Technical Note

Complex Anterior Cruciate Ligament Revision and Lateral Extra-Articular Tenodesis With Achilles Tendon Allograft: The "Monoloop" Technique

Mattia Chirico, M.D., Zyad Ayman Taha, M.D., Mattia Carminati, M.D., Roberto Civinini, M.D., and Fabrizio Matassi, M.D.

Abstract: Revision of anterior cruciate ligament reconstruction (ACL-R) presents many challenges that are not encountered in the primary setting and, therefore, requires thorough preoperative planning. Recently, there has been growing evidence showing that combining the anterolateral ligament (ALL) reconstruction with ACL-R revision reduces the risk of postoperative ACL rupture and meniscal tears, and therefore, the ALL reconstruction becomes essential to a complex ACL revision. The technique that we describe is mainly used in the setting of complex ACL revision with extensive tunnel osteolysis associated with rotational instability of the knee. This article presents a technique for a one-stage complex ACL-R revision combined with ALL reconstruction using an Achilles tendon allograft with a bone plug.

The increasing incidence of primary anterior cruciate ligament reconstruction (ACL-R) inevitably leads to an increased incidence of failure and, consequently, revision surgery. About 8% of patients undergoing ACL-R will undergo a subsequent revision procedure,[1,2] and 2.8% will undergo a rerevision procedure.[3] One of the main challenges to overcome during ACL-R revision is the extensive bone osteolysis, especially of the tibial tunnel, which can be addressed by one-stage revision in cases of a tunnel diameter <15 mm or two-stage revision in cases of a wider tunnel. The complications associated with a two-stage revision include prolonged operative time, articular knee cartilage damage between surgeries, long waiting times, and increased use of resources.[4] Another challenge facing surgeons is the necessity to perform extra-articular tenodesis of the ALL to improve rotational stability of the knee.[5]

From the University of Florence, Orthopaedic Clinic CTO, Careggi, Florence, Italy.

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Address correspondence to Dr. Mattia Chirico, M.D., Department of General Orthopedic, University of Florence, A.O.U. Careggi CTO, Florence, Italy. E-mail: mattia.chirico@unifi.it

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The Monoloop technique provides a solution by offering a single-stage surgical option to address complex ACL-R revision or rerevision cases with excessive tunnel enlargement due to osteolysis (even with tunnel diameter >15 mm), while simultaneously performing ALL reconstruction. This technique requires a long tendon graft with a large bone block (Fig 1) (Video 1).

Preoperative Planning

In preparation for the revision, it is essential to clinically evaluate the patient and obtain dedicated imaging (AP and lateral knee and full-leg radiograph; CT scan with dedicated study protocol of the tunnel's position and diameter; MRI) (Figs 2 and 3).

Patient Preparation

Following spinal anesthesia and antibiotic prophylaxis with 2 g of Cefazolin IV, the patient is positioned supine with the tourniquet at the proximal thigh. We use double holders (one at the level of the affected thigh and the other one on the contralateral iliac crest to avoid patient lateral shifting, while applying valgus stress to the knee). A roller is placed at the end of the operative table to maintain the affected knee at 90° of flexion. Knee arthroscopy is performed using standard anterolateral (AL) and anteromedial (AM) portals with a 30° arthroscope, and any associated lesions are inspected and treated accordingly.

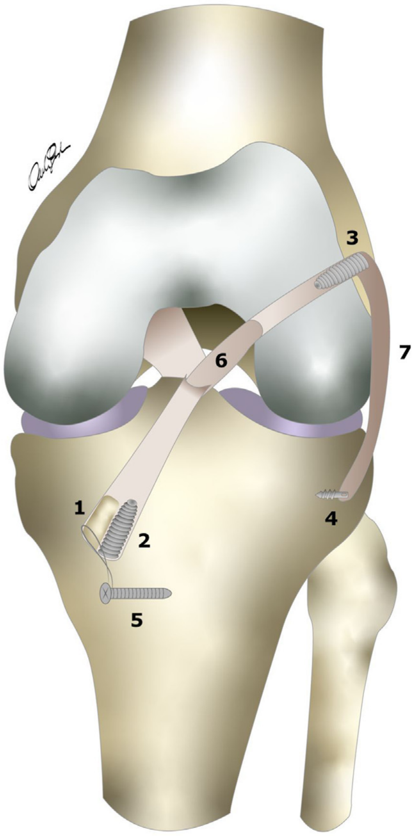

Fig 1. This image represents a final graphic illustration of the surgery with all the various essential elements **1.** bone plug; **2.** interference screw; **3.** metal screw; **4.** anchor; **5.** cortical screw; **6.** anterior cruciate ligament (tendon allograft); **7.** anterolateral ligament (tendon allograft).

Achilles Tendon Preparation

The fresh frozen Achilles tendon allograft must be of a minimum length of 20 cm with a large calcaneus bone block. After thawing in warm saline solution mixed with rifampicin for 20 minutes, the Achilles allograft is prepared on a separate table: a graft of about 250 mm in length and 10 mm in width is obtained with a bone plug of about 11 × 30 mm (or more in cases of larger defects) (Fig 4).

A 1.2-mm hole is drilled into the bone plug, and a 0.8-mm metal wire is inserted. This will be used for graft tensioning and double tibial fixation. The graft is then presoaked in a 5 mg/mL Vancomycin-soaked sterile gauze before insertion.

Tunnel Position and Landmarks

The ACL graft remnant is debrided. The tibial guide is used to drill a K-wire from the anteromedial tibia toward the anatomic tibial footprint aiming to create a tunnel angled at around 20° medially in the axial plane and 55° in the sagittal plane (Fig 5). The direction of the tibial tunnel should be planned using the preoperative CT scan and in relation to the previous tunnel position. Straight reamers are passed over the K-wire, starting with 8 mm and progressing up to 12 mm in diameter. The arthroscope is inserted inside the tibial tunnel to check that it is 3/4 debrided from the previous graft and that the tunnel's walls are intact (Fig 6).

For the femoral tunnel, the outside-in guide is used. The K-wire's extra-articular entry point is located at the femoral anatomic origin of the ALL and is directed toward the femoral ACL anatomic footprint (Fig 7). The femoral tunnel is then created by introducing progressive drills starting from a diameter of 4.5 mm up to the same diameter of the Achilles tendon graft (10 mm wide in this case) under arthroscopic visualization through the AM portal (Fig 8).

In preparation for the extra-articular tenodesis, a 6-cm incision is performed centered on the lateral femoral epicondyle, along the course of the fascia lata fibers toward Gerdy's tubercle (Fig 9). Following superficial dissection to the IT band, the posterior third of the IT band is incised along the length of its fibers. The distal end of the IT band is then lifted off Gerdy's tubercle with a sleeve of periosteum. The lateral collateral ligament (LCL) is then identified and isolated.

ACL Graft Passage and Fixation

The Achilles tendon allograft is pulled from the femoral side into the joint through the tibial tunnel until the bony plug is completely seated (Fig 10) The plug's position in the tibial tunnel is planned preoperatively, since it will affect the graft's final orientation. With the knee at 90° of flexion, the graft is fixed with an interference screw (Matrix ConMed) (10 × 30 mm) matching the diameter of the femoral tunnel (Fig 11).

The knee is cycled through 10 repetitions of flexion and extension and placed at 30° of flexion with posterior drawer force applied. A metal screw 9 × 25 mm (Profile, DePuy) is used to fixate the graft in the tibial tunnel (Fig 12). Double fixation is then obtained by tying the metal wire armed on the calcaneus bone plug to the monocortical screw placed slightly distally, which acts as a post (Fig 13). At the end of the procedure, proper tensioning and positioning of the ACL graft is arthroscopically confirmed during the cycles of flexion-extension (Fig 14).

Extra-Articular Tenodesis and Fixation

Blunt hemostat forceps are used to pass the free end of the graft underneath the IT band and then underneath the LCL in a proximo-distal fashion. The bone around Gerdy's tubercle is nibbled using a rongeur in order to help increase the graft's integration. A double-loaded suture anchor 4 mm (REVO, Arthrex) is inserted just distally to Gerdy's tubercle (Fig 15).

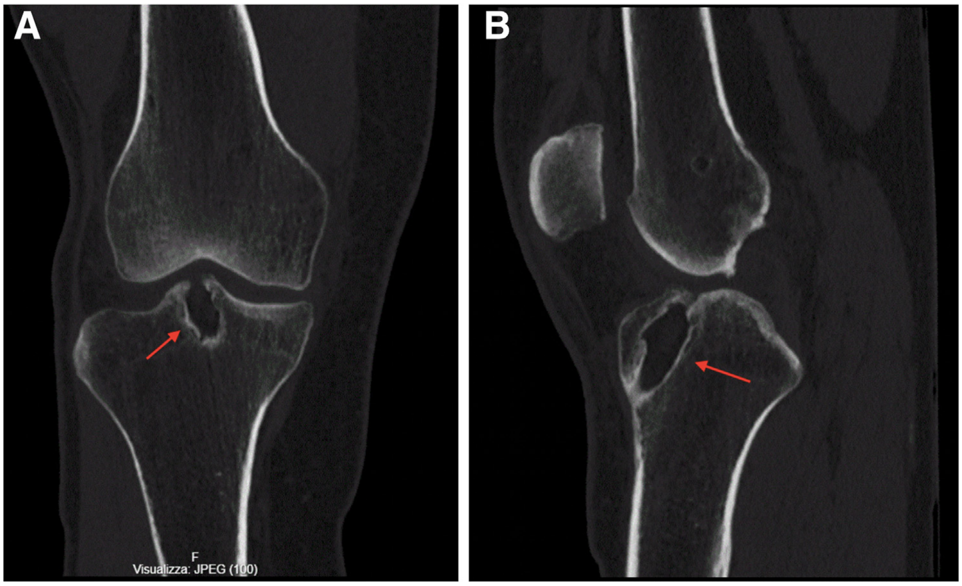

Fig 2. (A) Computed tomography (CT) preoperative. This patient's CT scan showed a semi-anatomic tibial tunnel with extensive osteolysis in coronal vision (rede arrow). (B) CT preoperative. This patient's CT scan showed a semi-anatomic tibial tunnel with extensive osteolysis in coronal vision in sagittal vision (red arrow).

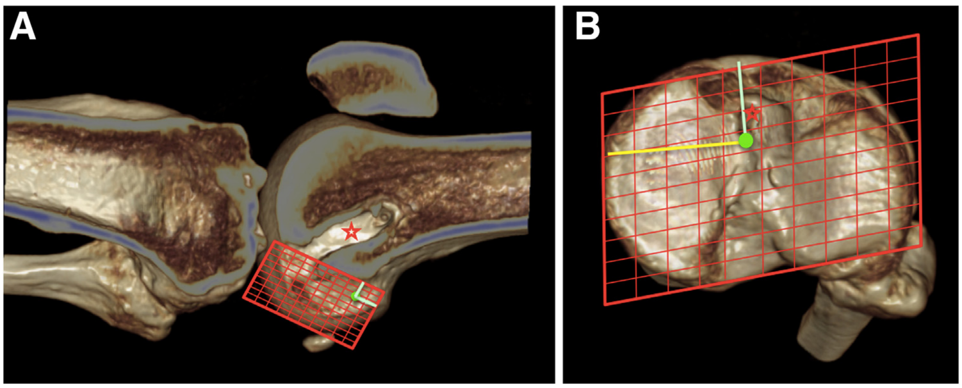

Fig 3. (A) Three-dimensional computed tomography images of a right knee showing femoral tunnel (star). In this case, the femoral tunnel instead is too high and anterior in relation to the anatomic anterior cruciate ligament footprint. Green dot is ideal for femoral tunnel position, according to Bernard Hertel methods. (B) Three-dimensional computed tomography images of a right knee showing aperture location of the tibia tunnel (star). In this case, it seems appropriately located. Green dot shows ideal tibial tunnel position, according to Bernard Hertel methods.

With the knee flexed at 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 suturing technique. This helps to distalize and add tension to the graft (Fig 16). The second suture loop is used to tie a knot around the graft in order to bring the graft toward the anchor (Fig 17). The fixation is reinforced anteriorly and posteriorly by suturing the graft to the overlying fascia lata with mattress stitches (Vicryl 0, Ethicon). The fascia lata is then sutured.

Final Stage

The tourniquet is removed, and meticulous hemostasis is performed. Wounds are irrigated and sutured. Elastic stockings are used in order to minimize knee and leg swelling. Final radiographs are performed to check hardware and tunnel positions (Fig 18).

Rehabilitation

The knee is kept in a brace allowing 0-90° flexion for the first 4 weeks, and then the brace is removed, allowing ROM 0-120° for the successive 4 weeks and full ROM afterward. A partial weight-bearing protocol is adopted followed by progressive weight-bearing to complete weight bearing. Early rehabilitation involves

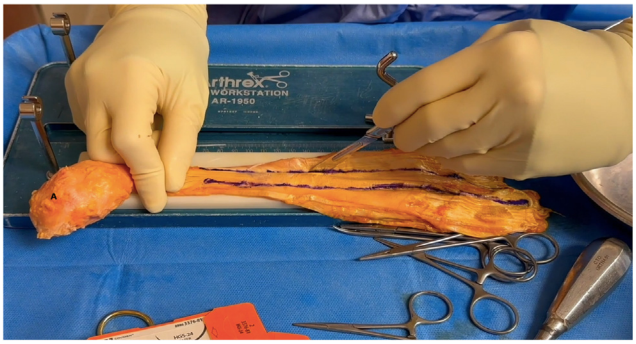

Fig 4. Graft preparation. (A) Achilles tendon allograft must be of a minimum length of 20 cm with a large calcaneus bone block. It is prepared on a separate table: a graft of about 250 mm in length and 10-mm width is obtained with a bone plug of about 11 × 30 mm (or more in cases of larger defects).

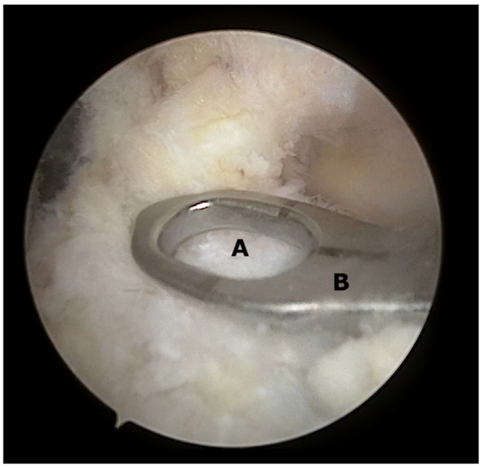

Fig 5. Arthroscopic view of the tibial footprint through the anterolateral portal. The letter "A" denotes the footprint. "B" denotes the tibial guide.

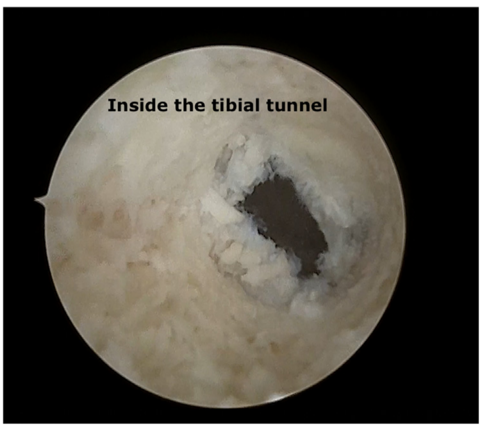

Fig 6. Arthroscopic view of the tibial tunnel because the arthroscope is inserted inside it to check that it is 3/4 debrided from the previous graft and that the tunnel's walls are intact.

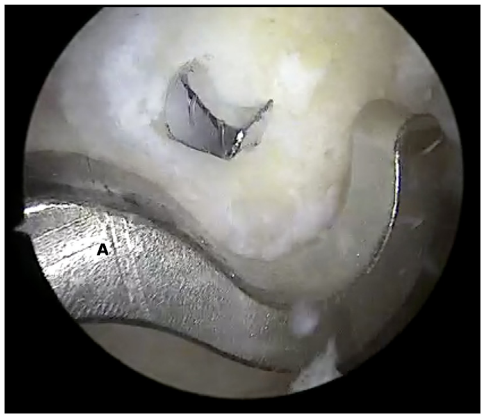

Fig 7. Arthroscopic view of the footprint femoral tunnel through the anteromedial portal. The K-wire's extra-articular entry point is located at the femoral anatomic origin of the anterolateral ligament and is directed toward the femoral anterior cruciate ligament anatomic footprint (arrow). The letter "A" denotes the femoral outside-in guide.

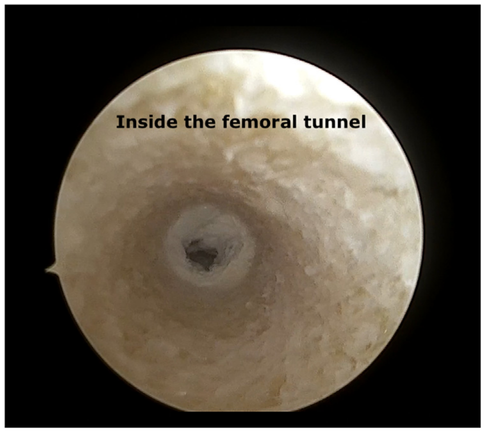

Fig 8. Arthroscopic view of femoral tunnel under arthroscopic visualization through the anteromedial portal.

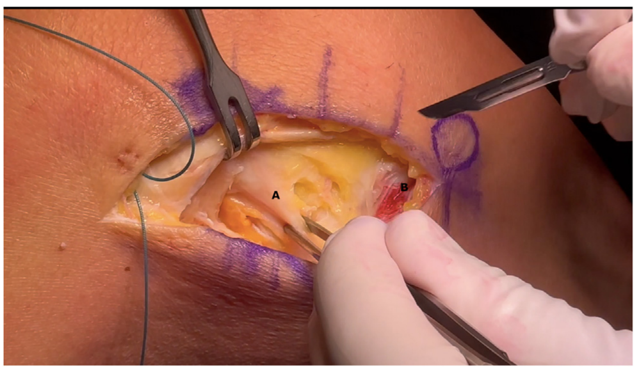

Fig 9. Lateral aspect of the femur: a 6-cm lateral incision is performed centered on the lateral femoral epicondyle. The distal end of the iliotibial band is then lifted off Gerdy's tubercle with a sleeve of periosteum. The lateral collateral ligament (LCL) is then identified and isolated. (A) LCL. (B) Gerdy's tubercle.

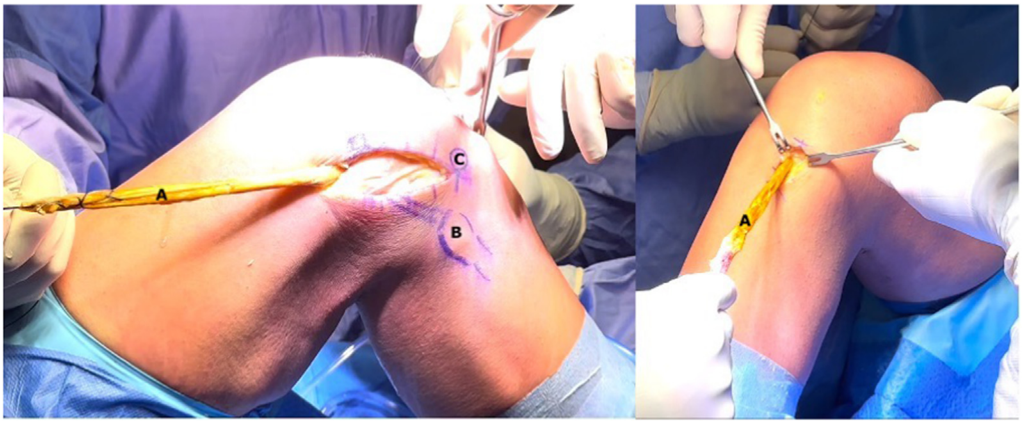

Fig 10. Graft passage. The Achilles tendon allograft is pulled from the femoral side into the joint through the tibial tunnel until the bony plug is completely seated. "A" denotes graft; "B" denotes fibula head; "C" denotes Gerdy's tubercle.

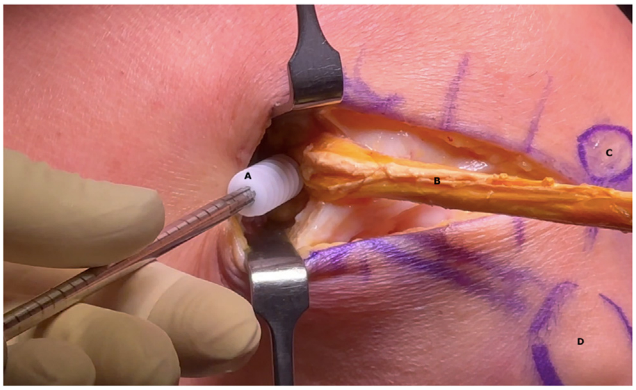

Fig. 11. Femoral fixation. Lateral aspect of the femur. The graft is fixed with an interference screw matching the diameter of the femoral tunnel. "A" denotes interference screw, "B" denotes tendon allograft, "C" denotes Gerdy's tubercle, and "D" denotes the fibula head.

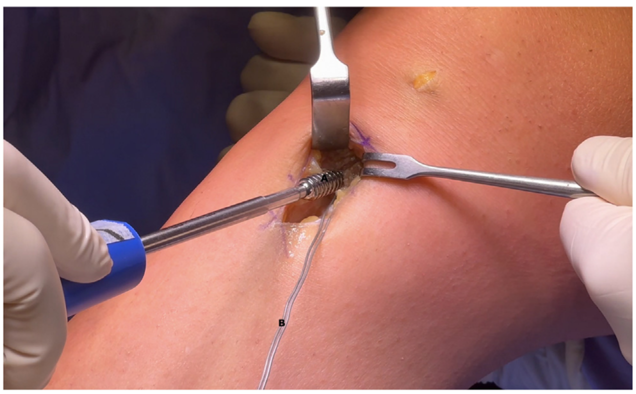

Fig 12. Tibial fixation: anteromedial aspect of the tibia. The knee is placed at 30° of flexion with posterior drawer force applied. A metal screw is used to fixate the graft in the tibial tunnel. "A" denotes the metal screw, and "B" denotes the metal wire.

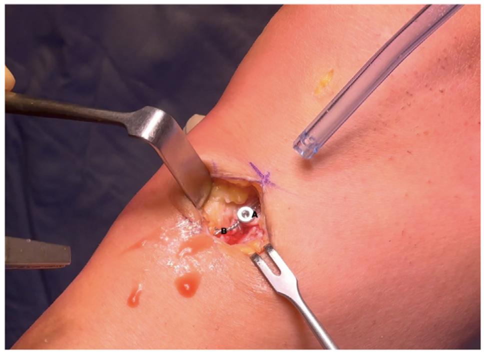

Fig 13. Double fixation: anteromedial aspect of the tibia. The metal wire (B) armed on the calcaneus bone plug to the monocortical screw (A) placed slightly distally is used for double fixation.

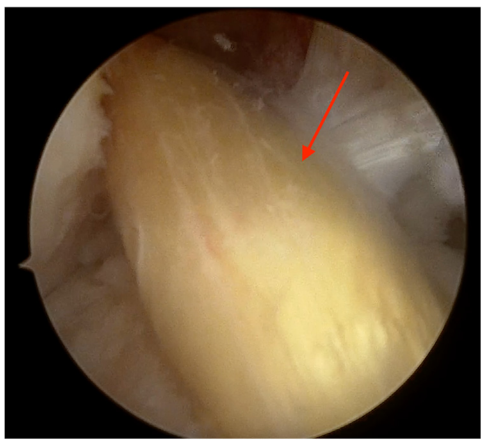

Fig 14. Arthroscopic view of the new anterior cruciate ligament (red arrow) by anteromedial portal.

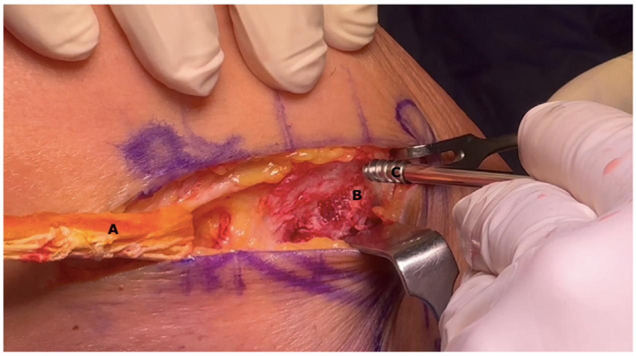

Fig 15. Anchor fixation. From the same approach window of the lateral epicondyle, the bone around Gerdy's tubercle is nibbled using a rongeur in order to help increase the graft's integration.

on quadriceps isometric strength and the extensor and flexor muscles of the hip.

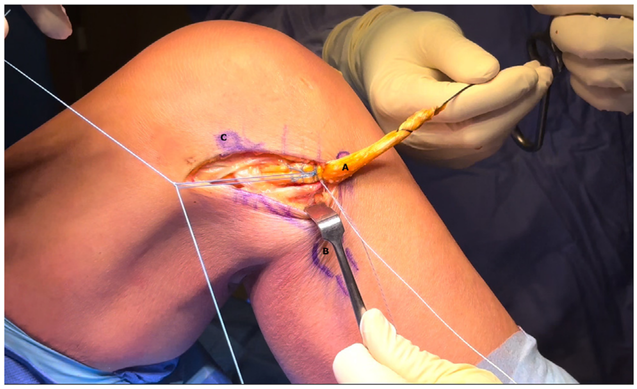

Fig 17. Fixation anterolateral ligament. From the same approach window of the lateral epicondyle, with the knee flexed at 30° and the foot in neutral rotation. The first suture is used to distalize and add tension to the graft. The second suture loop is used to bring the graft towards the anchor. "A" denotes graft; "B" denotes fibula head; "C" denotes epicondyle.

Discussion

Over the last few decades, anterior cruciate ligament reconstruction (ACL-R) has been one of the most frequently performed orthopaedic procedures.[6] ACL-R failure is most commonly due to surgical/technical errors (64.5%) followed by trauma (29.2%) and then biological factors (6.4%).[7] During primary ACL-R, the location of the tunnel created can be 1) anatomic, 2) nonanatomic: "does not'' overlap with the anatomic ACL footprint, and 3) semianatomic: partially overlaps with the anatomic footprint.

According to Vera Jaecker's et al.,[8] among surgical technique errors, nonanatomical femoral tunnel positioning was found to be the most common (83.1%) for ACL-R failure followed by nonanatomical tibial tunnel positioning (45.1%). One of the main challenges to overcome during ACL-R revision is the tunnel osteolysis, especially of the tibial tunnel, which can be addressed by one-stage revision in cases of tunnel diameter <15 mm or two-stage revision in cases of a wider tunnel.[9] Two-stage revision comes with complications, including prolonged operative time, articular knee cartilage damage between surgeries, long waiting times, and increased use of resources.

Growing evidence confirms that combining ALL with ACL-R reduces the risk ACL ruptures[10,11] and the incidence of postoperative meniscal lesions. Therefore, it becomes imperative to reconstruct the ALL, especially when facing complex ACL-R revisions or rerevisions.[12] The Monoloop technique is used in cases of ACL-R revision and rerevision, providing a solution when dealing with extensive tunnel osteolysis, especially of the tibial side, in a one-stage surgery using a single allograft. Surgeons can simultaneously perform an anatomic reconstruction of the ACL and ALL extra-articular tenodesis, using only one graft (Table 1). One tibial and one femoral tunnel is required, thus, avoiding any concerns for tunnel collision. The procedure is straightforward and fast, with a short surgical time.

However, during the procedure, the tension of the neo-ACL must be assessed to avoid a slack graft. The passage beneath the LCL is sometimes tricky, needing minimal dissection of the edges. Furthermore, during the first steps of the learning curve, the lateral surgical approach should be extended to avoid femoral tunnel malpositioning (Table 2).

In summary, the Monoloop technique offers a promising approach for ACL-R revision and rerevision surgeries, addressing tunnel osteolysis and providing a simultaneous reconstruction of the ALL. However, surgeons should be cautious about graft tension, graft passage, and surgical approach to ensure optimal outcomes in these complex cases (Table 3).

Fig 16. Anterolateral ligament tensioning. From the same approach window of the lateral epicondyle, the graft is tensioned. "A" denotes graft; "B" denotes fibula head; "C" denotes Gerdy's tubercle

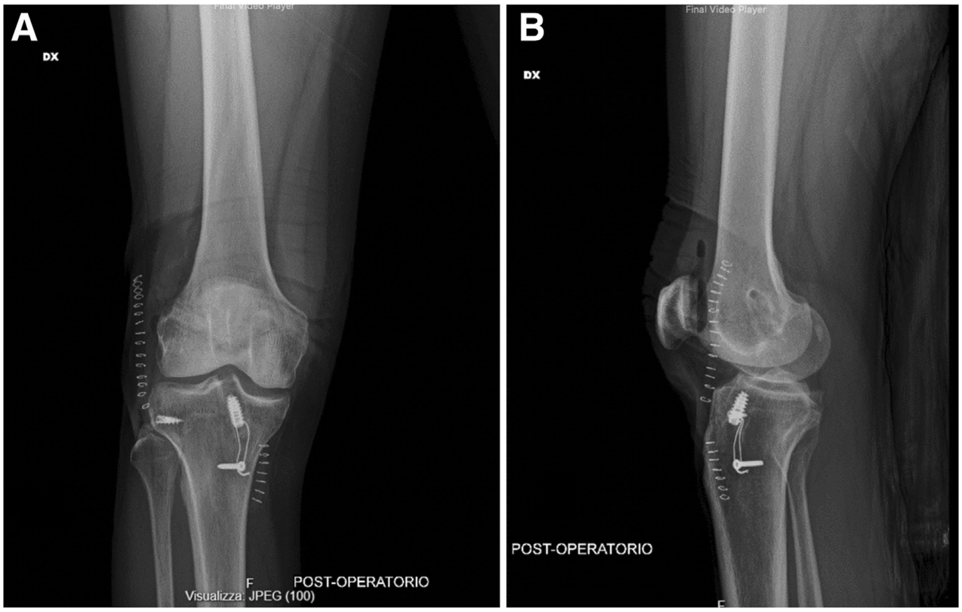

Fig 18. (A) Radiographs post-op of revision of anterior cruciate ligament reconstruction (ACL-R) by Monoloop technique. Anteroposterior vision. (B) Radiographs postoperative of revision of ACL-R by Monoloop technique. Lateral vision.

Table 1. Ten Key Points for Correct Procedure

Ten Steps	
1. Anterolateral (AL) and anteromedial (AM) portals	Standard portals use 30° arthroscopy. Check for associated intra-articular lesions.
2. Achilles tendon preparation	Requires a long tendon graft with a large bone plug. Resoaked in a 5 mg/mL vancomycin
3. Tibial tunnel	Aim towards the anatomic tibial footprint. Tunnel angled at around 20° medially in the axial plane and 55° in the sagittal plane.
4. Femoral tunnel	Starting from the anatomic origin of the ALL towards the femoral ACL anatomic footprint.
5. Lateral incision	Following superficial dissection to the IT band, The LCL is then identified and isolated.
6. ACL passage	The graft is pulled from the femoral side into the joint through the tibial tunnel until the bony plug is completely seated.
7. Femoral fixation	Knee 90°, bioabsorbable interference screw
8. Tibial fixation	30° of flexion with posterior drawer force applied and metal screw against bone block and monocortical screw for metal wire suture
9. ALL	The graft passed underneath the IT band and LCL. Fixed with anchor with the knee flexed at 30° and the foot in neutral rotation.
10. Check intra-articular	Check intra-articular ACL tension, position, and clinically the knee's stability.

ACL, anterior cruciate ligament; AL, anterolateral; ALL, anterolateral ligament; AM, anteromedial; IT, iliotibial; LCL, lateral collateral ligament.

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
• Technique for a one-stage rerevision ACL • Surgeons can simultaneously perform an anatomical reconstruction of both ACL and ALL, using only one graft. • Only one tibial and one femoral tunnel is required, thus avoiding any concerns for tunnel collision. • Manage large tibial bony defect with proper shaping of calcaneus bone block	• The tension of the neo-ACL must be assessed to avoid a slack graft. • The passage beneath the LCL of a big graft is sometimes tricky, needing minimal dissection of its edges. • During the first steps of the learning curve, the lateral surgical approach should be extended, to avoid femoral tunnel malpositioning.

Table 3. Pearls and Pitfalls

Pearls	Pitfalls
• Insert the arthroscope inside the tibial tunnel to check that it is 3/4 debrided from the previous graft and that the tunnel's walls are intact. • For the femoral tunnel the K-wire's extra-articular entry point is located at the femoral anatomic origin of the ALL and is directed towards the femoral ACL anatomic footprint. • Use curved forceps to pass the graft beneath the lateral collateral ligament (LCL). Minimal dissection at the anterior and posterior edge of LCL helps in passing the graft.	• Lateral extra-articular tenodesis of the ALL with the tibia in external rotation can cause lateral compartment stress and tightness. • Leaving the diameter of the bony bract too large compared with the tibial tunnel can make it difficult for the graft to pass through.

Disclosures

The authors report 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.

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