendon–bone (BTB) bone plug is fixed in the bone tunnel using an interference screw.

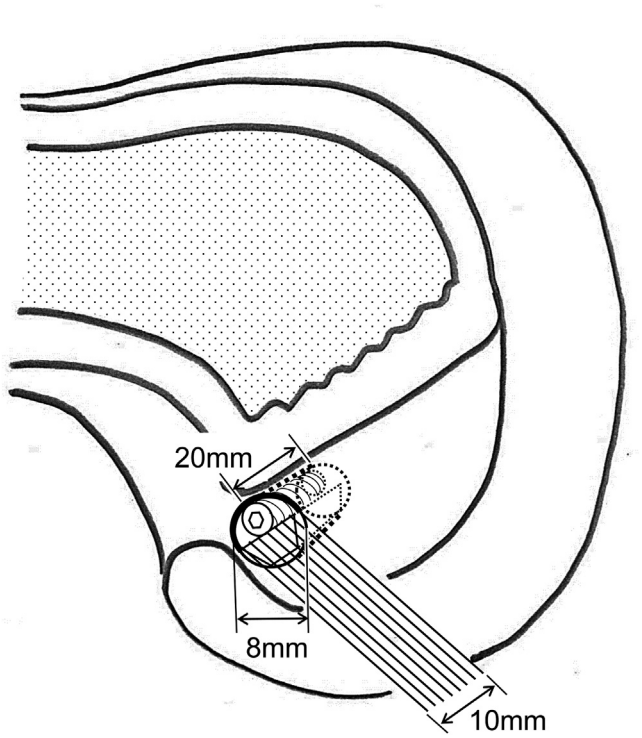

Fig. 7. Schematic diagram of the femoral tunnel after anterior cruciate ligament (ACL) reconstruction of the lateral femoral condyle (left knee) by this technique. The femoral tunnel has a nearly circular opening with a diameter of 8 mm at the ACL footprint and is cylindrical with a depth of 20 mm distally and anteriorly. A 10-mm patellar tendon was attached to an 8-mm-wide × 20-mm-long bone–patellar tendon–bone (BTB) bone plug and fixed in the bone tunnel using a 20-mm-long interference screw. The patellar tendon–bone transition can match the height of the medial wall of the lateral femoral condyle, mimicking the running of the ACL.

footprint (Fig 2D). If the tunnel for the primary surgery was created by an anterior approach, even if the intra-articular opening partially overlaps with the primary tunnel, it is possible to create a new tunnel with a different direction, and the center of the tunnel can be placed at the desired position with the inside-out procedure (Fig 3A). Furthermore, using the PM portal view, the surgeon confirms that the appropriate shape of the inner wall of the new tunnel, which is used in fixation of the BTB bone plug, is obtained (Fig 3B).

Tibial Tunnel Drilling

The tibial footprint of the anatomic ACL is identified and the K-wire is inserted into the center of the tibial tunnel using a standard tibial guide. The tibial tunnel is created by drilling with a 9-mm-diameter cannulated drill along this K-wire.

Graft Harvesting

BTB grafts are collected by harvesting a 10-mm-wide parenchymal section midline from the patellar tendon, along with bone plugs, 8 mm wide by 20 mm long, from the patella and tibial tuberosity. Bone plugs are collected as triangular prisms using a bone saw. The surplus part is excised to the size that passes through the 8-mm-diameter sizer, and a quadrangular prism with a cross section close to a trapezoid is formed (Fig 4A).

Graft Passage

A passing pin with looped nylon thread is passed through the femoral tunnel from the PM portal, and the nylon thread is pulled out from the tibial tunnel and used as a guide thread. Two No. 2 Fiberwires (Arthrex) attached to the patellar bone plug are passed through this nylon guide thread, and the bone plug is inserted into the femoral tunnel by pulling (Fig 4).

Graft Fixation

The BioComposite triple thread interference screw (Arthrex) with a diameter of 5 mm is inserted along the guidewire, which is inserted into the femoral tunnel through the PM portal and fixes the bone plug in the femoral tunnel (Fig 5). This is followed by confirming

Table 2. Advantages, Disadvantages, Risks, and Limitations of Techniques

PM portal technique
Anatomic ACL footprint of the lateral femoral condyle can be confirmed more accurately.
Femoral bone tunnel creation can be made by the inside-out procedure.
Requires proficiency in creating safe portals.
Femoral tunnel
Inside-out procedure and independent drilling are performed without being affected by the tibial bone tunnel. It is possible to make the bone tunnel as intended by the operator.
No cartilage damage or fracture risk associated with other approaches.
Aperture of the femoral bone tunnel takes a shape close to a perfect circle.
Since the direction of the bone tunnel is different from that of the primary surgery by other approaches, it is highly possible to create a new bone tunnel that does not require additional treatment for the bone defect during revision surgery.
Graft
Since the aperture of the femoral bone tunnel becomes a cylinder with a shape close to a perfect circle, the height of the ACL attachment to the femur can be imitated by aligning the length of the bone plug with the length of the bone tunnel.
Even if there is a partial overlap between the newly created bone tunnel and the primary bone tunnel, or if there is a bone defect during revision surgery, it can be filled with a BTB bone plug.
An interference screw inserted from the PM portal enables fixation of the bone plug along the entire length of the femoral bone tunnel without perforating the proximal posterior cartilage.
Reconstruction
An aperture of an anatomic bone tunnel can be created to mimic the running of the ACL.
Even with revision surgery, bone tunnel creation and graft tendon fixation can be performed, and 1-stage surgery is possible.
Risks, limitations, and disadvantages
Data on clinical results of the surgery are still few and unclear.

ACL, anterior cruciate ligament; BTB, bone–patellar tendon–bone; PM, posteromedial.

by PM portal view that there is no fracture of the LFC proximal posterior wall and that the graft is fixed.

To fix the graft on the tibial side, the knee is flexed at 20° and a 7 or 8 × 20-mm Profile titanium interference screw (DePuy Mitek) is used with maximum manual pulling.

Postoperative Computed Tomography

Postoperative computed tomography images are used to confirm the position of the tunnel and whether there is any complication of the fracture associated with the surgery (Fig 6). Additionally, it should be confirmed that the new and primary femoral tunnels are divergently created and that the femoral tunnel is filled with the BTB bone plug and interference screw (Fig 3D).

Discussion

A major problem in revision ACL reconstruction is the location of the femoral tunnel and bone loss at the time of primary surgery.[1,8,9] If the opening of the femoral tunnel is completely different from the anatomic position, there might be a few problems. But even if the opening is completely the same, enlargement will occur within the tunnel if the hamstring was used as a tendon graft, which may necessitate treatment of bone defects.[10] Also, if the tunnel is partially matched to the anatomic position and created in the same anatomic position using the same procedure as the primary surgery, the tunnels will widen since they are made in the same direction and cause bone defects. In order to overcome these problems, when performing revision ACL reconstruction using the BTB graft, we created a femoral bone tunnel using a unique guiding instrument through the PM portal approach and devised a method that can reconstruct the femoral tunnel in 1 stage.

Using the inside-out PM portal technique, it is possible to easily create a tunnel with minimal blurring,[6] even if the shape of the inner wall of the LFC in the revision case has changed. In addition, since the created femoral bone tunnel extends from the medial wall to the lateral wall of the LFC in the distal anterior direction, creating a femoral tunnel at the anatomic ACL footprint or insertion of BTB graft fixation material into the tunnel does not damage the femoral osteochondral cartilage (Figs 5 and 6). Moreover, there is a great advantage in that the direction of the femoral bone tunnel is different from that of other anterior inside-out and outside-in approaches.[11] Therefore, it is possible to create a new tunnel that is divergent from the tunnels created by other surgical techniques (Fig 3), and no bone loss occurs during the tunnel creation process. Additionally, the opening is more circular than the inside-out anterior approach to drill the LFC at a more vertical angle. For this reason, the protrusion of the implanted BTB bone plug using the PM technique[12] is less than that of using the conventional anterior approach. It is easy to match the height of the patellar tendon attachment part of the bone plug with that of the femoral tunnel opening, and it is also possible to imitate the ACL fiber direction (Fig 7).

This procedure may be a useful 1-stage BTB revision ACL reconstruction for reinjury after ACL reconstruction performed by other procedures (Table 2).

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