



Two-Stage Anterior Cruciate Ligament Reconstruction Revision Surgery for Severe Bone Defects With Anterolateral Ligament Reconstruction Technique

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Abstract: Anterior cruciate ligament revision surgery poses a number of specific difficulties. These include the lack of bone mass to enable effective fixation of the reconstruction, morbidity of the donor area when bone autograft is used to fill the tunnels, and absence of the semitendinosus and gracilis homolateral tendons in cases in which they have already been used in the primary surgical procedure. To address all these problems, we describe a 2-stage revision technique that uses bone allograft for tunnel filling and Achilles allograft for ligament reconstruction. In addition, the intervention includes an extra-articular phase in which the anterolateral ligament is reinforced to increase the rotational stability of the knee, thus improving the prognosis of operation.

Anterior cruciate ligament (ACL) reconstruction revision surgery is difficult, especially in cases with bone deficit. Difficulties arise when the previous tunnels are widened and their positioning interferes with the new tunnels. Occasionally, revision is possible in a single surgical procedure. For revision purposes, the newer tunnels are oriented to avoid the existing tunnels, the existing tunnels are filled with bone graft until the grip is good, or additional fixation systems such as interference screw fixation are used.¹

However, 1-stage revision is not always viable; 2-stage revision is required in such cases. An initial surgical procedure is performed to insert the bone graft into the tunnel.^{2,3} When the graft is fully integrated with the bone, a second surgical procedure is scheduled to implant a neoligament, with approximately 4 months between surgical procedures.

Multiple-stage reconstruction has some disadvantages: It requires more operations and longer recovery periods before the patient can return to activities of daily living. Delayed revision is associated with an increased arthrosis risk and meniscal tears.⁴ Therefore, 2-stage revision is reserved for cases wherein 1-stage reconstruction may yield a suboptimal graft choice,

Table 1. Step-by-step Procedure for 2-Stage ACL Reconstruction With Extra-articular Stage

First Surgical Stage: joint Lavage and Tunnel filling
Patient preparation
Examination under anesthesia
Diagnostic arthroscopy
Joint lavage and tunnel debridement
Tunnel filling with graft
Surgical wound closure
Rehabilitation and follow-up between first and second surgical stages
Second surgical stage: revision ACL and ALL reconstruction
Patient preparation
Examination under anesthesia
Diagnostic arthroscopy
Graft preparation
Femoral tunnel drilling
Tibial tunnel drilling
Intra-articular passage of graft and tibial fixation
Femoral fixation of graft
Extra-articular passage of graft and anterolateral tibial fixation
Final check
Surgical wound closure

ACL, anterior cruciate ligament; ALL, anterolateral ligament.

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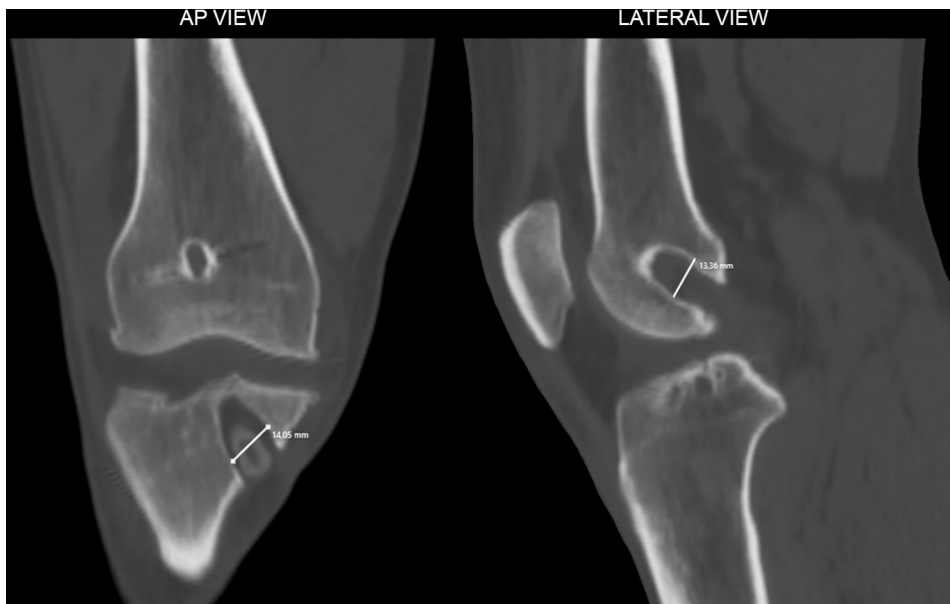


Fig 1. Enlarged bone tunnels. The right knee of a professional soccer player is shown after 2 anterior cruciate ligament reconstruction failures. Magnetic resonance images (anteroposterior [AP] and lateral views) show the preoperative situation of the patient, with enlarged bone tunnels; as a result, 1-stage revision was not recommended. The approximate diameter of the main tibial defect is 14 mm, and that of the femoral defect is 13.3 mm.

tunnel position, graft fixation, or biological environment for graft-bone interface healing.⁵⁻⁸

We use allografts for cavity filling and grafting, which helps avoid donor-area morbidity. In addition, we combine ACL repair with an extra-articular anterolateral ligament (ALL) reconstruction stage to increase the knee rotational stability.^{9,10} This study aimed to detail our 2-stage revision technique; the step-by-step procedure is outlined in [Table 1](#).

Technique

First Surgical Stage: Joint Lavage and Tunnel Filling

Patient Preparation. Standard preoperative evaluation is performed, and spinal anesthesia is used, except when impossible ([Figs 1](#) and [2](#)). The patient is placed in the supine position, with the soleal line beyond the edge of the operating table to enable knee flexion. A side stopper should be placed just above the knee, at the tourniquet level, to prevent hip external rotation. The contralateral leg is placed in the same position or on a leg holder.

Examination Under Anesthesia. The knee's range of motion and ligament stability are assessed in all planes; the tests performed include the Lachman and pivot-shift tests.^{11,12}

Diagnostic Arthroscopy. Incisions should be planned to avoid wound healing and infection problems. If possible, the previous incisions are used. We aim to use the usual (medial and lateral) portals for systematically

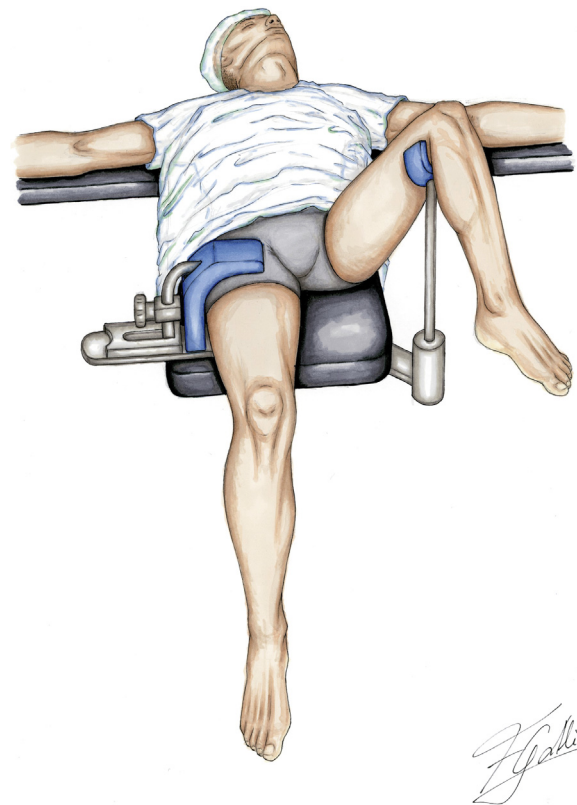
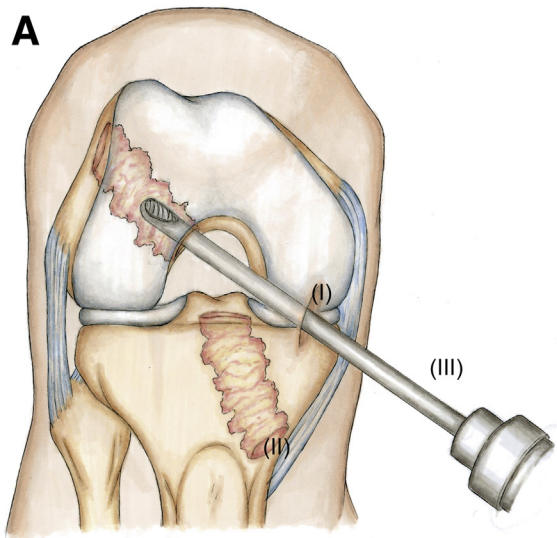


Fig 2. Patient preparation. The patient is positioned supine, according to the standard arthroscopic position. The popliteal line should be beyond the edge of the surgical table to be able to flex the knee comfortably. It is advisable to place a lateral stop just above the knee, at the level of the tourniquet, to avoid external rotation of the hip. The contralateral leg is placed in the same position or on a leg holder.



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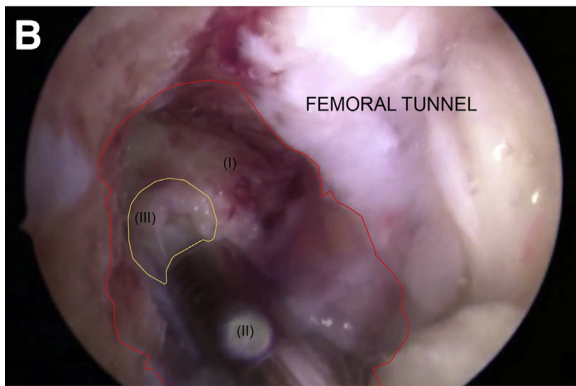
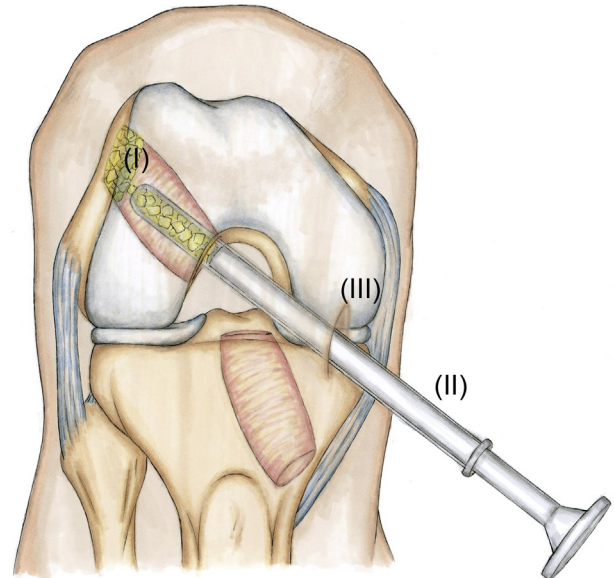


Fig 3. Joint lavage and tunnel debridement. (A) Cleaning and debridement procedure for enlarged tunnels. The remains of the failed anterior cruciate ligament reconstruction undergo morcellation and are removed throughout the anteromedial portal (I) and the tibial tunnel incision (II). Once the tunnels are exposed, they are cleaned thoroughly. It is important to eliminate the remains of the fixation systems used in the previous operation. This may require an extra-articular approach when it comes to cortical suspension systems. Finally, curettage of the tunnels is performed to bring up healthy bleeding bone tissue. The use of electrocoagulation or radiofrequency systems should be avoided owing to the deleterious thermal effect on the bone walls (III). The objective is to achieve the best possible substrate for bone graft integration. (B) Arthroscopic image showing cleaning and debridement of femoral tunnel. The widening of the tunnel is clearly visible (I, red line). The burr (II) is introduced from the anteromedial portal while the procedure is controlled from the anterolateral portal. One of the screws (III, yellow line) used to secure the previous anterior cruciate ligament reconstruction is shown.

exploring the joint. Alternating portals is very important in revisions because the structures normally used as references are more difficult to find owing to the altered local anatomy.¹² We aim to analyze the state of the failed graft and to repair existing meniscal or chondral damage.¹²

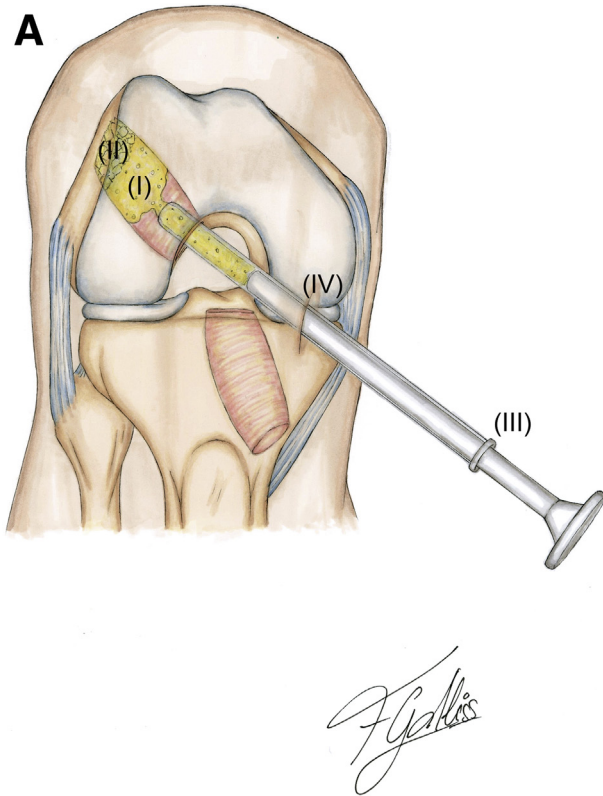
Joint Lavage and Tunnel Debridement. The failed graft remnants undergo morcellation and are removed (Fig 3, Video 1). Once the tunnels are exposed, we clean them meticulously, removing the fixation systems used in the primary surgical procedure. To obtain a good substrate for graft integration, the tunnels are curetted and irrigated to locate bleeding healthy bone tissue, avoiding using electrocoagulation or radiofrequency systems because of their deleterious thermal effects on bony walls.

Tunnel Filling. The tunnels are filled with dry graft to avoid graft migration (Figs 4-6, Video 1).⁶ Our approach



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Fig 4. Initial stage of tunnel filling. The placement of a bone chip plug (I) at the proximal end of the femoral tunnel is illustrated. Arthroscopy fluid is drained from the joint before applying the bone graft to avoid possible migration. Both ends of the tunnels are clogged using bone chips. It is of utmost importance to obtain good closure of the tunnel. To introduce the bone chips, a cannula (II) is used through the anteromedial portal (III), and the knee is flexed on demand to facilitate access to the tunnel.



plugged using cancellous chips (ReadiGRAFT; LifeNet Health, Virginia Beach, VA), and the rest of the tunnel is obliterated with a combination of

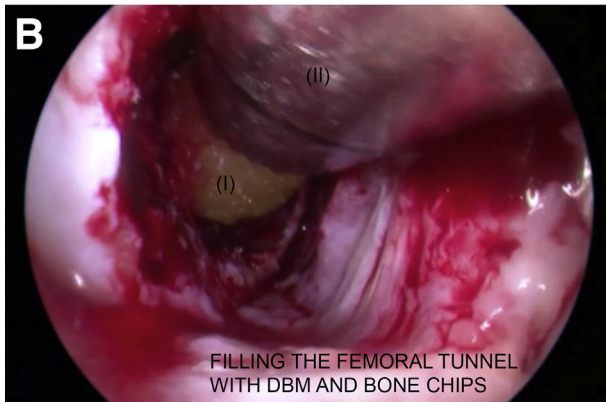
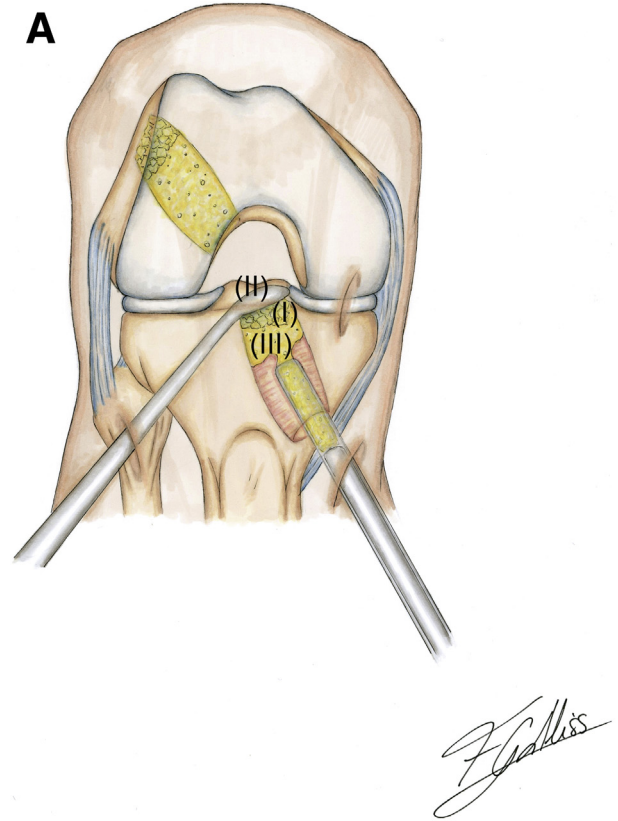


Fig 5. Intermediate stage of tunnel filling. (A) The central section of the tunnels is filled with a combination of demineralized bone matrix (DBM) and corticocancellous spongy chips (I). Once the tunnel has a “bone roof” (II), DBM is inserted from proximal to distal using a cannula and embolus (III). It is advisable to make small pauses to fill all the holes and compact the paste. Bone chips are used again to close the articular end of the tunnel. The cannula is inserted through the anteromedial portal (IV). (B) An intraoperative arthroscopic image taken from the anterolateral portal shows the introduction of DBM (I) through a cannula (II) introduced through the anteromedial portal in the previously debrided femoral tunnel.

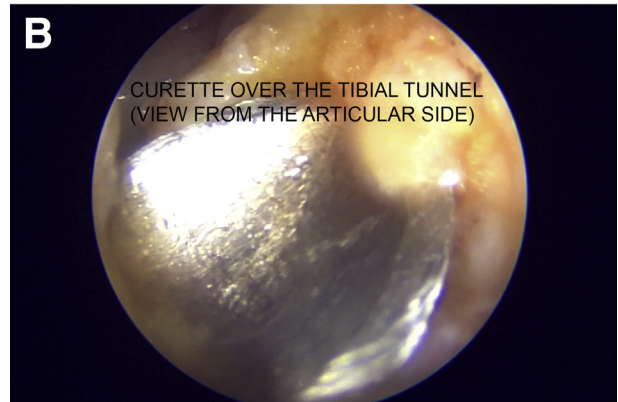
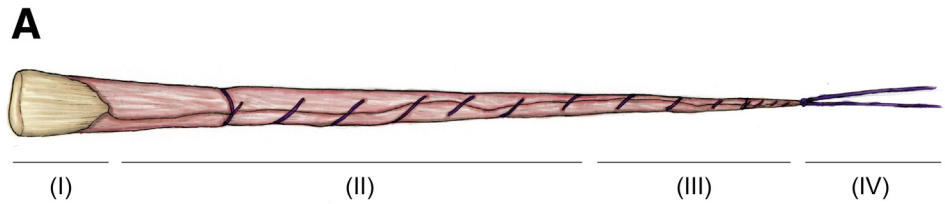


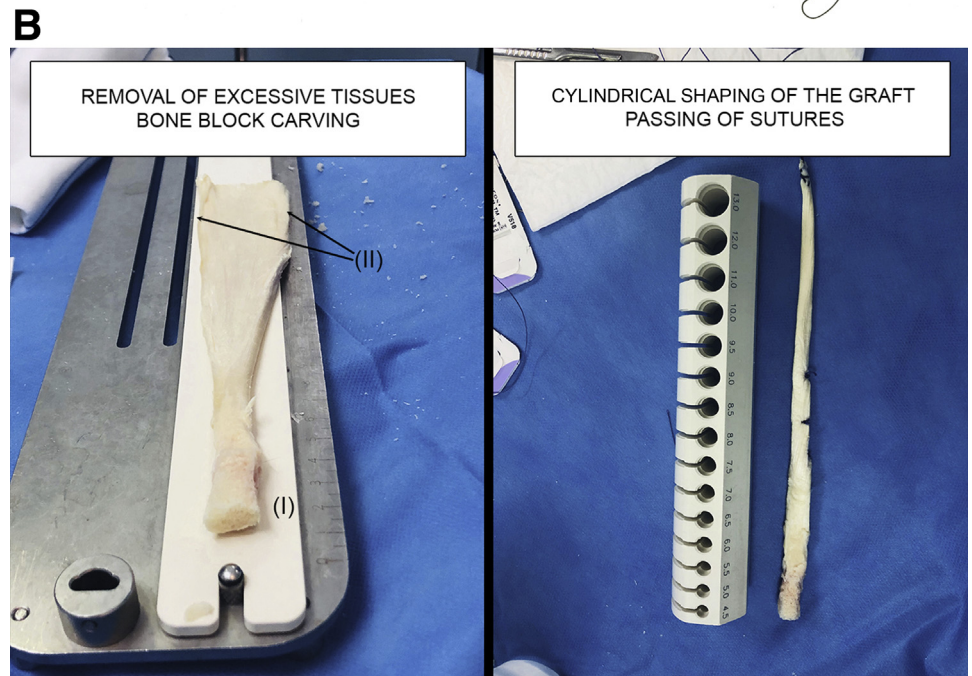
Fig 6. Final stage of tunnel filling. (A) Placement of bone chips as a roof in the proximal end of the tibial tunnel is shown, with the insertion of demineralized bone matrix (DBM) inside it. The proximal end of the tunnel is closed with bone chips (I), and a curette (II) is introduced through the anterolateral portal to prevent the DBM paste from entering the joint. DBM (III) is then inserted from proximal to distal with a technique similar to that used in the femoral tunnel. It is of utmost importance to fill all the gaps and to achieve a good press fit. (B) Intraoperative arthroscopic vision from the anteromedial portal shows the curette introduced from the anterolateral portal to prevent passage of chips into the joint.

aims to achieve complete cavity filling with a good press fit by combining allografts to avoid donor-area morbidity. The lateral end of the femoral tunnel is



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Fig 7. Graft preparation. (A) The Achilles graft is prepared for the anterior cruciate ligament and anterolateral ligament reconstruction. The bone block (I) is carved conically to act as a plug to facilitate tibial fixation without implants. The soft tissues are shaped cylindrically (II); we attempt to obtain a diameter of approximately 10 mm. The distal end of the graft is slightly narrower (III) to facilitate the passage of the reconstruction. Sutures (IV) are attached for graft passage. (B) Preparation of the Achilles graft is performed on a separate surgical table. We use Achilles tendon with a bone block that is carved conically (I). Excess material is trimmed (II), and the graft is shaped cylindrically. Finally, sutures are passed and secured to the reconstruction.



demineralized bone matrix putty and corticocancellous chips (ReadiGRAFT BLX DBM & CC Putty; LifeNet Health). This arrangement allows us to effectively seal the tunnels and fill them with paste in all nooks, yielding better outcomes than when bone cylinders or chips are used.

To insert both filling types, we use a cannula with a plunger through the anteromedial portal, flexing the knee on demand to facilitate access. It is advisable to take small breaks and to remove the applicator to fill all holes and compact the paste using an impactor.

The operation is repeated in the tibial tunnel, albeit using chips proximally. With a curette introduced through the anteromedial portal, we form a plug or stopper that prevents paste transfer to the joint. This paste will be inserted from the distal aspect of the

tunnel (from distal to proximal) using a technique similar to that used in the femoral tunnel.

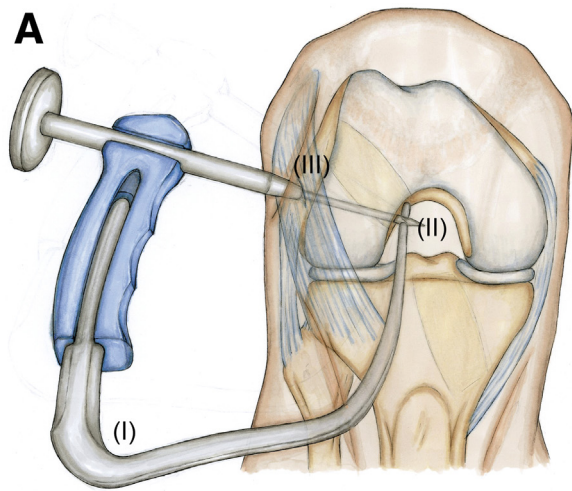
Surgical Wound Closure. Surgical wound closure is performed according to standard protocols.

Protocol Between First and Second Surgical Stages

Partial load bearing with an extension splint or no load bearing (depending on bone condition) is

Table 2. Graft Preparation Using Achilles Allograft With Bone Block

Carving bone Block into Truncated cone Shape
Trimming excess material
Turning graft into cylinder
Suturing graft
Fixing traction threads



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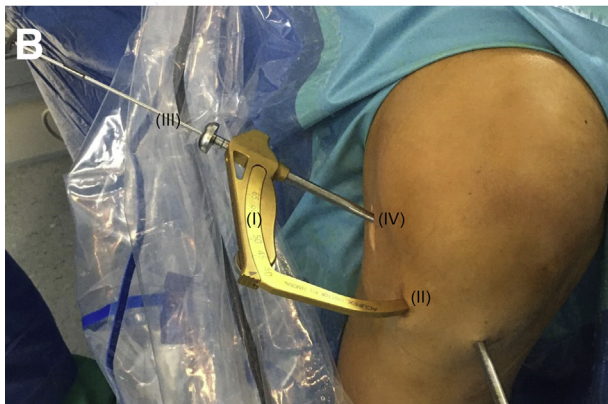
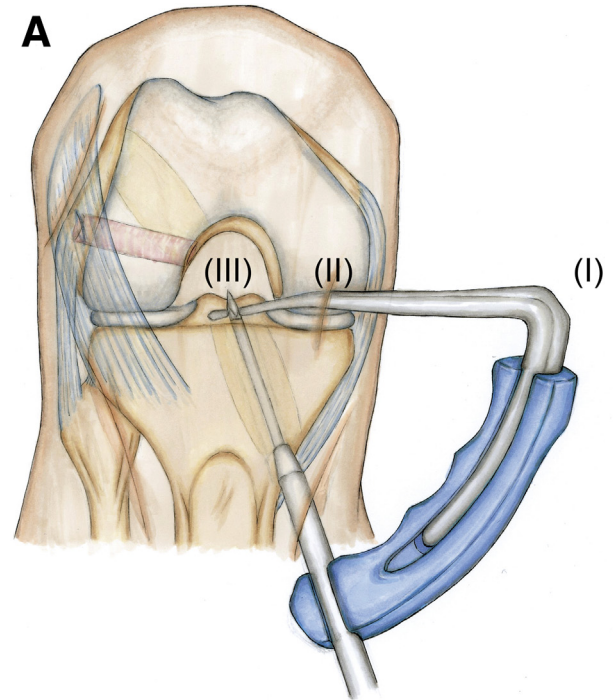


Fig 8. Femoral tunnel preparation. (A) Perforation of femoral tunnel using standard outside-to-inside technique. The femoral tunnel is drilled first to prevent the loss of arthroscopic fluid. The knee is taken into hyperflexion to facilitate visualization, and the arthroscope is inserted through the anterolateral portal. A femoral aiming guide (I) is placed through the anteromedial portal at the desired anchoring point (II). Because our technique includes an extra-articular reinforcement of the lateral ligament, the lateral entry point of the guidewire is located immediately anterior to the lateral femoral epicondyle (III). (B) Intraoperative clinical image showing femoral aiming guide (I) introduced through anterolateral portal (II) with guidewire (III) already placed in desired orientation. The lateral femoral entry point is located slightly anterior in relation to the lateral femoral epicondyle (IV).

recommended for the first 2 weeks. However, range-of-motion exercises can be started as soon as the patient can tolerate them. The load is gradually increased, focusing on low-impact, high-repetition exercises



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Fig 9. Tibial tunnel preparation. (A) Perforation of new tibial tunnel. A tibial aiming guide (I) is inserted through the anteromedial portal (II) with its tip located at the optimal anchoring point (III). The arthroscope is used from the anterolateral portal. An incision is made over the scars of the previous surgical procedures (if possible), and the guidewire is advanced toward the joint. Once correct positioning has been confirmed, the tunnel is drilled over the wire up to the diameter of the reconstruction. Because our technique uses the graft bone block itself as tibial fixation, the first distal centimeters of the tunnel are drilled to a diameter similar to that of the bone block. (B) Intraoperative clinical image showing tibial aiming guide (I) introduced through anteromedial portal (II) in desired orientation. The introduction of the guidewire is performed from distal to proximal using the same incision (III) from the previous surgical procedures when possible.

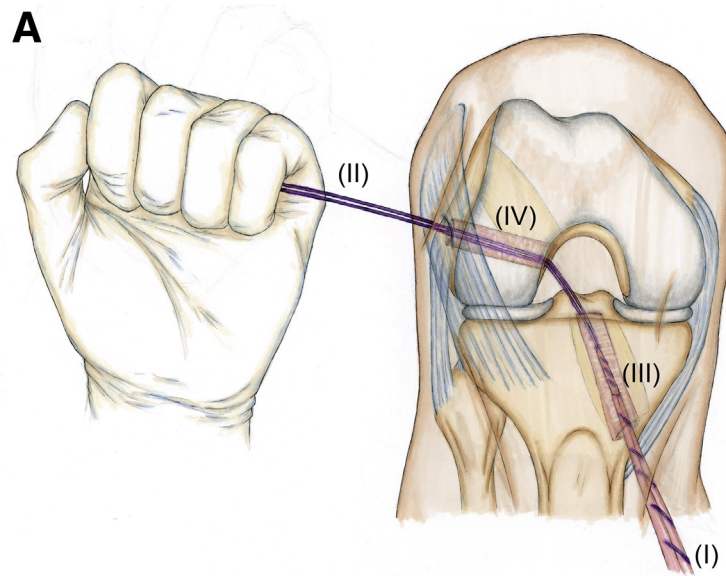
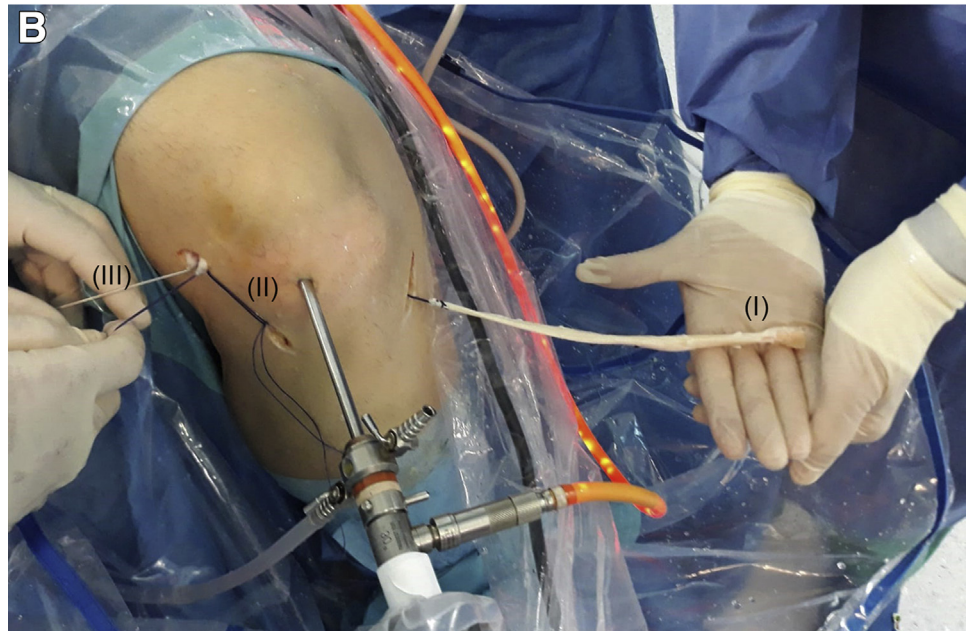


Fig 10. Intra-articular stage and initial tibial fixation. (A) Passage of Achilles graft (I). Through manual traction (II), the reconstruction is passed through the tibial (III) and femoral (IV) tunnels, leaving the excess uncut (because it will be used to reinforce the collateral ligament). (B) Intraoperative clinical image showing onset of passage of Achilles allograft (I) and sutures prepared for subsequent passage under iliotibial band (II). It is important to leave the nitinol guidewire of the femoral fixation screw (III) in place during the process to facilitate the subsequent fixation procedure.



(treadmill, stationary bicycle, or swimming pool activities), avoiding high-impact exercises. Scans are performed at 2 and 4 months to check tunnel filling. When the patient shows a good range of motion and bone graft integration (on the images), the second surgical stage is scheduled.¹³

Second Surgical Stage: Revision ACL and ALL Reconstruction

Patient Preparation and Examination Under Anesthesia. Patient preparation and examination

under anesthesia are performed as described for the first stage.

Diagnostic Arthroscopy. Along with the usual inspection, the tunnel-filling consistency is checked to ensure graft stability. Possible adhesions are cleaned, and chondroplasty is performed when necessary to prevent friction with the new graft.

Graft Preparation. In revision surgical procedures, we use an Achilles allograft with a calcaneal bone block (FlexiGRAFT; LifeNet Health) (Fig 7, Video 1). The

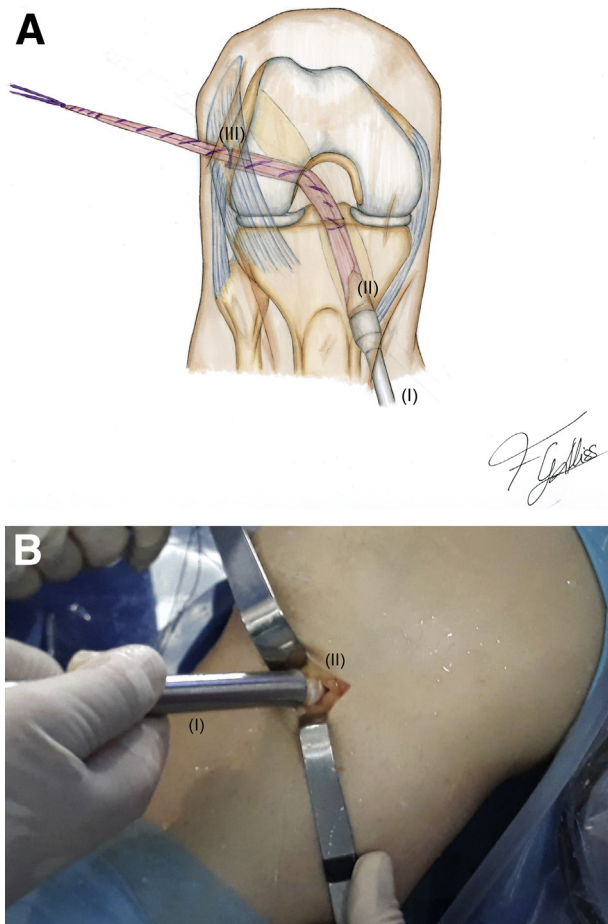


Fig 11. Intra-articular stage and subsequent tibial fixation. (A) Fixation procedure for Achilles graft in tibia. An impactor (I) is used to secure the tibial end of the reconstruction. The bone block (II) provides a stable and natural fixation. In the illustration, one can see how the allograft exits through the lateral aspect of the femur and across the iliotibial band (III) before being introduced again under it to its definitive fixation place in the proximal tibia. (B) Intraoperative clinical image showing impaction of Achilles bone plug in distal tibial tunnel. An impactor (I) is used to secure the tibial end of the reconstruction. The bone block (II) provides a stable and natural fixation without the need for surgical implants.

Achilles tendon provides adequate mechanical strength and sufficient length to both act as an ACL graft and reinforce the ALL in an extra-articular ALL reconstruction stage.^{6,11,12} In addition, we carve the bone block into a stopper that self-blocks in the tibial tunnel, resulting in a more natural fixation.¹⁴

The graft can be prepared on a separate table, concurrently with the arthroscopic procedure, to shorten the surgical time. The steps to be followed in this scenario are outlined in [Table 2](#).

Femoral Tunnel Preparation. We start with the femoral tunnel to avoid arthroscopic fluid loss ([Fig 8](#), [Video 1](#)).

We use an outside-in technique. With the knee in hyperflexion, we place the femoral guide—through the lateral portal—at the starting point of the tunnel, located on the medial wall of the femoral condyle, specifically in the center of the posterior half of an imaginary line along the anteroposterior length of the condyle.

Because our technique includes an extra-articular ALL reconstruction stage, the entry point of the guide is located somewhat proximally and posteriorly to the lateral femoral epicondyle. Then, by use of the guide, the needle is inserted. Once the needle is in the desired position, we gradually drill until we reach the diameter of the graft.

Tibial Tunnel Preparation. We position the articular end of the guide at the desired point, using the tibial spines or the anterior horn of the lateral meniscus as articular references ([Fig 9](#), [Video 1](#)). If possible, we choose an extra-articular end of the tunnel that takes advantage of the incisions made in previous surgical procedures. An incision is made in the entry area, and the drill guide is moved forward toward the joint. Once correct positioning is confirmed, the tunnel is gradually drilled until we reach the graft diameter. Because our technique uses the bone block of the graft itself as tibial fixation, we drill the first few distal centimeters of the tunnel up to a diameter similar to that of the bone block.

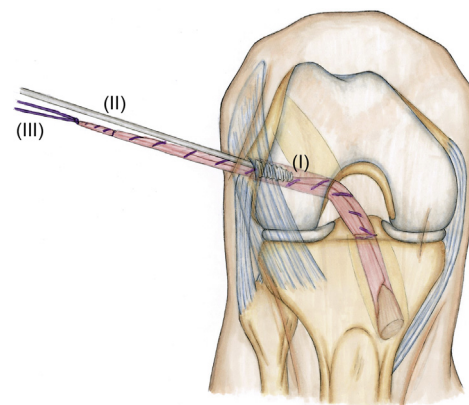


Fig 12. Femoral fixation of graft. To perform femoral fixation of the Achilles allograft, a resorbable interference screw (I) is used, which is inserted over a nitinol guidewire (II). This wire was introduced before tendon passage to facilitate the fixation procedure. Pre-tensioning of the graft is achieved by manual traction (III). Traction is applied to the graft with the knee at 20° of flexion. Then, a screw of the same diameter as the tunnel is inserted.

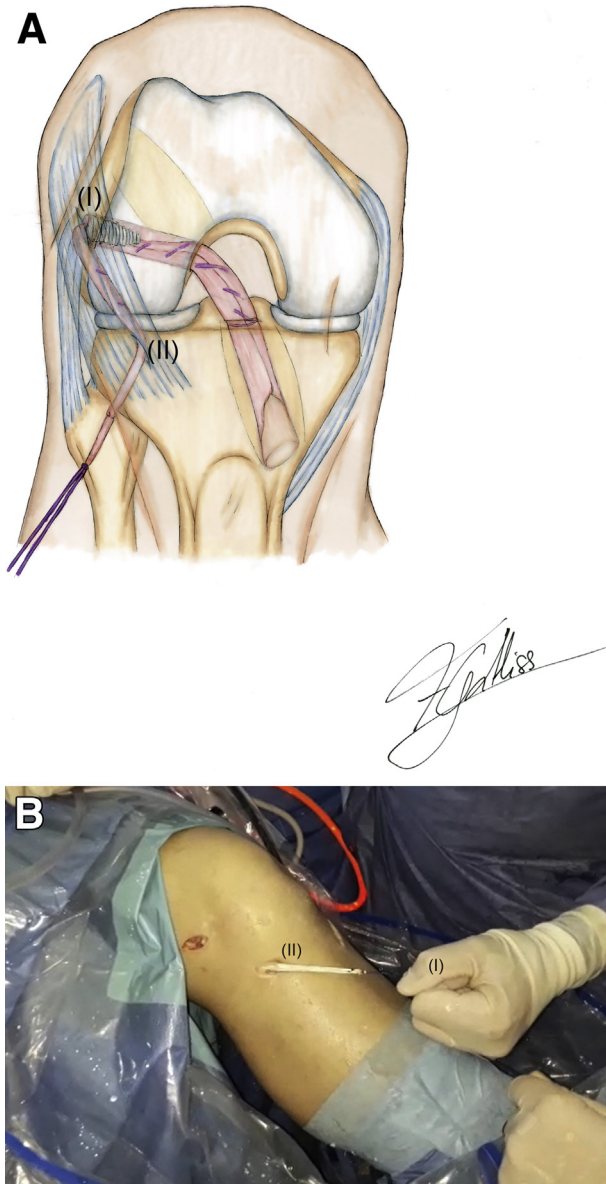


Fig 13. Extra-articular stage and tibial fixation. (A) Passage of Achilles allograft below iliotibial band and to its definitive fixation place in distal tibia. To reinforce the lateral ligament, by use of sutures placed previously, the lateral end of the Achilles graft is slid under the iliotibial band (I) and pulled to its distal fixation point. The iliotibial band is again opened distally (II) to allow graft passage. The distal fixation point is located halfway between the Gerdy tubercle and the head of the fibula. Fixation is performed with a staple while the knee is kept in 30° of flexion and with the foot in a neutral position. (B) Intraoperative clinical image showing traction performed by the surgeon (I) to achieve adequate tension before proceeding to distal fixation (II) of the lateral ligament reinforcement. Traction is performed while the knee is kept close to extension.

Intra-articular Stage and Tibial Fixation. By use of conventional suturing techniques, the graft is moved forward from the tibial tunnel to the femoral tunnel

until its tip is visible through the lateral aspect of the femur (Figs 10 and 11, Video 1). The neoligament is moved forward while cycles of knee flexion and extension are performed to facilitate the maneuver. An impactor is used to achieve a stable press fit between the bone block of the graft and the distal portion of the tibial tunnel. When distal fixation is achieved, we apply tension on the graft with the knee at 20° of flexion, and we perform several cycles of knee flexion and extension to facilitate the normal adaptation of the graft.¹⁵

Femoral Fixation of Graft. Femoral fixation is performed using an absorbable interference screw (Bio-sure; Smith & Nephew, Andover, MA) (Fig 12). For this purpose, the screw guide is inserted into the femoral tunnel through the lateral incision of the femur. While graft tension is maintained with the knee at 20° of flexion,¹⁶ a screw of the same diameter as the graft is placed. The excess graft is not cut because it will be used for the extra-articular reinforcement of the reconstruction.

Extra-articular Stage and Tibial Fixation. To reconstruct the ALL, the remaining end of the graft is reintroduced below the iliotibial band, joining the exit point of the femur with the point of tibial fixation by performing blunt dissection with Bengolea forceps (Fig 13, Video 1). Distally, the graft is pulled back over the iliotibial band through a small incision. The point of distal fixation is placed halfway between the Gerdy tubercle and the head of the fibula, approximately 15 mm below the joint line. Fixation is performed using a ligament fixation staple (Grapa Dentada; Citieffe, Bologna, Italy) while the knee is maintained at 30° of flexion and with the foot in the neutral position.

Final Check and Surgical Wound Closure

Before surgical wound closure, we perform several cycles of knee flexion and extension to check the performance of the graft (Fig 14). If this performance is satisfactory, normal layered wound closure is performed.

Discussion

The described technique is reserved for complex cases with significant bone loss because it involves 2 surgical procedures (with their associated risks) and a longer period of inactivity owing to the time required for reconstruction integration. However, in selected cases, this technique reduces morbidity in the donor areas (bone graft and ligaments), generates a safe substrate for integrating the reconstruction, facilitates fixation due to the allograft bone block, and provides greater rotational stability (Table 3).

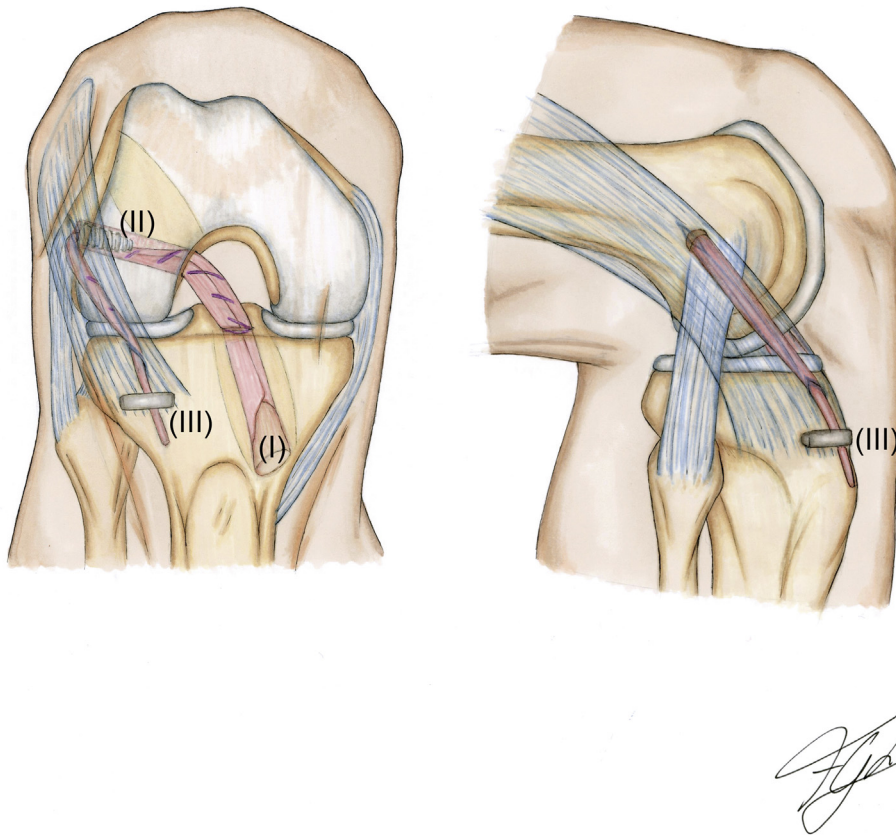


Fig 14. Final check and surgical wound closure. Anteroposterior (left) and lateral (right) views of the final reconstruction situation are shown with the knee in flexion. Tibial fixation of the anterior cruciate ligament part of the reconstruction (I) is performed by means of a bone block of the Achilles graft. Femoral fixation (II) is achieved with a resorbable interference screw. Tibial fixation of the lateral part of the reconstruction (III) uses a standard ligament staple to achieve secure anchorage.

Table 3. Advantages and Limitations of Technique

Advantages

- The surgeon can choose the orientation of the new tunnels without restrictions.
- The substrate for osseointegration of the reconstruction is optimal.
- The use of an Achilles graft makes it possible to replace the absent autologous graft.
- The use of an Achilles graft allows reconstruction of both the ACL and ALL.
- Donor-area morbidity is reduced.
- The bone block of the Achilles graft allows a natural fixation without using implants.
- Rotational stability is increased thanks to lateral ligament reinforcement.
- The iliotibial band is not weakened by other anterolateral techniques.
- The possibility of convergence of the ACL and anterolateral tunnels is avoided.
- A longitudinal incision in the lateral aspect of the knee is not necessary for lateral reinforcement.
- The ischemia time is shorter if the Achilles graft is prepared before tourniquet application.

Limitations

- Two surgical procedures, which multiplies associated risks
- Longer modification time of normal activity, during integration of tunnel filling
- More time with unstable knee, which increases risks of meniscal and/or chondral damage
- Higher rerupture risk (especially in young patients)
- More expensive than using autograft
- Dependence on tissue bank availability
- Higher risk of infection or disease transmission because of allograft use
- Slower biological incorporation of graft
- Fast rehabilitation not advisable

ACL, anterior cruciate ligament; ALL, anterolateral ligament.

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