Technical Note

Anatomical Single-Bundle Transtibial Anterior Cruciate Ligament Reconstruction

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Abstract: Anatomical anterior cruciate ligament (ACL) reconstruction is a reasonable transition from isometric ACL reconstruction to obtain better clinical outcomes, and most authors believe that it can only be performed through the medial portal technique. However, in our clinical practice, we found that anatomical ACL reconstruction can be performed easily and accurately by creating a tibial tunnel, which is accomplished by setting the tibial tunnel with correct angulation to the sagittal plane and tibial axis. Hence, we introduce this special transtibial anatomical ACL reconstruction technique, in which the most critical step is the creation of a shallow tibial tunnel with a proximal projection to the anatomical location of the femoral tunnel. This technique is indicated for primary ACL reconstructions in skeletally mature patients. We believe this Technical Note will give a special view on anatomical ACL reconstruction.

In the era of isometric anterior cruciate ligament (ACL) reconstruction, the transtibial technique was routinely performed. During the transition from isometric ACL reconstruction to anatomical ACL reconstruction,[1] studies have explored the possibility of anatomical ACL reconstruction through the tibial tunnel. Some studies have indicated that anatomical ACL reconstruction can be realized through a shallow tibial tunnel,[2] but other studies have concluded that anatomical ACL reconstruction is impossible or difficult to perform in a transtibial manner.[3-6]

However, in our clinical practice, we found that as long as the angulation of the tibial tunnel to the sagittal plane and the tibial axis are appropriately controlled during the creation of the tibial tunnel, an anatomical femoral tunnel creation can be realized. Thus, we introduce this anatomical transtibial single-bundle ACL reconstruction technique. Anatomical transtibial single-bundle ACL reconstruction is indicated for any complete ACL tear recommended for surgery in skeletally mature patients.

Technique

The procedure is performed with the patient in the supine position. A post is placed at the lateral side of the thigh to provide support when the knee is flexed (Table 1).

Graft Preparation (With Video Illustration)

The semitendinosus tendon and gracilis tendon are harvested and prepared to make a 7-stranded graft, using 2 no. 5 ultra-high molecular weight polyethylene sutures (Smith & Nephew; Andover, MA) as traction and fixation sutures on the proximal end (Fig 1 and Video 1). The graft is composed of 4-stranded semitendinosus tendon and 3-stranded gracilis tendon with a usual length of >7 cm and a usual width of 8 to 10 mm.

Locating the Tibial Tunnel

The inner orifice of the tibial tunnel is located in the middle of ACL tibial footprint (Fig 2). When there is no remnant on the tibial side, one transverse line and one longitudinal line are used to locate the tibial tunnel. The transverse line passes through the middle of the tip of the lateral tibial eminence and the anterior edge of the anterior horn of the lateral meniscus. The longitudinal line passes through the middle of the lateral slope of the

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Table 1. Step-by-step Procedures of the Anatomical Transtibial Single-Bundle ACL Reconstruction

1. The ST and GT are harvested. A 7-stranded graft is made from these 2 tendons.
2. The femoral tunnel is located at the center of the ACL footprint and marked with a radiofrequency probe. The location is at a point 5 mm anterior and 5 mm proximal to the lowest point of the lateral wall of the femoral notch.
3. The tibial tunnel is created, with its inner orifice located in the middle of the ACL tibial footprint, angulating the sagittal plane at approximately 40° and the tibial axis at approximately 50°, with a projection point on the femur within 5 mm to the desired location of the femoral tunnel.
4. The K wire within the tibial tunnel is adjusted to the marked point of the femoral tunnel and drilled in. The femoral tunnel is created.
5. A 2- to 3-cm-long longitudinal incision is made on the lateral midline of the thigh to access the anterolateral femur through the underside of the quadriceps.
6. The graft is pulled into the femoral tunnel. Proximal suspension fixation is completed by tying the sutures on a mini plate over the outer orifice.
7. Interference screw fixation is first performed on the tibial side.
8. The sutures from the distal graft end are tied at an adjustable loop, which is set through a transtibial ridge tunnel.

ACL, anterior cruciate ligament; GT, gracilis tendon; ST, semitendinosus tendon.

medial tibial eminence. The intersection of the 2 lines is defined as the location of the tibial tunnel (Fig 3).

Locating the Femoral Tunnel

The knee is flexed at 90°. The femoral tunnel is located at the center of the ACL footprint and marked with a radiofrequency probe (Fig 4).

When there is no ligament remnant in the footprint area for tunnel location, 2 reference points, namely the low reference point (LRP) and the high reference point (HRP), are first defined. The LRP is located at the lowest point of the lateral wall of the femoral notch, whereas the HRP is located at the over-the-top point. A point 5 mm anterior to the LRP is located and named the posterolateral bundle point (PLP). On the line connecting the HRP and the PLP, a point 5 mm proximal to the PLP is defined as the footprint center (Fig 5).

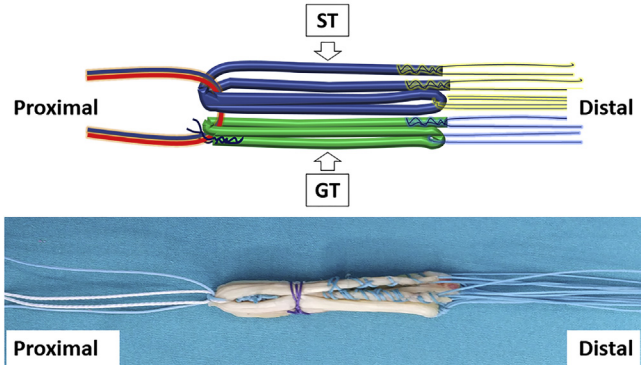

Fig 1. Graft preparation. A 7-stranded graft is made from the ST and GT. (GT, gracilis tendon; ST, semitendinosus tendon.)

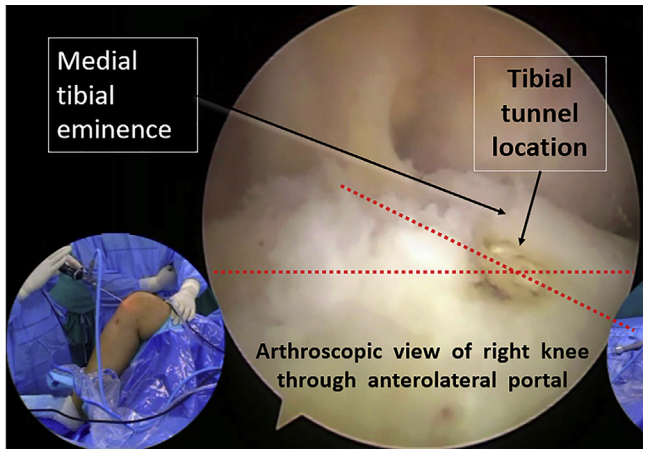

Fig 2. Location of the tibial tunnel. (Arthroscopic view of right knee in supine position through the anterolateral portal.) The inner orifice of the tibial tunnel is located at the midpoint of the ACL tibial footprint, with the crossing point of 2 lines passing through the lateral slope of the medial tibial eminence and the free edge of the anterior horn of the lateral meniscus as reference. (ACL, anterior cruciate ligament.)

Creating the Tibial Tunnel

A 5-mm offset point-to-hole tibial tunnel–aiming device (Aesculap, Tuttlingen, Germany) is placed into the joint through the anteromedial portal. With the hook of the device placed at the correct area, the spatial position of the tunnel-aiming device is adjusted to create a tibial tunnel in a plane that angulates the sagittal plane at 40° (Fig 6). In the tibial tunnel plane, the tibial tunnel angulates the tibial axis at 50° (Fig 7).

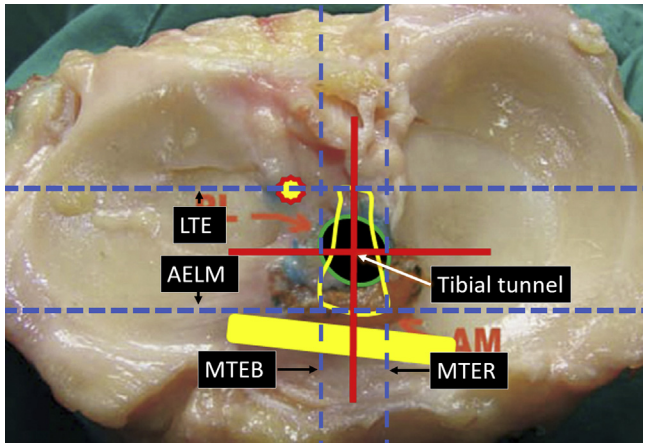

Fig 3. Illustration of the location of the tibial tunnel (right knee). The tibial tunnel is located at the intersection of the midline between the 2 transverse lines passing through the lateral tibial eminence and the anterior edge of the anterior horn of the lateral meniscus and the midline between 2 longitudinal lines passing through the ridge of the medial tibial eminence and the base of its medial slope. (AELM, anterior edge of the anterior horn of the lateral meniscus; LET, lateral tibial eminence; MTEB, base of the medial tibial eminence; MTER, ridge of the medial tibial eminence.)

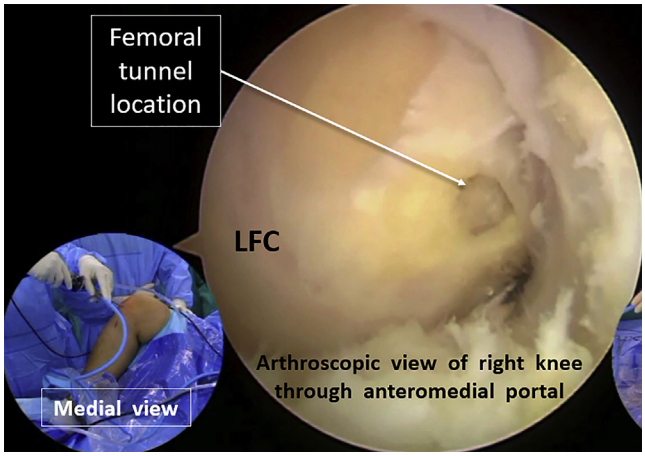

Fig 4. Location of the femoral tunnel. (Arthroscopic view of right knee in supine position through the anteromedial portal.) The femoral tunnel is located at the midpoint of the ACL femoral footprint. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle.)

A K wire is drilled into the tibia to the femur to ensure that it can reach a point within 5 mm from the femoral tunnel center (Fig 8). Microadjustment may be needed through multiple tries. The K wire is overdrilled to create the expected size of the tibial tunnel.

Creating the Femoral Tunnel

The direction of the K wire within the tibial tunnel is adjusted to the marked point of the femoral tunnel (Fig 9). The K wire is first drilled into the femur (Fig 10). Then, the K wire is overdrilled to create a femoral socket to expected size and length (which is usually 25-30 mm) (Figs 11 and 12). The K wire is overdrilled with a 4.5-mm drill through the femur.

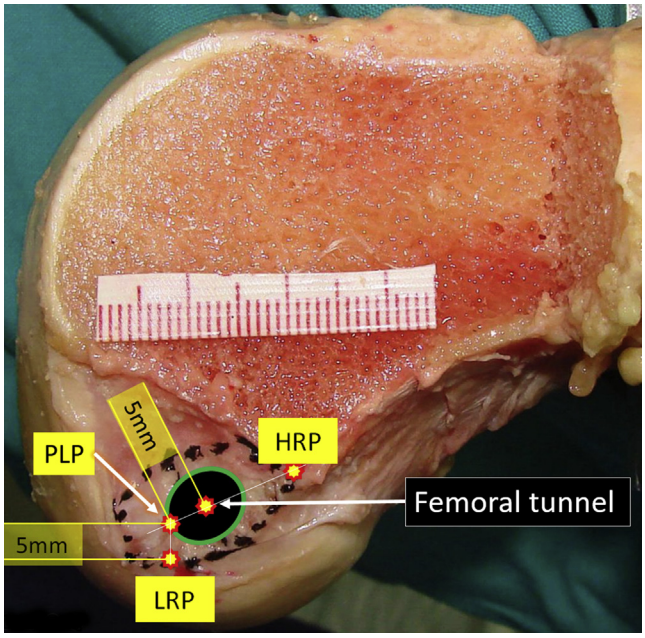

Fig 5. Illustration of location of the femoral tunnel (right knee). The femoral tunnel is located at a point between the PLP and HRP, with a distance of 5 mm to the PLP. (HRP, high reference point [i.e. the over-the-top point]; LRP, low reference point [i.e. the lowest point of the lateral wall of the femoral notch]; PLP, a point 5 mm anterior to the LRP.)

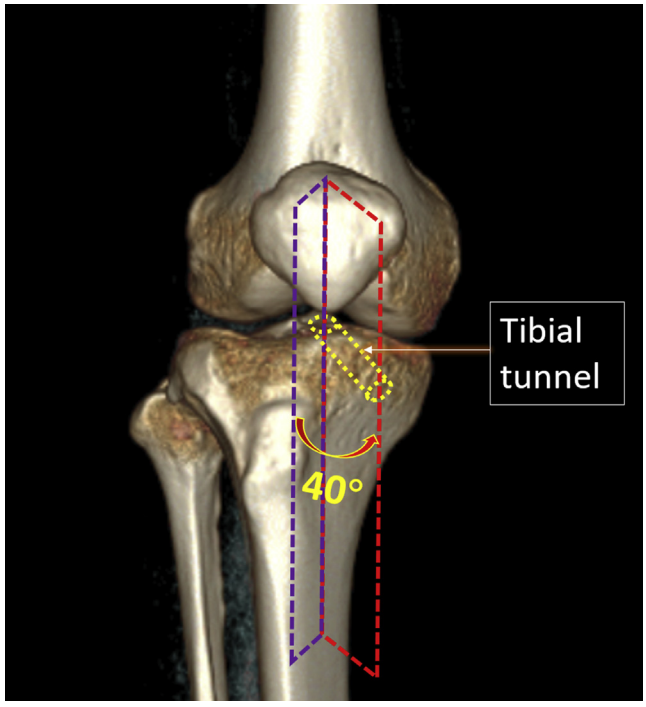

Fig 6. Angulation of the tibial tunnel to the sagittal plane. The tibial tunnel is created on a plane (tibial tunnel plane) with a 40° angulation to the sagittal plane.

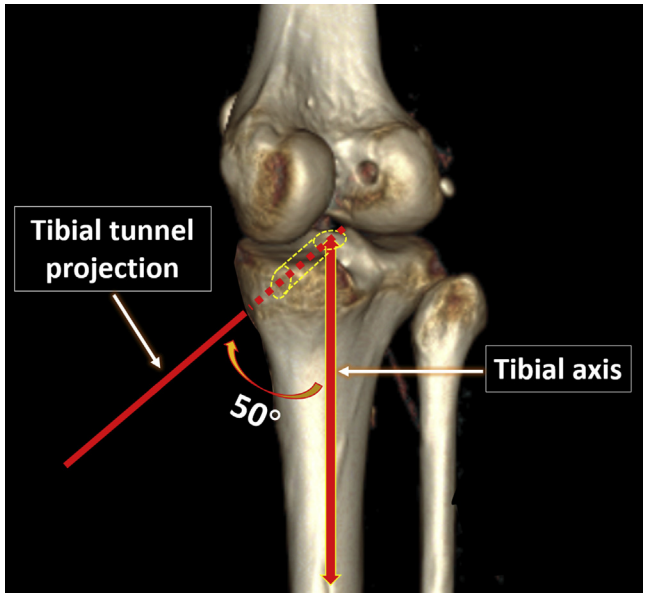

Fig 7. Angulation of the tibial tunnel to the tibial axis (right knee). On the tibial-tunnel plane, the tibial tunnel should be angulated to the tibial axis at 50°.

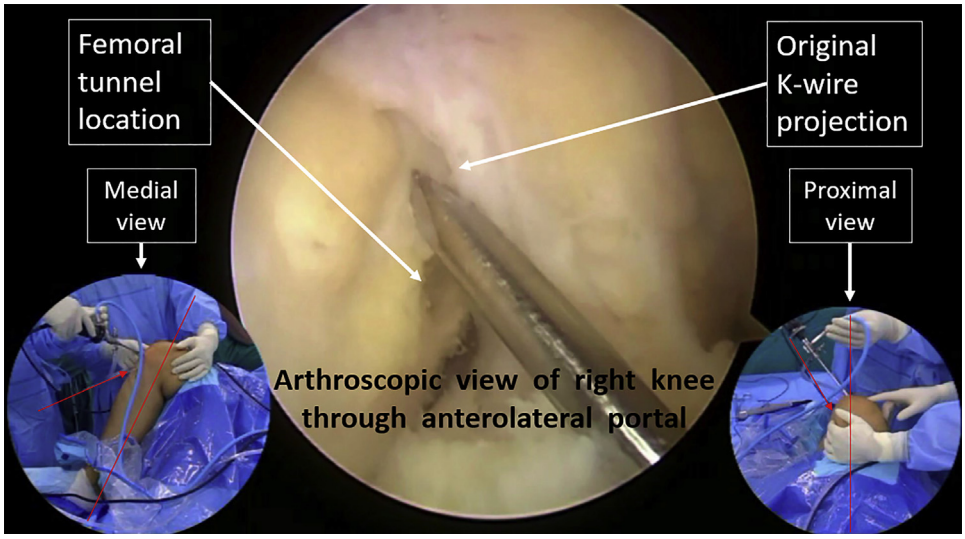

Fig 8. Desired projection of the tibial tunnel. (Arthroscopic view of right knee in supine position through the anteromedial portal.) The projecting point of the tibial tunnel on the lateral wall of the intercondylar notch is located within 5 mm distance to the marked point of the femoral tunnel.

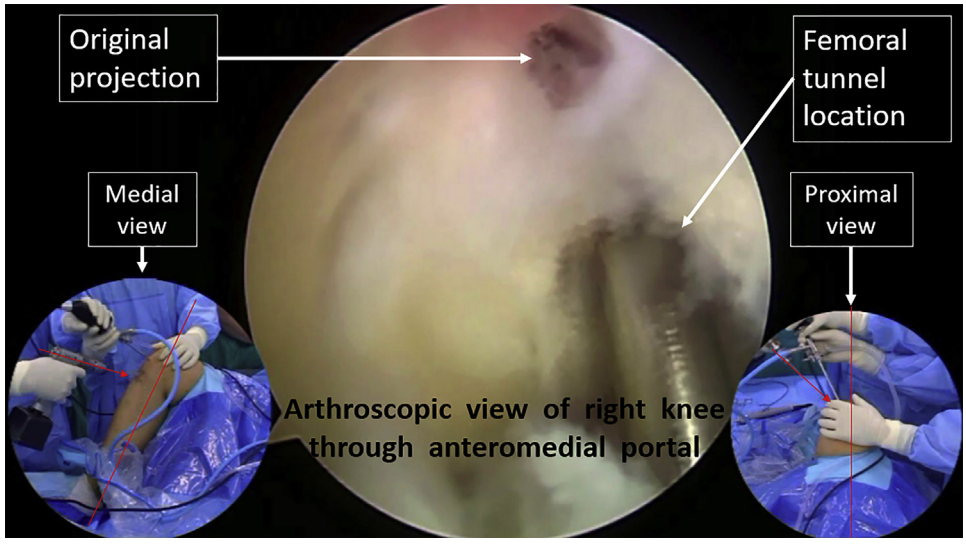

Fig 9. Adjusting the K wire through the tibial tunnel to pointing to the location of the femoral tunnel. (Arthroscopic view of right knee in supine position through the anteromedial portal.)

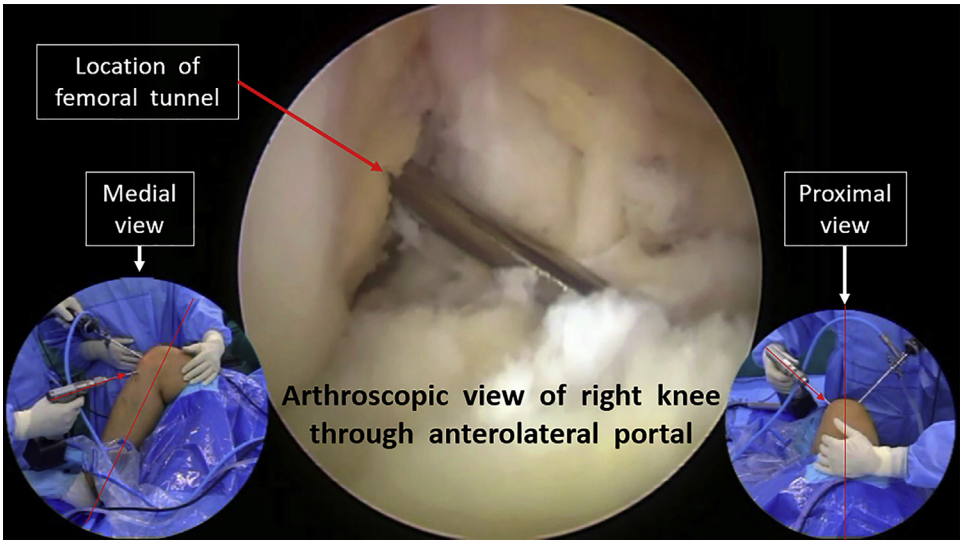

Fig 10. Drilling the K wire into the femoral location through the tibial tunnel. (Arthroscopic view of right knee in supine position through the anterolateral portal.)

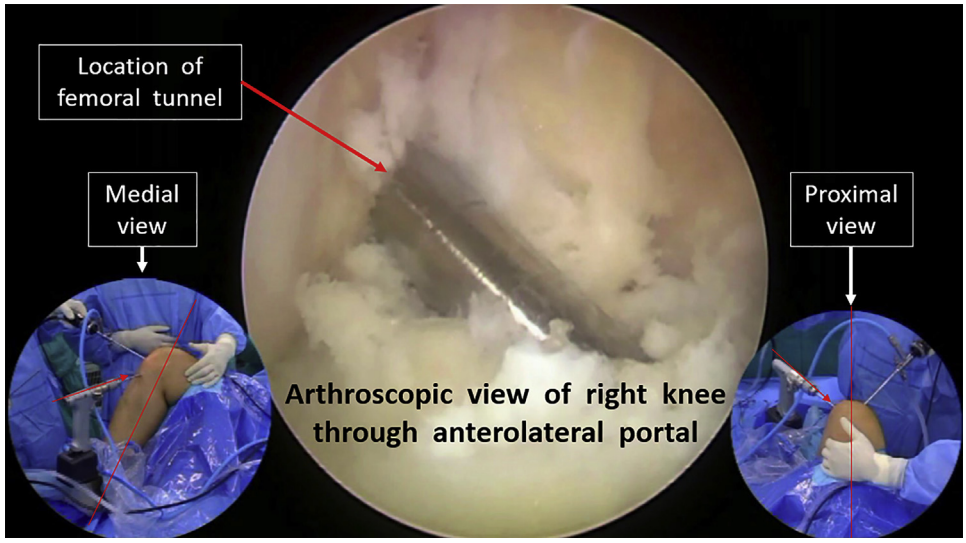

Fig 11. Creating the femoral tunnel through the tibial tunnel. (Arthroscopic view of right knee in supine position through the anterolateral portal.)

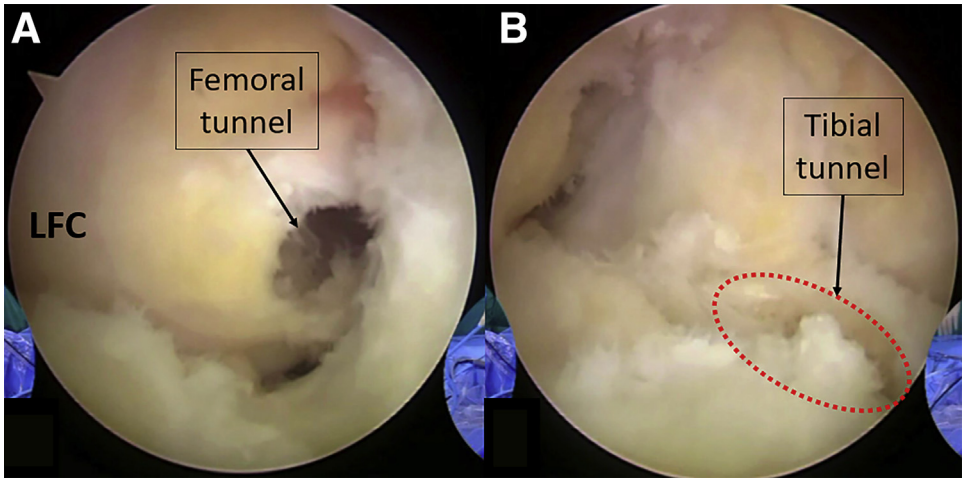

Fig 12. The inner orifices of the created tibial and femoral tunnels. (A, arthroscopic view of right knee through the anterolateral portal. B, Arthroscopic view of right knee in supine position through the anteromedial portal.) (LFC, lateral femoral condyle.)

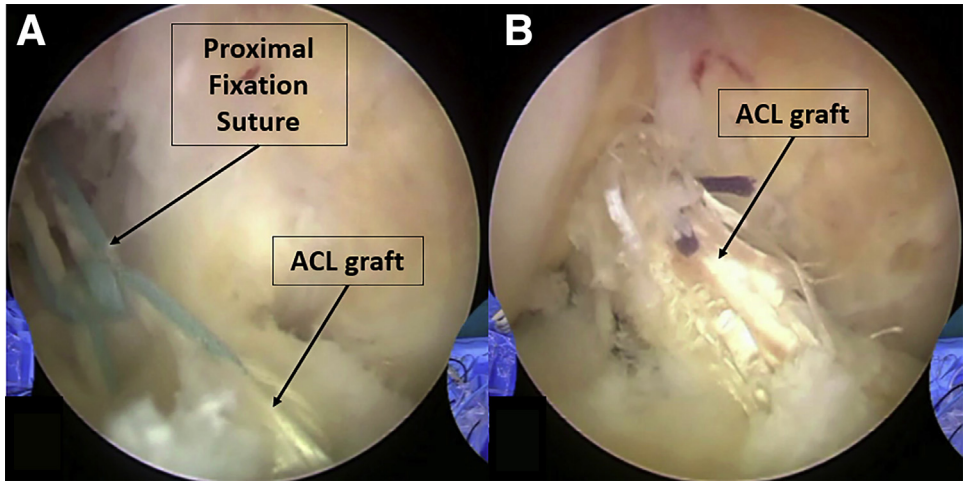

Fig 13. Placement of the graft into the femoral tunnel through the tibial tunnel. (Arthroscopic view of right knee in supine position through the anterolateral portal.) (ACL, anterior cruciate ligament.).

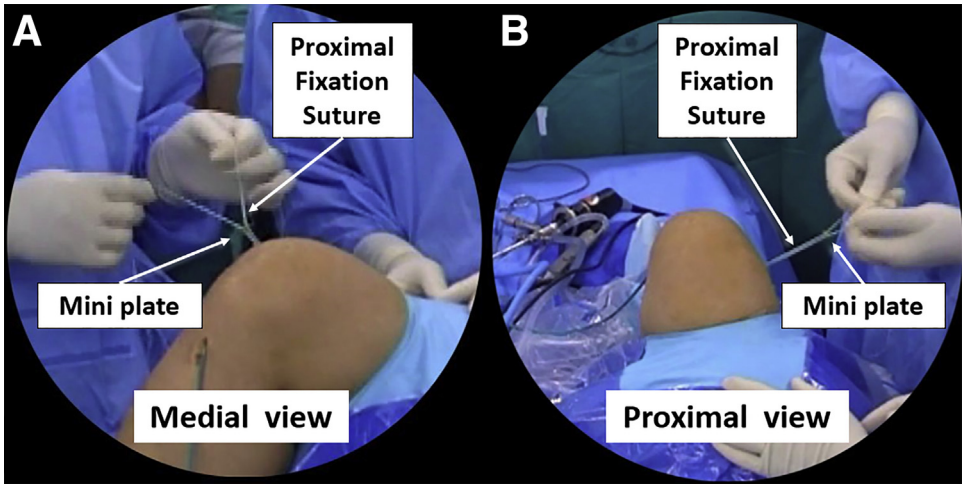

Fig 14. Passing proximal fixation sutures through the mini plate for proximal suspension fixation. (Right knee in supine position.) (A) View from the medial side. (B) View from the proximal side.

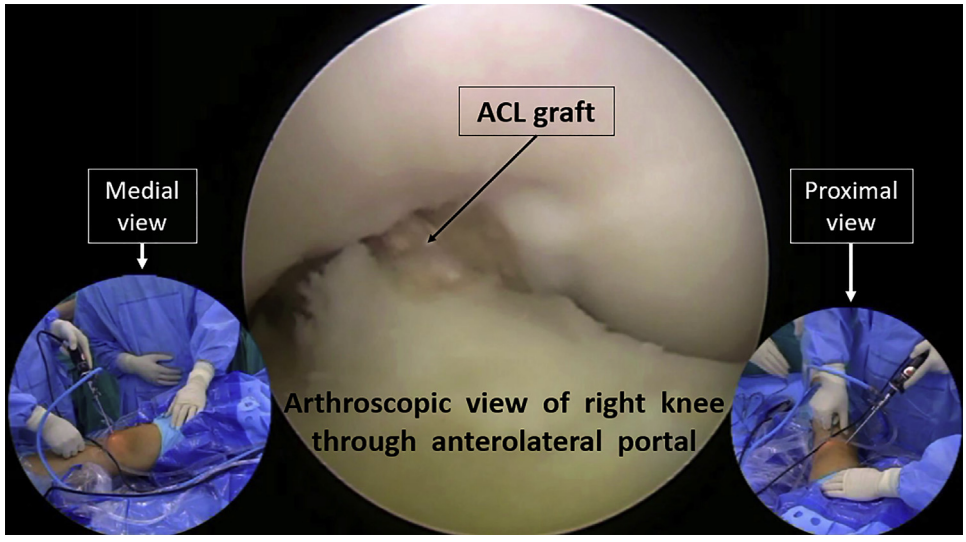

Fig 15. Femoral notch impingement examination. (Arthroscopic view of right knee in supine position through the anterolateral portal.) (ACL, anterior cruciate ligament.).

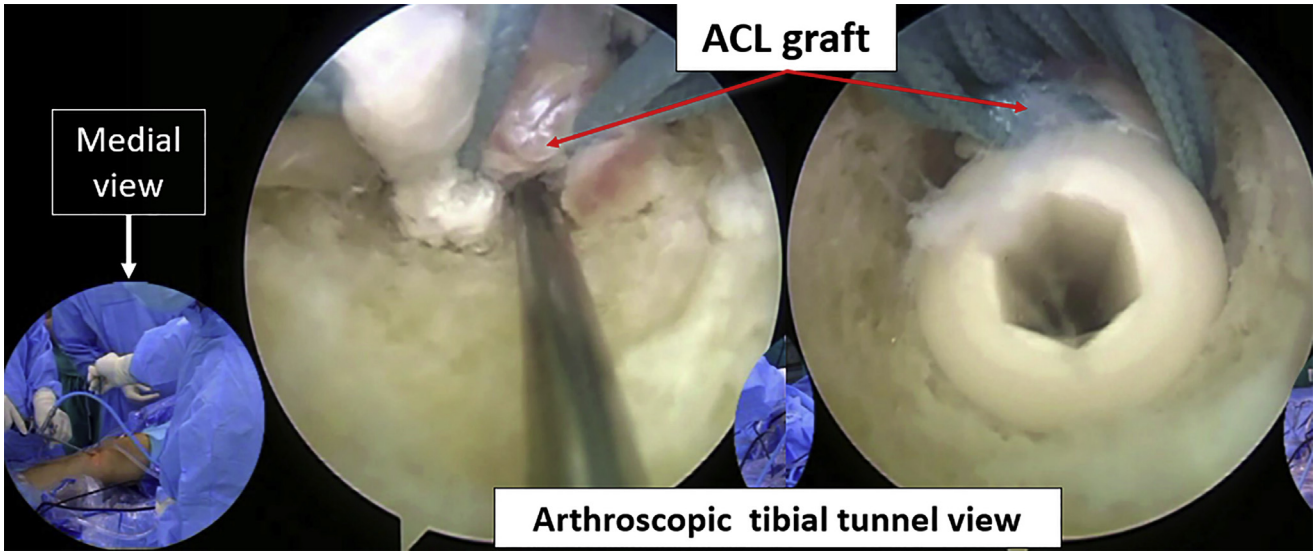

Fig 16. Interference screw fixation of the graft on the tibial side. The crew is place at the posterior side of the graft. (Arthroscopic view of right knee in supine position through the tibial tunnel.) (ACL, anterior cruciate ligament.).

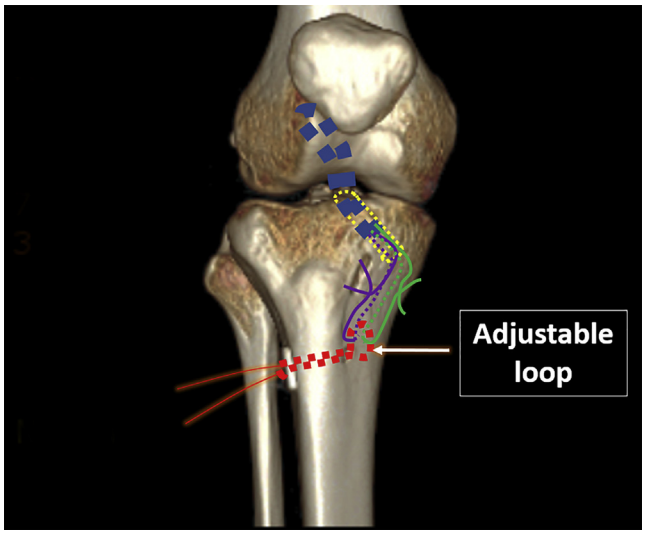

Fig 17. Distal fixation of the graft (right knee). The graft is fixed distally at an adjustable loop set through a transtibial ridge tunnel.

Graft Placement and Proximal Fixation

A 2- to 3-cm-long longitudinal incision is made on the lateral midline of the thigh, 2 cm proximal to the lateral femoral epicondyle. The iliotibial band is incised to access the anterolateral femur through the underside of the quadriceps.

The graft is pulled into the femoral tunnel (Fig 13). The traction sutures are pulled from the underside of the quadriceps out of the lateral incision. Proximal suspension fixation is completed by tying the sutures on a mini plate (Smith & Nephew) over the lateral orifice (Fig 14).

Table 2. Pearls and Pitfalls of Anatomical Transtibial Single-Bundle ACL Reconstruction

1. Enough graft size is needed for ensure final graft strength. Thus, a graft size ≥8 mm is the best choice. When a 7-stranded ST-GT is still not large enough, we recommend using the anterior half of the peroneus longus tendon as a supplement.
2. During creation of the tibial tunnel, elevation of the tibial-aiming device to create a shallow tibial tunnel is the most critical step. Drilling the K wire into the joint can help evaluate the projection of the tibial tunnel.
3. Locate the inner orifice of the tibial tunnel at the lateral slope of the medial tibial eminence. Otherwise, it will result in breakage of the medial slope of the medial tibial eminence and impingement between the graft and the medial femoral condyle.
4. When the lateral tibial eminence is too high, remove it to prevent inferior impingement of the graft.
5. Keep the tibial remnant to get tunnel sealing.
6. Make the lateral incision on the lateral midline of the thigh to prevent disturbance of the quadriceps.
7. The graft is fixed in full extension to prevent extension limitation.
8. The interference screw should be placed at the posterior side of the graft to prevent intra-articular extrusion.

ACL, anterior cruciate ligament; GT, gracilis tendon; ST, semitendinosus tendon.

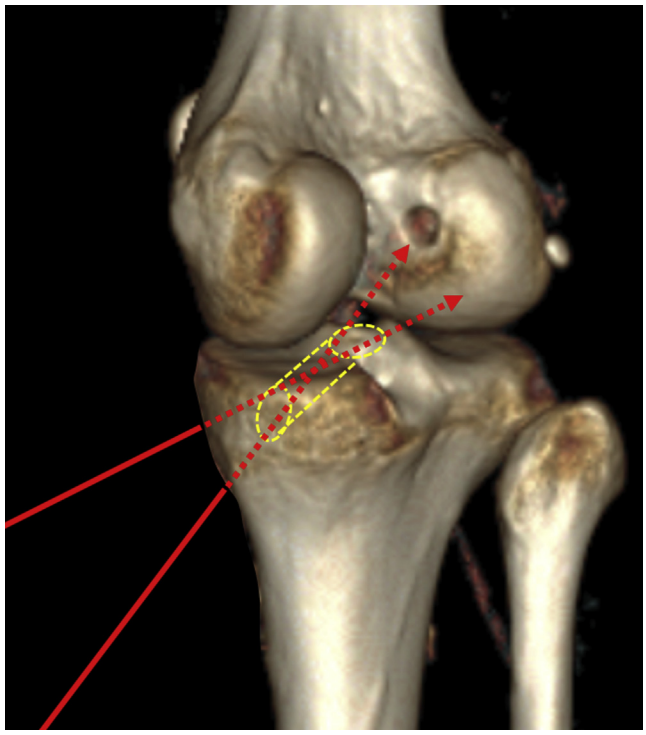

Fig 18. Change of direction of the femoral tunnel—aiming device within the tibial tunnel.

Graft Fixation on the Tibial Side

The knee is placed in full extension. Femoral notch impingement is first excluded (Fig 15). Interference screw fixation is first performed on the tibial side (Fig 16).

A 2-mm incision is made approximately 1 cm lateral to the anterior tibial ridge at a transverse plane distal to the orifice of the tibial tunnel. A 4.5-mm transtibial ridge tunnel is created. A set of mini plates with an

Table 3. Advantages and Disadvantages of Anatomical Single-Bundle Transtibial ACL Reconstruction

Advantages

1. No high-degree flexion of the knee is needed during femoral tunnel creation and a better view and proper location of the femoral tunnel can be expected.
2. The creation of an extremely short femoral tunnel can be avoided.
3. The outer orifice of the femoral tunnel is away from the lateral femoral epicondyle and iliotibial band irritation is prevented.
4. The hypertrophied lateral tibial eminence is removed during tibial and femoral tunnel creation and inferior impingent of it to the graft can be prevented.

Disadvantages

1. Multiple attempts to adjust the projection of the tibial tunnel to close to the location of the femoral tunnel are needed.
2. A relatively short tibial tunnel is fabricated, which may result in graft–tunnel length mismatch.
3. A long oval inner orifice of the tibial formed is formed, which may result in more exposure of the graft in the joint, especially when the tibial remnant is removed.
4. When an interference screw is used, screw protrusion into the joint occur easily when it is placed and the anterior side of the graft.

adjustable loop (Arthrex, Naples, FL) is pulled through this tunnel from the medial to the lateral side. Half of the sutures from the graft end are passed through the adjustable loop. The mini plate is pulled through the transverse tibial tunnel and flipped over the lateral orifice. The sutures limbs passing through the adjustable loop are tied to their counterparts to fix the graft at the adjustable loop (Fig 17). The adjustable loop is reduced to tension the graft finally.

Discussion

The specialty of this Technical Note is that it provides an easy and practical transtibial anatomical ACL reconstruction technique. This technique provides accurate location and fabrication of the femoral tunnel. The critical step of technique is the elevation of the tibial-aiming device to create a shallow tibial tunnel that angulates the sagittal plane at 40° and the tibial axis at 50°. Drilling the K wire into the joint close to the femur can evaluate the projection of the tibial tunnel that would be created. When the K wire deviates too far from the expected site, which is due to its very small angulation with the tibial axis, adjustment of the tibial tunnel—aiming device is needed (Table 2).

Usually, the protruding K wire can closely reach the marked point but cannot reach the exact point. However, when the projecting point of the tibial tunnel and the marked point of the femoral tunnel is within 5 mm, locating the femoral tunnel at the right point through the 8- to 10-mm wide tibial tunnel is not a problem, because the direction of the tubular femoral tunnel—aiming device can be adjusted to a wide range (Fig 18).[7]

This special technique of tibial tunnel creation results in a shallow tibial tunnel with a length of 35 to 40 mm and an outer orifice 15 to 20 mm below the medial tibial plateau. Because the length of graft that would be placed in the tibial tunnel is 25 to 30 mm, the tibial tunnel can accommodate the graft without tendon extrusion.

The main concern of using this technique is the breakage of the anterior wall of the tibial tunnel during the creation of a shallow tibial tunnel. In our clinical practice, we found that it rarely happens with proper location and spatial angulation control. In a few cases, even if anterior wall breakage happens due to very large angulation and very large tunnel, it seldom causes fixation problems because we rely on suspension fixation on the tibial side. The advantages and disadvantages of this technique are listed in Table 3.

We have conducted this anatomical transtibial ACL reconstruction in more than 600 patients and have found it to be easy to perform and that it can avoid the disadvantages of transportal ACL reconstruction. We hope this Technical Note will lead to the reconsideration of transtibial technique in anatomical ACL reconstruction.

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