Technical Note

Anterior Cruciate Ligament and Anterolateral Ligament Reconstruction With Pedicular Hamstrings Tendon Graft, Single-Strand Gracilis for ALL and Single Blind Femoral Tunnel

Thibaut Noailles, M.D., Cécile Toanen, M.D., Loïc Geffroy, M.D., Ronny Lopes, M.D., and Alexandre Hardy, M.D.

Abstract: Combined anterior cruciate ligament and anterolateral ligament reconstruction (ACL+ALL r) is a common procedure to treat rotational instability and to prevent ACL graft failure. Recent studies have described numerous combined reconstruction techniques to obtain the most anatomical procedure with the least graft donor site morbidity and the best clinical results. Hamstring (HG) grafts are the most popular graft in literature. Leaving pedicle HG can preserve enough blood supply to improve tendon-bone healing with additional mechanical fixation of the graft on the tibial side. A single femoral tunnel reduces bone loss and prevents convergence of 2 femoral tunnels. We describe an original ACL and ALL reconstruction technique that preserves hamstring tibial insertion with a single blind femoral tunnel.

Introduction

Anterior cruciate ligament tears (ACL) are one of the most frequent sports injuries.[1] The goal of surgery is intra-articular reconstruction of the ACL to treat sagittal instability. Despite the good results, postoperative rotatory instability persists in one-quarter of patients,[2,3] and graft failure occurs in 11%[4,5] of cases. For 10 years, reports have described combined surgery with extra-articular reconstruction of the anterolateral ligament (ALL).[6,7] The clinical results of combined ACL+ALL reconstruction are good for the treatment of rotatory instability,[8-10] with a reduced risk of retear.[11,12] Although the biomechanical principle of extra-articular reconstruction is well known,[13] the anatomical description of the ALL and biomechanical effects of ALL reconstruction compared to lateral tenodesis procedure are more recent.[14-16]

Numerous surgical techniques of combined ACL+ALL reconstructions using hamstrings have been reported.[17-28] In isolated ACL reconstructions, preservation of the hamstring tibial insertion enhances graft ligamentization by supplying vascularization.[29,30] When performing combined ACL and ALL reconstruction, only a few authors keep the semitendinous attached,[20,23] but the gracilis is always detached. Moreover, while many authors use a single femoral tunnel to avoid risk of convergence of the ACL and ALL femoral tunnels,[20-25,27,28] none of them use blind femoral tunnel, which would reduce bone loss and could improve graft incorporation. We describe a minimally invasive technique of combined ACL+ALL reconstruction (Video 1), keeping both pedicled hamstrings with a single blind femoral tunnel and a single strand gracilis graft for ALL reconstruction.

Surgical Technique

Pearls and pitfalls for each step of this procedure are given in Table 1, advantages, and limitations in Table 2.

Département de Chirurgie Orthopédique, Polyclinique de Bordeaux Nord, Bordeaux, France (T.N.); Service de Chirurgie Orthopédique, Centre Hospitalier Départemental Vendée, La Roche-sur-Yon, France (C.T.); Département de Chirurgie Orthopédique, Polyclinique de l'Atlantique, Saint Herblain Cedex, France (R.L.); and Clinique du Sport Paris V, Paris, France (A.H.).

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Address correspondence to Thibaut Noailles, M.D., Département de Chirurgie Orthopédique, Polyclinique de Bordeaux Nord, 15 rue Claude-Boucher, 33000 Bordeaux, France. E-mail: noaillesthibaut@yahoo.fr

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Table 1. Surgical Steps, Pearls, and Pitfalls

Surgical Steps	Pearls	Pitfalls
Graft harvesting	Leave the hamstrings pedicled to its tibial insertion.	To avoid a short harvesting, section the vincula then use a specialized stripper.
Drilling the single blind femoral tunnel for the ACL and ALL	1. Use a 110° outside-in femoral guide: - Positioned intra-articularly on the ACL femoral footprint for the ACL - Positioned extra-articularly posterior and proximal to the lateral epicondyle for the ALL 2. Drill a blind tunnel at 8 or 9 mm diameter and 20 mm length. 3. Enlarge the blind part of the tunnel with a 5-mm drill.	To avoid an extraarticular mispositioning of the femoral tunnel, draw the bony landmark of the lateral epicondyle before surgery.
Drilling the ALL tibial tunnel	Hand drilling a 5-mm complete tunnel: - Positioned proximally 1 cm below the joint line and 2 cm posterior to Gerdy's tubercule - Directed distally to the hamstrings' skin incision	Be careful of the hamstrings during drilling.
Drilling the ACL tibial tunnel	1. Use a 60° tibial guide. 2. Drill with 2 progressive drills to preserve the ACL remnant.	Be careful of the hamstrings during drilling.
Graft preparation and passage	1. Measure the length of the ACL graft using FiberStick. 2. Prepare the semitendinous in 3 strands using Endobutton for the ACL. 3. Leave the gracilis in one free strand for the ALL. 4. First advance the gracilis to the femur and then the semitendinous.	To avoid inappropriate length of the ACL graft, mark the distance between the tibial insertion of the hamstrings and the entrance of the ACL tibial tunnel.
Fixation of the ACL graft	Fixation at 20° of flexion with inverse Lachman	To avoid incarceration of the gracilis when tighten the endobutton, pull the gracilis down. Be careful of incarceration of ITB with the Endobutton.
Fixation of the ALL graft	Fixation in full extension and neutral rotation	To avoid lateral protrusion of the screw, push the screw completely into the ALL tibial tunnel.
Final check	Remove articular effusions before closing.	Confirm the lack of impingement between the notch and the ACL remnant/graft in full extension.

ACL, Anterior cruciate ligament; ALL, anterolateral ligament; ITB, Iliotibial band.

Positioning the Patient and Bony Landmarks

The patient is placed in the supine position. A leg holder is placed lateral to the thigh at the level of the tourniquet. With the Surginov foot holder knee positioner (Surginov, Saulx-les-Chartreux, France), the knee is initially in 90° flexion; however, it can be mobilized when needed with full range of motion (Fig 1).

Bony landmarks are marked, in particular, the joint spaces, the lateral epicondyle, Gerdy's tubercle, and the tibial insertion of the hamstrings (Fig 2). We found that there was always 6 cm between the femoral and tibial

Table 2. Advantages and Limitations of This Combined ACL+ALL Reconstruction

Advantages
- Combined ACL and ALL anatomical reconstruction decrease ACL and meniscus retear rate.
- Only hamstrings harvesting with ITB preservation
- Preservation of tibial insertion of both hamstrings with biological and mechanical advantages
- Single blind femoral tunnel allowing bone preservation and avoiding risk of tunnel convergence
- Only 3 systems of fixation with easy radiological identification of ALL tunnel
- Only one suspensory fixation at femoral side, avoiding irritation of ITB due to protruding screw
- Minimal scars with low risk of hematoma.
Limitations and Risk
- Longer procedure with additional surgical steps.
- Poor-quality hamstring harvesting not allowing sufficient length for ALL reconstruction required gracilis to be detached. This situation is rare.
- Improper femoral tunnel placement due to difficulty of finding anatomical position intra-articularly (ACL) and extra-articularly (ALL). Inaccurate femoral position of ALL may result in a nonisometric reconstruction.
- Femoral Endobutton not applied to the femoral cortex.
- Gracilis graft not passed under the ITB.

ACL, anterior cruciate ligament; ALL, anterolateral ligament; ITB, iliotibial band.

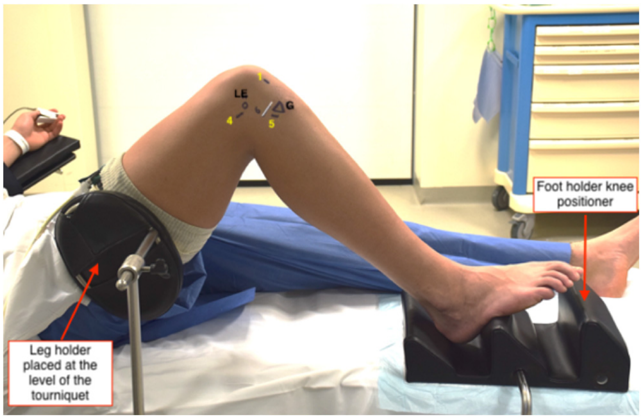

Fig 1. Lateral view of a right knee with installation with knee flexed initially at 90° and leg holder at the level of the tourniquet. G (triangle), Gerdy's tubercule; LE (circle), lateral epicondyle. White line denotes joint line. 1 denotes the anterolateral arthroscopic portal, 4 denotes a femoral tunnel skin incision, and 5 denotes anterolateral ligament (ALL) tibial tunnel skin incision.

skin incisions of the ALL and 6 cm between the medial joint space and the insertion of the hamstrings.

Harvesting the Hamstring Tendons

The autograft is harvested in the traditional manner with a vertical incision 6 cm above the joint space, 2 cm medial to the tibial tubercle, as described by Colombet.[31] The aponeurosis of the sartorius muscle is opened and the tendons of the gracilis (G) and the semitendinosus (ST) are harvested using a Linvatec stripper (ConMed, Utica, NY) after resection of the vinicula. The muscle strands are pulled out and the tibial insertions of the 2 tendons are always preserved. The tendons are presoaked with 500 mg of vancomycin in 100 mL of saline solution before being placed in the muscle compartments.[32]

Arthroscopy

Standard anterolateral and anteromedial arthroscopic portals are used. Intraarticular exploration of the menisci, and the cartilage is performed, including posteromedial compartment exploration. The notch is debrided: a tibial remnant of the ACL is preserved for proprioception,[33] and special attention is paid to the femur to identify the posterior trabecular bone/cartilage ridge junction.

Single Femoral Tunnel

A 1-cm lateral approach is created posterior and proximal to the epicondyle. The outside-in femoral guide (Arthrex, Naples, FL), set to 110°, the angle is placed in this approach and intra-articularly through anterolateral portal into the ACL femoral footprint. A blind femoral tunnel is created using a retrograde technique with a FlipCutter (Arthrex) measuring 8 or 9 mm in diameter, according the width of the hamstrings, by 20 mm in length (Fig 3A). The FlippCutter is retrieved, and a pin is placed into the blind femoral tunnel. Then, an enlargement of the blind tunnel is created with a 5-mm drill for easy passage of the Endobutton TightRope (Arthrex) and the single strand gracilis graft (Fig 3B). The shaver should be used to remove any posterior debris and the intra-articular entrance of the femoral tunnel (Fig 3C). Finally, the FiberStick (Arthrex) is placed in the femoral tunnel.

Tibial Tunnel for ALL

The ALL tibial tunnel is created free-handed, with a guide wire then the same 5-mm drill bit, beginning 1 cm below the joint line and 2 cm behind the Gerdy's tubercule in a downward and forward oblique direction toward the harvesting incision (Fig 4).

Tibial Tunnel for ACL

The ACL tibial tunnel is created through the harvesting incision above the ACL remnant using a tibial guide set to 60° angle (Fig 5). The 5-mm drill bit is used allowing guide wire repositioning if necessary and limiting damage to the bone during the second passage of the 8- or 9-mm drill bit.[34] This second passage is drilled slowing the motor to preserve the tibial remnant of the native ACL, according to the SAMBBA technique (Single Antero Medial Bundle Biological Augment) described by Sonnery-Cottet.[33] The ACL and ALL tibial tunnels are above the distal insertion of the hamstrings with never risk of convergence. The representation of the 3 bone tunnels is summarized in Figure 6.

Graft Preparation

The FiberStick, placed in the femoral tunnel, is retrieved from the joint and passed through the ACL

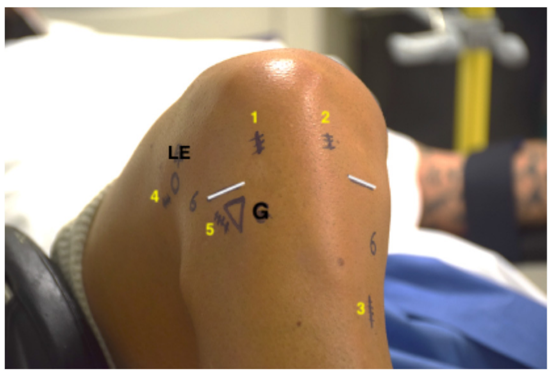

Fig 2. Front view of the right knee with bony landmarks and skin incisions. G (triangle), Gerdy's tubercule; LE (circle), lateral epicondyle. White lines denotes joint line. 1 denotes anterolatral arthroscopic portal, 2 denotes anteromedial arthroscopic portal, 3 denotes hamstring harvesting skin incision, 4 denotes femoral tunnel skin incision, and 5 denotes anterolateral ligament (ALL) tibial tunnel skin incision.

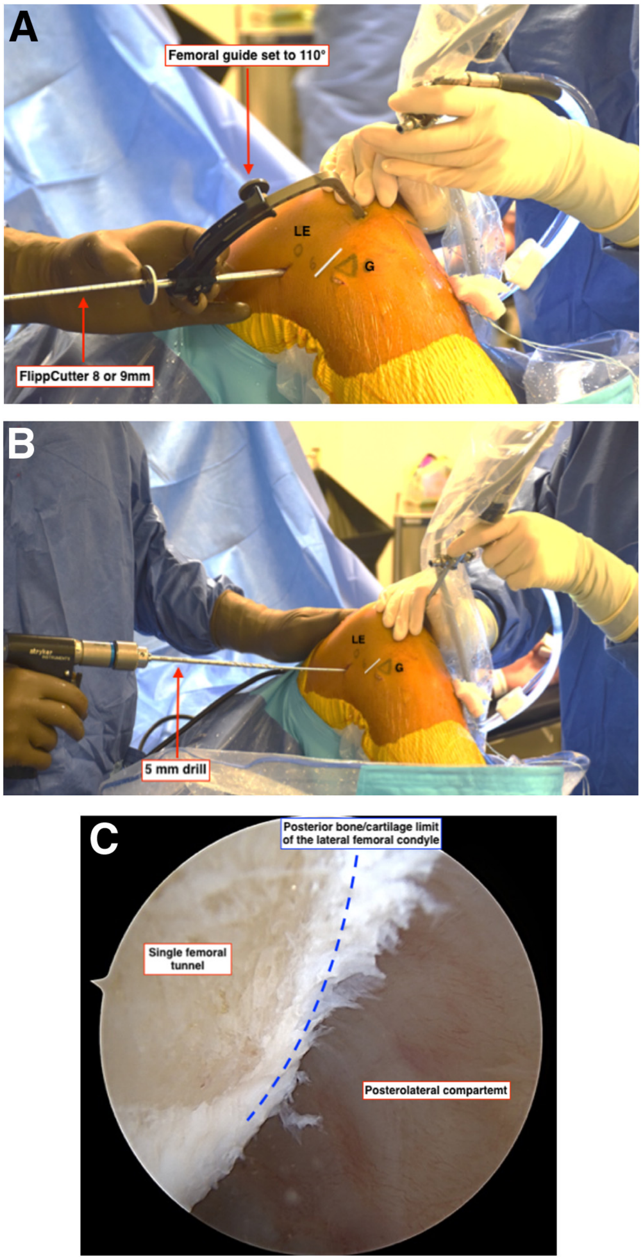

Fig 3. Lateral view for creation of the single blind femoral tunnel for anterior cruciate ligament and anterolateral ligament (ACL+ALL) using an out-in femoral guide set to 110° angle though a skin incision posterior and proximal to the lateral epicondyle. (A) Retrograde blind femoral tunnel for ACL graft using FlippCutter (diameter: 8 or 9 mm; length: 20 mm). G (triangle), Gerdy's tubercule; LE (circle), lateral epicondyle. White line denotes joint line. (B) Enlargement of the blind part of the blind femoral tunnel for ALL graft using a 5-mm drill though this lateral incision. G (triangle), Gerdy's tubercule; LE (circle), lateral epicondyle. White line denotes joint line. (C) Intra-articular view of the lateral femoral condyle to identify the limit between posterior bone and cartilage limit for a perfect placement of the single femoral tunnel.

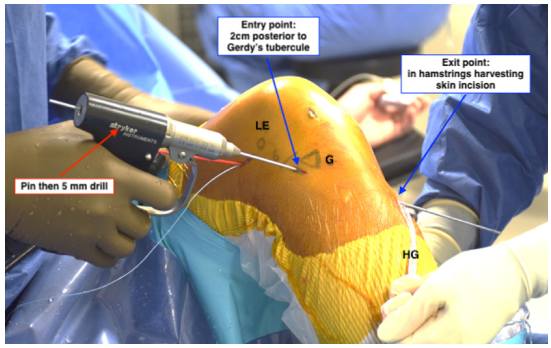

Fig 4. Through an incision posterior to Gerdy's tubercule, creation of the anterolateral ligament (ALL) tibial tunnel free-handed using a 5-mm drill. G (triangle), Gerdy's tubercule; HG, hamstrings; LE (circle), lateral epicondyle.

tibial tunnel until it emerged from the skin at the tibia. It is then deployed retrograde into the femoral tunnel (Fig 7), and the extraarticular entrance of the tibial tunnel is identified with an Halsted clamp. The FiberStick is used to measure the length of the ACL graft, from the blind femoral tunnel to extra-articular entrance of the tibial tunnel (blind femoral tunnel + articular portion + complete tibial tunnel) (Fig 8A).

The semitendinous (ST) tendon is marked with a surgical marker at the entrance of the tibial tunnel (an average of 2-3 cm above its bony insertion) and a second mark at the calculated distance (Fig 8B). The Endobutton TightRope is placed on the second mark. Then the ST tendon is folded into 3 strands between these 2 marks and sutured with a FiberLoop (Arthrex), from proximal to distal, for a sufficiently large 3-strand ST graft. This suturing results in a homogenous flat graft with perfect distribution of traction during fixation. The free end of the gracilis tendon is sutured for 2 cm using a FiberLoop (Fig 9 A and B).

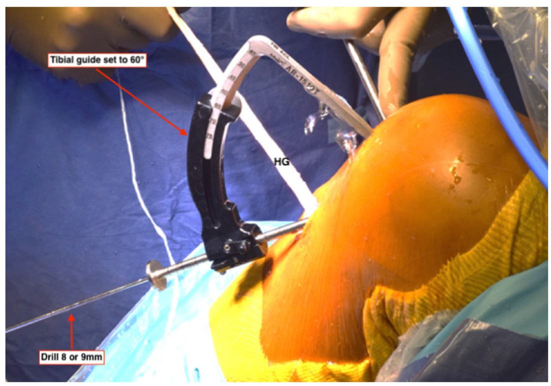

Fig 5. Creation of the anterior cruciate ligament tibial tunnel using a tibial guide set to 60° angle using 8- or 9-mm drill. This tunnel is made with particular attention to the pedicular hamstring tendons. HG, hamstrings.

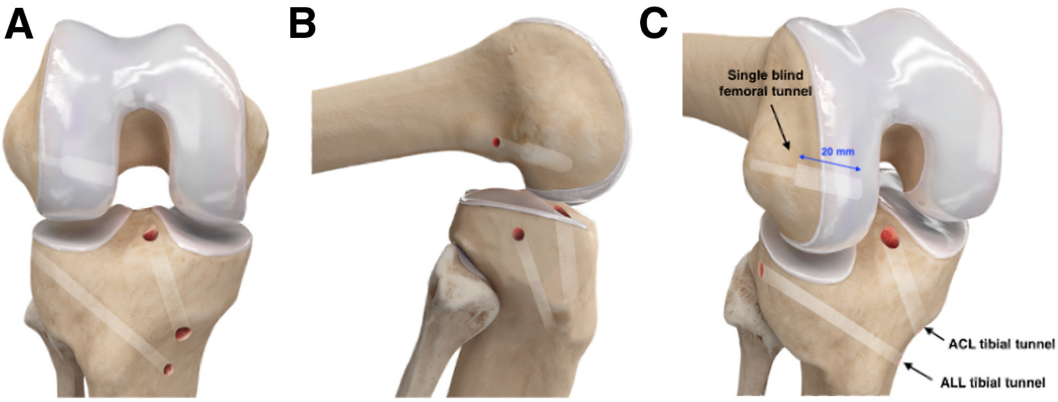

Fig 6. Summary of the 3 bone tunnels with front (A), lateral (B), and 3/4 views (C). Single blind femoral for anterior cruciate ligament and anterolateral ligament (ACL+ALL) with blind part of 5 mm and large part of 8 or 9 mm and 20-mm length, complete ACL tibial tunnel of 8 or 9 mm, and complete ALL tibial tunnel of 5 mm.

Graft Fixation

Thanks to the stiffened suture of the FiberStick, the 3-strand ST graft and the single-strand G graft (ST3+G1) forming ACL+ALL can be advanced to the femur. For an easy passage, the G1 is first to go through the femoral tunnel and then the ST3. The gracilis graft and the Endobutton TightRope emerge at the femur. The Endobutton is tightened behind and proximal to the lateral epicondyle, while the gracilis graft is pulled down (Fig 10 A and B) with knee flexed at 90°. There is no need of additional fixation of the ALL on the femoral side, as the gracilis is trapped by the femoral button. The ACL graft is then attached at 20° flexion using an absorbable tibial biocomposite FastThread interference screw (Arthrex) with an inverse Lachman maneuver and pulling down on the FiberLoop placed on the ST3 graft. The screw is located anterior to the ACL graft at the tibia, 20 mm long to favor synovialization in the tibial tunnel and 8 or 9 mm diameter according to the ACL tibial tunnel diameter. Finally, we verify that there is no conflict between the ACL graft and the roof of the notch during knee extension.

The single-strand gracilis forming ALL is advanced under the iliotibial band (ITB) from the proximal to the distal lateral approaches using Halsted clamp (Fig 11)

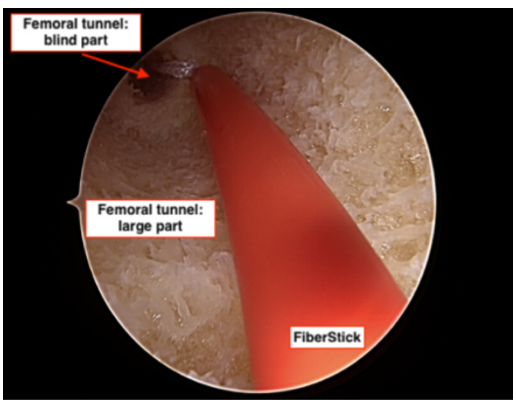

Fig 7. Deployment of the FiberStick into the femoral tunnel to measure anterior cruciate ligament (ACL) femoral tunnel + articular portion + ACL tibial tunnel before preparation of the ACL graft with 3 strands of semitendinous tendon.

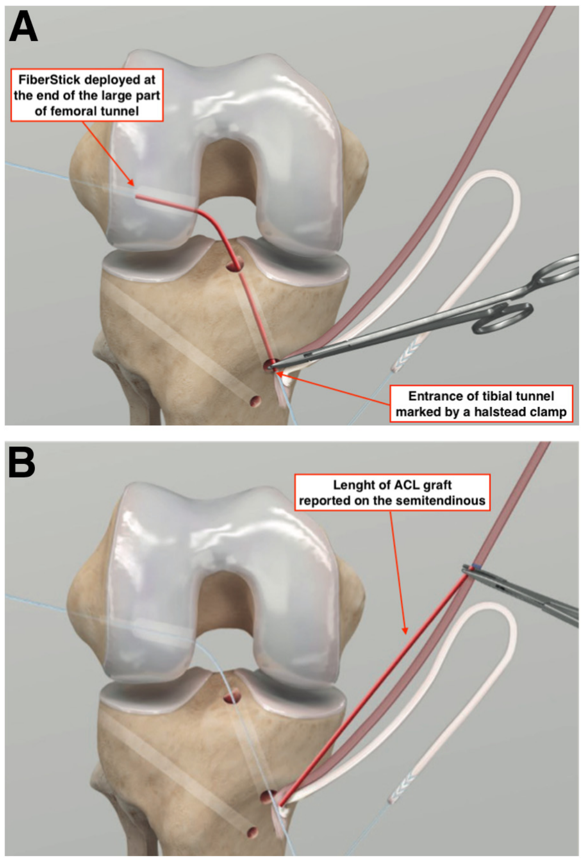

Fig 8. Measurement of the anterior cruciate ligament (ACL) graft using the FiberStick. (A) Length of ACL graft = large part of femoral tunnel + articular portion + ACL tibial tunnel. (B) Transfer of the FiberStick measurement corresponding of the length of the ACL graft to the semitendinous.

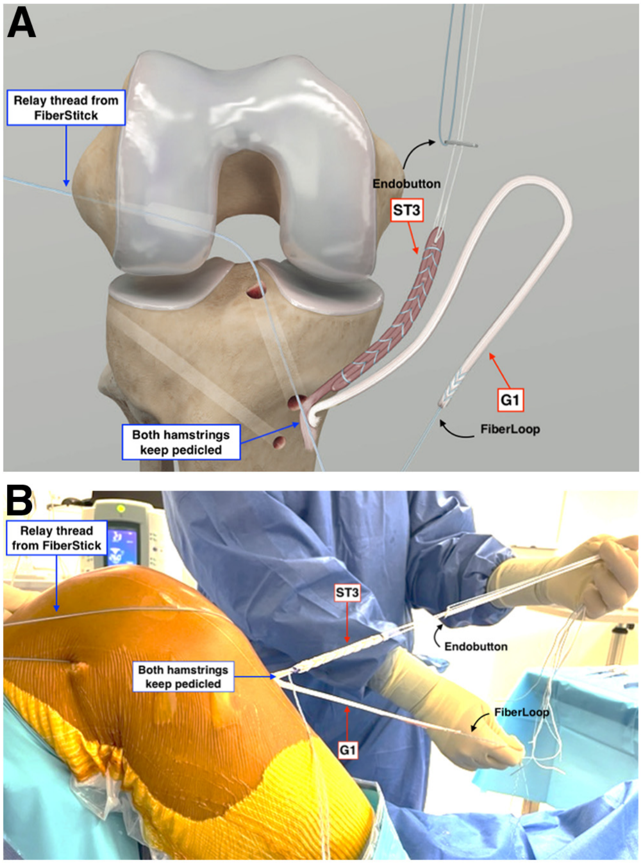

Fig 9. After measurement, preparation of anterior cruciate ligament graft with ST3 and Endobutton for femoral fixation and anterolateral ligament graft with G1 with FiberLoop. (A) Schema. (B) Perioperative aspect. ST3, 3-strand semitendinous; G1, single-strand gracilis.

and then introduced to the ALL tibial tunnel. The ALL graft is attached at neutral extension and rotation using an absorbable tibial biocomposite FastThread (6-mm diameter, 20-mm length) and pulling down on the FiberLoop placed on the G1 graft. The representation of the combined ACL+ALL reconstruction is summarized in Fig 12.

Closing

Infiltration of 20 cc of Naropeine 7.5 mg/mL at the harvesting site and an intra-articular injection of 20 cc of Naropeine 2 mg/mL are administered, according to the Enhanced Recovery After Surgery (ERAS) protocol. The incisions are then closed with intradermic absorbable 3.0 sutures, and a compression bandage on the suprapatellar recess is applied.

A compressive cryotherapy wrap is used in the recovery room. Radiographs are done before the patient is discharged from the outpatient department (Fig 13). The 3 bone tunnels can easily be identified.

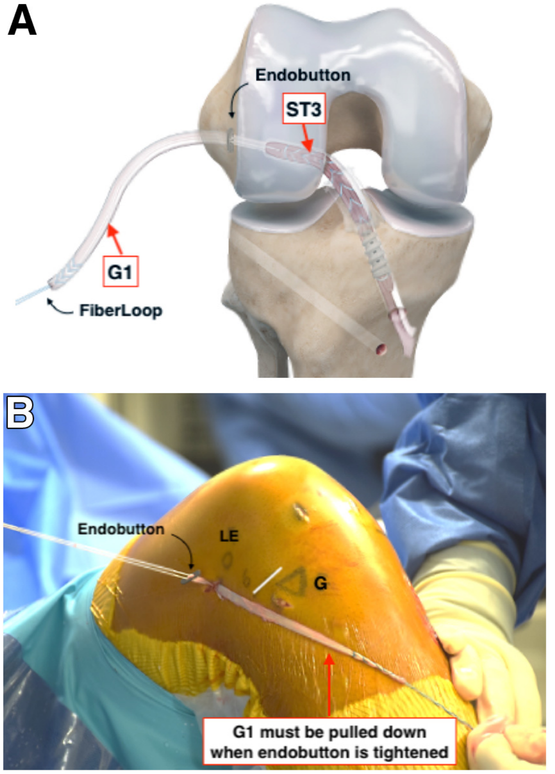

Fig 10. Front view of the femoral fixation of ACL graft (ST3) with the Endobutton on the lateral femoral condyle. (A) Schema. (B) Perioperative aspect. ST3, 3-strand semitendinous; G (triangle), Gerdy's tubercule; G1, single-strand gracilis; LE (circle), lateral epicondyle. White line denotes the joint line.

Discussion

This described technique (Video 1) provides an adequate control of anterior and rotatory laxity using a combined anatomical reconstruction of ACL and ALL,

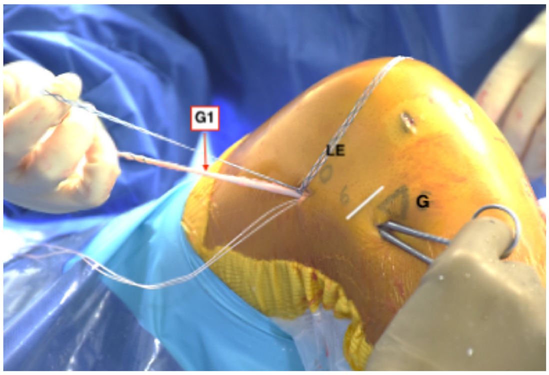

Fig 11. ALL graft (G1) is passed under iliotibial band from proximal to distal incision (posterior to the Gerdy's tubercule). G (triangle), Gerdy's tubercule; G1, single-strand gracilis; LE (circle), lateral epicondyle. White line denotes the joint line.

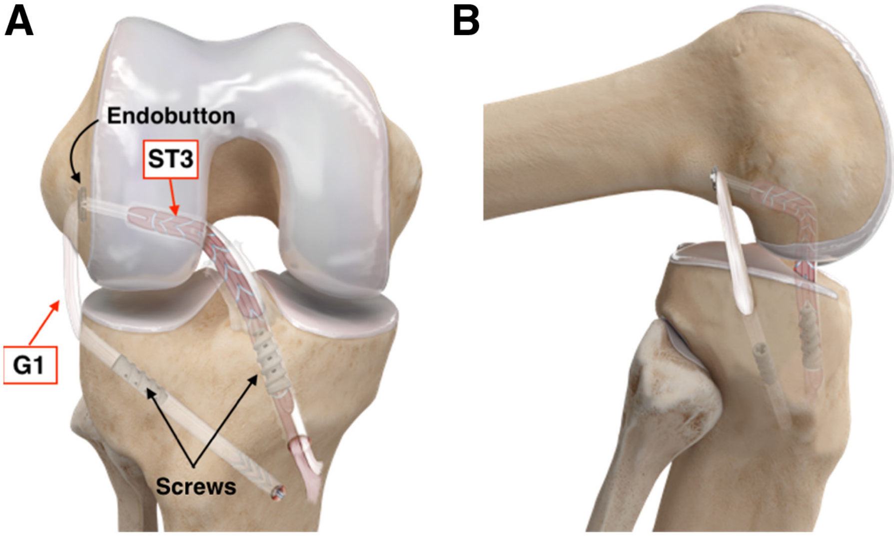

Fig 12. Summary of the combined anterior cruciate ligament and anterolateral ligament reconstruction (ACL+ALL) reconstruction: front view (A) and lateral side view (B).

performing a single blind femoral tunnel for preservation of bone stock without risk of tunnel convergence, and keeping both hamstrings attached for better graft ligamentization.

Combined ACL and ALL reconstructions are considerably increasing in popularity because of the "rediscovery" of the ALL by Steven Claes et al. in 2013[14]. Biomechanical studies reported that addition of ALL restores excellent knee kinematics and stability without overconstraining internal rotation[15] or increasing lateral compartment pressures[16] in contrast with lateral tenodesis procedures. Excellent medium and long-term results have been reported with a reduced risk of reoperation for graft failure or secondary meniscal tear are reported compared to isolated ACL reconstruction: Laboudie et al.[12] found a 4.9-fold lower reoperation rate at 4.8 years and Sonnery-Cottet et al.,[11] a 5.5-fold lower rate at 8.6 years. Moreover, ALL reconstruction reduces rotatory instability,[10] despite controversial results in preoperative high-grade pivot shift.[3]

Numerous combined reconstruction techniques have been described in the literature. To preserve the fascia lata and the deep fibers of the Kaplan Fiber Complex,[13] many authors use the hamstring tendons for combined ACL+ ALL reconstruction with low harvesting morbidity[35] and a single harvesting site. Preservation of

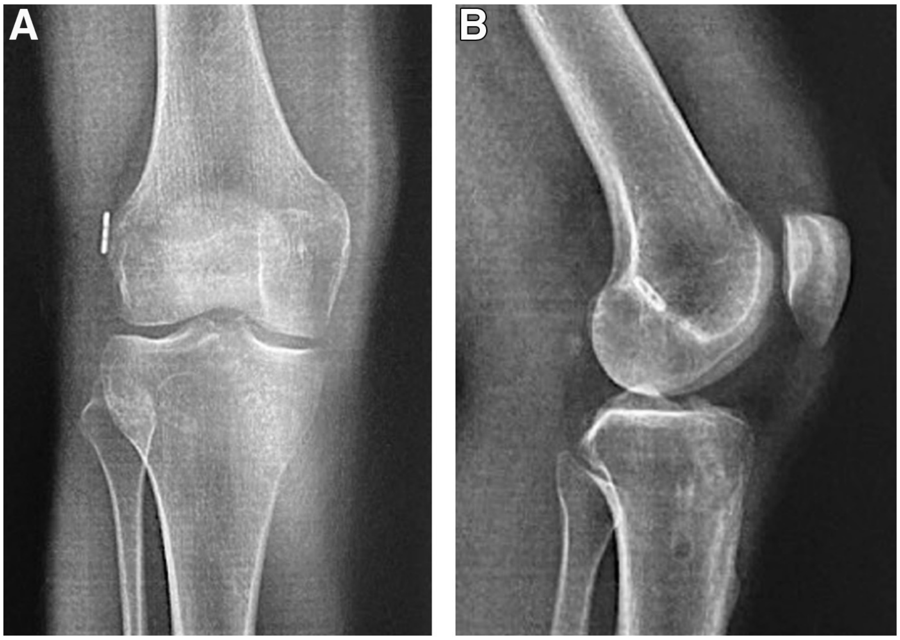

Fig 13. Knee radiographs of the combined ACL+ALL reconstruction. (A) Front radiograph. (B) Lateral radiograph.

the tibial insertion of hamstrings in isolated ACL reconstruction provide better graft incorporation by supplying vascularization[29,30,36] and better tibial fixation by native and mechanical fixation.[37,38] In combined ACL+ALL reconstruction, only a few authors keep the semitendinous attached,[20,23] but the gracilis is always detached. We believe that preserving the tibial insertion of both hamstrings could enhance the incorporation of both grafts, ACL and ALL, in the same way as in isolated ACL reconstruction. When hamstrings are carefully harvested by sectioning all the vincula, we did not find insufficient length to reconstruct the ALL using single-strand gracilis graft.

Among the combined reconstruction techniques using hamstrings, only Helito[17] used a single-strand gracilis graft with a single tibial fixation site to reconstruct the ALL. Other authors reported the use of a single-strand gracilis, but with 2 tibial fixation sites (tibial bone bridge or 2 tibial tunnels).[19,20,23,25] Dimensions of the ALL are 33 to 42 mm in length, 4 to 7 mm in width, and 1 to 2 mm in thickness.[39] In cadaveric and ultrasonic studies,[40,41] dimensions of the gracilis varied from 120.9 to 139.6 mm in length and 5.1 to 8.9 mm in 3.1 to 5.6 mm in thickness. Thus, in anatomical viewpoint, a single-strand gracilis is suitable to reconstruct the ALL. Moreover, in a biomechanical cadaveric study comparing native ALL, ALL reconstruction folded into 2 strands and with ITB, Wytrykowki et al.[42] reported a maximum load failure, respectively, at 140 N, 200.7 N, and 161.1 N. However, the gracilis was significantly stiffer than native ALL or ITB. In another biomechanical study, Smeets et al.[43] reported an ultimate stress of 155 MPa for single-strand gracilis and 75 MPa for ITB, without studying the maximal load failure of the native ALL. Thus, in biomechanical viewpoint, using a single-strand gracilis graft is strong enough to reconstruct the ALL. We believe that a single-strand gracilis could be just as strong with a stiffness closer to that of the native ALL.

Insertions of the native ALL are posterior and proximal to the lateral epicondyle of the femur and 2 cm posterior to the center of Gerdy's tubercule on the tibia.[44,45] Considering the tibial insertion of the ALL as easily identifiable and reproducible, our surgical technique use a single tibial fixation site as other authors.[17,18,21,22,24,26,27]

Finally, a single blind femoral tunnel has the advantage of preserving bone stock and preventing the risk of convergence of the femoral tunnels, which can occur up to 67% of cases.[46]

This described surgical technique of combined ACL+ALL reconstruction preserves tibial insertions of both hamstrings in all cases, uses a single blind femoral tunnel and a single-strand gracilis to reconstruct the ALL. This simple, reproducible, and minimally invasive technique is adaptable to all different anatomies of the anterior cruciate ligament and anterolateral ligament. The medium and long-term clinical results need to be evaluated.

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