Technical Note

Anatomic Double-Bundle Transtibial Anterior Cruciate Ligament Reconstruction With Ligament Advanced Reinforcement System

Jin Tang, B.M., and Jinzhong Zhao, M.D.

Abstract: It has been reported that anterior cruciate ligament reconstruction (ACLR) with the Ligament Advanced Reinforcement System (LARS) could obtain similar clinical outcomes to ACLR with autograft. However, in most related reports, single-bundle ACLR was performed. Given that double-bundle ACLR is more favorable than single-bundle ACLR biomechanically, it is reasonable to try double-bundle ACLR with the LARS clinically. Thus, we introduce an anatomic double-bundle transtibial ACLR technique with the LARS, in which the most critical step is to create a shallow tibial tunnel for the anteromedial bundle to further create the corresponding femoral tunnel in a transtibial manner, as well as to fix both bundles in full extension of the knee.

Anterior cruciate ligament reconstruction (ACLR) with the Ligament Advanced Reinforcement System (LARS) (LARS AC; LARS, Arc sur Tille, France) has been receiving increasing attention in recent years. Although high failure rates or complication rates after ACLR with LARSs were reported in some studies,[1-3] it has been reported ACLR with LARSs could obtain similar clinical outcomes to ACLR with autograft.[4-8] However, analysis of ACLR techniques in these studies revealed that only single-bundle ACLR (SBACLR) was performed. Given that anatomic double-bundle ACLR (DBACLR) has been proved advantageous biomechanically compared with anatomic SBACLR,[9,10] it is reasonable to try DBACLR with the use of LARSs as graft material. On the basis of our clinical experience performing anatomic double-bundle transtibial ACLR with autograft,[11,12] we have found that DBACLR with LARSs is feasible and, even more, creation of the femoral tunnels through the tibial tunnels is feasible. Thus, this article introduces our technique of anatomic transtibial DBACLR with LARSs.

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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, Video 1). Two LARS devices are used for DBACLR, with the diameter of each synthetic ligament being 7.5 mm, with 120 filaments in each ligament. Anteromedial (AM), anterolateral, and transpatellar tendon portals are fabricated. The knee is first examined, and concomitant lesions are treated. Femoral notchplasty is performed when indicated. The high lateral tibial eminence is removed to prevent its impingement to the posterolateral (PL) bundle after ligament reconstruction.

Femoral Tunnel Locations

The knee is flexed at 90°. The highest point of the posterior outlet of the femoral notch (POFN) and the most proximal edge of the lateral wall of the femoral notch (LWFN) are exposed and marked with a radiofrequency probe, and the over-the-top point is located on the POFN and in the middle of the highest point of the POFN and the most proximal edge of the LWFN (Fig 1). A low reference point is located at the lowest (most posterior) point of the LWFN. The PL-bundle femoral tunnel is located at a point 5 mm anterior to the low reference point, and the AM bundle is located

Table 1. Step-by-Step Procedures for Anatomic Transtibial Double-Bundle ACLR With LARS

1. Two 7.5-mm-diameter LARS devices are prepared for use.
2. The OTT is located in the middle of the highest point of the POFN and the most proximal edge of the LWFN.
3. The femoral tunnels are located and marked with a radiofrequency probe with reference to the lowest point of the LWFN and the OTT.
4. The tibial tunnels are located and marked with a radiofrequency probe.
5. The projection of the AM-bundle tibial tunnel is defined.
6. The AM-bundle tibial tunnel is created.
7. The projection of the PL-bundle tibial tunnel is defined.
8. The PL-bundle tibial tunnel is created.
9. A K-wire is drilled to the marked point of the PL-bundle femoral tunnel through the PL-bundle tibial tunnel and over-drilled with a 4.5-mm drill.
10. A K-wire is drilled to the marked point of the AM-bundle femoral tunnel through the AM-bundle tibial tunnel and over-drilled with a 7.5-mm cannulated drill.
11. The PL-bundle femoral tunnel is created with a 7.5-mm cannulated drill.
12. An incision is made on the anterior edge of the iliotibial band 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 fixation of the LARS devices is completed by placing interference screws at the outer orifices of the femoral tunnels.
15. Distal fixation of the LARS devices is completed by placing interference screws at the outer orifices of the tibial tunnels.

ACLR, anterior cruciate ligament reconstruction; AM, anteromedial; LARS, ligament advanced reinforcement system; LWFN, lateral wall of femoral notch; OTT, over-the-top point; PL, posterolateral; POFN, posterior outlet of femoral notch.

in the middle of the PL-bundle point and the over-the-top point and marked with a radiofrequency probe (Fig 2A).

Creation of Tibial Tunnels

When there is remnant on the tibial side, the midpoints of the anterior and posterior halves of the anterior cruciate ligament tibial footprint are defined as the locations of the AM- and PL-bundle tunnels, respectively (Fig 2B). When there is no remnant on the tibial side, 1 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 AM- and PL-bundle tunnels, respectively.[11]

A 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 that angulates the sagittal plane at 10° to 15° (AM-bundle plane). 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 that angulates the sagittal plane at 30° to 45° (PL-bundle plane). In the PL-bundle plane, the tibial tunnel angulates the tibial axis at approximately 30°.[11]

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 and is over-drilled with a 4.5-mm cannulated drill (Fig 3A). A K-wire is drilled from the AM-bundle tibial tunnel to the marked point of the AM-bundle femoral tunnel freehandedly or with a

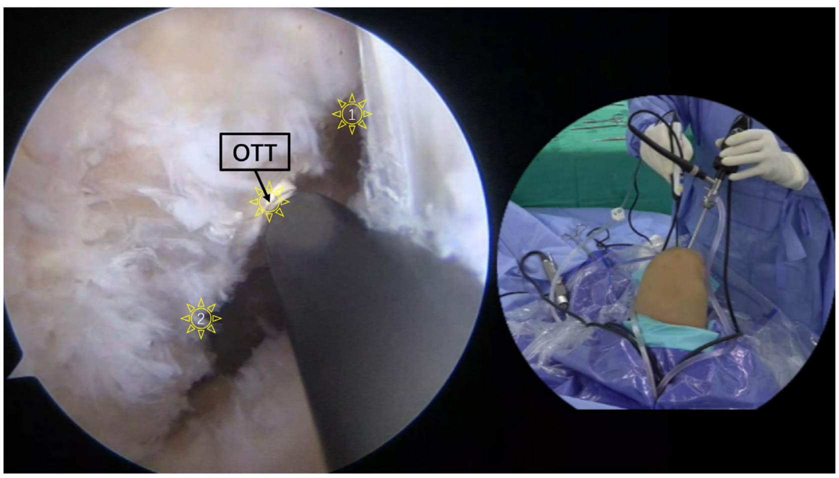


Fig 1. Location of over-the-top point (OTT). The OTT is located in the middle of the highest point of the posterior outlet of the femoral notch (1) and the most posterior point of the edge of the lateral wall of the femoral notch (2). (Arthroscopic view through the trans-patellar tendon portal and outside view of right knee)

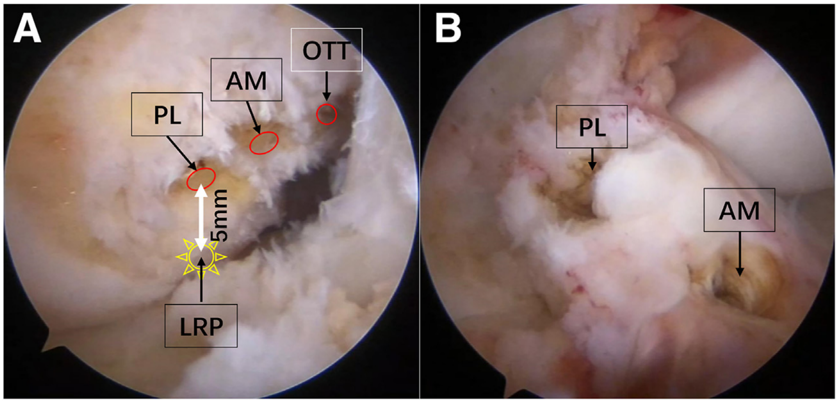


Fig 2. Arthroscopic views of locations of femoral tunnels through anteromedial portal (A) and tibial tunnels through anterolateral portal (B) in right knee. A low reference point (LRP) is located at the lowest point of the lateral wall of the femoral notch, and the over-the-top point (OTT) is located. The posterolateral bundle (PL) is located at a point 5 mm anterior to the LRP (arrow). The anteromedial bundle (AM) is located in the middle of the PL-bundle point and the OTT. On the tibial side, 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.

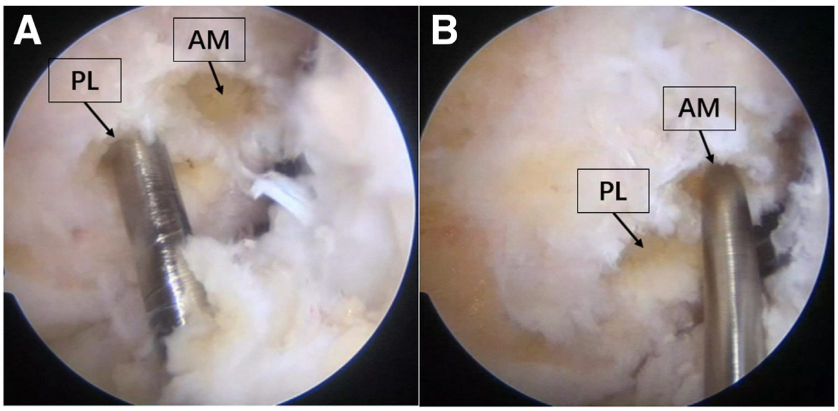
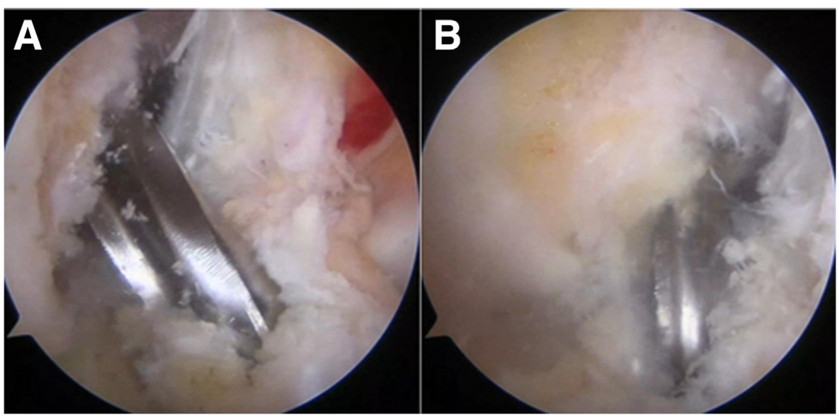


Fig 3. Preliminary creation of posterolateral (PL)—bundle femoral tunnel through PL-bundle tibial tunnel (A) and drilling of guide-wire from anteromedial (AM)—bundle tibial tunnel to AM-bundle femoral tunnel (B) (arthroscopic views of right knee through anteromedial portal).

Fig 4. Final creation of anteromedial-bundle femoral tunnel through anteromedial-bundle tibial tunnel (A) (arthroscopic view of right knee through anterolateral portal) and posterolateral-bundle femoral tunnel through posterolateral-bundle tibial tunnel (B) (arthroscopic views of right knee through anteromedial portal).



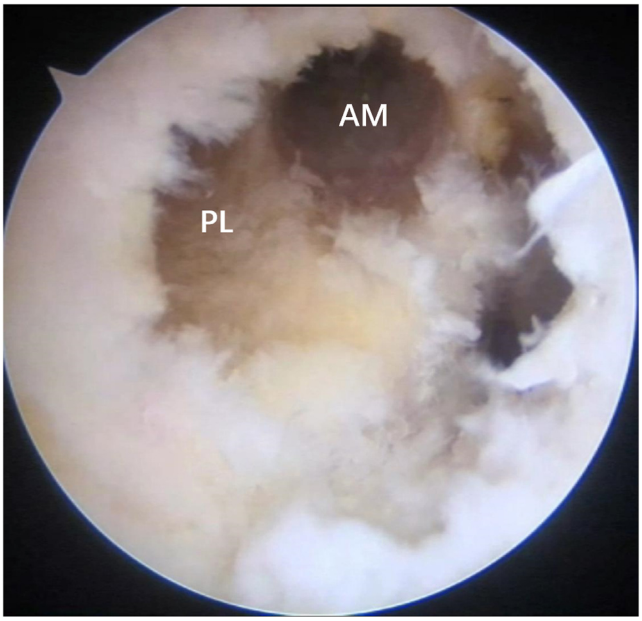


Fig 5. Inner orifices of 2 femoral tunnels (arthroscopic view of right knee through anteromedial portal). (AM, anteromedial bundle; PL, posterolateral bundle.)

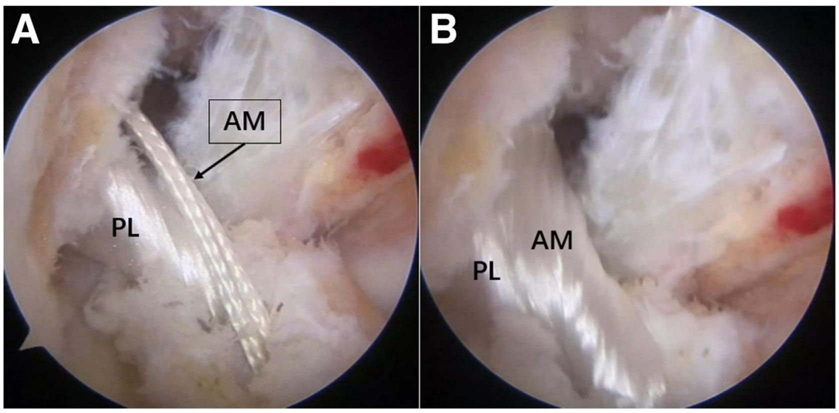


Fig 6. Graft placement (arthroscopic views of right knee through anterolateral portal). (A) Placement of graft in posterolateral bundle. (B) Placement of graft in anteromedial bundle (AM). (PL, posterolateral bundle or traction suture for posterolateral bundle.)

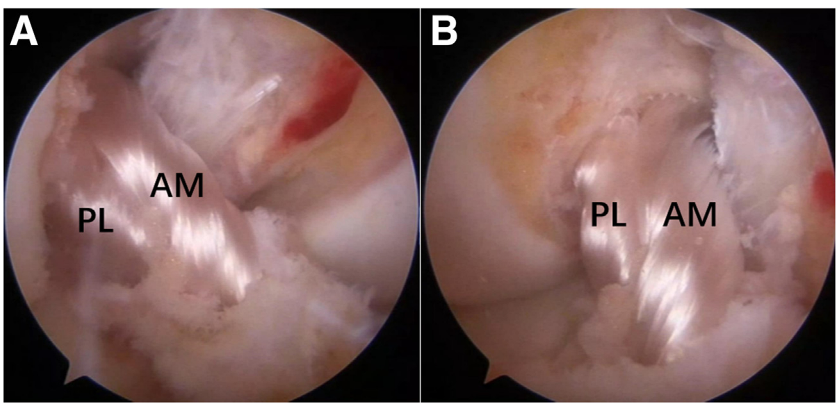


Fig 7. Arthroscopic views of right knee through anterolateral portal (A) and anteromedial portal (B) showing spatial arrangement of 2 bundles of reconstructed anterior cruciate ligament at 90° of knee flexion. (AM, anteromedial bundle; PL, posterolateral bundle.)

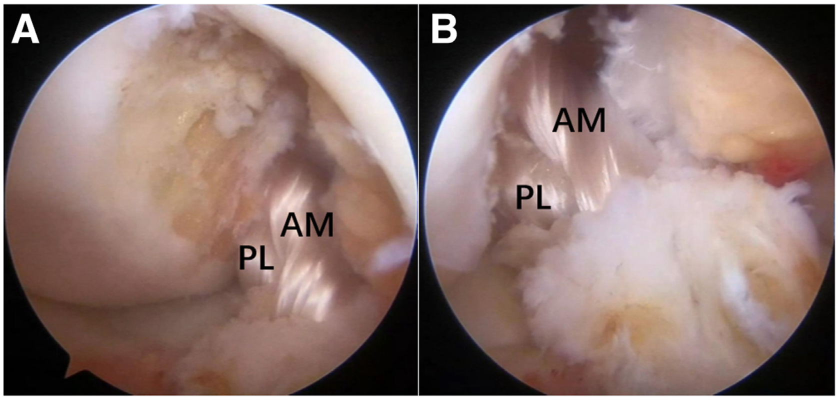


Fig 8. Arthroscopic views of right knee through anterolateral portal (A) and anteromedial portal (B) showing spatial arrangement of 2 bundles of reconstructed anterior cruciate ligament at 30° of knee flexion. (AM, anteromedial bundle; PL, posterolateral bundle.)

femoral tunnel guide (Fig 3B) and is then over-drilled with a 7.5-mm cannulated tibial-tunnel drill (Fig 4A). The PL-bundle femoral tunnel is created with a 7.5-mm cannulated tibial-tunnel drill (Fig 4B). The bony debris in the PL compartment and the femoral tunnels is washed out (Fig 5).

Graft Placement and Proximal Fixation

A 3- to 4-cm-long longitudinal incision is made at the anterior edge of the iliotibial band, 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 traction sutures of each graft are pulled through the corresponding tibial and femoral tunnels and pulled out of this incision.

The PL-bundle graft is pulled into the femoral tunnel through the tibial tunnel first, and the AM-bundle graft is placed subsequently (Fig 6). Proximal fixation is completed with 8-mm wide, 25-mm-long metal interference screws at the outer orifices of the femoral tunnels. The proximal sections of the LARS outside the femoral tunnels are cut off.

Graft Fixation on Tibial Side

Full range of motion (ROM) of the knee is performed to exclude femoral notch impingement and to ensure enough space is left between the AM bundle and the LWFN for the PL bundle to pass during high-degree knee flexion (Figs 7 and 8). The knee is placed in full extension. A K-wire is hammered through the outer segment of the AM-bundle ligament just at the outer orifice of the tibial tunnel to prevent intra-articular migration of the ligament during subsequent maneuvers. One 8-mm-wide, 30-mm-long metal

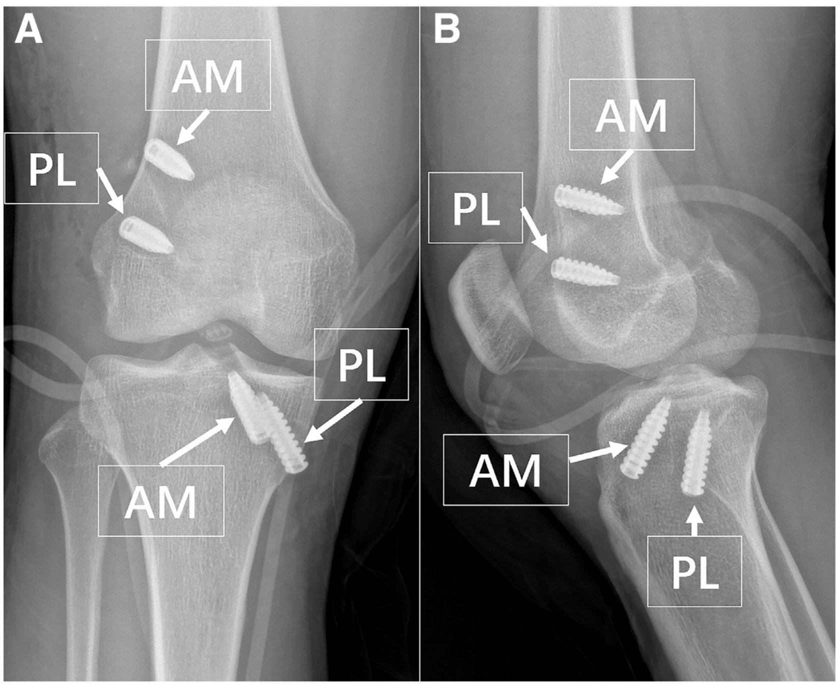


Fig 9. Postoperative anteroposterior-view (A) and lateral-view (B) radiographs of right knee indicating positions of interference screws for graft fixation. (AM, anteromedial bundle; PL, posterolateral bundle.)

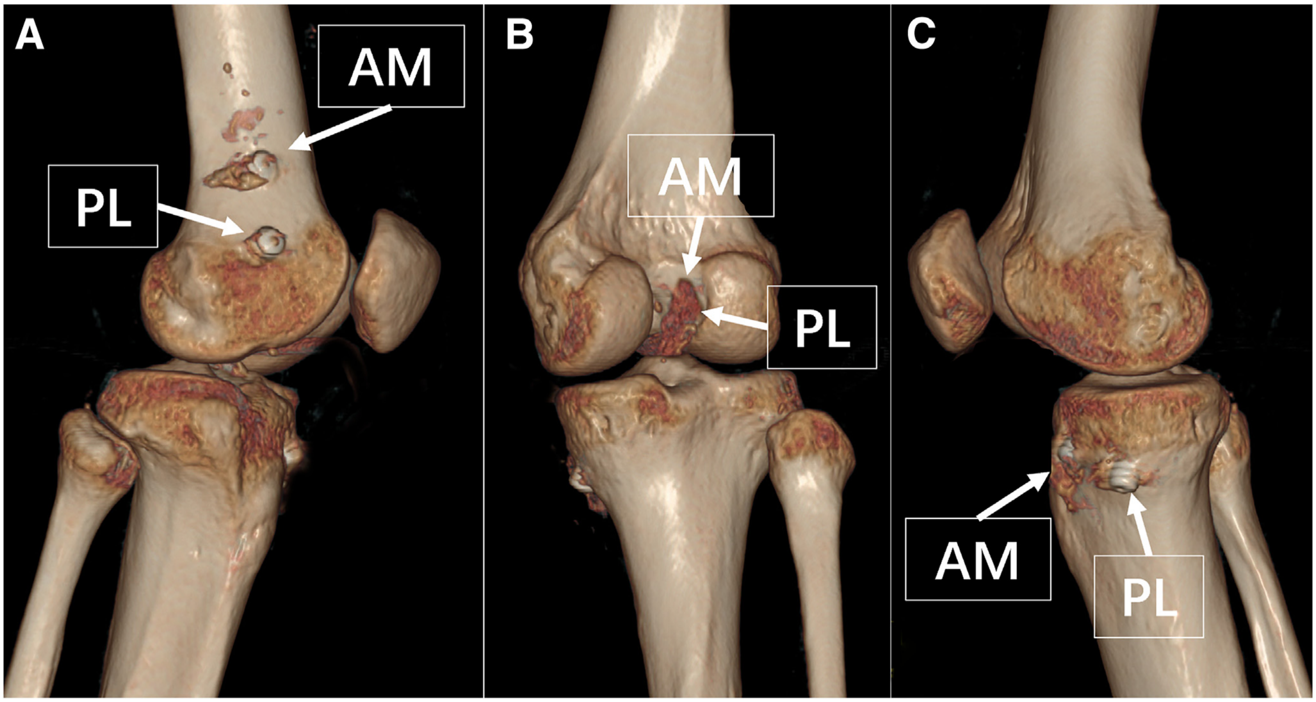


Fig 10. Postoperative computed tomography scans indicating locations of interference screws on femoral side (A) (lateral view of right knee), intra-articular ligament bundles (B) (posterior view of right knee), and interference screws on tibial side (C) (medial view of right knee). (AM, anteromedial bundle; PL, posterolateral bundle.)

interference screw is placed into the tunnel just behind the graft. The ligament sections outside the tibial tunnel are cut off. Distal fixation of the PL bundle is performed in a similar way (Figs 9-11).

Discussion

The LARS device, which is made from polyethylene terephthalate and experiences no obvious strength decrease after implantation, may avoid the strength-

Fig 11. Postoperative magnetic resonance imaging indicating spatial relation of 2 bundles in intercondylar notch (right knee). (AM, anteromedial bundle; PL, posterolateral bundle.)

Table 2. Pearls and Pitfalls of Anatomic Transtibial Double-Bundle ACLR With LARS

To fully make use of the high strength of the synthetic ligament, LARSs with more filaments are preferred. However, two 7.5-mm LARSs, each with 120 filaments, may be the best choice for double-bundle ACLR. LARSs that are too large may exceed the accommodation limit of the footprints.
The fault tolerance of the LARS is extremely low because of its high rigidity and strength. Thus, ideal locations of the tunnels, especially the femoral tunnels, and ligament fixation at the proper knee angle are critical.
During marking of the tibial and femoral tunnels, the soft tissue over the bone surface should be removed. Otherwise, the tunnels may be placed in the wrong location, especially those on the tibial side.
During creation of the AM-bundle tibial tunnel, the most critical step is elevation of the tibial aiming device to create a shallow tibial tunnel. Drilling a 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 surgeon should make the lateral incision at the anterior edge of the iliotibial band and reach the anterolateral side of the distal femur through the underside of the quadriceps to prevent their disturbance.
Interference screws should be placed along the axis of the femoral or tibial tunnels to enable as much anchorage of the ligament as possible. Otherwise, fixation of the LARS may be compromised.
The surgeon should not drive the interference screw totally into the cancellous bone canal. Leaving 1 thread outside the outer orifices of the tunnels will maximize the squeezing of the device by the screw.
The outer segment of the LARS should be cut off to prevent irritation of the overlying soft tissue by the stump.
The devices are finally fixed in full extension of the knee to prevent extension limitation.

ACLR, anterior cruciate ligament reconstruction; LARS, ligament advanced reinforcement system.

decrease defect of autograft implantation and display the advantages of DBACLR over SBACLR. However, DBACLR with the LARS has not been reported, with technical difficulty as the main reason. Because the LARS is not an extensible device, incorrect tunnel location and fixation may cause ROM limitation of the knee. Thus, it is reasonable to perform single-bundle isometric ACLR with the LARS to avoid ROM limitation.[13] However, as we know, single-bundle isometric ACLR cannot restore the rotational stability of the knee[9,14,15]; thus, double-bundle anatomic ACLR with the LARS is still worth trying. To take advantage of the high strength and avoid the disadvantage of the high stiffness of the LARS, precise location of the tunnels, especially the femoral tunnels, and proper fixation of the devices are required. In terms of technological advancement, it is recommended that surgeons first familiarize themselves with anatomic DBACLR with autograft[11] and then try DBACLR with the LARS.

The crucial points of the described technique are listed in Table 2. In this technique, correct creation of the AM-bundle tibial tunnel is challenging but necessary so that the AM-bundle femoral tunnel can be successfully created through this tibial tunnel. The main trick to create the ideal AM-bundle tibial tunnel is to elevate the tibial aiming device to create a shallow AM-bundle tibial tunnel that angulates the tibial axis at 60°. A tibial tunnel that is too deep may result in inaccessibility of the anatomic point of the femoral tunnel, whereas a tibial tunnel that is too shallow may result in breakage of its anterior wall. Furthermore, after ACLR with the LARS, healing of the synthetic ligament to bone is not expected. Thus, secure fixation of the device by a metal interference screw is required. Squeezing the graft at the

Table 3. Advantages of Disadvantages of Anatomic Double-Bundle ACLR With LARS

Advantages
When we are pursuing ultra-strong ACLR, double-bundle ACLR with the LARS meets the requirements.
Through transtibial methods, the femoral tunnels are created with optimal directions and lengths.
Through transtibial femoral tunnel creation, the high tip of the lateral tibial eminence is removed to eliminate inferior impingement of the graft.
Disadvantages
Too-deep placement of the interference screws reduces fixation security, whereas too-shallow placement of them results in irritation of the overlying soft tissue by the screws and ligament stumps.
Precise location of the femoral tunnels requires complete debridement of the lateral wall of the femoral notch and results in ACL stump removal, which may lead to impediment of soft-tissue ingrowth to the synthetic ligament.
It is somewhat time-consuming to adjust the projection of the tibial tunnel.
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; ACLR, anterior cruciate ligament reconstruction; LARS, ligament advanced reinforcement system.

Table 4. Limitations and Complications Related to ACLR With LARS

ACLR with the LARS may be related to high failure rates, ranging from 15.4% to 33.3% at mid-term follow-up.[1-4,17]
ACLR with the LARS may result in severe synovitis.[18-20]
ACLR with the LARS may result in severe osteoarthritis or chondrolysis.[21,22]
ACLR with the LARS may result in massive foreign body reaction and severe osteolysis.[23]

ACLR, anterior cruciate ligament reconstruction; LARS, ligament advanced reinforcement system.

outer cortical orifices is critical. Otherwise, placing the entire screw into the cancellous bone tunnel will reduce the fixation strength.

The main concern with our 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 occurs with the proper location of the inner orifice of the tibial tunnel and spatial projection control. In the seldom cases in which anterior wall breakage occurs owing to a location that is too anterior and an angulation that is too large, fixation of the device at a more distal position with staples is performed. Although, in the literature, ACLR with the LARS has posed some limitations and has been related to some low-incidence complications (Table 4), it is worth pursuing advances in ACLR with the LARS for better clinical outcomes.[16]

Disclosures

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