Technical Note

Combined Anatomic Anterior Cruciate and Anterolateral Ligament Reconstruction With Quadriceps Tendon Autograft and Gracilis Allograft Through a Single Femoral Tunnel

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Abstract: Despite technical advances in anterior cruciate ligament (ACL) reconstruction surgery, there remains a need to improve postoperative outcomes with respect to graft failure rates. Recently, it has been shown that combined ACL—anterolateral ligament (ALL) reconstruction (using a graft composed of a tripled semitendinosus and single-strand gracilis tendon) is associated with a significant reduction in graft rupture rates compared with isolated ACL reconstruction. It is recognized that the hamstring tendons are not always available (revision scenario) or are not always the primary ACL graft choice. Some surgeons prefer to use quadriceps tendon ACL grafts because of the suggestion that these grafts may be associated with equal or better functional scores. However, if surgeons wish to try to reduce the risk of graft failure by performing an ALL reconstruction, either a combined reconstruction or the use of an independent ALL graft, with a separate femoral socket, could be considered. The disadvantage of an independently performed extra-articular procedure is the risk of femoral socket collision with the femoral ACL tunnel. This Technical Note therefore describes the use of a combined ACL-ALL reconstruction using quadriceps tendon autograft (ACL graft), gracilis allograft (ALL graft), and a single femoral tunnel.

It is well recognized that high graft rupture rates are an important problem after anterior cruciate ligament (ACL) reconstruction. This is particularly the case in young patients involved in pivoting sports, in whom the literature has consistently shown graft failure rates of around 30%.[1-7] It is promising that a recent, large comparative study has shown a significant reduction in ACL graft rupture rates after combined ACL—anterolateral ligament (ALL) reconstruction (using hamstring tendons) compared with isolated ACL reconstruction.[8,9] A separate large clinical series has also reported that there is no increase in the reoperation rates after combined ACL-ALL reconstruction compared with isolated ACL reconstruction and has shown a very low rate of specific complications.[10] These encouraging outcomes are further supported by systematic reviews that have shown a significant reduction in the rate of persistent pivot shift when an extra-articular tenodesis is performed in addition to ACL reconstruction, as well as no increase in the long-term risk of osteoarthritis. The confidence gained from good clinical outcomes and a low complication rate has led to an increasing trend for surgeons to perform an additional extra-articular procedure to improve the results of ACL reconstruction.[11,12]

The aforementioned combined ACL-ALL reconstruction uses a graft composed of a tripled semitendinosus and single-strand gracilis tendon. However, the hamstring tendons are not always available in the

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Table 1. Advantages, Indications, Contraindications, Tips and Pearls, and Pitfalls and Risks of Technique

Advantages
Use of a single femoral tunnel avoids the risk of femoral tunnel collision.
The technique is based on modification of an existing technique with comprehensive reporting of outcomes and complications.
Hamstring tendon donor-site morbidity is avoided.
The technique allows combined ACL-ALL reconstruction when hamstring tendons are not available.
The technique provides anatomic reconstruction of the ACL and ALL.
ALL reconstruction is minimally invasive, avoiding stiffness due to EAT.
Indications
Revision ACL reconstruction
Chronic ACL injury
Higher-grade preoperative pivot-shift test
Lateral notch sign
Pivoting or high-demand athlete
Age < 20 yr
Contraindications
Performance of this technique without treatment of known causes of ACL failure
Lack of knowledge about extra-articular procedures and ALL anatomy
Autograft QT and gracilis allograft of insufficient size (minimum of 22 cm for gracilis)
Tips and pearls
The surgeon should harvest the QT carefully to avoid damage to the graft proximally and should try to avoid penetration intra-articularly. The surgeon should harvest a $10 \times 10 \times 20$—mm patellar bone plug and carefully extract the plug with an osteotome.
Before the QT bone plug is harvested, the gracilis tendon should be carefully sutured to the QT with a FiberLoop, giving continuity between the ACL and ALL grafts.
The surgeon should measure the lengths and/or diameters of the grafts right after harvesting and preparation.
The skin incision should be performed proximal and posterior to the LFE for the femoral ALL landmark.
The anatomic tibial landmark for ALL reconstruction is between the Gerdy tubercle and fibular head.
The surgeon should avoid leaving the femoral screw protruding on the femur.
The ALL graft should be passed under the iliotibial band.
Pitfalls and risks
A protruding femoral screw can irritate the iliotibial band—the surgeon should remember that the single femoral tunnel is likely to be more horizontal than the typical femoral tunnel orientation in isolated ACL reconstruction.
The femoral tunnel length should be measured to ensure that the screw selected is an appropriate length.
Levering on the bone plug should be avoided because this can lead to fracture of the plug or the patella.
The remaining QT segment is carefully closed to avoid joint leakage.
Patients can have lateral discomfort for up to 3 mo because of the iliotibial tract incision. They should be counseled regarding this risk preoperatively.
Care should be taken when drilling the tibial tunnel to avoid an anterolateral plateau fracture or ACL tibial tunnel collision. Drilling should be limited to 15-mm sockets.

ACL, anterior cruciate ligament; ALL, anterolateral ligament; EAT, extra-articular tenodesis; LFE, lateral femoral epicondyle; QT, quadriceps tendon.

revision scenario, and other reasons for graft choice may also preclude their use, for example, surgeon preference. An alternative, increasingly popular graft choice is the quadriceps tendon (QT). A recent study has shown that it may offer the advantages of improved functional outcomes and reduced graft failure compared with hamstring tendons, without any increase in surgical morbidity.[13] When using a QT ACL graft, if the surgeon wishes to also perform an ALL reconstruction, this can be performed with an independent graft and a separate femoral socket, as previously described. However, such an approach risks collision between the ACL and ALL femoral tunnels. This is also an issue with other types of currently popular extra-articular tenodesis procedures that are performed independently of the ACL reconstruction. For this reason, there are considerable advantages associated with combined ACL-ALL grafts that use a single femoral tunnel.

This Technical Note describes a technique for combined anatomic ACL and ALL reconstruction using a QT autograft (ACL graft) and gracilis tendon allograft (ALL graft) and a single femoral tunnel (Video 1). Advantages, indications, contraindications, tips and pearls, and pitfalls and risks are summarized in Table 1.

Surgical Technique

Patient Setup

After induction of anesthesia, the patient is positioned supine on the operating table in the standard arthroscopy position with a lateral post just proximal to the knee, at the level of the padded tourniquet (Fig 1A). A foot roll is placed to prevent the hip from externally rotating and to maintain knee flexion at 90° when required but also to permit unrestricted range of motion (Fig 1B). Examination under anesthesia is performed.

Surgical Landmarks

After preparation of the skin and draping, surgical landmarks for quadriceps graft harvesting, arthroscopic

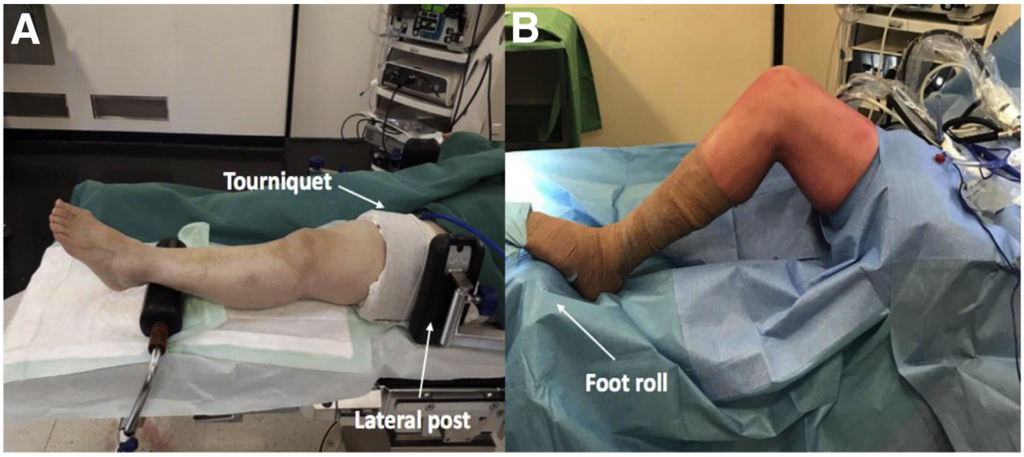

Fig 1. (A) Patient setup for a left knee; a lateral post is positioned at the level of the padded tourniquet. (B) A foot roll is used to keep knee flexion at 90°.

portals, and ALL reconstruction are marked. These are described in the following sections and are shown in Figure 2.

Graft Harvesting and Preparation

QT autograft harvesting is performed through a midline skin incision of 6 to 7 cm placed just proximal to the superior border of the patella (Figs 2 and 3A). Through this incision, a minimum graft length of 8 to 9 cm (measured from the superior border of the patella), with all 4 layers of the central QT, is easily obtainable with a desired depth of 11 to 13 mm and a width of 10 mm (Fig 3B). Before the QT bone plug is harvested, a gracilis tendon allograft (minimum length, 22 cm; Fig 3D) is sutured to the proximal 2 cm of the QT with a FiberLoop (Arthrex, Naples, FL), thus giving continuity between the QT ACL graft and the gracilis ALL graft (Fig 3C).

The patellar bone plug is then harvested using a saw blade (Fig 3E). The bone plug harvest should yield a length of 20 to 25 mm, width of 10 mm, and depth of 10 mm to obtain a total QT—bone plug graft length of 11 to 13 cm (Fig 3F). The graft is then prepared on the back table by drilling 2 tunnels through the bone with a 2-mm drill. The holes are loaded with an absorbable No. 2 Vicryl suture (Ethicon, Somerville, NJ). The graft is then ready for sizing and implantation (Fig 3F).

ACL and ALL Reconstruction

The ALL femoral and tibial positions are located before arthroscopy is performed. Three bony landmarks are marked: the head of the fibula, the Gerdy tubercle, and the lateral epicondyle (Fig 2). On the tibial side, 2 small incisions, separated by approximately 2 cm, are made 1 cm distal to the joint line. The first is placed just posterior to the Gerdy tubercle and the second, just anterior to the fibular head (Fig 2). On the femoral side, a small incision is made slightly posterior and proximal to the lateral epicondyle on the femur (Fig 2).

A 4.5-mm drill bit is then used to create two 15-mm sockets in the tibia via the 2 small incisions (Fig 4A). The entrances to the tunnels are widened using the drill to ease passage of the graft. The 2 sockets are connected in a subcortical manner using a right-angled clamp (Fig 4 B and C). A suture (No. 2 Ethibond; Ethicon) is then passed in a retrograde manner from the anterior tibial tunnel aperture to the posterior aperture to create a loop for graft passage (Fig 4 D-F).

The correct intended femoral tunnel position is confirmed by checking that the subsequently placed ALL graft will have normal kinematics and non-isometry. To verify this, the Ethibond suture is looped on itself and is clamped with a hemostat, which is held with its tip slightly posterior and proximal to the lateral epicondyle, at the area previously incised. The knee is

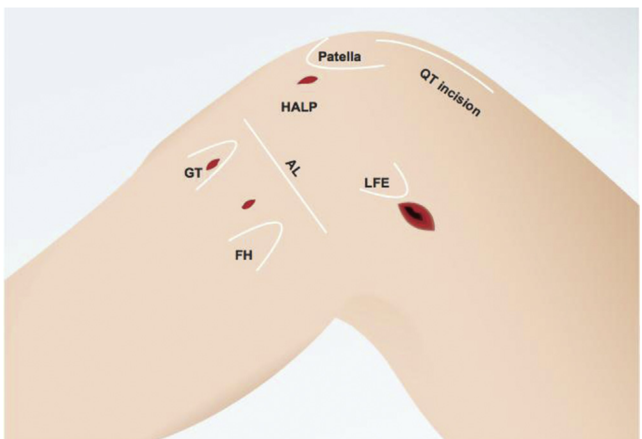

Fig 2. Left knee view showing landmarks for quadriceps graft harvesting (quadriceps tendon [QT] incision), with a high anterolateral portal (HALP) to avoid the Hoffa tissue. For anterolateral ligament reconstruction, 3 bony landmarks are marked: the head of the fibula (FH), the Gerdy tubercle (GT), and the lateral epicondyle (LFE). The articular joint line (AL) is also drawn.

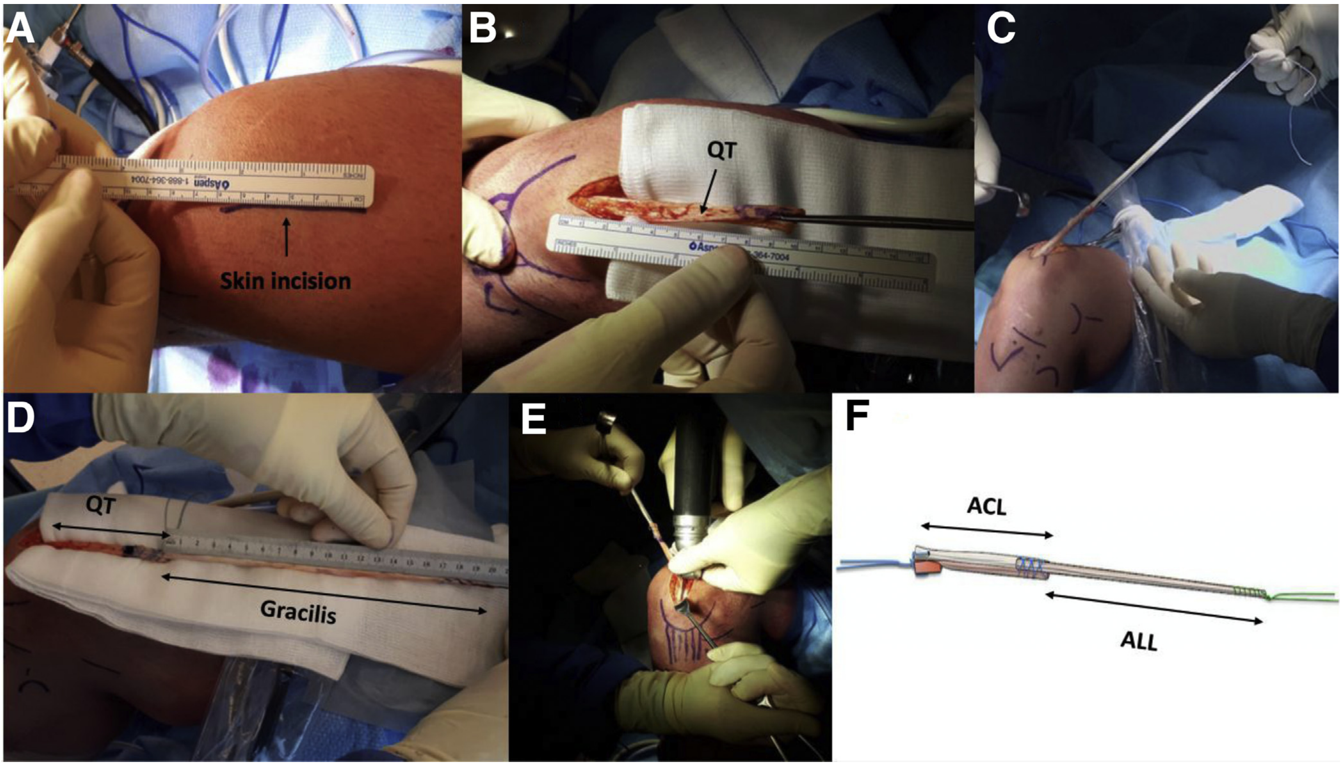

Fig 3. Left knee view. Graft harvesting and preparation of quadriceps tendon (QT) autograft for anterior cruciate ligament (ACL) reconstruction and gracilis tendon allograft for anterolateral ligament (ALL) reconstruction (A, B, D, F), both sutured together with a FiberLoop (C). (E) The patellar bone plug is harvested using a saw blade.

then taken through the range of motion. If the tip of the hemostat is correctly positioned just proximal and posterior to the lateral epicondyle, then the graft will be tight in extension and slack in flexion.

Diagnostic knee arthroscopy is performed. A high anterolateral portal is preferred to avoid the Hoffa fat pad (Fig 2), and any meniscal or cartilage injuries identified are treated. The intercondylar area is prepared by shaving the inside wall of the lateral femoral condyle.

The femoral tunnel of the ACL is made using an outside-in technique (outside-in jig; Arthrex). When the jig is positioned, external viewing is used to confirm that the outside-in femoral guidewire will enter the lateral femoral condyle at the previously confirmed femoral tunnel position, just proximal and posterior to the lateral epicondyle. On arthroscopic viewing, the jig is positioned so that the wire will exit the medial wall of the lateral femoral condyle at the footprint of the native ACL. The tunnel is then drilled over the guidewire to the same size as the ACL graft diameter. This is performed with sequentially larger reamers starting with 6 mm (Fig 5A).

The tibial jig (outside-in jig) is set at 55° and positioned to achieve guidewire placement within the native ACL tibial footprint. The jig is also positioned so that the tibial guidewire enters the external medial tibial cortex 1 cm medial to the tibial tuberosity. After the guidewire is inserted and the correct position is confirmed, it is over-reamed to achieve a tunnel that is of equal diameter to the prepared QT bone plug. This is also performed in a sequential manner (Fig 5B).

After the tunnels are drilled, with the knee at 90° of flexion, the graft is passed through the tibial tunnel to the femur under arthroscopic control. It is ensured that the QT bone plug remains within the tibial tunnel. Therefore, the intra-articular ACL graft is formed from the QT autograft, but the gracilis allograft, which will be used for ALL reconstruction, exits through the single femoral tunnel at the lateral condyle (Fig 6A).

A bioabsorbable interference screw (Bio-Interference screw; Arthrex) with a diameter 1 size less than the tunnel size is used for femoral graft fixation. This is inserted over a nitinol guidewire (Fig 6A). The ACL graft is then secured on the tibial side with a bioabsorbable interference screw (Bio-Interference screw) that is the same size as the tibial tunnel diameter. This is introduced over a nitinol wire, with tension on the sutures placed in the bone block, with the knee at approximately 30° of flexion (Fig 6B). To complete the tibial fixation, the sutures fixed on the bone graft plug are passed into a 2-mm drill hole placed in the anterior aspect of the tibial tuberosity and tied together.

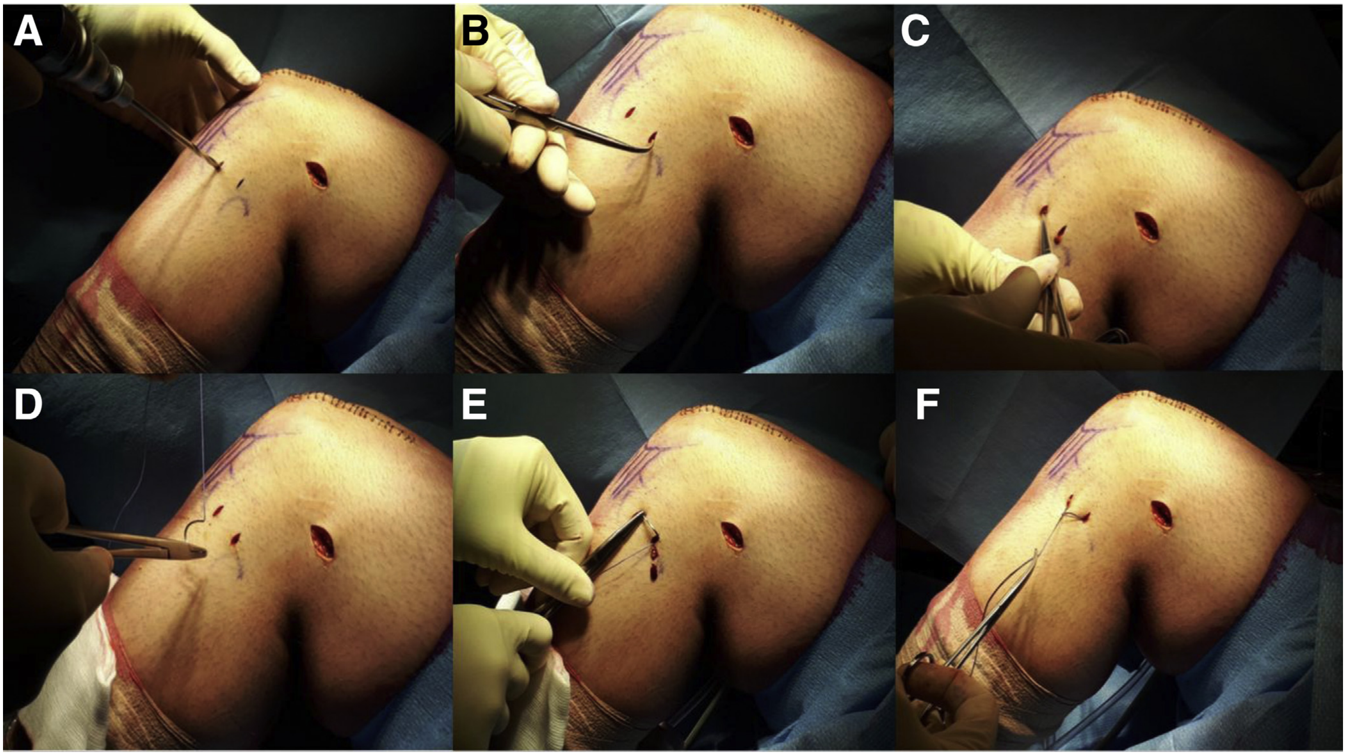

Fig 4. Left knee view showing bony landmarks for anterolateral ligament reconstruction. (A) A 4.5-mm drill bit is used to create a bony tunnel in the tibia, and the entrances to the tunnels are widened to ease passage of the graft. (B, C) The 2 tunnels are connected in a subcortical manner using a right-angled clamp. (D-F) A suture (No. 2 Ethibond) is passed in a retroverted fashion to create a loop and ease graft passage.

After fixation of the ACL graft, the remaining portion of the gracilis allograft is used for the ALL reconstruction (Fig 7A). An arthroscopic grasper is passed from the posterior ALL tibial tunnel, deep to the iliotibial band, to the femoral tunnel location, and the suture connected to the free end of the gracilis tendon is retrieved (Fig 7 A and B). The allograft is then passed through the tibial bone tunnel using the previously passed suture (Fig 7B). The arthroscopic grasper is passed from the femoral tunnel, deep to the iliotibial band, to the anterior tibial tunnel and used to bring the end of the gracilis allograft back out from the proximal femoral incision (Fig 7C). For ALL fixation, the knee is brought into full extension, giving an automatic neutral rotation (which prevents any risk of over-tightening in external rotation of the tibia), and the sutures holding the ACL graft are passed around the ALL graft and tied several times (Fig 7C). Excess suture and graft are incised. No drains and no immobilization are used after reconstruction.

Postoperative Re-education

Compressive cryotherapy (Game Ready program 2; CoolSystems, Concord, CA) is commenced immediately in the recovery room for 4 hours continuously and then for 30 minutes every 3 hours for 15 days. A standard ACL rehabilitation program is instituted, allowing immediate, brace-free, full weight bearing with crutches for 4 weeks and progressive range-of-motion exercises. Early rehabilitation is focused on obtaining full extension and vastus medialis activation. A gradual return to sports activities is allowed starting at 4 months for nonpivoting sports, at 6 months for pivoting noncontact sports, and at 8 to 9 months for pivoting contact sports.

Discussion

Good clinical results are reported in the contemporary literature after combined ACL-ALL reconstruction specifically with respect to reduced rates of graft rupture and improved return-to-sport rates.[8,9] In addition, a recent study of over 500 combined ACL-ALL reconstructions with a mean follow-up period of 2 years has shown that there is no evidence that this procedure is associated with the increased risk of complications or the frequent reoperations that were reported after historical nonanatomic lateral extra-articular tenodesis (LET)−type procedures, which led to them being widely abandoned in the 1980s.[10] These promising results, along with a wealth of anatomic, biomechanical, and clinical studies, have really increased the confidence in extra-articular procedures, and there is no

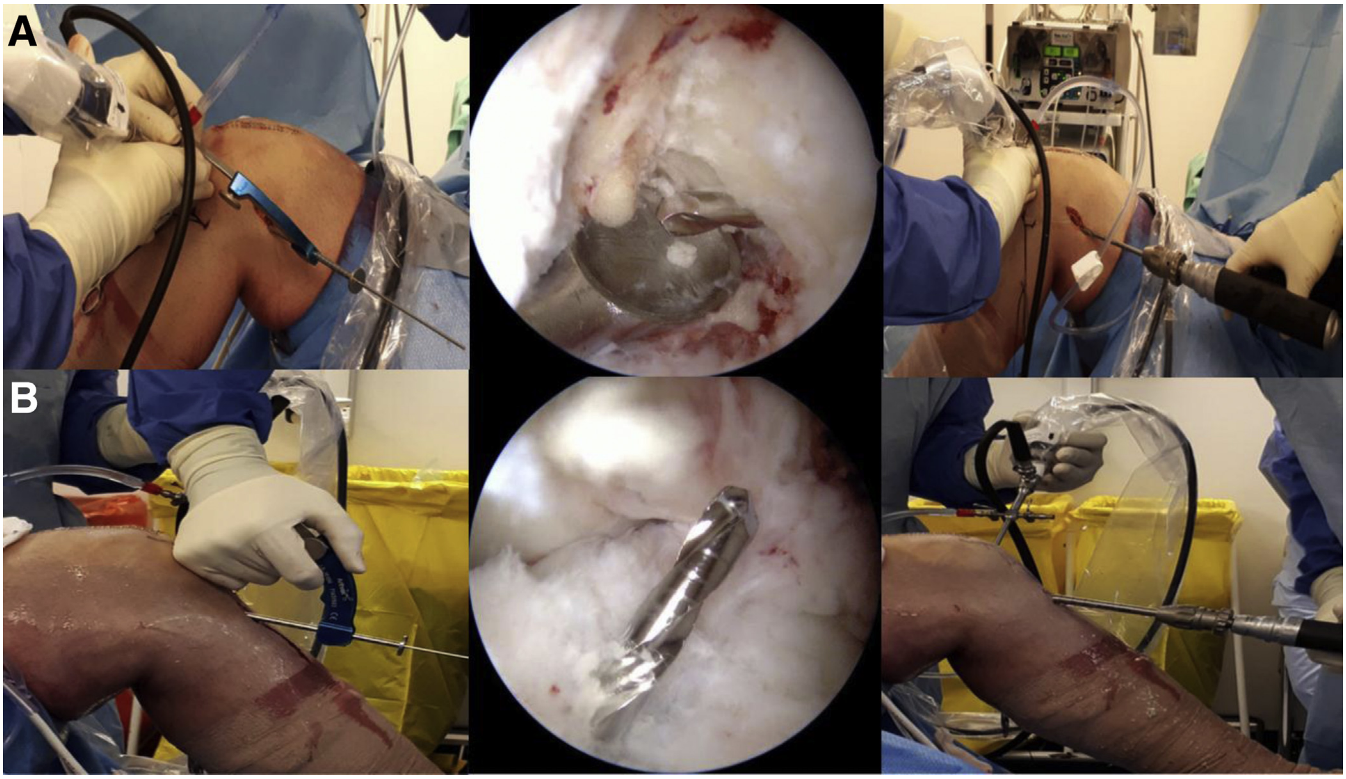

Fig 5. Left knee view. The femoral guidewire is placed outside to the lateral femoral condyle at the appropriate landmark marked for optimal anterolateral ligament isometry, exiting intra-articularly into the medial wall of the lateral condyle at the footprint of the native anterior cruciate ligament (ACL). (A) Drilling is performed using first a 6-mm reamer and then 2 mm progressive until measured tendinous ACL end size. The tibial tunnel is made within the native ACL tibial footprint. (B) The tibial guidewire (outside-in jig) is placed at 55° from the external medial tibial cortex into the ACL remnant. The diameter of the tunnel is equal to the diameter of the prepared quadriceps tendon bone plug of the ACL graft. As on the femoral side, progressive drilling is performed until the measured ACL size.

doubt that they are being performed increasingly frequently.[14-19]

Numerous different types of LET procedures have been reported, but few are supported by comprehensive reporting of outcomes and explicit reporting of complications.[11,20,21] One of the potential complications is tunnel collision between the ACL reconstruction and LET. This is only a concern when the extra-articular

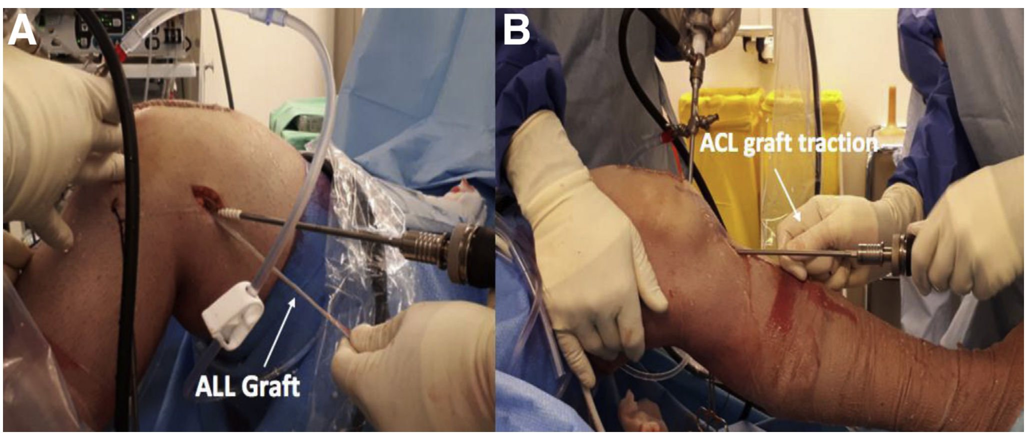

Fig 6. Left knee view. (A) Femoral anterior cruciate ligament fixation is first performed with a bioabsorbable interference screw (Bio-Interference screw) with a diameter 1 size less than the tunnel size using a nitinol guidewire. (ALL, anterolateral ligament.) (B) The graft on the tibial side is secured with a bioabsorbable interference screw (Bio-Interference screw) the same size as the tunnel diameter with the knee at approximately 30° of flexion also using a nitinol guidewire; traction is placed on the anterior cruciate ligament (ACL) graft during fixation.

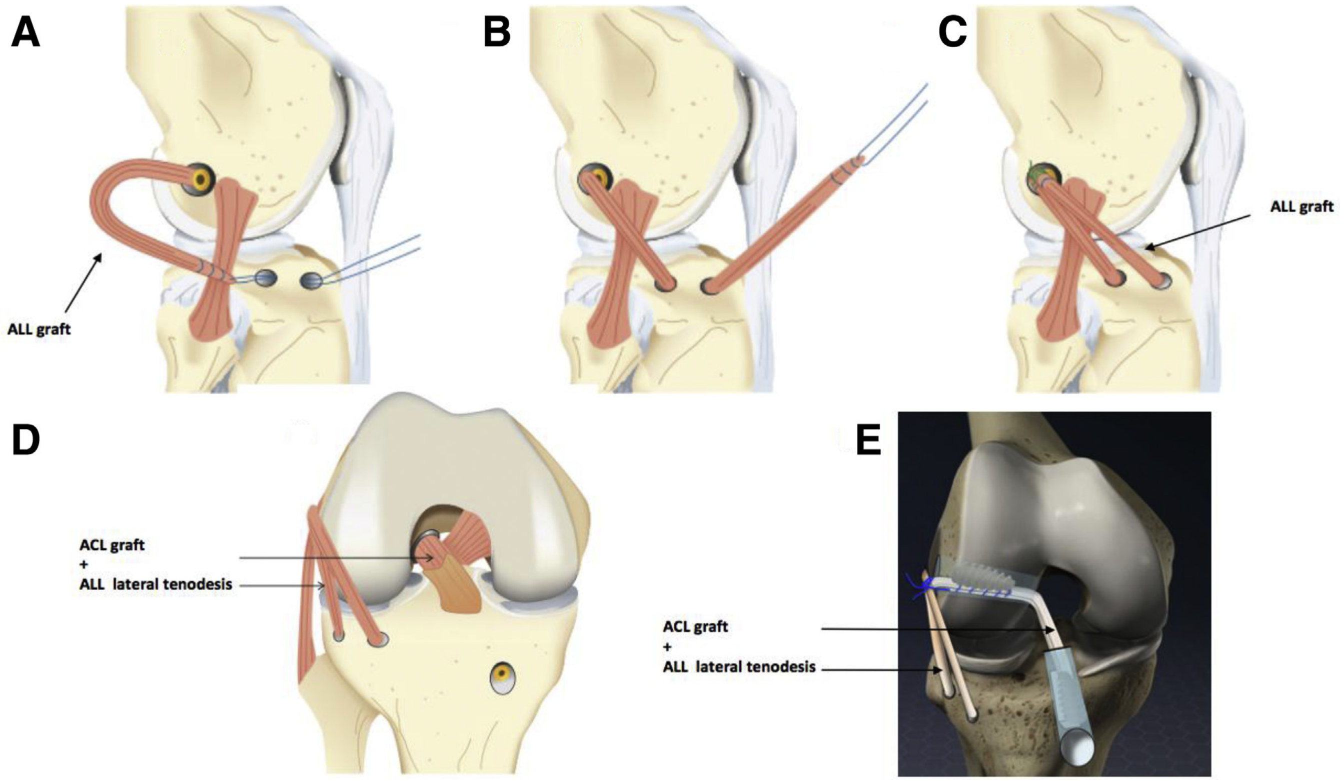

Fig 7. Left knee lateral and anteroposterior views. (A) After anterior cruciate ligament (ACL) fixation, the remaining portion of the gracilis allograft is used for anterolateral ligament (ALL) reconstruction. An arthroscopic grasper is used to pass, deep to the iliotibial band, the gracilis to the posterior tibial bone tunnel. (B) The allograft is passed through the tibial bone tunnel using the previously passed suture. (C) By use of the arthroscopic grasper passed deep to the iliotibial band, the gracilis allograft is brought back proximally once again out the proximal femoral incision. For ALL fixation, the knee is brought into full extension, giving an automatic neutral rotation, and the sutures holding the ACL graft are circled around the ALL graft. (D) Excess suture and graft are incised, and the knee is taken through the range of motion. (E) Anteroposterior view of final result of ACL and ALL grafts.

procedure is performed with fixation independently of the ACL reconstruction but not when a combined reconstruction is performed using a single femoral tunnel.

Although good results are reported with combined ACL-ALL reconstruction using a single femoral tunnel and a graft composed of a tripled semitendinosus and single-strand gracilis, the hamstring tendons are not always available (revision procedure, needed for multiligament reconstruction, previously used for non-ACL reconstruction), and even if they are, their use may not be compatible with the specific preferences or requirements of the patient or surgeon. An alternative, increasingly popular graft choice is the QT. A recent study has shown that it may offer the advantages of improved functional outcomes and reduced graft failure compared with hamstring tendons but without any increase in surgical morbidity.[13] It also offers the advantages of potentially more rapid tibial tunnel integration (because of the bone block), decreased anterior knee pain compared with bone—patellar tendon—bone grafts, and a reduced risk of long-term hamstring weakness.[22] The technique described in this article therefore permits an alternative graft choice to hamstring tendons but still uses the basic tenets of combined ACL-ALL reconstruction by using a single femoral tunnel positioned anatomically to allow restoration of normal knee kinematics.

The gracilis allograft is a good option for the ALL reconstruction because its use means that the morbidity associated with autograft is avoided. Furthermore, a biomechanical study has shown that the 2-strand gracilis, when used for ALL reconstruction, has a maximum load to failure of approximately 200 N, which is higher than the native ALL, at 140 N, and is therefore an appropriate choice.[23]

The risks of this technique include iatrogenic intraoperative patellar fractures after QT bone block harvesting. To minimize the risk of this complication, some authors have proposed the use of a QT graft for isolated ACL reconstruction without an associated bone block.[24] However, other authors prefer a QT bone block to achieve a greater graft length and achieve better and faster integration into the bone tunnel than a soft-tissue graft.[25] Other risks of the procedure include anterolateral tibial fracture or tunnel collision if placement of the tunnels is not performed properly. However, in a series of over 500 combined ACL-ALL reconstructions that focused on the explicit reporting of reoperation rates and complications (using hamstring tendons but an otherwise similar technique), no tibial fractures or occurrences of tunnel collision were identified.[10] This finding suggests that with careful adherence to the recommended surgical technique, the risk of complications is extremely low.

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