Technical Note

# Anterior Cruciate Ligament Revision Using Bone—Patellar Tendon—Bone Autograft and Lateral Extra-articular Tenodesis

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**Abstract:** Revision of anterior cruciate ligament reconstruction presents various challenges not encountered in the primary settings, including malpositioned tunnels, tunnel widening, and the lack of consensus on the ideal graft to be used. This Technical Note describes a one-stage anterior cruciate ligament reconstruction revision using a bone—patellar tendon—bone autograft combined with lateral extra-articular tenodesis. This technique represents the ideal approach to tackle complex revision cases primarily characterized by tibial and femoral tunnel osteolysis and rotational knee instability. The bone—patellar tendon—bone autograft offers numerous advantages mainly providing a double bone plug, which is critical when encountering cases with tibial and femoral tunnel widening. In addition, a lateral extra-articular tenodesis alongside the revision enhances rotational knee stability reducing stress on the graft and ensuring better graft survival.

Anterior cruciate ligament reconstruction (ACLR) has become one of the most-performed orthopaedic procedures, and therefore cases of graft failure requiring revision surgery are encountered more frequently. Recent studies indicate that approximately 8% of patients undergoing ACLR will necessitate a revision procedure.[1] Revision of ACLR (RevACLR) is a demanding surgery that requires meticulous preoperative planning and a precise treatment strategy, mainly guided by the position and dimensions of the previous tunnels.[1]

Extensive tibial and femoral tunnel widening, with anatomical or semianatomical previous tunnels, can be addressed with a single-stage revision using a bone—patellar tendon—bone (BPTB) autograft with a tibial and patellar bone plug. Despite the donor-site comorbidity, the BPTB autograft remains the gold standard to address double-tunnel widening.[2] Another challenge is the rotational instability of the knee, which can result in residual rotatory instability if addressed with RevACLR alone. Recent scientific literature recommends additional extra-articular lateral ligament augmentation in complex revisions. This enhances rotational stability reducing stress on the graft and ensuring optimal graft survival.[3,4]

This Technical Note describes the surgical technique for RevACLR to tackle cases of double-tunnel widening (femoral and tibial) using the BTPB autograft and lateral extra-articular tenodesis (LET) (Video 1).

## Surgical Technique

### Preoperative Planning

Our revision protocol comprises a comprehensive clinical evaluation of the patient along with a series of dedicated imaging (knee and lower-limb standing anteroposterior and lateral x-ray scanogram, computed tomography scan with tunnel position and diameter study protocol, and magnetic resonance imaging) (Figs 1 and 2).

### Patient Preparation and Graft Harvest

After spinal anesthesia and antibiotic prophylaxis with 2 g of intravenous cefazolin, the patient is placed supine with a tourniquet at the proximal thigh. Dual supports are used to prevent the patient shifting laterally when applying valgus stress to the knee.

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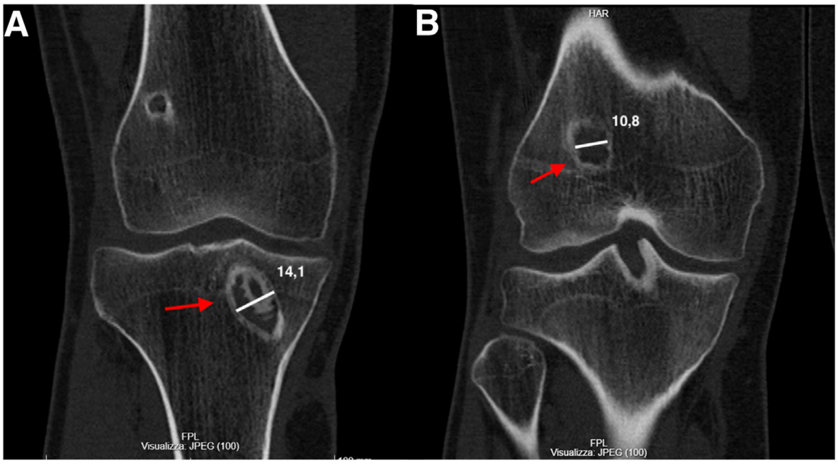


**Fig 1.** Anteroposterior coronal plane computed tomography scan of the right knee on presentation. (A) The previous tibial tunnel (red arrow) shows extensive osteolysis with a maximum tunnel diameter of 14.1 mm. (B) The previous femoral tunnel (red arrow) maximum width is 10.8 mm.

A midline incision of 8 to 10 cm is performed with the knee at 90° of flexion from the inferior border of the patella to the tibial tuberosity (Fig 3). The middle third of the patellar ligament is marked at 10 mm width, and then a blade is used to longitudinally incise the marked segment along the tendon's fibers. Next, the dimensions of the bone plugs are outlined as follows: 20 mm long and 9 mm wide for the patellar plug and 30 × 10 mm for the tibial tubercle (Fig 4). The dimensions of the bone plugs are case specific and can be larger in cases of extensive bone loss. An oscillating saw of 10 mm angled at 30° toward the midline is used to create trapezoidal-shaped patellar and tibial bone plugs. Thin osteotomes are used to carefully separate the bone plugs. The graft is then prepared on a separate table. The bony ends are then prepared by drilling a 1.5-mm hole in each plug through which a 0.8-mm K-wire is passed.

After graft harvest, an initial complete diagnostic arthroscopy should be performed to rule out any associated lesions. Any identified lesions should be treated accordingly.

## Tunnel Preparation

The ACL graft remnant is debrided, and the previous tunnels are inspected. The direction of the tibial and femoral tunnels should be planned preoperatively using the computed tomography scan on the basis of the previous tunnels' position and the extent of bone loss. To prepare the tibial tunnel, the tibial guide is used to drill a K-wire, approximately 20° medially on the axial plane and 55° on the sagittal plane, from the anteromedial tibia toward the anatomical tibial footprint (Fig 5). Straight reamers of increasing diameters are passed over the K-wire from 8 mm up to 10 or 11 mm in diameter under arthroscopic visualization. The

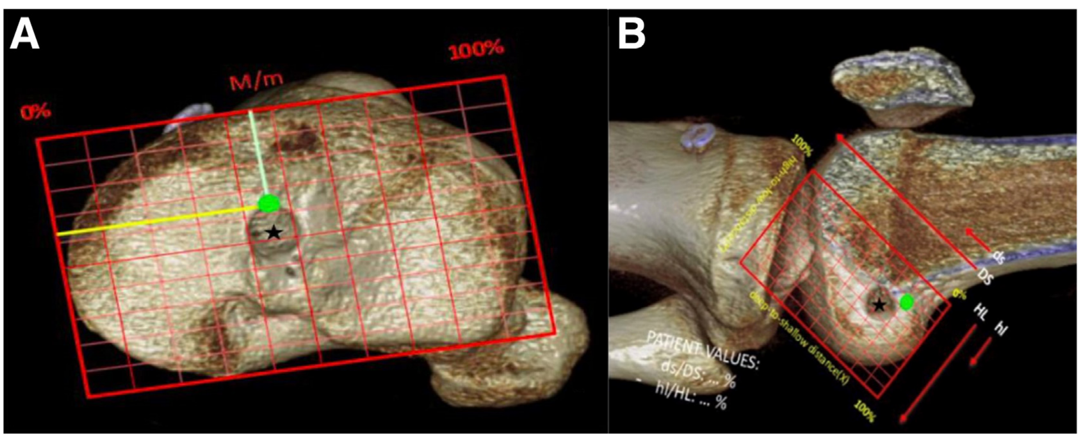


**Fig 2.** Three-dimensional computed tomography scan of the right knee showing the previously constructed anterior cruciate ligament tibial tunnel (black star) is posterior in relation to the anatomical tibial footprint (green dot) according to the Bernard-Hertel grid (A). (B) The femoral tunnel (black star); in this case it seems anterior in relation to the ideal femoral tunnel (green dot).

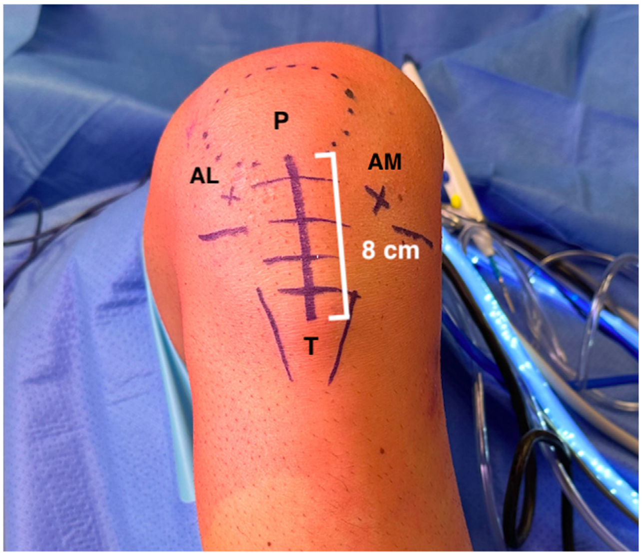


**Fig 3.** Patellar tendon harvesting from the right knee: a standard midline incision of 8-10 cm is performed with the knee at 90° of flexion from the inferior border of the patella (P) to the tibial tuberosity (T). (AL, anterolateral; AM, anteromedial.)

femoral tunnel is prepared using an outside-in technique (Fig 6). The tunnel is created by reaming over the K-wire starting from 5 mm up to 9 or 10 mm. The tunnels are then arthroscopically visualized to verify the integrity of the walls and previous graft debridement (Figs 7 and 8).

### Passage and Fixation of the ACL Graft

The BPBT autograft is passed from the tibial tunnel into the joint and then into the femoral tunnel until the respective bone plugs are fully seated (patellar bone plug in the femur and tibial bone plug in the tibia) (Fig 9). With the knee at 90° flexion and while maintaining traction on the graft from the femoral side, a metallic interference screw is inserted into the femoral tunnel (8 × 25 mm; DePuy Synthes, Warsaw, IN) corresponding to 2 mm less than the femoral tunnel's diameter (Fig 10). The knee is put through cycles of flexion and extension and is then placed at 30° of flexion with posterior drawer force applied. At this position, a metallic interference screw is placed into the tibial tunnel to obtain primary tibial fixation (9 × 25 mm; DePuy Synthes) (screw diameter 1-2 mm less than that of the tibial tunnel; Fig 11). Double tibial

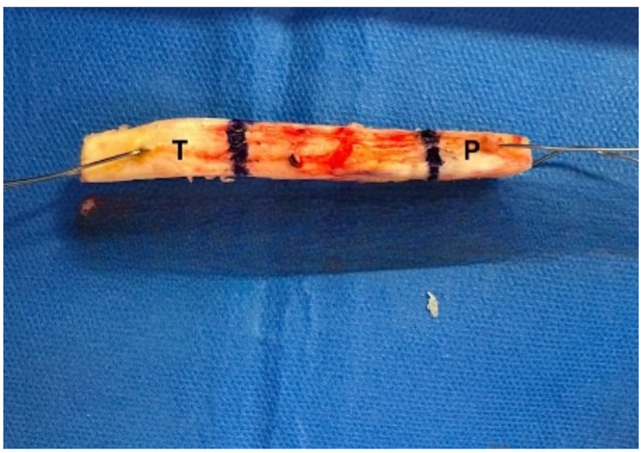


**Fig 4.** Bone−patellar tendon−bone autograft preparation on a separate table. The final dimensions of the bony plugs are (T) tibial plug 30 mm × 10 mm and (P) patellar plug 20 mm × 9 mm.

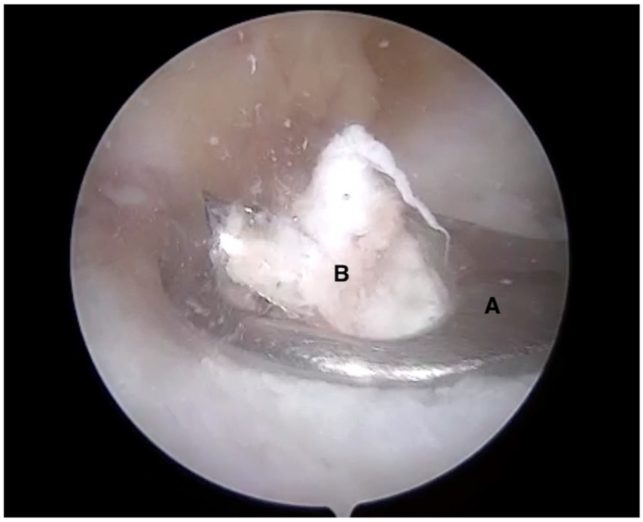


**Fig 5.** Arthroscopic view of the right knee through the anterolateral portal. The tibial guide (A) is used to drill a K-wire from the anteromedial tibia toward the anatomical tibial footprint (B).

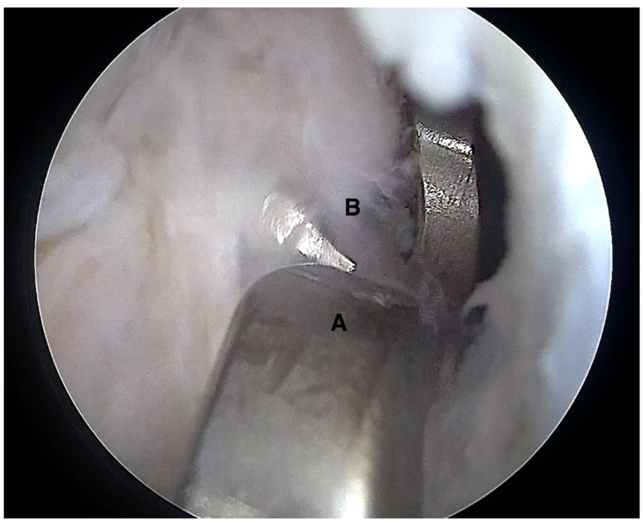


**Fig 6.** Arthroscopic view of the medial wall of the lateral femoral condyle through the anteromedial portal. The femoral outside-in guide (A) is used to drill a K-wire toward the femoral anatomic anterior cruciate ligament footprint (B).


**Fig 7.** Arthroscopic inspection of the tibial tunnel of the right knee (the arthroscope is inserted inside the tunnel from outside) to check integrity of the wall and appropriate debridement of at least 3/4 of the previous graft.

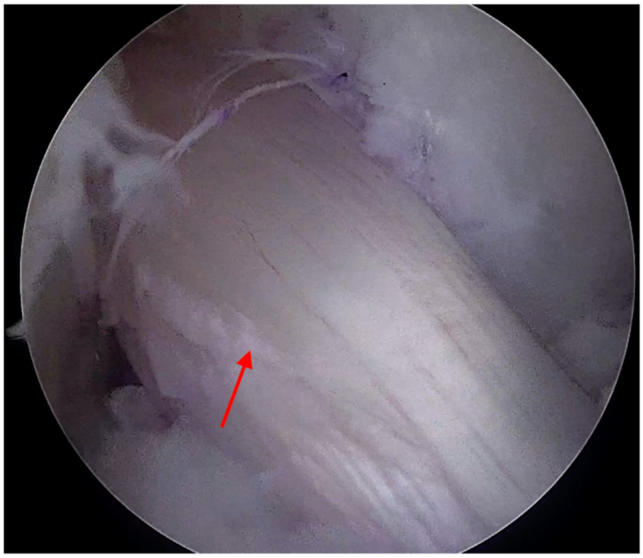

**Fig 9.** Final arthroscopic inspection of anterior cruciate ligament graft (red arrow) through the anterolateral portal of the right knee.

fixation is obtained by tying the K-wire armed to the bone plug to an additional metallic screw (low profile; 3.5 × 18 mm; Zimmer, Warsaw, IN) placed 1 cm distal to the tibial tunnel, which acts as a post (Fig 12).

## Lateral Extra-articular Tenodesis

The preferred technique is the modified Ellison technique. A lateral incision is made from the Gerdy tubercle 2 to 3 cm proximally to the femoral insertion of the lateral collateral ligament (LCL). The iliotibial band (ITB) is identified. The ITB is incised 1 cm anterior to its posterior border along its fibers to obtain a 10-mm-long by 10-mm-wide sleeve, which remains attached to the ITB proximally. The sleeve is then dissected distally off Gerdy's tubercle and subsequently sutured with a 0 VICRYL stitch, which is used as a carrier. The LCL is identified. A clamp is used to pass the graft underneath the LCL in a proximodistal fashion. A 4-mm double-suture anchor (REVO; Arthrex, Naples, FL) is inserted just distal to Gerdy's tubercle. With the knee flexed at

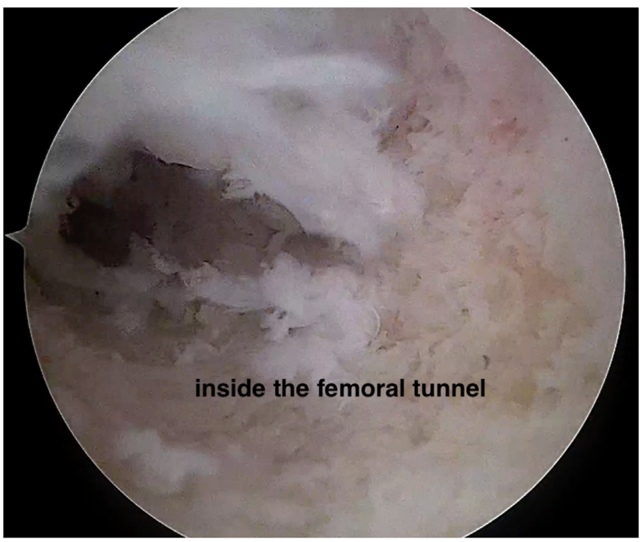


**Fig 8.** Arthroscopic inspection of the femoral tunnel through the anteromedial portal of the right knee.

**Fig 10.** Femoral fixation: with the knee at 90° flexion while maintaining traction on the graft, when inserting a metal screw (red arrow) in the femoral tunnel, the diameter of the screw should be 2 mm less than the diameter of the femoral tunnel.

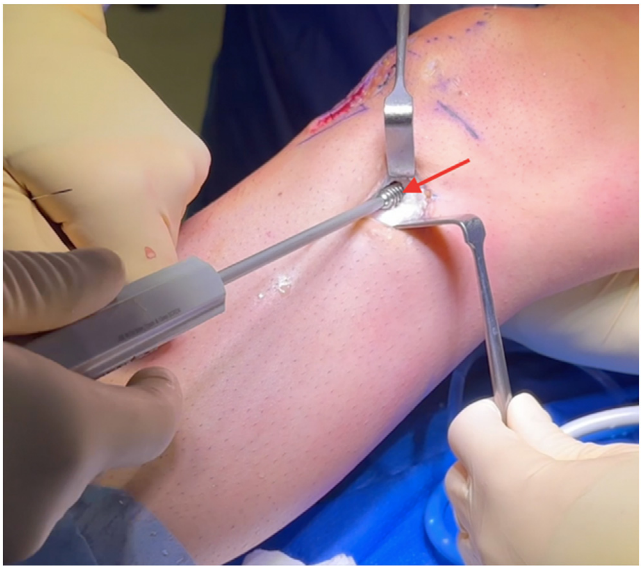

**Fig 11.** Tibial fixation: the knee is placed at 30° of flexion with posterior drawer force applied. A metal screw (red arrow) is inserted in the tibial tunnel to fix the graft (screw diameter should be 1-2 mm less than the diameter of the tunnel).

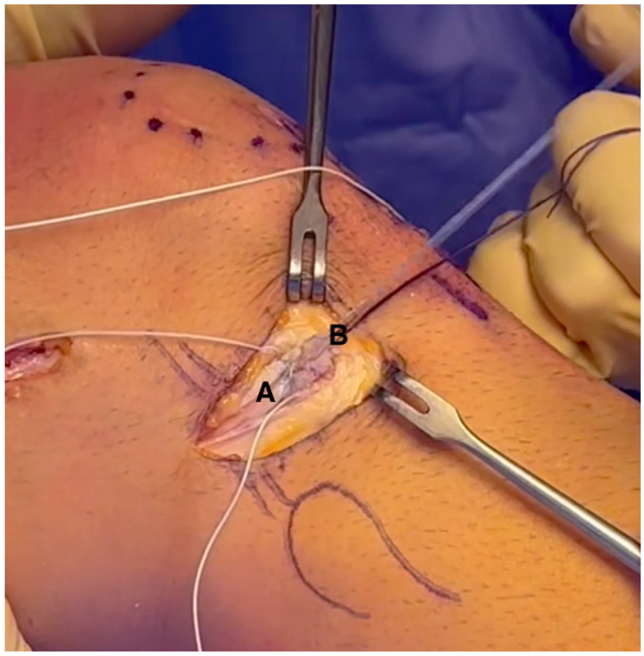


**Fig 13.** Lateral extra-articular tenodesis performed after graft fixation: the iliotibial band graft (A) is passed underneath lateral collateral ligament and fixed to a 4-mm double-suture anchor (REVO; Arthrex, Naples, FL) inserted just distally to Gerdy's tubercle (B).

30° and the foot in neutral rotation, the first suture is used to tie the free end of the graft to the anchor using the Krackow suture technique. The second suture is used to tie a knot around the graft to bring it closer to the anchor (Fig 13). The fascia lata is then sutured. The tourniquet is deflated, and meticulous hemostasis is performed, wounds are irrigated and sutured, and elastic stockings are applied.

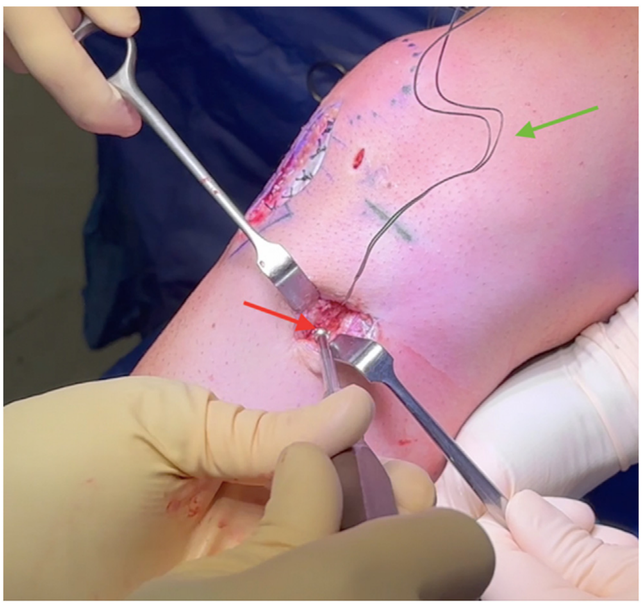

**Fig 12.** Double tibial fixation of the graft: a metallic screw is inserted into the anteromedial tibial cortex just distal to the tibial tunnel. The graft fixation is completed by tying the wire (green arrow) armed on the bone plug around the screw (red arrow).

### Rehabilitation

In the first 4 weeks, the goal is to achieve a range of motion (ROM) from 0 to 90°, progressing up to a ROM of 0 to 120° in the next 4 weeks, and eventually reaching full ROM. A partial load protocol is adopted, followed by progressive loading up to full weight-bearing. Early rehabilitation involves isometric strength training of quadriceps and hip extensor and flexor muscles. If any meniscus repair is necessary, the rehabilitation protocol is adjusted/changed /modified accordingly.

## Discussion

RevACLR is technically more demanding than primary ACLR, and the reported outcomes of revision have been inferior to those of primary ACLR.[3] The main challenge not encountered in the primary setting is previous tunnel positioning tunnel widening and graft choice.

Several studies have reported better patient-reported outcome and lower failure rates with autografts compared with allografts.[5] Among the different autograft options, the BPTB autograft has been considered the gold standard for RevACLR.

The use of BTPB autograft for RevACLR allows for a one-stage revision addressing both femoral and tibial

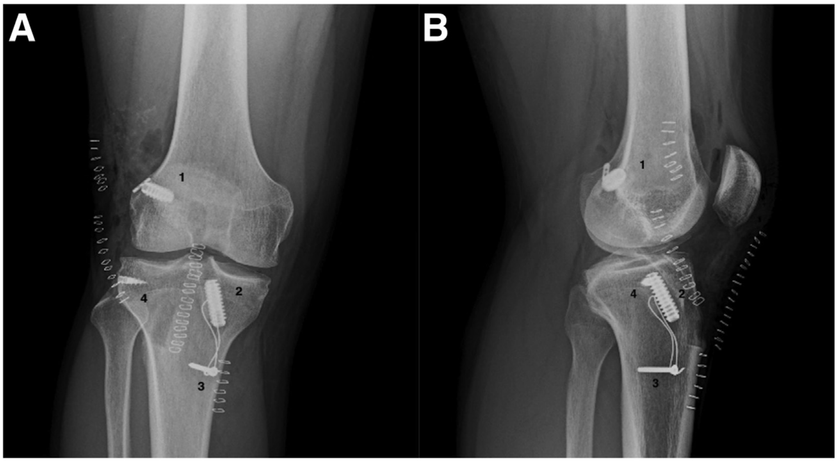


**Fig 14.** Anteroposterior (A) and lateral (B) radiograph after anterior cruciate ligament reconstruction using bone−patellar tendon −bone autograft and LET showing the graft fixed into the femoral (1) and tibial (2) tunnels using metal screws; double tibial fixation to a post (3); LET using a double suture anchor (4). (LET, lateral extra-articular tenodesis.)

**Table 1.** Advantages and Disadvantages

| Advantages | Disadvantages |
|---|---|
| Manage large bone defects with the bony plugs to address previous anatomical tibial and femoral tunnels | Donor-site morbidity (especially anterior knee pain) |
| Autogenous graft with large diameter and better mechanical properties | Loss of strength of extensor apparatus |
| Case-specific bony plugs dimensions according to the bone defect | Increased incidence of patellofemoral osteoarthritis |
| One-stage surgery | |

**Table 2.** Pearls and Pitfalls

| Pearls | Pitfalls |
|---|---|
| Use arthroscope to make sure the tunnels' walls are 3/4 debrided from the previous graft and walls are intact. | Patellar bone plug length should not exceed 20 mm to avoid graft incarceration during intraarticular passage. |
| Perform double-tibial fixation by tying the K-wire armed on the bone plug around the second fixation screw placed distally. | An excessively large harvest of patellar bone plug can cause fractures. |
| The shape of the bone plugs should be trapezoidal to reduce the risk of patellar or tibial fractures. | Noncentralized patellar ligament harvest can cause extensor mechanism weakening and patellar ligament rupture. |
| Progressive reamers allow graft debridement from previous tunnels. | |

tunnels' bone defect. The technique is patient-specific, and depending on the extent of the bone defect measured preoperatively, it is possible to harvest bony plugs of varying dimensions. Bone-to-bone healing within the tunnels provides faster graft integration.[6] Additional double tibial screw fixation allows stiff fixation and a shorter isometric graft, which is essential with the commonly encountered extensive tibial bone.

Because the tibial bone defect is usually larger than the femoral one, it could be fitting to hoist the graft through the tibia so the smaller plug, usually harvested from patella, will easily pass first through the tibia. The graft is pulled until the larger bone plug is completely seated on the tibia.

The major disadvantage of BPTB autograft is the donor-site comorbidity, above all anterior knee pain especially when kneeling. It seems to be associated with the removal of bone plugs, inferior translation of the patella due to closure of the patellar tendon defect or potential injury to the infrapatellar branch of the saphenous nerve.[2] The rehabilitation program could be strenuous if the patient must go through anterior knee pain and weakening of the knee extensor mechanism. The advantages and disadvantages are summarized in Table 1.

It is now clear from overwhelming evidence that performing LET in conjunction with RevACLR is essential for graft survival. Revision per se constitutes a major indication for performing LET. Adding rotational stability to the knee is crucial to maintain the graft's stability, which is essential for graft integration when there is initial extensive bone loss.[3,4]

This paper provides a step-by-step description of our methods when performing RevACLR using a BPTB autograft combined with LET. The final x-rays are demostrated in Figure 14. The pearls and pitfalls are summarized in Table 2. This technique provides a reliable solution to encounter cases presenting with extensive bone loss and double tunnel widening yielding good clinical outcomes with rotational stability and low comorbidity.

## Disclosures

All authors (T.R., A.D.M., Z.A.T., P.F., F.M.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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