



# Anatomic Double-Bundle ACL Reconstruction With Extra-articular Anterolateral Ligament Reconstruction and Internal Brace

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**Abstract:** Anterior cruciate ligament reconstruction (ACLR) with additional procedures could be necessary for patients with increased preoperative pivot shift. Double-bundle (DB) ACLR provides more footprint coverage and recreates the 2 functional anteromedial (AM) and posterolateral (PL) bundles, which are believed to give better joint function and stability than single-bundle (SB) ACLR. Internal brace augmentation with suture tape is proposed along with tendon graft in ACLR to protect the newly reconstructed ligament during rehabilitation. Additional reconstruction with anterolateral ligament (ALL) during ACLR has shown significant reduction in the level of persistent pivot shift. In Technical Note we present a modified surgical technique of combined anatomic DB ACLR and ALLR with hamstring autograft and internal brace, using button suspensory fixation device and aperture screws. The objective of this technique is to decrease residual anterior and rotational instability after ACLR and ALLR.

Double-bundle (DB) anterior cruciate ligament reconstruction (ACLR) gives better joint function and stability than single-bundle (SB) ACLR biomechanically.<sup>1</sup> Suture tape augmentation has been proposed to protect the newly reconstructed ligament during rehabilitation.<sup>2</sup> The anterolateral ligament (ALL) has been reported to have a synergistic function with ACL toward the stability of knee rotation.<sup>3-5</sup>

In this Technical Note we present a modified surgical technique of combined anatomic DB ACLR and ALLR

with hamstring autograft and internal brace, using button suspensory fixation device and aperture screws. The objective of this technique is to decrease the residual anterior and rotational instability after ACLR and ALLR.

## Technique

### Surgical Indications

The indications for anatomic DB ACLR and ALLR with hamstring autograft and internal brace are shown in Table 1.

### Patient Preparation and Bony Landmarks

The patient is positioned supine with a leg holder. Bony landmarks are marked as follows: lateral and medial joint lines, lateral femoral epicondyle, tibial tuberosity, fibular head, Gerdy's tubercle, and anterolateral ligament footprint (Fig 1).

### Table 1. Indications

- Grade 2 pivot shift or greater
- Athletes participating in pivoting contact sports
- Severe anterior laxity (side-to-side difference >10 mm)
- Length of the anterior cruciate ligament footprint on the femoral and tibial sides >14 mm
- Width of femoral intercondylar notch >12 mm

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The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

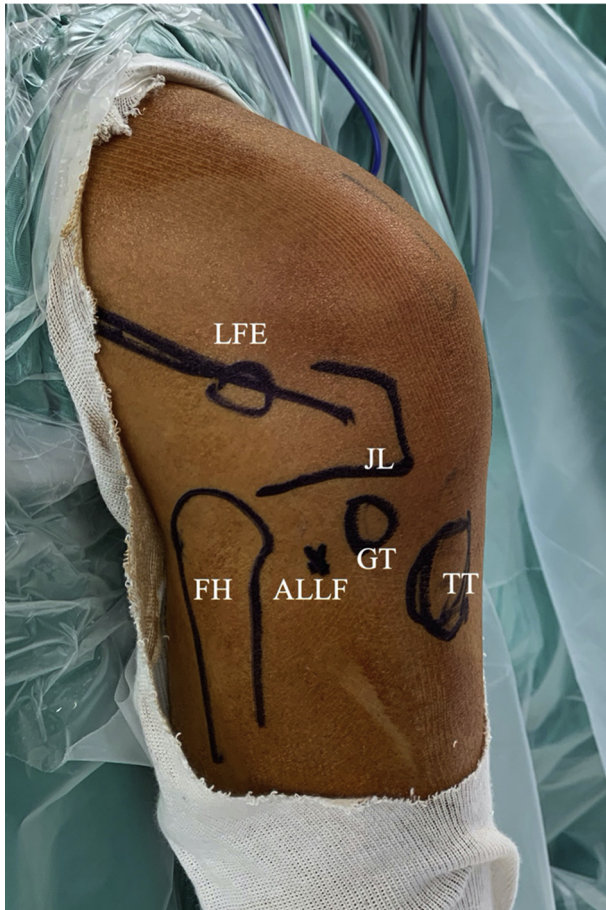
Received June 16, 2020; accepted October 29, 2020.

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2212-6287/201154

<https://doi.org/10.1016/j.eats.2020.10.069>



**Fig 1.** Bony landmarks of DB ACLR and ALLR for right knee in a leg holder. ACLR, anterior cruciate ligament reconstruction; ALLF, anterolateral ligament footprint; ALLR, anterolateral ligament reconstruction; DB, double-bundle; FH, fibular head; GT, Gerdy's tubercle; JL, joint line; LFE, lateral femoral epicondyle; TT, tibial tuberosity.

## Surgical Technique

### Graft Harvesting

The semitendinosus and gracilis autografts are harvested with full length from the insertion site with a tendon stripper.

### Graft Preparation: AM Bundle

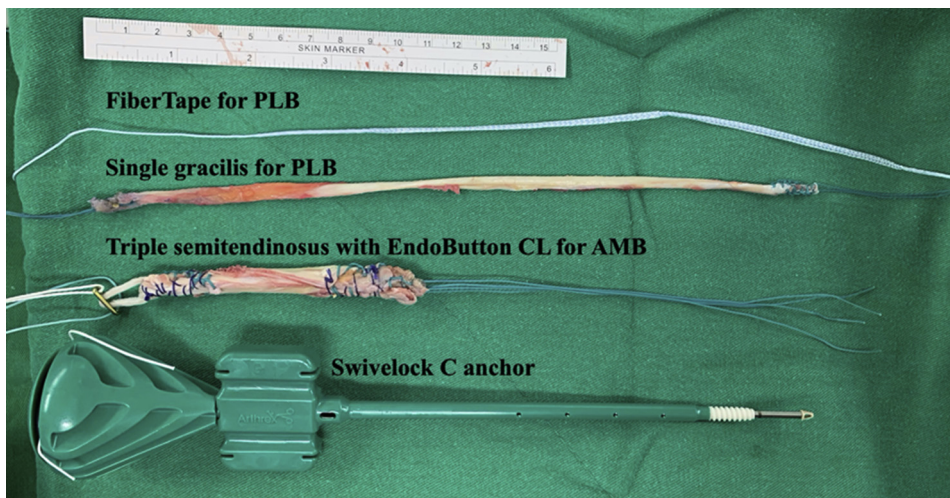
The semitendinosus is prepared in a triple-folded fashion, with tibial ends sutured with no. 2 Ethibond (Ethicon, Somerville, NJ). A 15-mm EndoButton CL (Smith & Nephew Endoscopy, Andover, MA) is attached at the femoral side for AMB fixation. The diameter of the graft is 7 to 9 mm, and the length of the graft is ~850 to 900 mm according to the tendon quality harvested (Fig 2).

### Graft Preparation: PL Bundle and ALL Graft

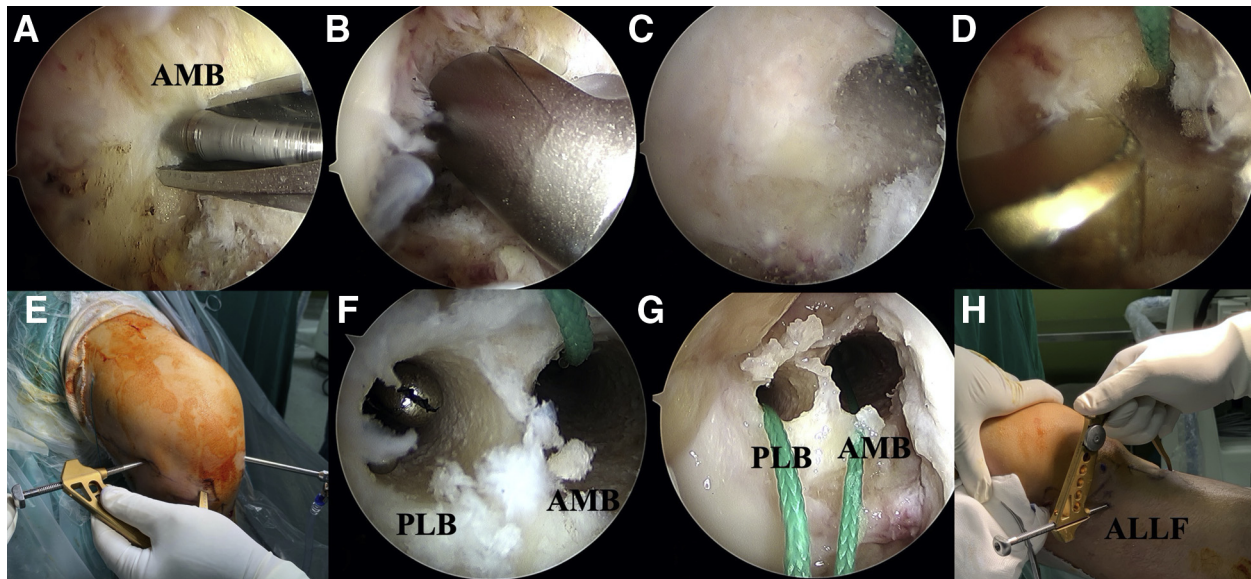
The gracilis is whipstitched with no. 2 Ethibond sutures at both ends without folding. The FiberTape (Arthrex, Naples, FL) is taken from one 4.75 × 19.1-mm Biocomposite Swivelock C anchor (Swivelock C; Arthrex). It is shuttled together with gracilis tendon as an internal brace for PLB and ALL (Fig 2).

### Femoral and Tibial Tunnel Preparation: Femoral AM Tunnel

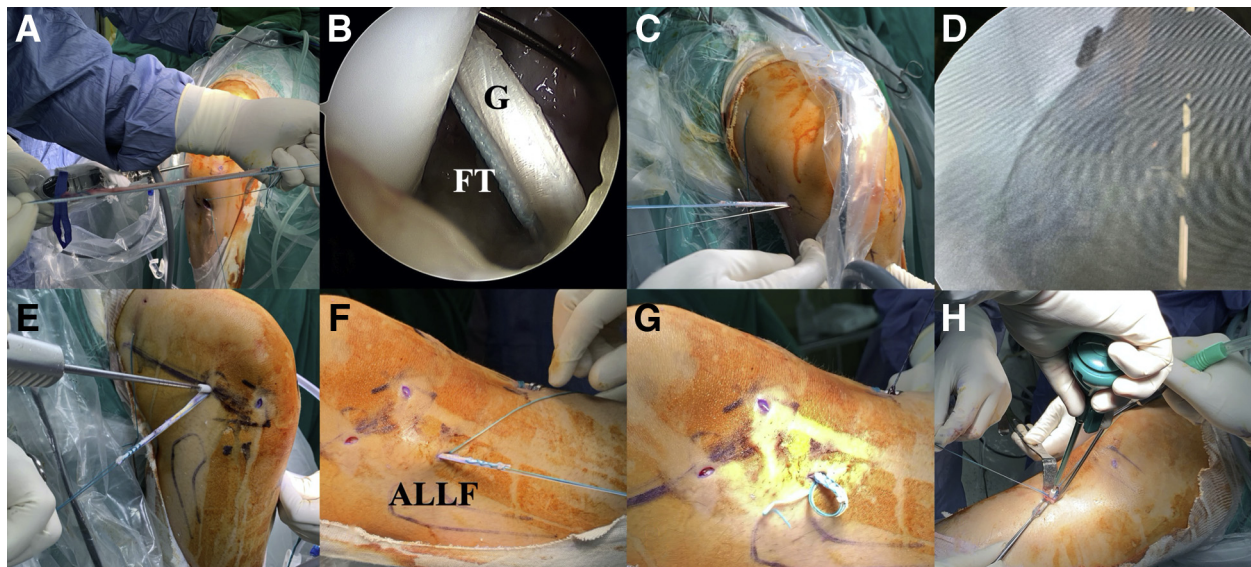
The ACL remnant is kept, and the centers of AMB and PLB are marked with a microfracture awl inserted from the anteromedial portal (AMP) under direct vision using a 30° arthroscope from the anterolateral portal (ALP). A Clancy curved drill guide (Smith & Nephew) is introduced through the AMP, ensuring its tip rests in the middle of the AMB femoral footprint (Fig 3A). A flexible passing pin is then inserted through the curved drill guide and advanced through the femoral condyle until it exits the distal thigh. Sounding of the lateral



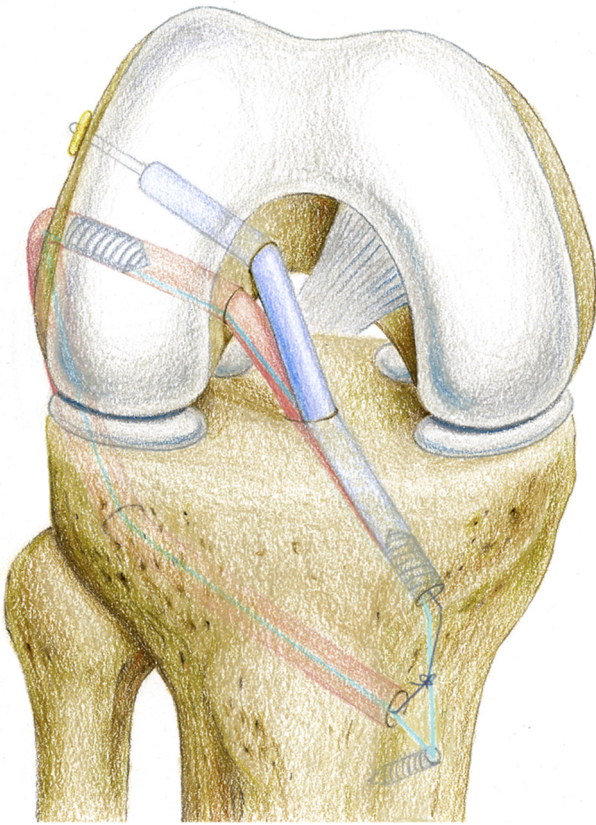
**Fig 2.** Graft preparation and instruments needed for fixation. The semitendinosus is prepared in a triple-folded fashion, with tibial end sutured with no. 2 Ethibond. A 15-mm EndoButton CL is attached at the femoral side for AMB fixation. The gracilis is whipstitched with no. 2 Ethibond at both ends without folding. The FiberTape is taken from one 4.75 × 19.1-mm Biocomposite Swivelock C anchor. AMB, anteromedial bundle; PLB, posterolateral bundle.



**Fig 3.** Femoral and tibial tunnel preparation. (A) Viewing from anterolateral portal (ALP) of right knee, a Clancy curved drill guide is introduced through the anteromedial portal (AMP). A flexible passing pin is aimed at the middle of the AMB femoral footprint and advanced through the femoral condyle until it exits the distal thigh. (B) A Clancy flexible reamer is inserted over the passing pin and advanced to the determined depth. (C) A no. 5 Ethibond suture is shuttled through the AMP and pulled out from proximal femoral cortex. (D and E) Viewing from AMP, a outside-in ACL drill guide is introduced from the ALP with the tip placed at the center of the PLB femoral footprint. The drill sleeve is placed just proximally and posteriorly to the lateral femoral epicondyle. (F) A 5-mm-wide femoral tunnel is created by a rigid reamer in an outside-in manner. A suture grasper is put in the femoral PL tunnel for further suture passing. (G) After tibial ACL tunnel is made, one no. 5 Ethibond suture is shuttled through tibial ACL tunnel and taken out from femoral PL tunnel by the grasper that was placed in advanced. This suture is used to shuttle the PLB graft (single gracilis) and FiberTape as an internal brace. (H) The tibial drill guide is set at 55°, and its tip is aimed ~2 cm below ACL tibial tunnel, avoiding undesirable tunnel connection. The cannulated sleeve of the guide is placed posteriorly and proximally to the Gerdy's tubercle (ALL tibial footprint, ALLF). A 5-mm tunnel is created from lateral to medial and forms the ALL tibial tunnel. AMB, anteromedial bundle; PLB, posterolateral bundle.



**Fig 4.** Graft shuttling and fixation of right knee. (A, B, and C) The single gracilis (G) and FiberTape (FT) are tied together with the PLB suture and shuttled intraarticularly through tibial ACL tunnel. They are pulled out from femoral PL tunnel until they exit the skin of lateral thigh. The length outside the lateral femoral cortex should be enough to create extraarticular ALL. (D) The AM bundle graft is an EndoButton on the femoral cortex. (E) A 6 × 25-mm hydroxyapatite interference screw is used to fix the PLB in an outside-in manner. (F) The single G and FT are shuttled from the lateral end of the femoral PL tunnel, underneath the iliotibial band, to the lateral end of the tibial ALL tunnel (ALLF). (G) G and FT are shuttled through the tibial ALL tunnel from lateral to medial side of the tibia, making sure both G and FT are inside ALL tibial tunnel. (H) Augmentation fixation is done by fixing as many sutures as possible intraosseously by a 4.75-mm Swivelock anchor. ALLF, anterolateral ligament footprint.



**Fig 5.** The final anatomic double-bundle ACL reconstruction with extra-articular anterolateral ligament reconstruction and internal brace of right knee. Blue, anteromedial bundle of ACL; red, posterolateral bundle of ACL; light blue, FiberTape.

femoral outer cortex is performed to obtain the total osseous length. The curved drill guide is then removed, and a Clancy flexible reamer is inserted over the passing pin (Fig 3B) and advanced to the determined depth. A no. 5 Ethibond suture is placed through the slot of the flexible guide pin and pulled into the knee through the AMP and then pulled out from the proximal femoral cortex (AMB suture) (Fig 3C). The other side of the suture is retrieved retrogradely through the tibial tunnel once it is made.

#### Femoral and Tibial Tunnel Preparation: Femoral PL Tunnel

After the femoral AM tunnel is made by the flexible reamer, the scope is then shifted into the AM portal. The outside-in ACL drill guide (Smith & Nephew) is introduced from the AL portal with the tip placed at the site of the PLB femoral footprint (Fig 3D, E). Outside the joint, the accompanying drill sleeve is placed just proximally and posteriorly to the lateral femoral epicondyle. After guide pin placement, a 5-mm-wide femoral tunnel is created by a rigid reamer in an outside-in manner. This technique guarantees the femoral AM and PL

tunnels to be positioned divergent to each other and prevents tunnel connection. A suture grasper is put in the femoral PL tunnel for further suture passing (Fig 3F).

#### Femoral and Tibial Tunnel Preparation: Tibia ACL Tunnel

The ACL tibial drill guide is placed in AMP (viewed from ALP) and positioned in the center of the ACL tibial insertion. A tibial tunnel 1 mm larger than the diameter of AMB graft (triple semitendinosus) is made. Then, one no. 5 Ethibond suture is passed from the tibial ACL tunnel into the joint and taken out from the femoral PL tunnel. This suture is used to shuttle the PLB graft (single gracilis) and FiberTape as an internal brace (Fig 3G).

#### Femoral and Tibial Tunnel Preparation: Tibial ALL Tunnel

The tibial drill guide is set at 55°, and its tip is aimed ~2 cm below ACL tibial tunnel, avoiding undesirable tunnel connection. The cannulated sleeve of the guide is placed posteriorly and proximally to the Gerdy's tubercle, where a stamp incision is made (Fig 3H). Then, a pin is drilled from lateral to the medial side of the tibia and a consecutive 5-mm tunnel is created by a rigid reamer. A no. 5 Ethibond suture is then shuttled from lateral to the medial tibia, facilitating further graft passage (tibial ALL tunnel).

#### Graft Shuttling and Fixation

After all tunnels were prepared, there is one no. 5 Ethibond suture from tibial ACL tunnel to femoral AM tunnel (AMB suture) and another suture passed from the tibial ACL tunnel to the femoral PL tunnel (PLB suture) (Fig 3G). The third no. 5 Ethibond suture is placed from lateral tibia ALL footprint to the medial side of the tibia (tibial ALL suture). First, the single gracilis and FiberTape are tied together with the PLB suture (Fig 4A), shuttled intraarticularly through the tibial ACL tunnel, and pulled out from femoral PL tunnel until they exit the skin of lateral thigh (Fig 4B, C). The length outside the lateral femoral cortex should be enough to create extraarticular ALL, which is determined by the length of gracilis incorporated inside the tibial ACL tunnel. In general, the single gracilis is long enough to occupy the full length of the tibial ACL tunnel and  $\geq 25$  mm long inside the tibia ALL tunnel.

Thereafter, the AM bundle suture is tied with both limbs of EndoButton (Smith & Nephew Endoscopy) and shuttled proximally until the button is flipped and fixed on the femoral cortical surface (Fig 4D). A 6 × 25-mm hydroxyapatite interference screw (BioRCI-HA screws; Smith & Nephew) is used to fix the PLB in an outside-in manner (Fig 4E). Then another hydroxyapatite interference screw 1 mm larger than the drilled

**Table 2.** Surgical Steps, Tips, Pearls, and Pitfalls

Surgical Step	Tips and Pearls	Pitfalls
Bony landmarks	Mark lateral and medial joint lines, lateral femoral epicondyle, tibial tuberosity, fibular head, and Gerdy's tubercle.	There may be difficulty in recognizing these landmarks in larger patients.
Graft harvesting	Semitendinosus and gracilis autograft are harvested with full length from the insertion site.	1. A closed/open loop tendon stripper can be used in this technique. 2. All muscle remnants should be cleaned before final harvesting.
Graft preparation	1. Semitendinosus: triple folded, a 15-mm EndoButton CL at the femoral end, Krackow sutures at tibia end (AM bundle graft). 2. Gracilis: not folded, Krackow sutures at both ends (PL bundle graft). 3. FiberTape: from 1 Swivelock C anchor, tied with Gracilis tendon as an internal brace.	1. Other kinds of the suspensory device can be used to fix the AM bundle graft. 2. In general, the single gracilis is long enough to occupy the full length of the tibial ACL tunnel and $\geq 25$ mm long inside the tibia ALL tunnel. 3. Double gracilis, although stronger, may not provide enough length in the tibial ACL tunnel and tibia ALL tunnel.
Femoral AM tunnel preparation	1. View from the anterolateral portal. 2. A Clancy curved drill guide is introduced through the anteromedial portal. 3. A flexible passing pin is inserted through the curved drill guide and advanced through the femoral condyle to obtain the total osseous length. 4. A Clancy flexible reamer is advanced to the determined depth. 5. The size of the flexible reamer used is determined by the diameter of the femoral end of the triple-folded semitendinosus graft.	1. The transportal technique with a rigid reamer to create a femoral AM tunnel is abandoned in this technique to avoid undesirable medial femoral condyle cartilage injury during tunnel drilling. 2. Make sure the posterior wall of the femoral AM tunnel is preserved after AM tunnel preparation
Femoral PL tunnel preparation	1. View from the anteromedial portal. 2. Outside-in ACL drill guide is introduced from the anterolateral portal with the tip placed at the site of the PL bundle femoral footprint. 3. The accompanying drill sleeve is placed proximally and posteriorly to the lateral femoral epicondyle (the femoral footprint of ALL). 4. Create a 5-mm-wide femoral tunnel with a rigid reamer in an outside-in manner. 5. Divergent femoral AM and PL tunnels are created.	1. The chance of AM and PL tunnel coalescence is low because of the different AM and PL tunnel creation techniques. 2. The IT band should be opened thoroughly through the small incision, facilitating reamer drilling and further gracilis graft and FiberTape passing beneath it.
Tibial ACL tunnel preparation	1. The ACL tibial drill guide is placed from the anteromedial portal and positioned in the center of the ACL tibial insertion, viewed from the anterolateral portal. 2. A tibial tunnel 1 mm larger than the diameter of AMB graft (triple semitendinosus) is made. 3. One no. 5 Ethibond suture is passed from the tibial ACL tunnel into the joint and then taken out from the femoral PL tunnel.	Be sure not to damage the suture passed through the femoral AM tunnel, which will be used to shuttle the AMB graft into the femoral AM tunnel later, during tibial ACL tunnel drilling.

(continued)

**Table 2.** Continued

Surgical Step	Tips and Pearls	Pitfalls
Tibial ALL tunnel preparation	<ol style="list-style-type: none"> <li>4. This suture will be used to shuttle the PLB graft (single gracilis) and FiberTape as an internal brace.</li> <li>1. The tibial drill guide is set at 55° with its tip aimed ~2 cm below the entrance of the ACL tibial tunnel, avoiding undesirable tunnel connection.</li> <li>2. The cannulated sleeve of the guide is placed posteriorly and proximally to the Gerdy's tubercle (the tibial footprint of ALL).</li> <li>3. A pin is drilled from lateral to the medial side of the tibia.</li> <li>4. A 5-mm tunnel is created by a rigid reamer.</li> <li>5. A no. 5 Ethibond suture is then shuttled from lateral to the medial tibia, facilitating further graft passage.</li> </ol>	<ol style="list-style-type: none"> <li>1. The degrees of tibial drill guide can be set according to the size of the patient. The main objective is to drill a tibial ALL tunnel from lateral to the medial side of the tibia, facilitating graft passage.</li> <li>2. The exit of the medial side of the tibia ALL tunnel should be apart from the entrance of the tibial ACL tunnel, decreasing the chance of tibial fracture.</li> </ol>
Graft shuttling and fixation	<ol style="list-style-type: none"> <li>1. First, the single gracilis and FiberTape are tied together with the PLB suture, shuttled intraarticularly through the tibial ACL tunnel, and pulled out from the femoral PL tunnel until they exit the skin of the lateral thigh. The length outside the lateral femoral cortex should be enough to create extra-articular ALL, which can be determined by the length of gracilis incorporated inside the tibial ACL tunnel.</li> <li>2. The AM bundle suture is then tied with both limbs of EndoButton and shuttled proximally until the button is flipped and fixed on the femoral cortical surface.</li> <li>3. A 6 × 25-mm hydroxyapatite interference screw is used to fix the PLB in an outside-in manner.</li> <li>4. A hydroxyapatite interference screw 1 mm larger than the drilled tibial ACL tunnel is used to fix the tibial end in the tibial ACL tunnel for both grafts and FiberTape at 60° knee flexion.</li> <li>5. The single gracilis and FiberTape are shuttled from the lateral end of the femoral PL tunnel, underneath the iliotibial band, to the lateral end of the tibial ALL tunnel as the ALLR.</li> <li>6. The single gracilis and FiberTape are then shuttled to the medial side of the tibia through the lateral side of the tibia ALL tunnel.</li> <li>7. Both limbs of no. 2 Ethibond sutures of the gracilis and FiberTape are tied together with the other ends at 20° knee flexion and neutral knee rotation.</li> <li>8. An augmented fixation is done by fixing as many sutures as possible intraosseously by a 4.75-mm Swivelock anchor.</li> </ol>	<ol style="list-style-type: none"> <li>1. Make sure the AM bundle suture lies in front of PLB graft before shuttling inside the joint. This method provides more anatomic orientation of both bundles.</li> <li>2. Some tension of PLB should be applied when shuttling the AMB graft inside the joint, avoiding strangulation of passed PLB graft with moving AMB graft.</li> <li>3. Be sure to keep the knee at 20° flexion and neutral rotation to avoid overconstraint of the lateral compartment when tying the gracilis and FiberTape.</li> </ol>

ACL, anterior cruciate ligament; ALL, anterolateral ligament; ALLR, anterolateral ligament reconstruction; AM, anteromedial; AMB, anteromedial bundle; IT, iliotibial; PL, posterolateral; PLB, posterolateral bundle.

**Table 3.** Advantages, Risks, and Limitations**Advantages**

1. The ACL femoral footprint can be occupied by as many sutures as possible with this intra-articular double-bundle technique.
2. Different preparation methods for femoral AM and PL tunnel are used (AM tunnel, transportal drilling with a flexible reamer; PL tunnel, outside-in drilling with a rigid reamer), which creates a divergent trajectory of both tunnels, avoiding undesirable tunnel coalescence.
3. Lateral augmentation of the knee (anterolateral ligament reconstruction in the index technique) can be accomplished without harvesting the iliotibial band.
4. Isometric points of anterolateral ligament fixation are used (proximally and posteriorly to the lateral femoral epicondyle and just posteriorly and proximally to the Gerdy's tubercle).
5. Only 2 stabbing wounds are needed in the lateral knee. It is less invasive than the Lemaire procedure.

**Risks**

1. Chances of tunnel coalesce, although low, may still occur between femoral AM/PL tunnel, and tibia ACL/ALL tunnel.
2. Nonisometric tunnel creation may still occur, especially in oversized patients.
3. The femoral interference screw at the femoral PL tunnel may be too prominent to cause painful friction symptoms with the iliotibial band and should be checked before wound closure.
4. The gracilis tendon and FiberTape should pass beneath the iliotibial band; otherwise, it will cause lateral knee impingement and pain.

**Limitations**

1. The diameter of the triple-folded semitendinosus graft is normally <8 mm (7 to 8 mm). Therefore, another bundle of graft intra-articularly should be reconstructed (the PLB with single gracilis and FiberTape).
2. The diameter of the single-strand gracilis graft is normally <5 mm. However, if it is folded twice, the length of the prepared graft (as the PL bundle) may not be long enough to provide  $\geq 25$  mm inside the tibia ALL tunnel.
3. Therefore, a FiberTape from a 4.75-mm Swivelock anchor is used for augmentation with the single-strand gracilis tendon to provide initial stability and increase the diameter of the PL bundle.
4. The absolute indications are not wholly established yet.

tibial ACL tunnel is used to fix the tibial end in the tibial ACL tunnel of both grafts and FiberTape at 60° knee flexion.

Last, the single gracilis and FiberTape are shuttled from the lateral end of the femoral PL tunnel, underneath the iliotibial band, to the lateral end of the tibial ALL tunnel as the ALLR (Fig 4F). They are then shuttled through the tibial ALL tunnel from lateral to medial side of the tibia, making sure both gracilis and FiberTape are inside ALL tibial tunnel (Fig 4G). Then both limbs of no. 2 Ethibond sutures of the gracilis and FiberTape are tied together at 20° knee flexion and neutral knee rotation. Augmentation fixation is done by fixing as many sutures as possible intra-osseously by a 4.75-mm Swivelock anchor (Fig 4H).

The final construct is shown in Fig 5. The whole procedure of the surgery is shown in the Video 1. The pearls and pitfalls of the surgical steps are shown in Table 2. The advantages, risks, and limitations of this technique are shown in Table 3.

**Postoperative Management**

The postoperative rehabilitation protocols are summarized in Table 4.

**Discussion**

There are 11% to 30% recurrent and persistent instabilities reported after ACLR.<sup>6,7</sup> Anatomic ACLR with additional procedures is probably necessary for patients with increased preoperative rotational instability.<sup>8,9</sup>

DB ACLR has been proven to provide improved knee rotational stability.<sup>10</sup> Suture tape augmentation has been proposed to be used along with allograft or autograft ACLR<sup>11,12</sup> with lower failure rates than the conventional ones.<sup>13,14</sup> The objective of suture tape augmentation is to protect the newly reconstructed ligament during rehabilitation.<sup>2</sup>

Inderhaug et al.<sup>15</sup> showed that intra-articular ACLR alone would not reestablish normal kinematics after combined ACL and anterolateral injury. A 2018 survey found that 38% of respondents used some type of adjunctive anterolateral reconstruction for selected cases.<sup>16</sup> ALL was reported to have a synergistic function with ACL toward the stability of knee rotation<sup>3-5</sup> without increasing long-term risk of osteoarthritis.<sup>17,18</sup> It was also associated with a 2-fold reduction in the failure rate of medial meniscus repair and a 3-fold reduction in ACL graft rupture rates.<sup>9,19</sup>

Graft fixation also impacts the stability and healing of ACLR. Cortical suspensory fixation is characterized by circumferential graft-to-tunnel healing. Different fixation methods have been reported in the literature when ACLR and ALLR are considered.<sup>19</sup> Sonnery-Cottet et al.<sup>19</sup> fixed their autologous hamstring tendon with aperture screws, and Boutsidiadis et al.<sup>20</sup> used adjustable-loop suspensory fixation device with aperture screws. Both groups recreated SB ACLR and ALLR successfully. In the current study, we develop this technique to provide DB ACLR with ALLR at the same time. Further clinical results should be followed to discover the clinical significance in reducing residual rotational instability in comparison to conventional techniques.

**Table 4.** Postoperative Management

Activity	Timing Postoperatively
Jogging	3 months
Sprinting and competitive exercises	6 months
Return to full sports activities	9 months
Patients without meniscus repair	
No brace needed	
Continuous passive motion	Immediately after surgery
Walking with crutches	First 2 weeks
Full weightbearing	After 2 weeks
Patients with meniscus repair	
ROM brace	First 6 weeks
0° to 60°	First 4 weeks
Full range of motion	After 4 weeks
Partial weightbearing with crutches	First 4 weeks

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