Technical Note

Remnant Tissue Preserved Transtibial Anterior Cruciate Ligament Reconstruction With Femoral Tunnel Created Behind the Resident's Ridge

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Abstract: Although the transtibial (TT) technique for single-bundle (SB) arthroscopic anterior cruciate ligament (ACL) reconstruction has been widely used, surgeons often disadvantageously create the femoral bone tunnel at the arthroscopically noon position, which is alleged the "ACL isometric point," when the femoral bone tunnel could be created behind the resident's ridge with TT-SB ACL reconstruction by paying attention to the location of the tibial tunnel inlet and the angle of tibial tunnel. This alternative approach preserves ACL remnant tissue, which might contribute to better postoperative remodeling and regeneration of proprioceptive mechanoreceptors. This technique reduces surgical invasiveness and can enhance postoperative graft remodeling and proprioceptive recovery. To successfully use the devices required for this procedure, surgeons must understand the proper techniques. Hence, this technical note aims to demonstrate TT-SB ACL reconstruction with remnant tissue preservation.

Although the transtibial (TT) technique for single-bundle (SB) arthroscopic anterior cruciate ligament (ACL) reconstruction is widely used, there is a risk of nonanatomic placement.[1] Using this technique, surgeons commonly create the femoral bone tunnel at the arthroscopically noon position, which is the alleged "ACL isometric point,[2]" and orient the graft vertically, leading to rotatory instability postsurgery.[3] In addition, unsatisfactory clinical outcomes for this technique purportedly have been reported.[4] To overcome the disadvantages of the TT technique while exploiting its advantages, modifications were proposed to obtain more anatomically located femoral tunnels. A past study described creating a femoral bone tunnel behind the resident's ridge with TT-SB ACL reconstruction when the tibial bone tunnel inlet was created at a coronal angle relative to the tibial axis, which averages 25.5°, and a sagittal angle relative to the tibial axis, which averages 52.3°.[5]

ACL remnant tissue is frequently resected at the time of ACL reconstruction[6] yet may help accelerate the remodeling phase of the graft, as its proprioceptive mechanoreceptors may provide a source of reinnervation.[7-11] In addition, remnant tissue preservation may contribute to high rates of return to sports and high patient satisfaction with satisfactory clinical results in highly active patients.[12]

The femoral attachment of ACL remnant tissue may influence the stability of the ACL-injured knee.[13] Theoretically, the femoral attachment of the ACL remnant tissue of Crain types 1, 2, and 3[14] (Table 1) can be preserved when the femoral bone tunnel is created behind the resident's ridge.

To maximize ACL remnant tissue preservation (RTP) at the time of TT-SB ACL reconstruction,[15] we developed RTP behind the resident's ridge TT-SB ACL reconstruction. This Technical Note aims to guide surgeons through the appropriate use of this technique using an offset guide (Smith & Nephew Endoscopy, Andover, MA).

ACL injury is diagnosed based on clinical findings, such as a positive Lachman test and magnetic resonance imaging findings. A positive finding of rotatory

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Table 1. Description of the Crain Classification

Type 1	The injured ACL wrapped around the PCL and the normal ACL attachment on the femur was empty
Type 2	ACL healing to the roof of the notch and the lateral wall was empty
Type 3	The attenuated ACL remnant tissue healed to the lateral wall more anterior and distal than its anatomical origin
Type 4	The ACL remnant tissue was torn and resorption of the femoral end was observed

ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

instability, such as a positive pivot-shift test, is included in the diagnostic criteria. The contraindication of this technique is chronic ACL injury, as a previous report revealed that the biomechanical contribution of the ACL remnant tissue would be lost.[16]

Surgical Technique (With Video Illustration)

This technique is carried out under regional or general anesthesia without a pneumatic tourniquet. The patient is placed in a supine position with the operative knee held in the leg drop position with 90° of knee flexion. Standard anterolateral and anteromedial portals are made, and a routine arthroscopic evaluation is performed.

The ipsilateral semitendinosus tendon is extracted using a tendon harvester (Smith & Nephew Endoscopy). When necessary, it is further augmented by extracting the gracilis tendon. The harvested graft is trimmed and quadrupled, and both ends are firmly sutured. After measuring the femoral tunnel, suspensory fixation devices (ENDOBUTTON CL; Smith & Nephew Endoscopy) are connected so that ≥10 mm of the quadrupled tendon is inserted into the femoral bone tunnel. The structures are mechanically connected by passing polyester tape (ENDOBUTTON Tape, Smith & Nephew Endoscopy) through the chain-like junction.[5]

Using a shaver and a thermal device to create the femoral bone tunnel, the proximal end of the remnant femoral stump located behind the resident's ridge (Fig 1) is minimally debrided (Fig 2). During this procedure, careful attention must be given to ACL remnant tissue so that it is not injured. Anatomic insertion of the anteromedial bundle (AMB) is identified behind the resident's ridge (Fig 3). A longitudinal slit is made at the center of the tibial ACL remnant tissue (Fig 4), into which the tibial ACL guide is inserted (Fig 5). The center of the tibial bone tunnel is placed at the AMB footprint from the lateral to the medial tibial spine.[17] The center of the AMB insertion is defined in relation to 3 surrounding landmarks, namely, the anterior ridge, lateral groove, and intertubercular fossa, according to Tensho et al.,[18] and bony prominences corresponding to the ACL tibial footprint are identified (Fig 6). The coronal angle relative to the tibial axis averages 25.5°, and the sagittal angle relative to the tibial axis averages 52.3°.[5] There, a tibial tunnel with a diameter of 8.5 to

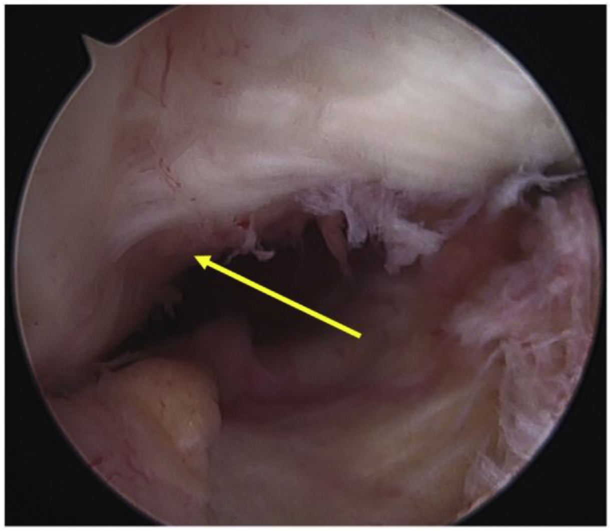

Fig 1. Arthroscopic image of Crain type 3 ACL remnant tissue of the right knee from the anterolateral portal. The patient is placed in a supine position with the operative knee held in the leg drop position at 90° flexion. ACL remnant tissue around the cartilage margin is shaved to enable visibility of the resident's ridge (yellow arrow). (ACL, anterior cruciate ligament.)

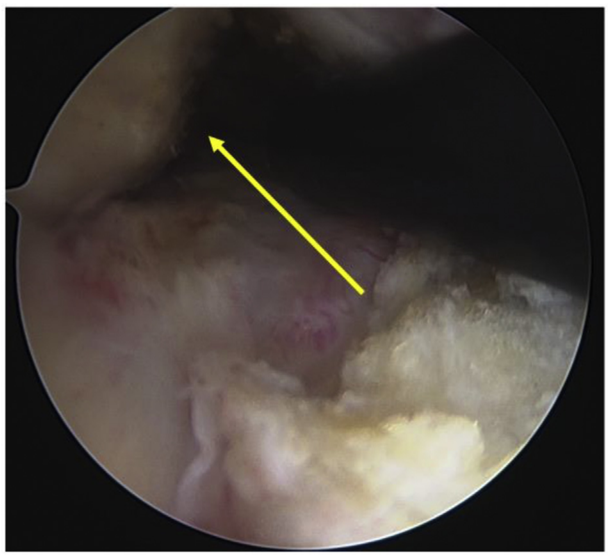

Fig 2. The proximal end of the remnant femoral stump located behind the resident's ridge is minimally debrided using a thermal device to create the femoral bone tunnel (yellow arrow). Care should be taken not to injure the midsubstance of the femoral attachment of ACL remnant tissue. Arthroscopic image from the anterolateral portal of the right knee in the leg drop position at 90° flexion. (ACL, anterior cruciate ligament.)

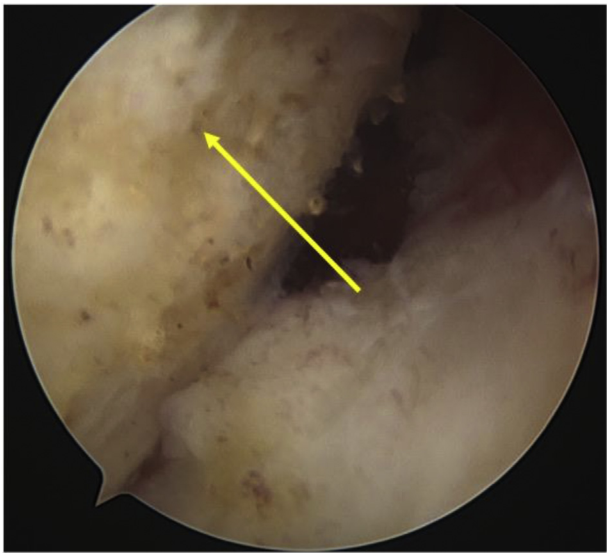

Fig 3. Minimal debridement of the proximal end of the remnant femoral stump located behind the resident's ridge using a thermal device. Yellow arrow indicates the resident's ridge. Arthroscopic image of the lateral meniscus of the right knee in the leg drop position at 90° of flexion.

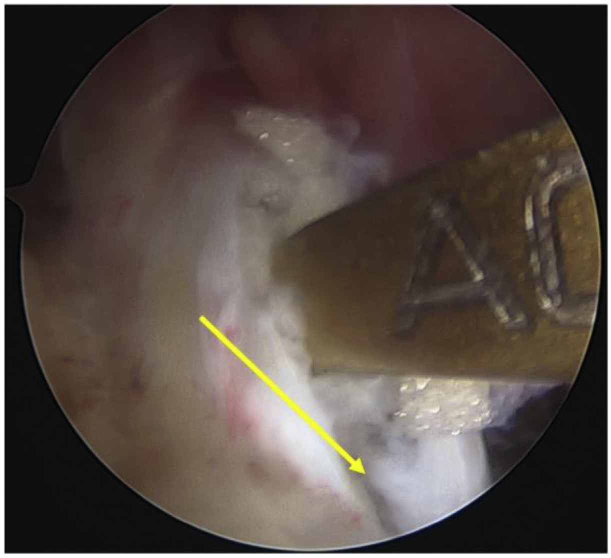

Fig 5. A tibial ACL guide is inserted into the slit. The center of the tibial bone tunnel is placed at the AMB, which is defined according to the anterior ridge. Arthroscopic image of the right knee in the leg drop position at 90° flexion. Yellow arrow indicates tibial bone tunnel. (ACL, anterior cruciate ligament; AMB, anteromedial bundle.)

9 mm is made, and the femoral bone tunnel insertion is positioned inferior to the "over-the-top" position. The 6-mm femoral aimer (Smith & Nephew Endoscopy) is inserted through the tibial tunnel to prevent posterior wall blowout with varus and internal rotation of the tibia to create a figure-4 position[19] so that the femoral bone tunnel is placed lower and deeper behind the resident's ridge. The 2.4-mm guide pin insertion point is confirmed based on the anteromedial portal, considering a location behind the resident's ridge (Fig 7). Then, 4.5-mm arthroscopic drilling is performed, accompanied with 8-mm overdrilling to make a socket-shaped tunnel (Fig 8). The length of the femoral bone tunnel is measured using a depth gage and the length of suspensory fixation device is calculated. A hamstring

Fig 4. A longitudinal slit is made at the center of the tibial ACL remnant tissue using a sharp scalpel. Arthroscopic image of the right knee in the leg drop position at 90° flexion. (ACL, anterior cruciate ligament.)

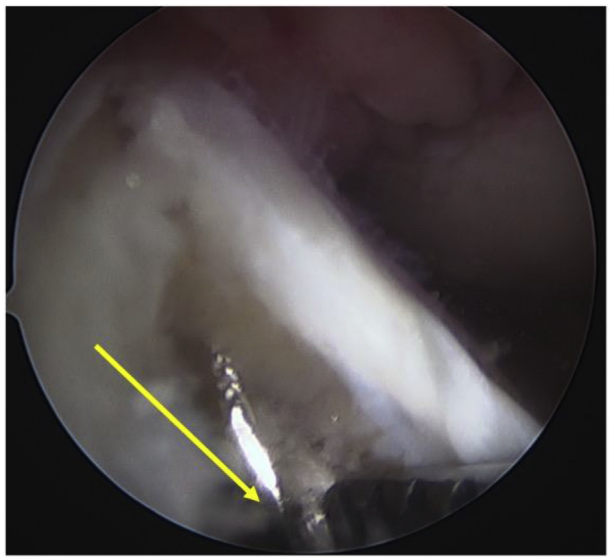

Fig 6. Creation of a tibial tunnel with a diameter of 8.5-9 mm. To create the femoral tunnel at the appropriate position, the coronal angle relative to the tibial axis averages 25.5° and the sagittal angle relative to the tibial axis averages 52.3°. The yellow arrow indicates the AMB footprint. Arthroscopic image of the right knee in the leg drop position at 90° flexion. (AMB, anteromedial bundle.)

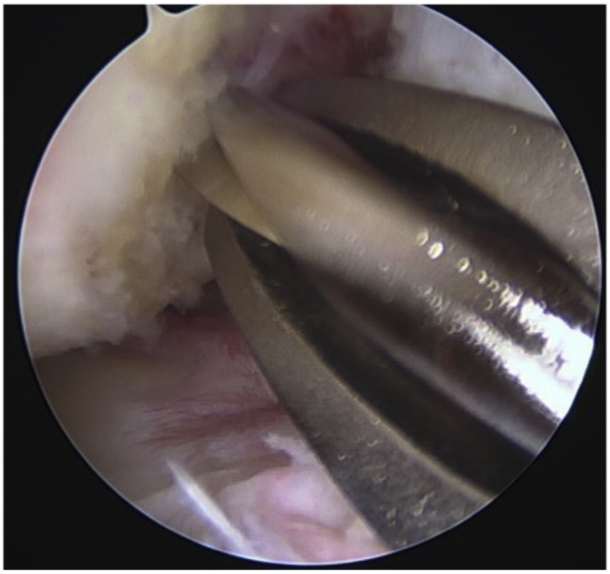

Fig 7. Creation of the femoral tunnel with a diameter of 8.5-9 mm using an offset guide inserted through the tibial tunnel to prevent posterior wall blowout with a figure-four position so that the femoral bone tunnel is created lower and deeper, thus resulting in a placement behind the resident's ridge. The 2.4-mm guide pin insertion point was confirmed via anteromedial portal considering the location behind the resident's ridge. Arthroscopic image of the right knee in the figure-four position.

graft is introduced into the joint cavity through the tibial tunnel and ACL remnant tissue and then placed in the femoral socket (Fig 9 and Video 1). The graft is fixed to the femoral cortex by flipping the ENDOBUTTON and fixating the graft using the turnbuckle stapling graft fixation technique. A traction force of 40 N is applied to the graft, with the knee at 10° flexion.[20] Details about

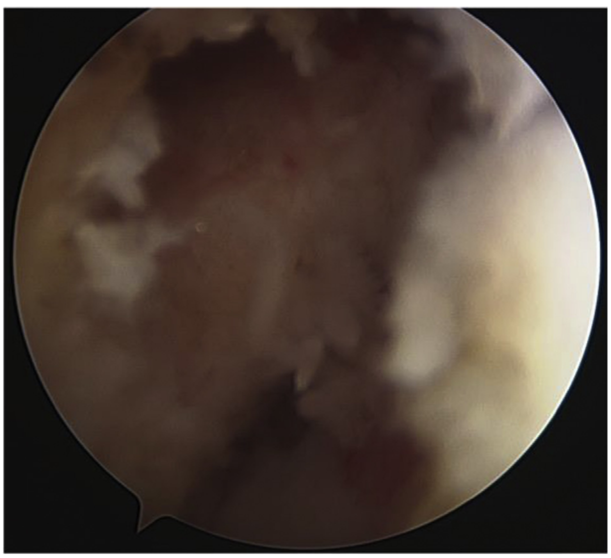

Fig 8. A femoral socket-shaped tunnel with a diameter of 4.5 and 8 mm created behind the resident's ridge.

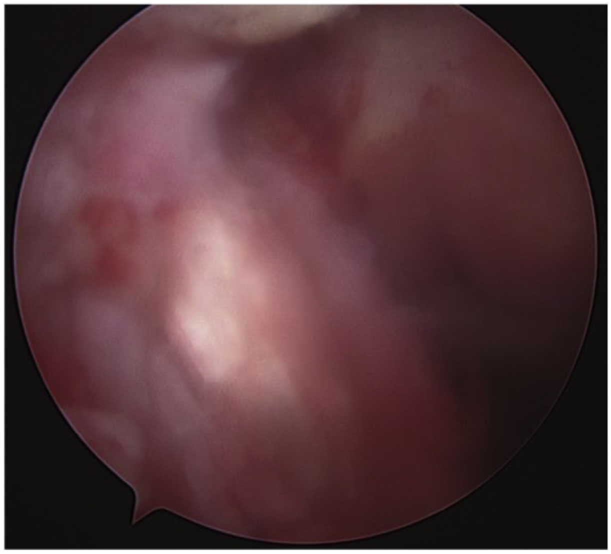

Fig 9. A hamstring graft placed inside the ACL remnant tissue. (ACL, anterior cruciate ligament.)

the pearls and pitfalls and advantages and disadvantages of this technique are shown in Tables 2 and 3, respectively.

A knee brace is applied at 10° fixed knee flexion for 12 weeks postoperatively. All patients use a continuous passive motion apparatus for 2 days postoperatively. Partial weight-bearing is permitted for 2 weeks postoperatively and is gradually increased to full weight-bearing at 4 weeks postoperatively. Jogging is permitted at 3 months postoperatively, and sprinting and any strenuous competitive activities are permitted 6 months postoperatively, if the patient has recovered adequate muscle strength based on that of the uninjured knee.[21]

Discussion

Although TT-SB ACL reconstruction comes with the risk of nonanatomic "noon" femoral tunnel placement due to constrained drilling, in particular, when performing TT-SB ACL reconstruction, care should be taken not to orient the graft vertically. In addition, when performing RTP-ACL reconstruction, care should also be taken not to resect the femoral attachment of ACL remnant tissue. Using the appropriate technique with the proper precautions, we can safely and less invasively treat ACL injury without creating a vertical femoral tunnel or resecting the femoral attachment of ACL remnant tissue, which is the greatest advantage of RTP TT-ACL reconstruction. It is important to note that RTP TT-ACL has the risk of damaging the femoral remnant stump if the femoral bone tunnel is created at the insertion of "mid-substance."[22] By shaving the remnant stump behind the resident's ridge, this risk is mitigated. On the contrary, there is a residual concern about the risk of tibial cartilage injury and medial

Table 2. Pearls and Pitfalls of Remnant Tissue-Preserved Transtibial ACL Reconstruction With Femoral Tunnel Created Behind the Resident's Ridge

Pearls
• Hold the operative knee held in the leg drop position at 90° flexion.
• Only the proximal end of the remnant femoral stump located behind the resident's ridge is minimally debrided.
• Identify bony prominences corresponding to the ACL tibial footprint.
• Use appropriate placement of the tibial guide creates a tibial tunnel.
• Hold the figure-four position when inserting the guide pin into femoral ACL footprint.
• Use appropriate placement of the offset guide.
• Avoid posterior-femoral wall blowout when creating the socket-shaped tunnel.
Pitfalls
• Inappropriate portals
• Handling error due to insufficient synovectomy
• Poor visualization of the femoral ACL footprint due to insufficient debridement of ACL remnant tissue
• Chondral damage when inserting the slotted canula
• Tibial cartilage injury and MCL injury resulting from creating the tibial bone tunnel too proximally and medially
• Posterior-femoral wall blowout

ACL, anterior cruciate ligament; MCL, medial collateral ligament.

collateral ligament injury, which can occur if the tibial bone tunnel is created too proximally and medially; hence, accurate understanding of the technique and precautions of TT-ACL reconstruction is a prerequisite for safely performing this procedure. A past study demonstrated that a greater sagittal angle of the tibial bone tunnel relative to tibial axis resulted in a lower, deeper intra-articular femoral bone tunnel placement behind the resident's ridge.[5] In addition, when the femoral tunnel was created behind the resident's ridge, it was placed at average distances of 13.4 mm from the tibial tunnel inlet and 9.7 mm below the tibial joint line, medial to the center line of the tibial axis, to avoid tibial cartilage injury. Further study is required to clarify whether this procedure is always applicable when treating patients with ACL injury.

Beyond its risks and limitations, this technique enables ACL reconstruction, reduces surgical invasiveness, and can preserve ACL remnant tissue because of the placement of the femoral tunnel behind the resident's ridge.

Table 3. Advantages and Disadvantages of Remnant Tissue-Preserved Transtibial Anterior Cruciate Ligament Reconstruction With Femoral Tunnel Created Behind the Resident's Ridge

Advantages
• No need for an additional skin incision to create a femoral tunnel
• Reduced surgical invasiveness
• No need for an experienced assistant
Disadvantages
• Risk of inappropriate femoral tunnel creation
• Technical error and device problems

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