

Anatomic Double-Bundle Transtibial Anterior Cruciate Ligament Reconstruction

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Abstract: Double-bundle anterior cruciate ligament (ACL) reconstruction (DBACL) is a reasonable transition from single-bundle ACL reconstruction to obtain better clinical outcomes, and most authors believe that it can only be performed through a medial portal. However, in our clinical practice, we have found that anatomic DBACL can be performed easily and exactly through transtibial tunnels just by positioning the tibial tunnels appropriately. Thus, we would like to introduce this anatomic double-bundle transtibial ACL reconstruction technique, in which the most critical step is to create a shallow tibial tunnel for the anteromedial bundle with a proximal projection to the anatomic location of the corresponding femoral tunnel. We believe this Technical Note will give an interesting view of anatomic DBACL.

In the development of anterior cruciate ligament (ACL) reconstruction techniques, anatomic double-bundle ACL reconstruction (DBACL) is a major step from anatomic single-bundle ACL reconstruction.^{1,2} Compared with anatomic single-bundle ACL reconstruction, anatomic DBACL has been proved advantageous biomechanically. However, anatomic DBACL is not so popular in clinical practice for various reasons, with technical difficulty as the main reason. Regarding DBACL methods, most authors recommend a trans-medial portal technique and consider that anatomic DBACL cannot be realized with a transtibial technique,³ although better graft maturation was revealed with the transtibial technique.⁴ However, in our clinical practice, we have found that if the projections of the tibial tunnels are appropriately controlled during their creation, an anatomic creation

of the 2 femoral tunnels through the tibial tunnels can always be realized. Thus, we would like to introduce this anatomic transtibial DBACL technique. The indication for this technique is any complete ACL tear indicated for surgery in young, active, skeletally mature patients.

Table 1. Step-by-Step Procedures for Anatomic Transtibial Double-Bundle ACL Reconstruction

1. The ST and GT are harvested. A 4-stranded graft is made from each tendon.
2. The femoral tunnels are located and marked with a radiofrequency probe.
3. The tibial tunnels are located and marked with a radiofrequency probe.
4. The projection of the AM bundle tibial tunnel is defined.
5. The AM bundle tibial tunnel is created.
6. The projection of the PL bundle tibial tunnel is defined.
7. The PL bundle tibial tunnel is created.
8. A K-wire is drilled to the marked point of the PL bundle femoral tunnel through the PL bundle tibial tunnel.
9. The PL bundle femoral tunnel is created.
10. A K-wire is drilled to the marked point of the AM bundle femoral tunnel through the AM bundle tibial tunnel.
11. The AM bundle femoral tunnel is created.
12. An incision is made on the lateral midline of the thigh to reach the anterolateral femur through the underside of the quadriceps.
13. The grafts are pulled into the femoral tunnels through the tibial tunnels.
14. Proximal suspension fixation is completed by tying the sutures on a mini-plate over each orifice.
15. The sutures from the distal graft ends are tied at an adjustable loop that is set through a transtibial ridge tunnel.

ACL, anterior cruciate ligament; AM, anteromedial; GT, gracilis tendon; PL, posterolateral; ST, semitendinosus tendon.

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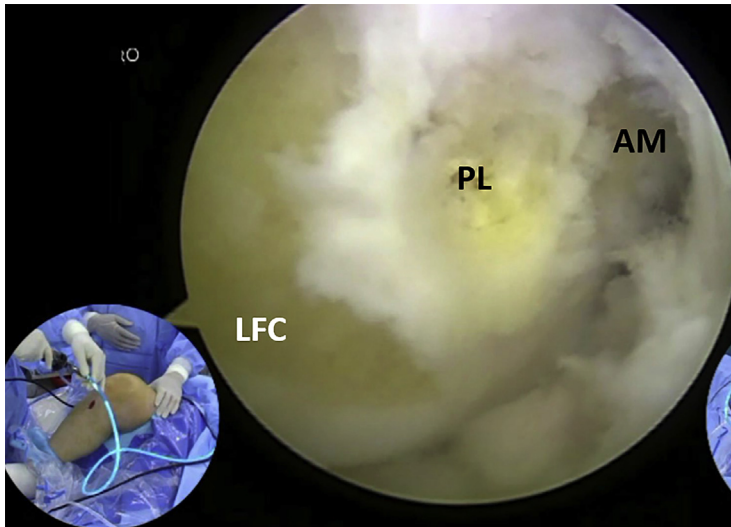


Fig 1. Locations of femoral tunnels in right knee through anteromedial portal. The 2 femoral tunnels are located at the centers of the proximal and distal halves of the footprint. (AM, anteromedial bundle; LFC, lateral femoral condyle; PL, posterolateral bundle.)

Surgical Technique

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

Graft Preparation

The semitendinosus tendon and gracilis tendon are harvested, braided with nonabsorbable sutures, and prepared to make two 4-stranded grafts, with one from each tendon. Two No. 5 nonabsorbable sutures (Smith & Nephew, Andover, MA) are used as traction and fixation sutures on the proximal end of each graft (Fig 1). The semitendinosus tendon graft is used to reconstruct the anteromedial (AM) bundle, and the gracilis tendon graft is used to reconstruct the posterolateral (PL) bundle.

Location of Femoral Tunnels

The knee is flexed at 90°. The 2 femoral tunnels are located at the center of the proximal and distal halves of the footprint and marked with a radiofrequency probe (Fig 1, Video 1).

When no ligament remnant is left in the footprint area for tunnel location, a low reference point is located at the lowest point of the lateral wall of the femoral notch and a high reference point is located at the over-the-top point. The PL bundle is located at a point (PLP) 5 mm anterior to the low reference point. The AM bundle is located at a point 10 mm proximal to the PLP on the line passing through the PLP and the high reference point (Fig 2).

Creation of Tibial Tunnels

The inner orifices of the tibial tunnels are located in the middle of the anterior and posterior halves of the ACL tibial footprint (Fig 3). When no remnant is left on

the tibial side, a longitudinal line is drawn passing through the middle of the lateral slope of the medial tibial eminence. A segment is formed on this longitudinal line by 2 crossing transverse lines passing through the tip of the lateral tibial eminence and the anterior edge of the anterior horn of the lateral meniscus, respectively. The midpoints of the anterior and

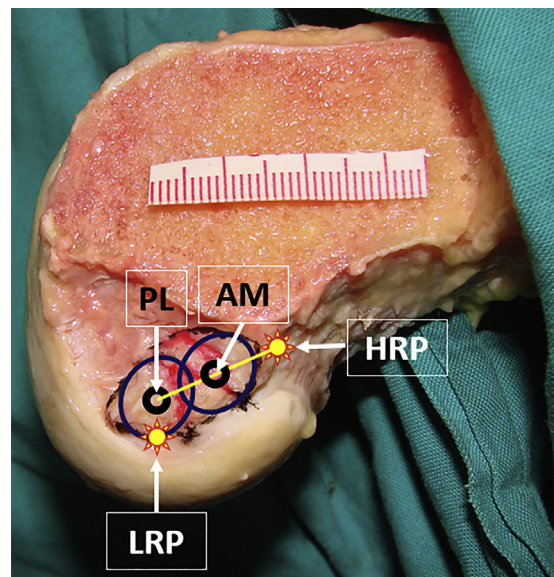
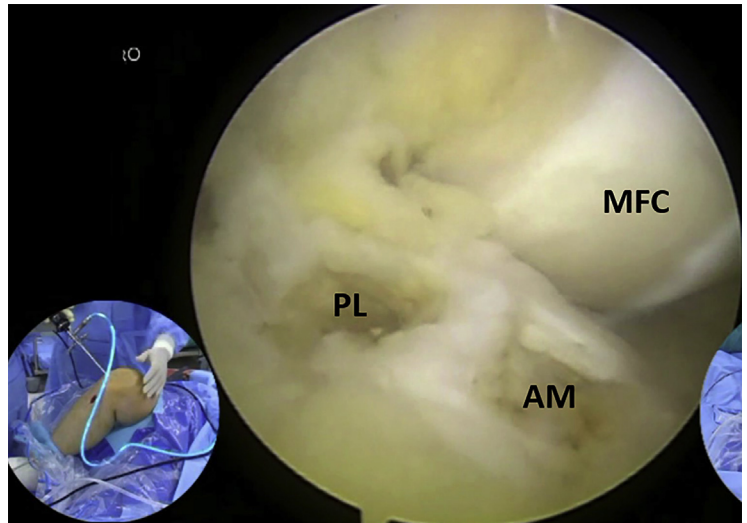


Fig 2. Locations of femoral tunnels in right knee. A low reference point (LRP) is located at the lowest point of the lateral wall of the femoral notch, and a high reference point (HRP) is located at the over-the-top point. The posterolateral bundle (PL) is located at a point (PLP) 5 mm anterior to the LRP. The anteromedial bundle (AM) is located at a point 10 mm proximal to the PLP on the line passing through the PLP and the HRP.

Fig 3. Locations of tibial tunnels in right knee through anterolateral portal. The inner orifices of the tibial tunnels are located in the middle of the anterior and posterior halves of the anterior cruciate ligament tibial footprint. (AM, anteromedial bundle; MFC, medial femoral condyle; PL, posterolateral bundle.)



posterior halves of the segment are defined as the locations of the AM and PL tunnels, respectively (Fig 4).

A 5-mm offset point-to-hole tibial tunnel aiming device (Aesculap, Tuttlingen, Germany) is placed into the joint through the AM portal. The AM bundle tibial tunnel is created in a plane (AM bundle plane) that angulates the sagittal plane at 10° to 15° (Fig 5). In the AM bundle plane, the AM tibial tunnel angulates the tibial axis at approximately 60°. The PL bundle tibial tunnel is created in a plane (PL bundle plane) that angulates the sagittal plane at 30° to 45° (Fig 6). In the PL bundle plane, the tibial tunnel angulates the tibial axis at approximately 30°.

Before the direction of the tibial tunnel is finalized, the K-wires for tibial tunnel creation are protruded to the femoral side to assess the projections

of the tibial tunnels. When they are projected to points with less than 5 mm of distance from the marked points of the corresponding femoral tunnels, the tibial tunnel projections are considered acceptable. Multiple tries are usually needed to obtain the desired projections.

Creation of Femoral Tunnels

A K-wire is drilled freehandedly from the PL bundle tibial tunnel to the marked point of the PL bundle femoral tunnel (Fig 7). The femoral tunnel is created to the expected size and depth. Then, a K-wire is drilled freehandedly from the AM bundle tibial tunnel to the marked point of the AM bundle femoral tunnel (Fig 8). The AM bundle femoral tunnel is created.

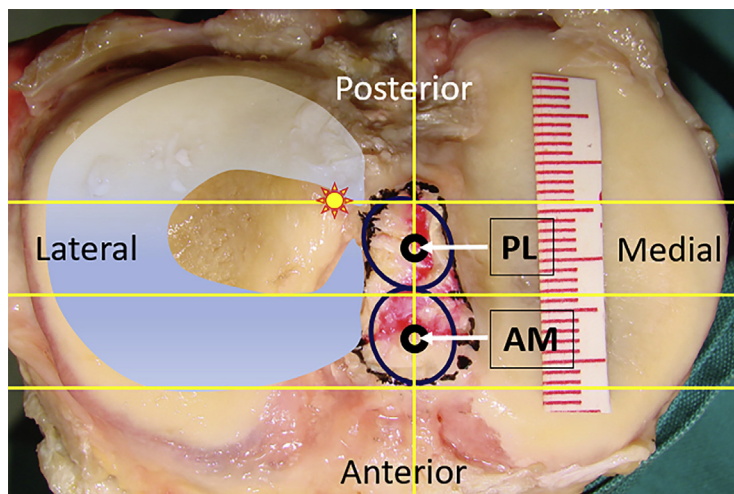


Fig 4. Locations of tibial tunnels in right knee. A longitudinal line is drawn passing through the middle of the lateral slope of the medial tibial eminence. A segment is formed on this longitudinal line by 2 crossing transverse lines passing through the tip of the lateral tibial eminence and the anterior edge of the anterior horn of the lateral meniscus, respectively. The midpoints of the anterior and posterior halves of the segment are defined as the locations of the anteromedial and posterolateral tunnels, respectively. (AM, anteromedial bundle. PL, posterolateral bundle.)

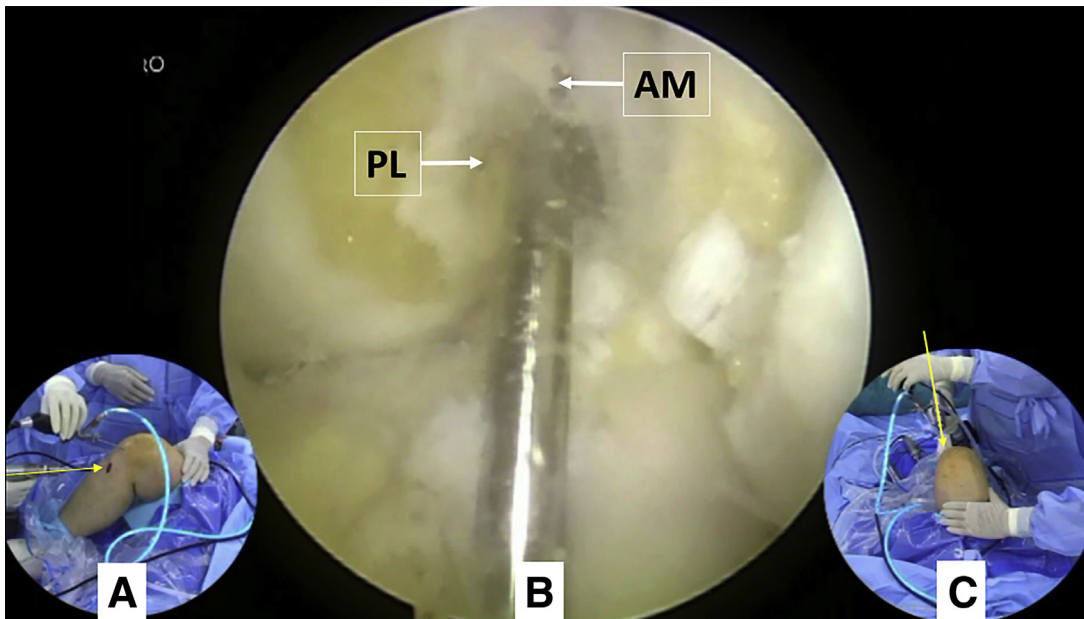


Fig 5. Defining projection of tibial tunnel for anteromedial bundle (AM). (A) Medial view of direction of K-wire (arrow) to create tibial tunnel for AM. (B) The K-wire to establish the AM tibial tunnel is protruded to a site with less than 5 mm of distance from the marked point of the femoral tunnel for the AM (arthroscopic view of right knee through anteromedial portal). (C) Proximal view of direction of K-wire (arrow) to create tibial tunnel for AM. (PL, posterolateral bundle.)

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 PL bundle graft is pulled into the femoral tunnel through the femoral tunnel first, and the AM bundle graft is placed in subsequently (Fig 9). When the AM bundle graft is 2 mm larger than the PL bundle graft, the AM bundle graft is placed in first, followed by placement of the PL bundle graft.

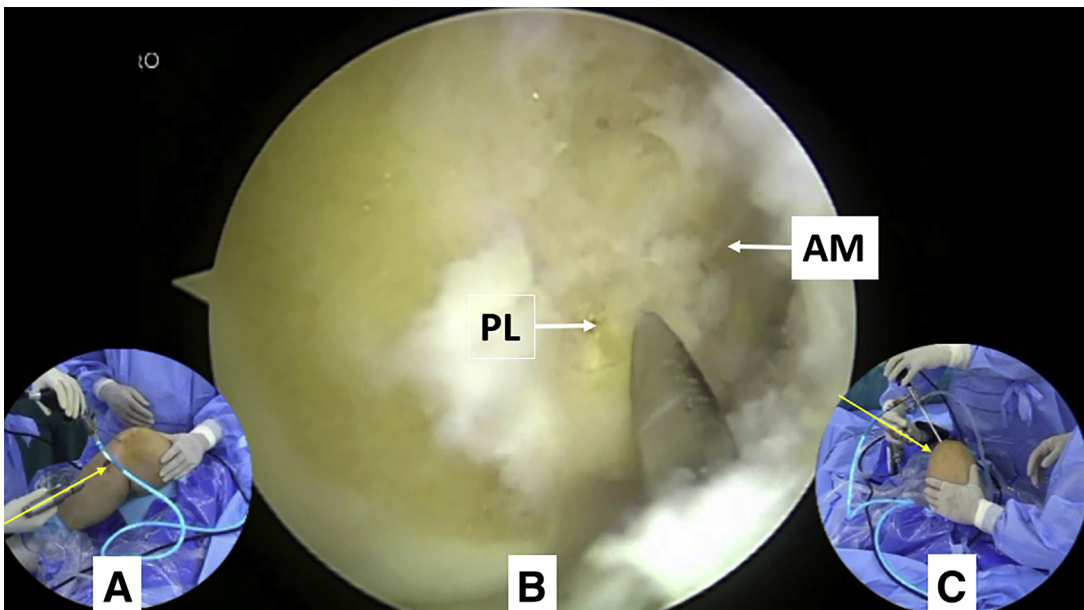


Fig 6. Defining projection of tibial tunnel for posterolateral bundle (PL). (A) Medial view of direction of K-wire (arrow) to create tibial tunnel for PL. (B) The K-wire to establish the PL tibial tunnel is protruded to a site with less than 5 mm of distance from the marked point of the femoral tunnel for the PL (arthroscopic view of right knee through anteromedial portal). (C) Proximal view of direction of K-wire (arrow) to create tibial tunnel for PL. (AM, anteromedial bundle.)

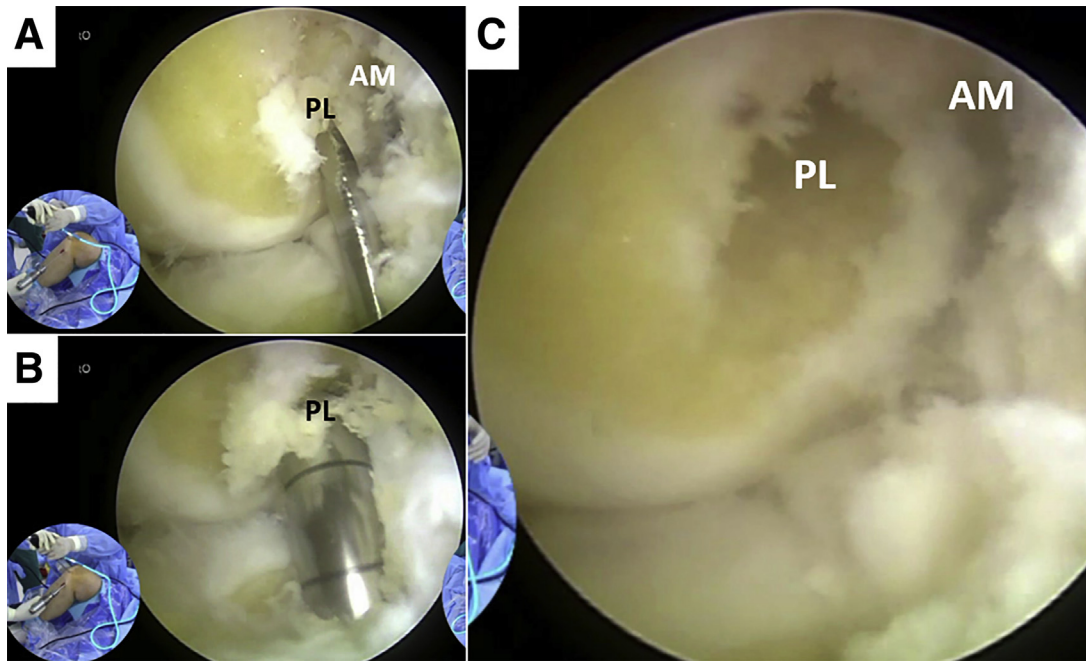


Fig 7. Creating femoral tunnel for posterolateral bundle (PL) through posterolateral tibial tunnel (arthroscopic view of right knee through anteromedial portal). (A) A K-wire is drilled freehandedly through the posterolateral tibial tunnel to the marked point of the femoral tunnel for the PL. (B) The femoral tunnel for the PL is created through the posterolateral tibial tunnel. (C) Created femoral tunnel for PL. (AM, anteromedial bundle.)

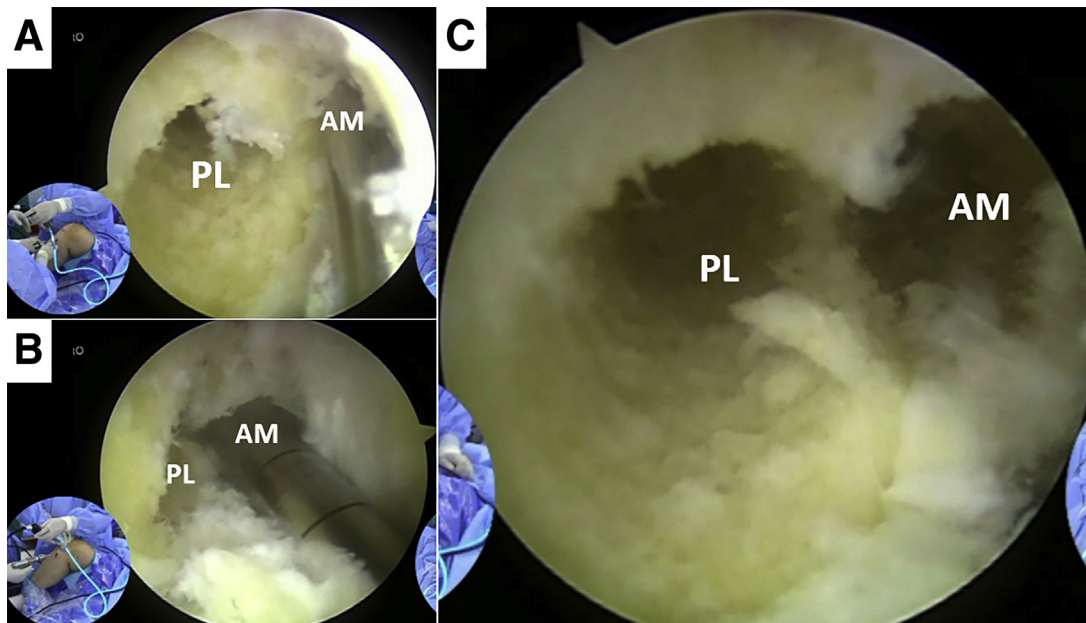


Fig 8. Creating femoral tunnel for anteromedial bundle (AM) through anteromedial tibial tunnel (arthroscopic view of right knee through anteromedial portal). (A) A K-wire is drilled freehandedly through the anteromedial tibial tunnel to the marked point of the femoral tunnel for the AM. (B) The femoral tunnel for the AM is created through the anteromedial tibial tunnel. (C) Created femoral tunnel for AM. (PL, posterolateral bundle.)

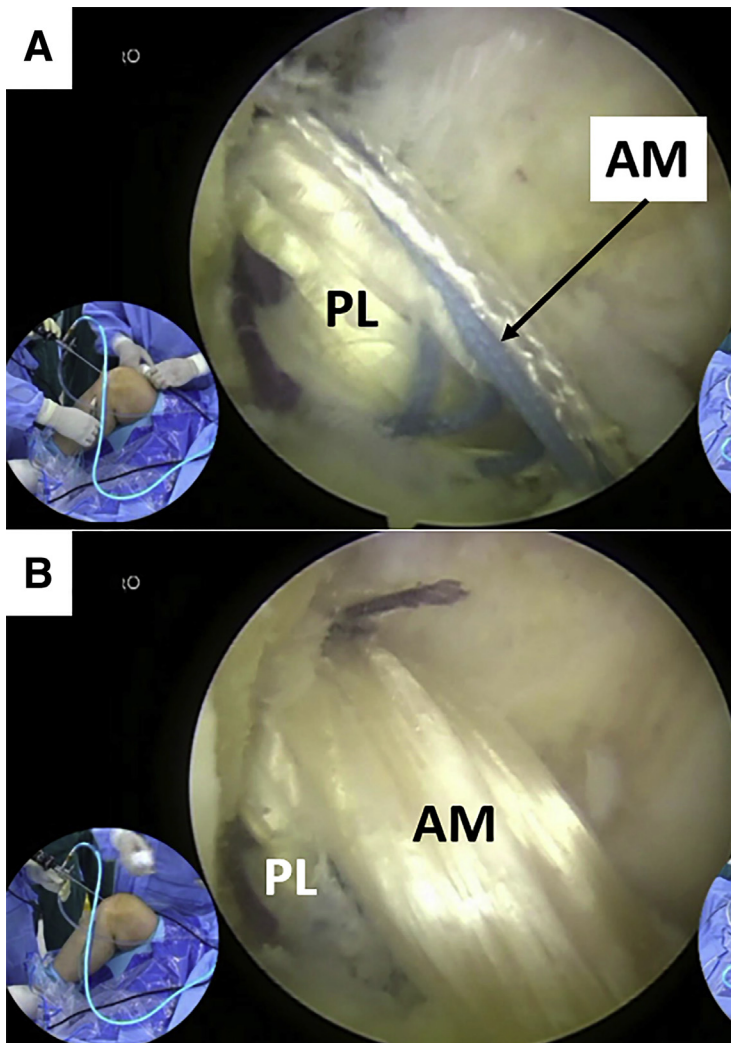


Fig 9. Graft placement (arthroscopic view of right knee through anterolateral portal). (A) Placement of graft in posterolateral bundle. (B) Placement of graft in anteromedial bundle (AM). (PL, posterolateral bundle or traction suture for posterolateral bundle.)

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 mini-plates (Smith & Nephew) over the lateral orifices⁵ (Fig 10).

Graft Fixation on Tibial Side

The knee is placed in full extension. One interference screw is placed into the AM bundle tibial tunnel just behind the graft. A 2-mm incision is made approximately 1 cm lateral to the anterior tibial ridge at a transverse plane distal to the orifices of the tibial tunnels. A 4.5-mm transtibial ridge tunnel is created. A set of mini-plates with an adjustable loop (Arthrex, Naples, FL) is pulled through this tunnel from the medial to the lateral side. Half of the sutures from the graft ends are passed through the adjustable loop. The mini-plate is

pulled through the transverse tibial tunnel and flipped over the lateral orifice. The suture limbs passing through the adjustable loop are tied to their counterparts to fix the graft at the adjustable loop (Fig 11).⁵ Finally, the adjustable loop is reduced to tension the graft.

Discussion

The technique note has 2 interesting aspects: We provide a spatial projection—controlling technique with reference to its angulation to the sagittal plane and the tibial axis, instead of to some anatomic structure such as the medial collateral ligament or the tibial tubercle, and we provide a projection adjustment technique for the K-wire within the tibial tunnels.

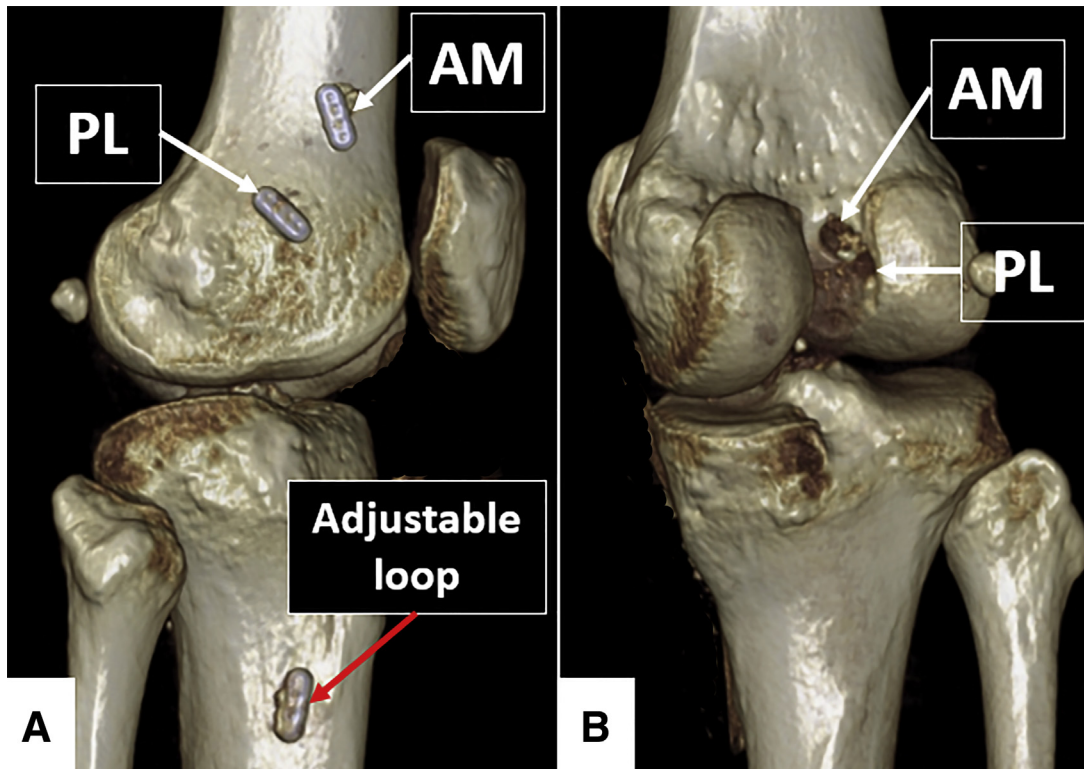


Fig 10. Proximal fixation of grafts on mini-plates (A) and inner orifices of femoral tunnels (B) on 3-dimensional computed tomography (right knee). (AM, anteromedial bundle; PL, posterolateral bundle.)

The crucial points of the described technique are listed in [Table 2](#). In this technique, the creation of the AM bundle tibial tunnel is challenging. The main trick in

this technique is to elevate the tibial aiming device to create a shallow AM bundle tibial tunnel that angulates the tibial axis at 60° ([Fig 12](#)). Too deep a tibial tunnel may result in inaccessibility of the anatomic point of the

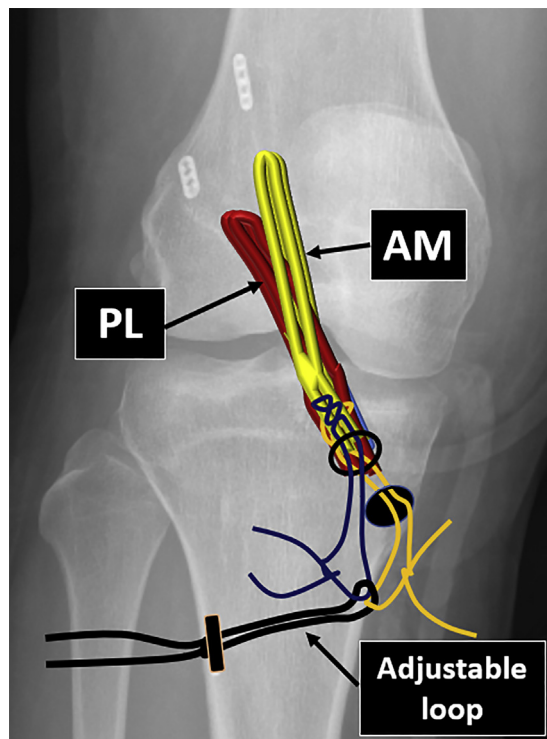


Fig 11. Distal fixation of grafts at adjustable loop (right knee). (AM, anteromedial bundle; PL, posterolateral bundle.)

Table 2. Pearls and Pitfalls of Anatomic Transtibial Double-Bundle ACL Reconstruction

A sufficient graft size is needed to ensure final graft strength. Thus, a total graft size > 10 mm is the best choice. When the total cross-sectional area of the graft is not large enough, the AHPLT is harvested. Thus, a 6-stranded graft is made from the GT and AHPLT to reconstruct the AM bundle, whereas a 4-stranded graft, made from the ST, is used to reconstruct the PL bundle.

During marking of the tibial and femoral tunnels, the soft tissue over the bone surface should be removed. Otherwise, the result will be the wrong location of the tunnels, especially on the tibial side.

During creation of the AM bundle tibial tunnel, elevating the tibial aiming device to create a shallow tibial tunnel is the most critical step. Drilling the K-wire into the joint can help to evaluate the projection of the tibial tunnel.

When the lateral tibial eminence is too high, it should be removed to facilitate placement of the tibial tunnel guide and prevent inferior impingement of the graft.

The lateral incision should be made on the lateral midline of the thigh to prevent disturbance of the quadriceps.

The larger graft should be placed first. Otherwise, it is somewhat difficult to squeeze in the larger graft when the smaller graft is placed first.

The graft is fixed in full extension to prevent extension limitation.

ACL, anterior cruciate ligament; AHPLT, anterior half of peroneus longus tendon; AM, anteromedial; GT, gracilis tendon; PL, posterolateral; ST, semitendinosus tendon.

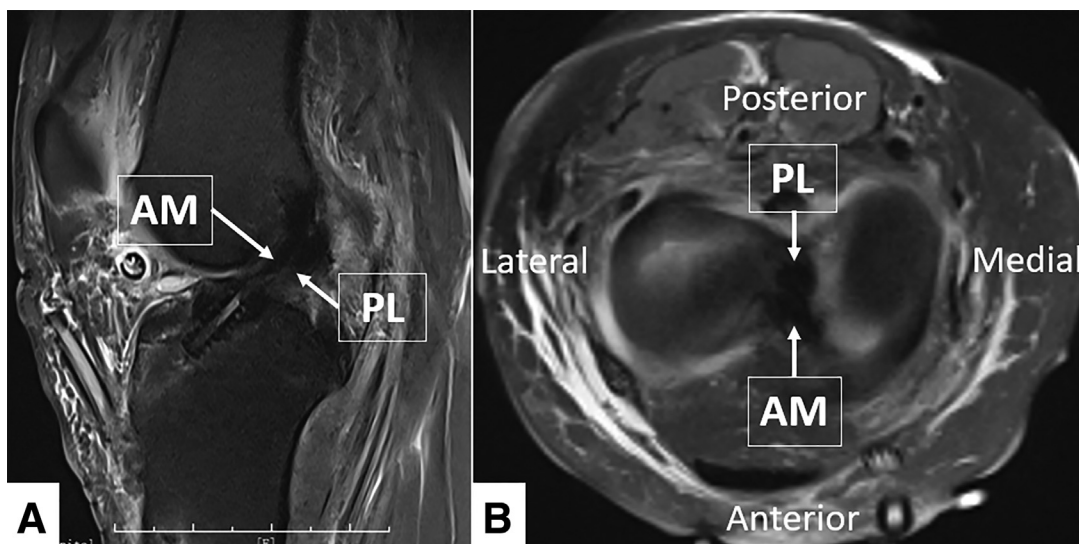


Fig 12. Postoperative magnetic resonance imaging (right knee) indicating the spatial relation of the 2 bundles in the intercondylar notch and the shallow tibial tunnel for the anteromedial bundle (AM) (A) and the spatial relation of the 2 bundles at the inner orifices of the tibial tunnels (B). (PL, posterolateral bundle.)

femoral tunnel, and too shallow a tibial tunnel may result in breakage of its anterior wall.

The possibility of projection adjustment within the tibial tunnel depends on its length and diameter. Because the diameter of the AM bundle tibial tunnel is at least 8 mm and its length is as short as 30 to 35 mm, the extent of change in the direction of the femoral tunnel aiming device within the tibial tunnel is quite great.⁵ During creation of the tibial tunnels, drilling of the K-wire to the femoral side to evaluate the projection of the tibial tunnel is essential. Adjustment of its angulation to the sagittal plane and the tibial axis is always needed. When the projecting point of the tibial tunnel and the marked point of the femoral tunnel are within a 5-mm distance, locating the femoral tunnel at the correct point through the tibial tunnel is not a problem.

Table 3. Advantages and Disadvantages of Anatomic Double-Bundle ACL Reconstruction

Advantages

When we are pursuing ultra-strong ACL reconstruction with grafts with a large cross-sectional area, separating the graft into 2 bundles increases the graft-tendon contact area.

Through transtibial methods, the femoral tunnel is created with the optimal direction and length.

Through transtibial femoral tunnel creation, the high tip of the lateral tibial eminence is removed to eliminate inferior impingement of the graft.

Disadvantages

Adjusting the projection of the tibial tunnel is somewhat time-consuming.

Transtibial creation of the femoral tunnels results in oval and always-overlapping inner orifices on both the tibial and femoral sides. It may not be possible to obtain a bone bridge between the 2 bundles at the inner orifices.

ACL, anterior cruciate ligament.

The main concern with the described technique is that during creation of a shallow AM bundle tibial tunnel, breakage of the anterior wall of the tibial tunnel may result (Table 3). In our clinical practice, we have found that this rarely happens with proper location of the inner orifice of the tibial tunnel and spatial projection control. Even on the rare occasion that anterior wall breakage happens because of too anterior a location and too large an angulation, this seldom causes fixation problems because we rely on suspension fixation instead of on inference screw fixation on the tibial side.

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