Technical Note

Over-the-Top Double-Bundle Revision Anterior Cruciate Ligament Reconstruction Technique With Hybrid Hamstring Tendon Autograft-Allograft and Associated Lateral Extra-articular Tenodesis

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Abstract: Revision anterior cruciate ligament (ACL) presents many technical challenges that are not commonly seen in primary ACL reconstruction. The purpose of this article is to describe an alternative technique consisting of over-the-top double-bundle ACL revision combined with lateral extra-articular tenodesis using hybrid hamstring tendon autograft-allograft. This technique provides a valid treatment option in ACL revision surgery.

With increasing anterior cruciate ligament (ACL) reconstruction and higher exercise demand, the incidence of failure of primary ACL reconstruction (ACLR) is also increasing year by year.[1] Because of the technical issues involved in revision ACLR with regard to persistent rotatory instability, malpositioned or widened tunnels, and limited graft options, revision ACLR is more challenging than primary reconstruction.[2]

In revision ACLR, a single-stage technique and over-the-top (OTT) procedure are usually selected in cases where a bone tunnel cannot be created at an anatomical position because of tunnel enlargement and overlap with the malpositioned tunnel of primary ACLR or cases with open physes.[3] Owing to providing excellent rotatory stability, lateral extra-articular tenodesis (LET) is usually combined with the OTT procedure in revision ACLR.[4,5] The newly research reveals by Grassi et al. the OTT ACLR demonstrated good clinical outcomes in laxity control at 10-year minimum follow-up and did not generate lateral knee or patellofemoral osteoarthritis.[6] Although satisfactory clinical outcomes have been reported for OTT ACLR, there are still some concerns, including graft slippage from the lateral posterior condyle, anterior laxity at deep knee flexion angles, and nonanatomic graft position.[7] To address the concerns regarding OTT reconstruction and make good use of the initial tunnel in revision ACLR, this article presents an alternative single-stage technique for revision ACLR combining the OTT double-bundle technique using autograft-allograft hybrid hamstring tendon with modified Lemaire LET augmentation, as previously described by Grassi et al.[6] and Ferretti et al.[8]

Surgical Technique

Preoperative Planning

A thorough history includes the patient's basic information and the surgical method of the primary reconstruction so as to assess the factors contributing to the failure of primary ACLR. Preoperative radiographic images include a series of x-rays, full-length alignment films, and 3-dimensional computed tomography evaluating the prior graft tendon, prior tunnel locations, tunnel bone dissolution, and intercondylar socket stenosis. Magnetic resonance imaging is used to assess concomitant injuries such as meniscal tear or cartilage damage after the primary ACLR. The location of these previous tunnels can be classified according to 3

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Received October 11, 2023; accepted December 31, 2023.

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2212-6287/231474

https://doi.org/10.1016/j.eats.2024.102944

situations in the 3-dimensional computed tomography image: (1) anatomic, (2) nonanatomic (does not overlap with the anatomic ACL footprint), and (3) semi-anatomic (does overlap with the anatomic footprint).[3] Scenarios 1 and 2 are usually solved in a one-stage operation by enlarging the prior tunnel and drilling a newly revised tunnel in the anatomic location, respectively. Scenario 3 is usually managed with two-stage surgery; namely, bone grafting in the previous tunnel followed by ACLR revision a few months later. However, the double-bundle OTT technique described in this article can provide a first-stage surgical option for cases where the primary femoral tunnel was close to the site of the posterolateral bundle, and there was not enough space to recreate the idea single bundle femoral tunnel.

OTT Double-Bundle ACLR Revision

Standard Knee Arthroscopy Examination and Management

Patients lie supine under spinal or general anesthesia and a tourniquet is applied to the thigh. Anteromedial and anterolateral portals are made to perform the diagnostic arthroscopy (Fig 1, Video 1). Before performing the OTT ACLR revision, menisci and articular cartilage are evaluated and treated if needed.

Hamstring Tendon Harvesting and Preparation

A small 3-cm oblique skin incision is made on the anteromedial proximal tibia. The semitendinosus and gracilis tendons are harvested with an open tendon stripper. At the same time, the allograft is added, and the 3 tendons are braided into a 25-cm tendon and sutured using No. 2 FiberWire (Arthrex, Naples, FL) (Fig 2, Video 1). Before drilling the bone tunnels, the diameter of graft tendon is measured and later wrapped in wet gauze.

Femoral Tunnel Preparation

For the femoral tunnel preparation, the arthroscope is moved to the anteromedial portal to improve visibility of the posterior aspect of the lateral femoral condyle and prior femoral tunnel (Fig 3, Video 1). In this case, we make full use of the primary femoral position of the posteromedial bundle. The residual soft tissue in the tunnel from the previous surgery is carefully debrided. (Importantly, any soft tissue obstructing the OTT position must be carefully debrided.) Subsequently, a small 3- to 5-cm incision is made around the lateral femoral condyle to reach the posterior joint capsule. A curved Kelly clamp with a suture loop is passed from the posterior joint capsule to the lateral posterior condyle (Fig 4, Video 1). The suture loop is then pulled out from the tibial tunnel as railroad the graft in anteromedial bundle position. Another suture loop is passed from the

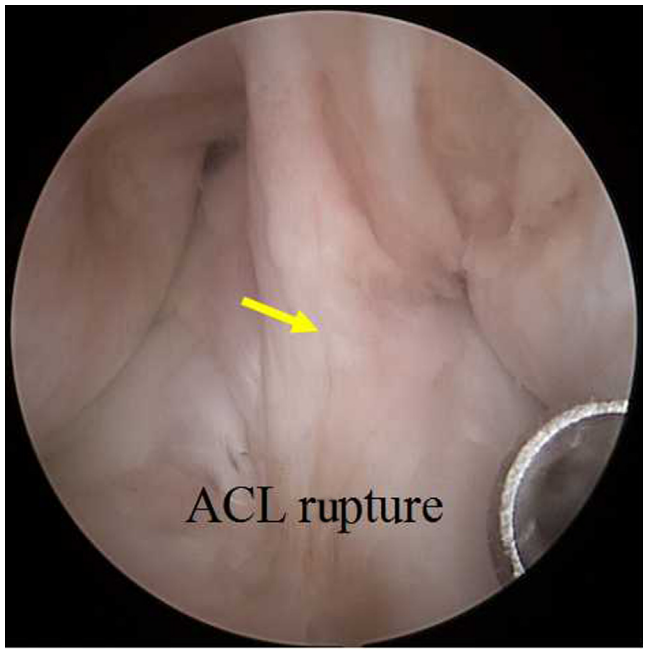

Fig 1. Patients lie supine under spinal or general anesthesia. Anteromedial and anterolateral portals are made to perform diagnostic arthroscopy. The primary ACL rupture (yellow arrow) is observed via the anteromedial portal under arthroscopy. (ACL, anterior cruciate ligament.)

anteromedial portal into the primary tunnel by the suture passer and pulled out from the tibial tunnel as railroad the graft in posterolateral bundle position (Fig 5, Video 1).

Tibial Tunnel Preparation

For the tibial tunnel preparation, the soft tissues and hardware in the tibial tunnel are debrided thoroughly to cancellous bone (Fig 6, Video 1). Subsequently, the position of the anterior tibial tunnel is carefully

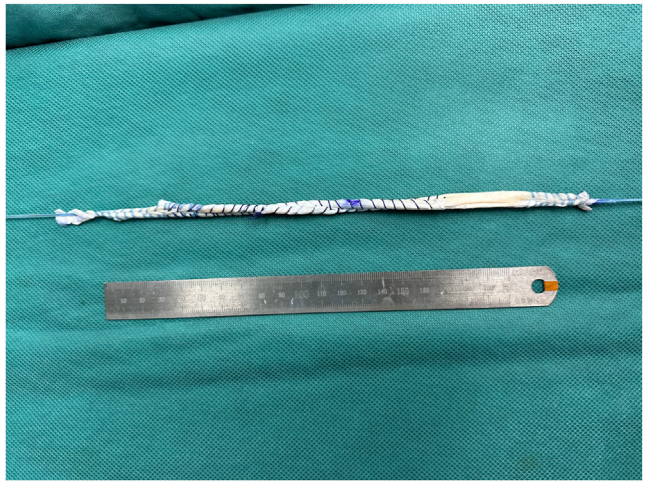

Fig 2. Intraoperative view of the hybrid hamstring tendon autograft-allograft sutured with No. 2 FiberWire.

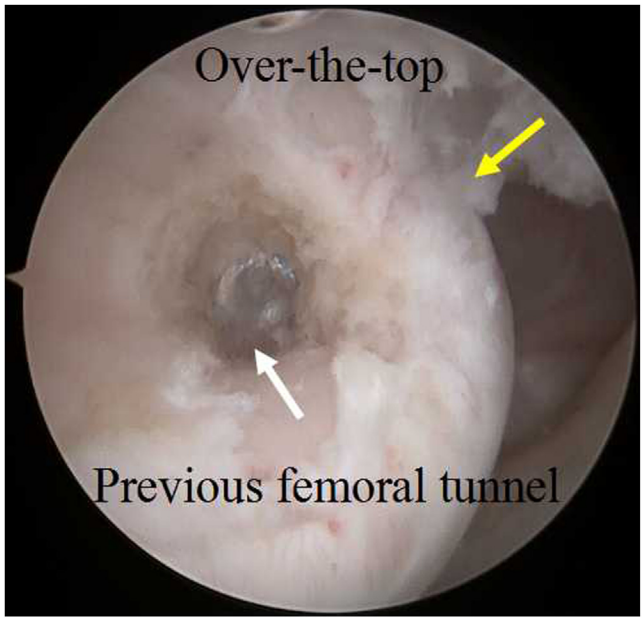

Fig 3. The previous femoral tunnel (white arrow) and over-the-top position (yellow arrow) from the failed anterior cruciate ligament reconstruction are observed via the anteromedial portal under arthroscopy.

evaluated. If the tibial tunnel position is appropriate, the corresponding tibial tunnel is reamed to appropriate diameter of tendon graft. First, a 2.0 guide pin is inserted along the primary tibial tunnel and a straight reamer is passed through the guide pin starting at 8 mm, gradually reaching the appropriate tunnel. The

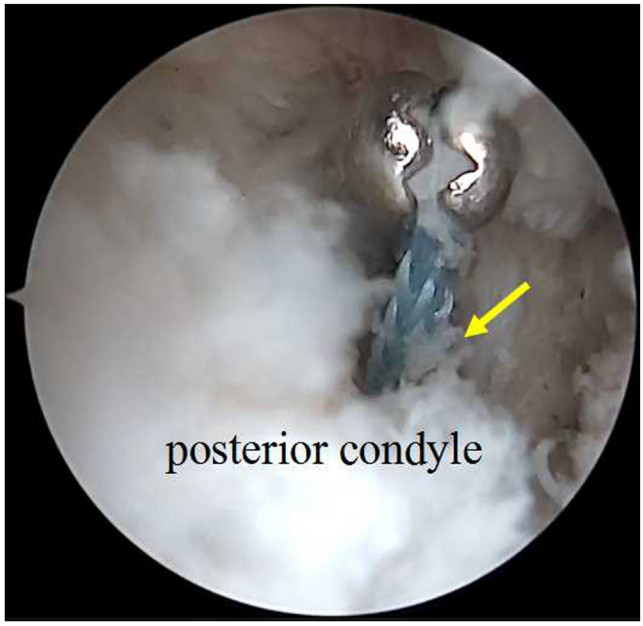

Fig 4. A curved Kelly clamp with a suture loop is passed from the posterior joint capsule to the lateral posterior condyle (yellow arrow).

suture loops of the femoral tunnel and OTT position are pulled out separately from the tibial tunnel. The tendon graft is pulled through the OTT position and then pulled into the primary femoral tunnel from the OTT position by the pre-positioned suture loop, finally penetrating the tibial tunnel. After repeated knee flexion and extension activities to test the isometric properties of the tendon graft, it is tensioned and fixed using a 25-mm length PEEK interference screw (Arthrex, Naples, FL) (Fig 7, Video 1). Finally, the free sutures of the tendon graft are again fixed with a 4.75-mm SwiveLock (Arthrex, Naples, FL).

Lateral Extra-articular Tenodesis

The incision of the lateral femoral condyle is extended to 2 cm above Gerdy's tubercle. Later, cut the subcutaneous fat and expose the iliotibial band (ITB). The 8-cm long and 1-cm wide ITB is detached from Gerdy's tubercle, and the free end of the detached ITB is sutured with a No. 2 FiberWire. Next, the lateral collateral ligament is confirmed by palpation. Finally, the sutured ITB is passed under the lateral collateral ligament and fixed into the lateral condyle of the femur via interference screw (Fig 8, Video 1).

Discussion

Compared with primary ACLR, ACLR revision is accompanied by a higher failure rate and a lower level of activity, and these worse outcomes are aggravated in ACLR revision because of extensive femoral tunnel osteolysis or overlap between prior and planned tunnels.[9] Consequently, two-stage ACL revision is commonly performed after tunnel bone graft is accomplished.[2] Although numerous studies have demonstrated that two-stage ACL revision may lead to satisfactory outcomes, it takes at least 3 months for the bone graft to heal after revision surgery, and the risk of additional intra-articular injury is increased because of residual knee instability during this period.[10] In addition, the limited graft, increased recovery time, and expensive clinical fees are other concerns.

The OTT technique was originally described and reported good clinical outcomes later for primary ACLR by Grassi et al and Roberti di Sarsina et al.[6,11] Currently, numerous surgeons are vulnerable to using the OTT technique in revision ACLR because of eliminating the influence of prior femoral tunnel malpositioning or widening and permitting the surgeon to perform a single-stage revision ACLR.[3,12] Kamei et al. reported the OTT technique had 8.4% failure rate and good functional outcomes equivalent to those of anatomic single- and double-bundle revision ACLR.[13,14] As for persistent rotatory instability, LET has been demonstrated to improve biomechanical stability and gradually popular combined with the OTT technique in revision ACLR[15] a prospective study has

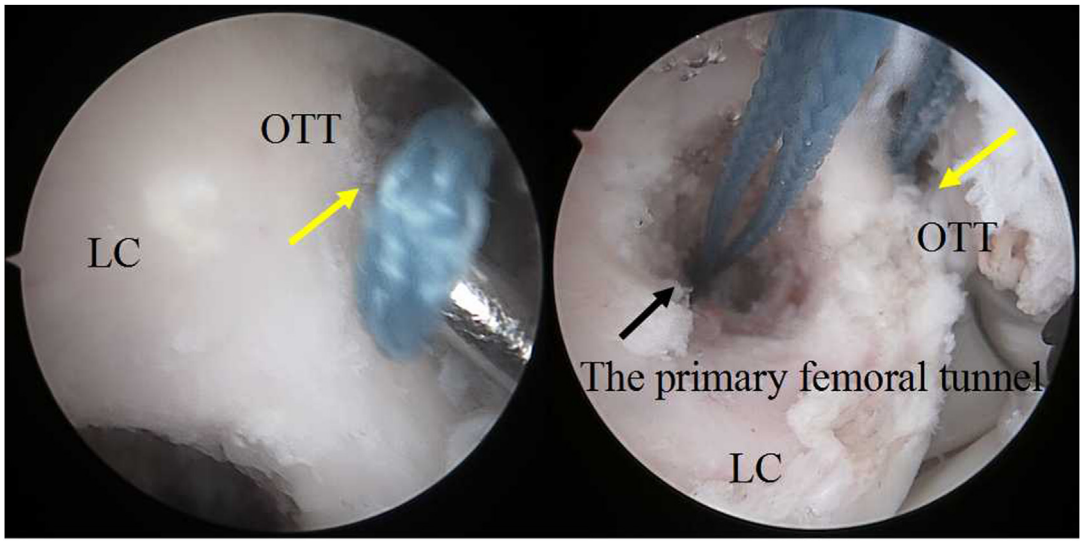

Fig 5. The OTT suture (yellow arrow) and the primary femoral tunnel (black arrow) are retrieved through the tibial tunnel by the suture passer. (LC, lateral condyle; OTT, over-the-top.)

demonstrated that LET combined with OTT ACLR has favorable long-term clinical outcomes in 86% of patients.[16] Recent studies by Grassi et al.[6] and Zaffagnini et al.[15] have shown that OTT combined with LET has good clinical results and low re-rupture rates at 10-year follow-up. Furthermore, it does not increase the risk of lateral compartment osteoarthritis. However, some researchers have concerns that previous clinical studies have also shown a high risk of graft slippage from the lateral posterior condyle after OTT ACLR, which results in slackening of the graft and eventual failure.[7] In addition, in the case of extreme knee flexion, relaxation of ligaments and poor stability have always been concerns, especially in ACL revision.

Double-bundle ACLR has been shown to be superior to traditional single-bundle ACLR in terms of rotational stability.[17] In addition, a recent study by Zaffagnini et al.[18] revealed that double-bundle ACLR better controls pivot shift compared with single-bundle ACLR by means of a navigation system. The initial double-bundle OTT technique was performed in 2003 by Marcacci et al.[19] in patients with primary ACLR. In their OTT technique, the gracilis and semitendinosus tendons were harvested, maintaining their tibial insertion; passed separately through the femoral tunnel, OTT position, and tibial tunnel; and ultimately secured with a transosseous suture knot. In 2012, Marcacci et al.[20] subsequently demonstrated a nonanatomic OTT

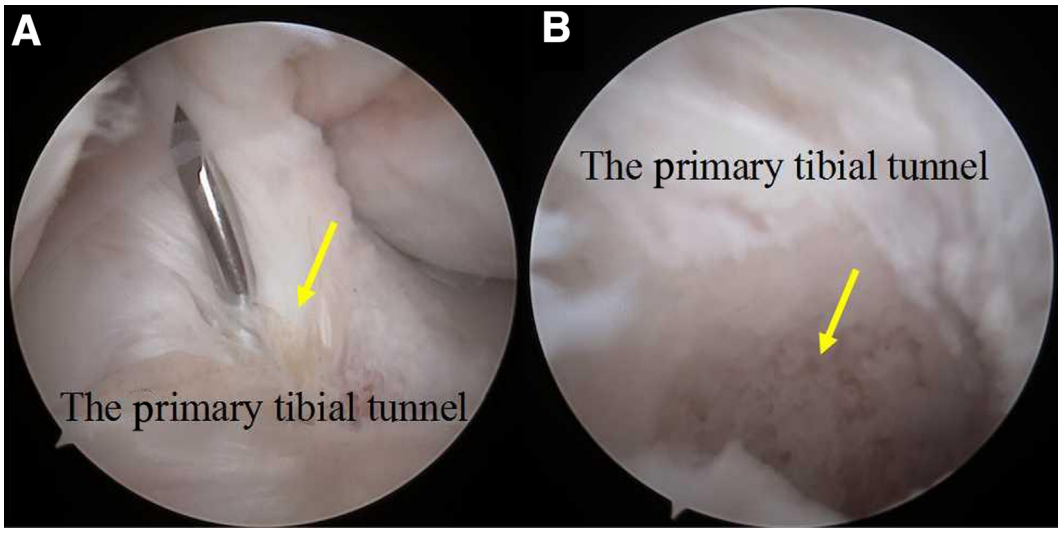

Fig 6. (A) The guide pin is inserted over the primary ACL tibial footprint. (B) Debridement of the primary tibial tunnel to cancellous bone. (ACL, anterior cruciate ligament.)

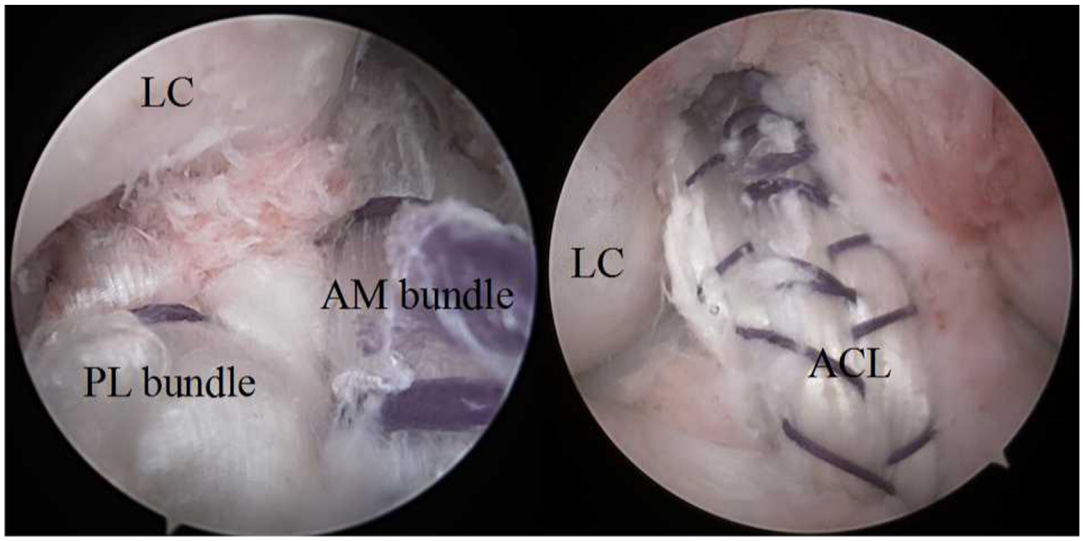

Fig 7. Final presentation of the intra-articular ACL graft. (ACL, anterior cruciate ligament; AM, anteromedial; LC, lateral condyle; PL, posterolateral.)

double-bundle ACLR revision using a fresh frozen Achilles tendon allograft with soft tissue fixation.

Unlike the technique used in 2003 by Marcacci et al.,[19] in this technique, the novel OTT double-bundle revision technique combined with LET using hybrid hamstring tendon autograft-allograft was first performed and introduced (Fig 9). The primary femoral tunnel was used for the posterolateral bundle and the OTT position was used for the anteromedial bundle. Our technique eliminates the need to drill new femoral tunnels in patients with malpositioned and widened tunnels, which avoids subsequent trauma and possible pitfalls preparing the femoral tunnels. It can also decrease the risk of graft slippage because the tendon graft goes through femoral tunnels. Moreover, we combined LET with double-bundle OTT ACL revision by the ITB, which increases the stability of knee. In addition, we did not depend on the total graft length compared with the technique by Marcacci et al.[19] Instead of the divided tendon and soft tissue fixation at the OTT position, the interference screw fixation and complete graft tendon in our technique might show stronger biomechanical properties.

Improper selection of tendon graft is a very important factor in failure of primary ACLR. Because of the advantages of convenient tendon removal, excellent biomechanical strength, and little influence on the tendon area of patients, hamstring tendon has gradually become the most popular graft for clinicians.[21] However, when using the OTT technique, the double hamstring tendon is not folded, and the diameter cannot meet the requirements of the minimum diameter (6 mm) of the bone tunnel. If the hamstrings are folded in half, they cannot meet the requirements of the shortest tendon length (24 cm) of the OTT technique. Moreover, the autogenous graft choices may be exhausted for the patient in OTT revision ACR. Therefore, we combined allograft with contralateral autograft in OTT ACL revision.

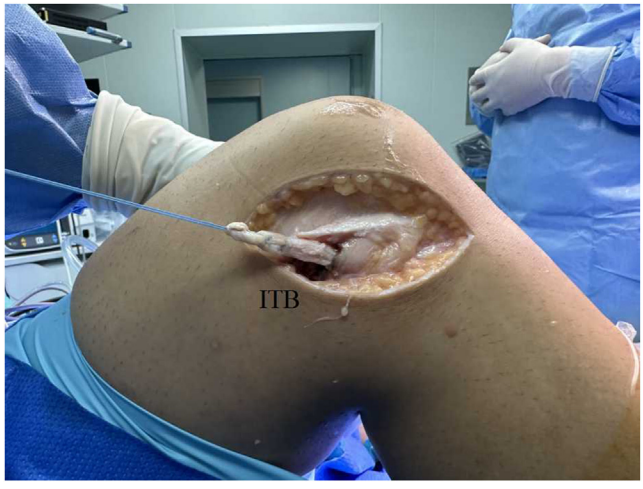

Fig 8. The plasty of the ITB is sutured with a No. 2 FiberWire suture. (ITB, iliotibial band.)

Conclusions

This technical note describes the surgical technique for double-bundle OTT revision ACLR with associated LET by hybrid hamstring tendon autograft-allograft. This technique provides a valid treatment for revision ACLR, especially in patients with malpositioned and widened tunnels which were close to the femoral position of posterolateral bundle. Obviously, the surgical technique described in this article has potential unique advantages and several disadvantages (Tables 1 and 2). Thus, future work is needed to explore the

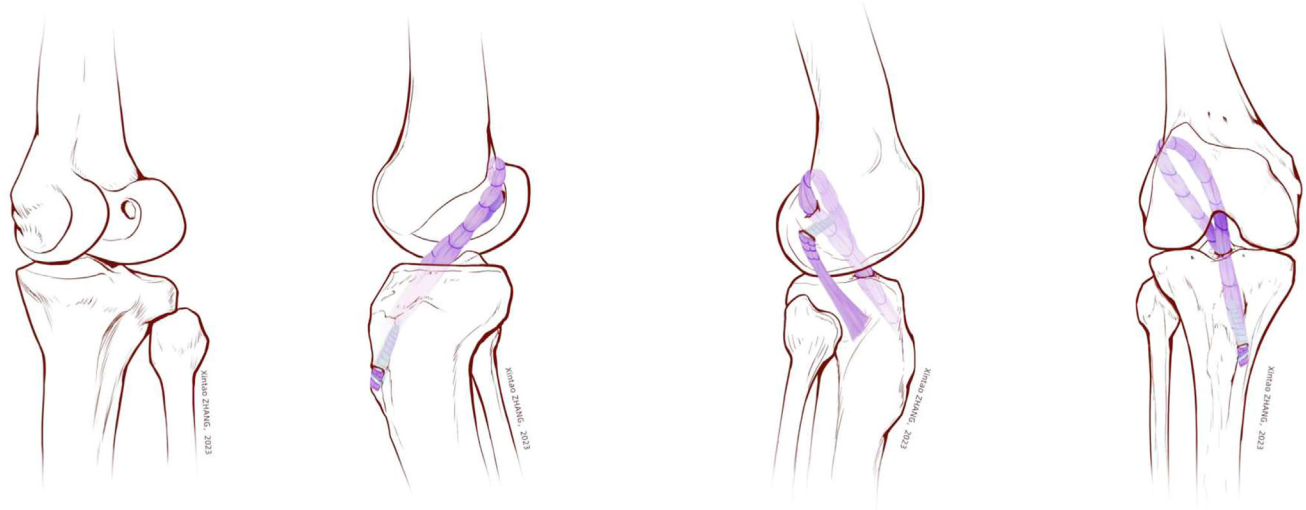

Fig 9. Over-the-top double-bundle revision ACLR technique with hybrid hamstring tendon autograft-allograft and associated lateral extra-articular tenodesis. (ACLR, anterior cruciate ligament reconstruction.)

Table 1. Tips and Tricks

Indicated in patients with prior tunnel placement overlapping one of the planned tunnels and/or extensive femoral tunnel widening.
The soft tissues in the primary tunnel should be thoroughly debrided to improve tendon-to-bone healing.
The graft tendon should be sutured at least diameter of 6-mm and 24-cm length.
Fix the graft tendon in isometric function and neutral rotation.
The graft tendon is fixed using interference screw fixation instead of staples.

Table 2. Advantages and Disadvantages

Advantages	
	Eliminates the need to drill new femoral tunnels in patients with malpositioned and widened tunnels
	One-stage revision decreases the recovery time of ACLR revision patients
	Restores and improves rotatory stability by combining with LET
	Minimizes the risk of graft slippage from the lateral posterior condyle
	Maximizes anatomic reconstruction
Disadvantages	
	Extra incision increases the risk of incision infection
	Allograft use increases the risk of immune rejection and graft failure
	Increases the cost of surgery by using interference screw fixation

ACLR, anterior cruciate ligament reconstruction; LET, lateral extra-articular tenodesis.

biomechanical properties of and long-term clinical outcomes with this technique for ACLR revision.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: This study was supported by the National Natural Science Foundation of China (82272568).

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