Technical Note

Four-Stranded Semitendinosus Tendon Anterior Cruciate Ligament Reconstruction With Mini-invasive Anterolateral Ligament Reconstruction

Ibrahim Saliba, M.D., M.Sc., and Alexandre Hardy, M.D., M.Sc.

Abstract: Anterior cruciate ligament reconstruction (ACLR) is presently acknowledged as a prevalent procedure within the field of sports medicine surgery. Among the various graft options available, autograft hamstring tendons have emerged as one of the frequently used choices. This selection is primarily driven by the advantages it offers, such as reduced postoperative knee pain and a comparatively smoother surgical recovery process, when compared with the use of bone—patellar tendon—bone autografts. Quadrupled (4-stranded) semitendinosus tendon grafts have gained substantial popularity in recent years. This graft option offers the advantage of preserving the gracilis tendon while simultaneously exhibiting exceptional biomechanical strength. Furthermore, clinical studies have shown that the combination of ACLR and anterolateral ligament reconstruction yields superior outcomes, circumventing the application of nonanatomic extra-articular procedures involving the use of the fascia lata. The objective of this technical note is to outline a meticulous approach for ACLR using a 4-stranded semitendinosus tendon graft, applying a double-suspensory fixation method, and incorporating a minimally invasive procedure for anterolateral ligament reconstruction.

Anterior cruciate ligament (ACL) injuries are prevalent among individuals engaged in athletic and physically demanding activities, often leading to substantial functional impairment.[1] The primary objective of ACL reconstruction (ACLR) is to achieve knee stability and facilitate a return to previous levels of activity, if not a slightly diminished capacity. Among the various reconstruction techniques available, hamstring tendon (HT) autografts and bone—patellar tendon—bone autografts represent the most commonly used approaches.[2,3] Notably, HT grafts offer several specific advantages, including diminished postoperative patellofemoral crepitation, less anterior pain and extension loss of the knee joint, and reduced morbidity and smaller skin incisions at the harvest site in comparison to bone—patellar tendon—bone autografts.[4] However, existing evidence remains insufficient to definitively ascertain which graft type yields superior long-term functional outcomes after ACLR.[4,5] Furthermore, clinical research has shown significant benefits associated with combined ACL—anterolateral ligament (ALL) reconstruction when compared with isolated ACLR. These advantages encompass reduced rates of graft rupture, a decreased likelihood of secondary meniscectomy, greater knee stability, and higher rates of successful return to sports activities.[6] The aim of this technical note is to describe in detail anatomic single-bundle ACLR with ACL stump preservation using a 4-stranded semitendinosus graft fixed with an adjustable suspensory fixation system (GraftLink; Arthrex, Naples, FL) and a mini-invasive ALL reconstruction with a 2-stranded gracilis tendon (GT).

Surgical Technique

Graft Harvest and Preparation

A longitudinal incision of approximately 2 to 3 cm in length is made on the skin overlying the palpable pes anserine (Fig 1), by use of a No. 23 scalpel, midway between the tibial tubercle and the posteromedial border of the tibia (Video 1). Blunt dissection is carefully conducted through the subcutaneous tissue to mitigate the risk of infrapatellar and sartorial nerve branch injury. The semitendinosus tendon (ST) and GT are subsequently

From the Department of Orthopedic Surgery, Clinique Du Sport, Paris, France.

Received November 6, 2023; accepted February 17, 2024.

Address correspondence to Ibrahim Saliba, M.D., M.Sc., Department of Orthopedic Surgery, Clinique Du Sport, 28 Boulevard Saint-Marcel, Paris, France, 75005. E-mail: bob_saliba@hotmail.com

2212-6287/231633
https://doi.org/10.1016/j.eats.2024.102988

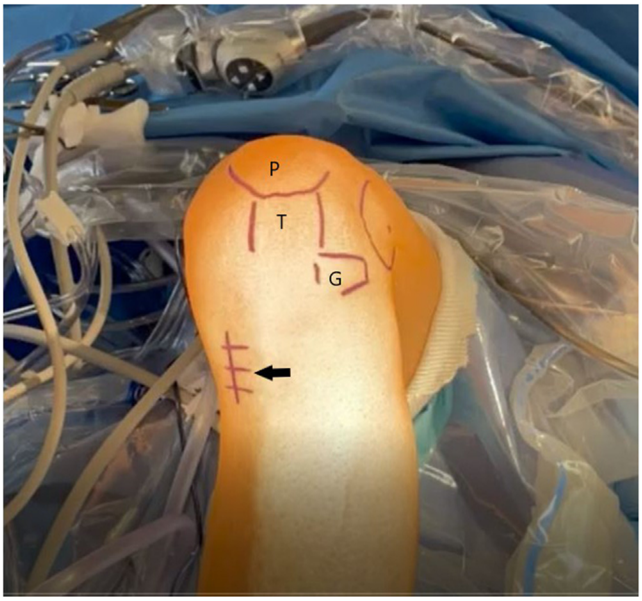

Fig 1. Anterior view of left knee showing anatomic landmarks identified through skin before incision. The arrow indicates the pes anserine harvest site. (G, Gerdy tubercle; P, patella; T, patellar tendon.)

harvested by the standard technique, ensuring the removal of any residual muscle tissue and separation from the tibial crest before preparation (Fig 2).

The ST is used for ACLR, with a minimum required length of 24 cm. It is threaded through a loop of the TightRope Attachable Button System (ABS) (Arthrex), after which it is folded over. A whipstitch suture is executed at the graft's extremity (free end) using FiberLoop thread (Arthrex). The graft is then passed through the loop of the ACL TightRope RT implant (Arthrex) and folded over once again to create a quadrupled ST graft. The

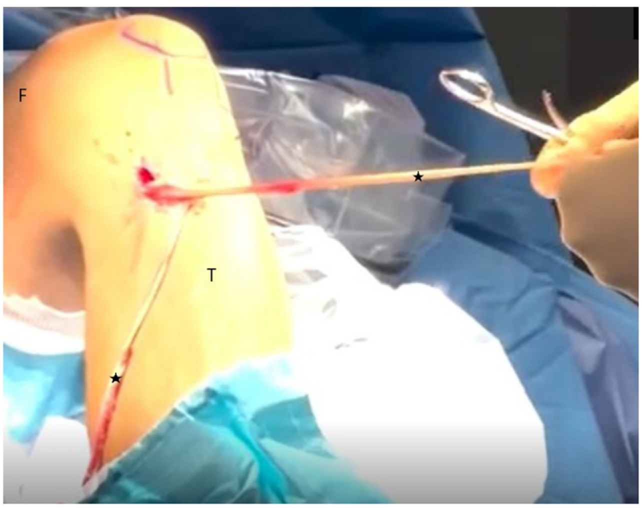

Fig 2. Anteromedial view of left knee flexed at 90° showing harvest of semitendinosus and gracilis tendons (stars), ensuring removal of any residual muscle tissue before separation from tibial crest. (F, femur; T, tibia.)

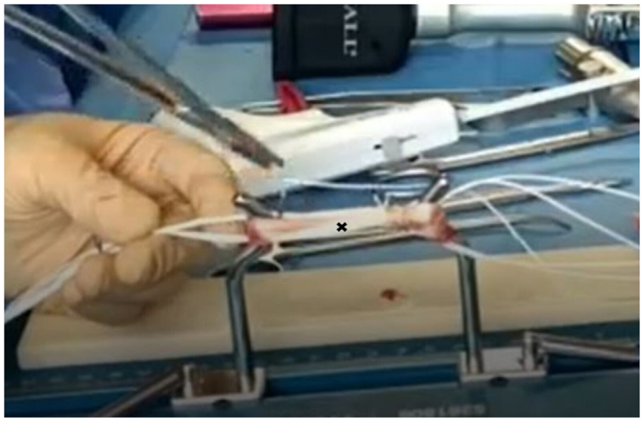

Fig 3. The semitendinosus tendon is used for anterior cruciate ligament reconstruction, with a minimum required length of 24 cm. It is threaded through a loop of the TightRope Attachable Button System, after which it is folded over. A whipstitch suture is executed at the graft's extremity (free end) using FiberLoop thread. The graft is then passed through the loop of the anterior cruciate ligament TightRope RT implant and folded over once again to create a quadrupled semitendinosus graft (X). The 4 strands are securely tied together using TigerWire thread in 3 successive knots.

4 strands are securely tied together using TigerWire thread (Arthrex) in 3 successive knots (Fig 3). A reference mark is delineated on the graft, precisely 20 mm away from the femoral end, to facilitate subsequent control by the surgeon in determining the position of the suture button on the lateral cortex. The resulting graft diameter is measured accordingly.

The GT, on the other hand, is reserved for ALL reconstruction and should possess a minimum length of 10 cm. It is folded over to produce a doubled graft after being passed through the loop of the ACL TightRope RT implant, and a whipstitch suture is performed at the free extremity of the graft using FiberLoop. The 2 strands of the graft are then securely tied together using TigerWire, forming 3 consecutive knots (Fig 4).

Preparation for ALL Reconstruction

While the harvested grafts are being prepared, the second phase of the procedure is concurrently executed. A 2-cm skin incision (Fig 5) is made on the lateral aspect of the lateral epicondyle (LEp), and the fascia lata is longitudinally sectioned to access the LEp via palpation. A guide pin is inserted at the ALL femoral insertion zone, which is located proximally and posteriorly to the LEp. As reported by Stordeur et al.,[7] the pin is carefully drilled in an anterior and proximal orientation (Fig 6) to prevent any potential collision with the ACLR femoral tunnel. Next, a 7-mm diameter tunnel, guided by the pin, is drilled to a length of 30 mm, and a suture loop is passed through this tunnel. Additionally, another 2-cm skin incision is made midway between the Gerdy tubercle and the styloid process of the fibula.

Fig 4. The gracilis tendon is used for anterolateral ligament reconstruction and should possess a minimum length of 10 cm. It is folded over to produce a doubled graft (X) after being passed through the loop of the anterior cruciate ligament TightRope RT implant, and a whipstitch suture is performed at the free extremity of the graft using FiberLoop. The 2 strands of the graft are then securely tied together using TigerWire, forming 3 consecutive knots.

A guide RetroButton Pin (Arthrex) is drilled following a horizontal and anteroposterior direction to avoid later communication with the ACLR tibial tunnel (Fig 7). Similarly, a 7-mm-diameter blind tunnel, guided by the pin, is drilled, and a suture loop is passed through the tunnel. Finally, a third suture loop is passed between the 2 incisions, completing this phase of the procedure.

Arthroscopic Surgery

Arthroscopic surgery starts with the systematic exploration of the 3 compartments of the knee joint to evaluate the presence of chondropathy or meniscal lesions. If necessary, partial meniscectomy or meniscal suture is performed. A ramp lesion should always be sought, and a trans-notch view is used for this purpose. In cases requiring repair, a posteromedial portal may be used. Fibrotic tissue is meticulously excised using a shaver, while the medial aspect of the lateral femoral condyle and the tibial footprint are carefully prepared, aiming to preserve the remnants to the greatest extent feasible.

The entry point for the femoral tunnel is established using a femoral offset guide, at 90° of knee flexion. Accurate positioning is verified based on the criteria for the Isometric, in the Direct fibers, Equidistant and Eccentric, Anatomic, and Low in tension position.[8] Subsequently, with the knee maximally flexed, a 2.4-mm guide RetroButton Pin is drilled from the entry point through the lateral femoral cortex (Fig 8), extending outside the skin. A femoral tunnel, measuring between 15 and 20 mm in length and matching the diameter of the ST graft, is then created. A suture loop is passed through the femoral tunnel. To confirm the absence of communication between the femoral tunnels (ALL and ACL), the arthroscope is introduced via the anteromedial portal.

Moving on to the tibial tunnel, the tibial tunnel guide is positioned at the ACL remnant on the tibial footprint. A guide pin is drilled through the joint, and successive reamers of increasing diameters, beginning with the 7-mm reamer, are used until the desired graft size is

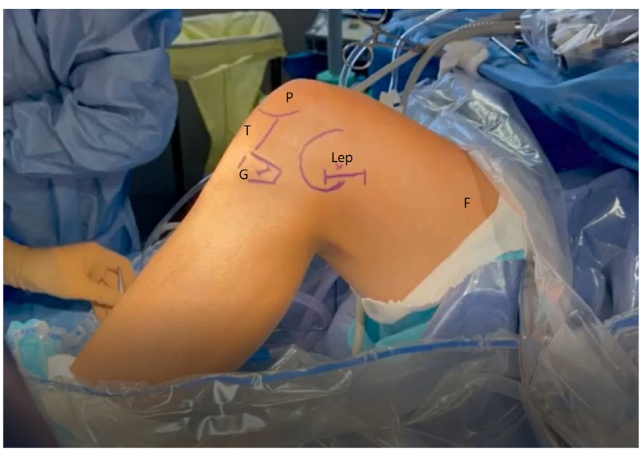

Fig 5. Lateral view of left knee flexed at 90° showing anatomic landmarks identified through skin. (F, femur; G, Gerdy tubercle; Lep, lateral epicondyle; P, patella; T, patellar tendon.)

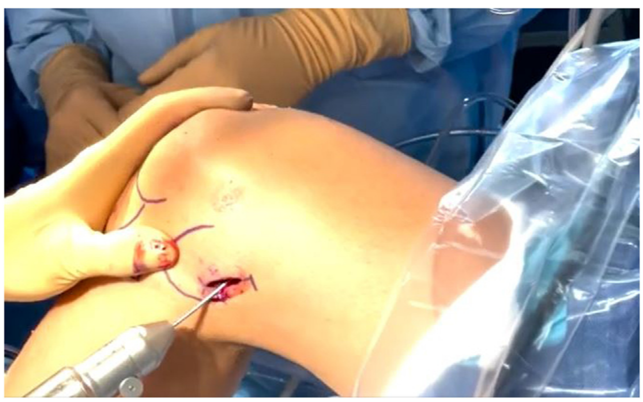

Fig 6. The femoral tunnel of the anterolateral ligament reconstruction is drilled in a proximal and anterior direction to prevent collision with the anterior cruciate ligament reconstruction femoral tunnel.

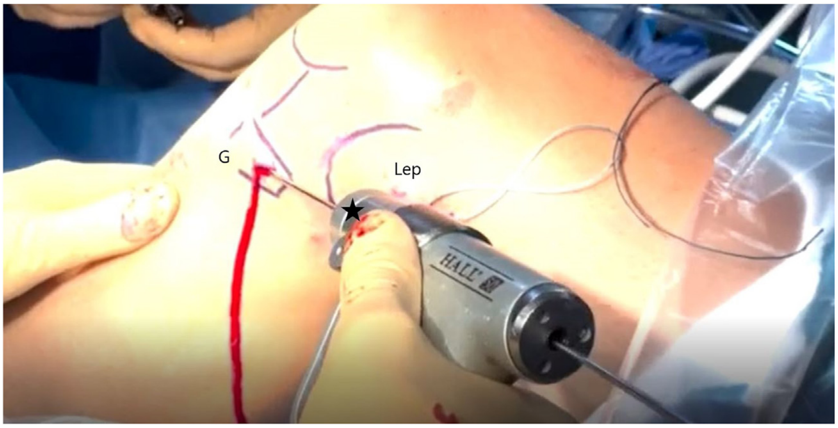

Fig 7. Lateral view of left knee flexed at 90° showing guide RetroButton Pin being drilled (star) midway between Gerdy tubercle (G) and styloid process of fibula following horizontal and anteroposterior direction to avoid later communication of anterolateral ligament reconstruction tibial tunnel with anterior cruciate ligament reconstruction tibial tunnel. (Lep, lateral epicondyle.)

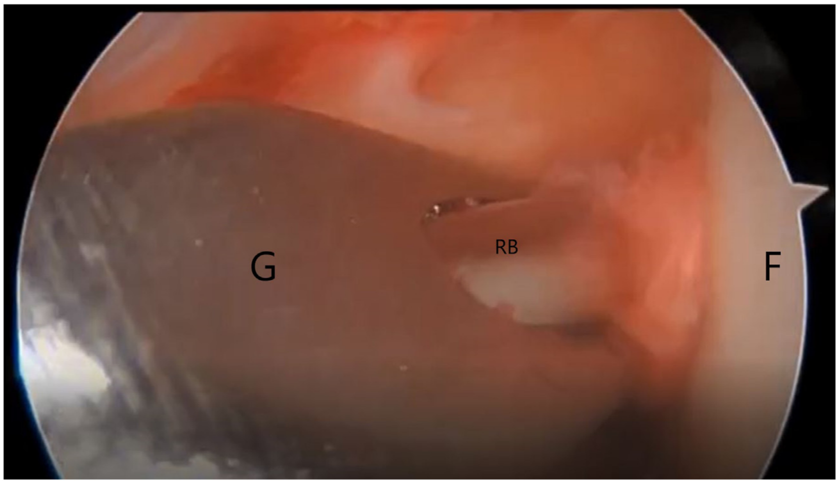

Fig 8. Arthroscopic view showing entry point of anterior cruciate ligament femoral tunnel, established using femoral offset guide (G), at 90° of knee flexion in left knee. A 2.4-mm guide RetroButton Pin (RB) is drilled through the lateral femoral cortex. (F, lateral femoral condyle.)

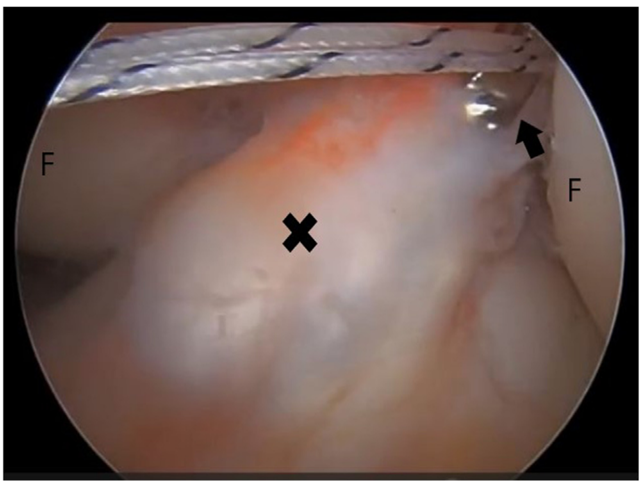

Fig 9. Preservation of anterior cruciate ligament (ACL) remnant during ACL reconstruction tibial tunnel drilling, in accordance with single anteromedial bundle biological augmentation (SAMBBA) technique. The arrow indicates the tip of the wire used to drill the ACL reconstruction tibial tunnel (emerging through the ACL remnant). (F, femur; X, ACL remnant on tibial side.)

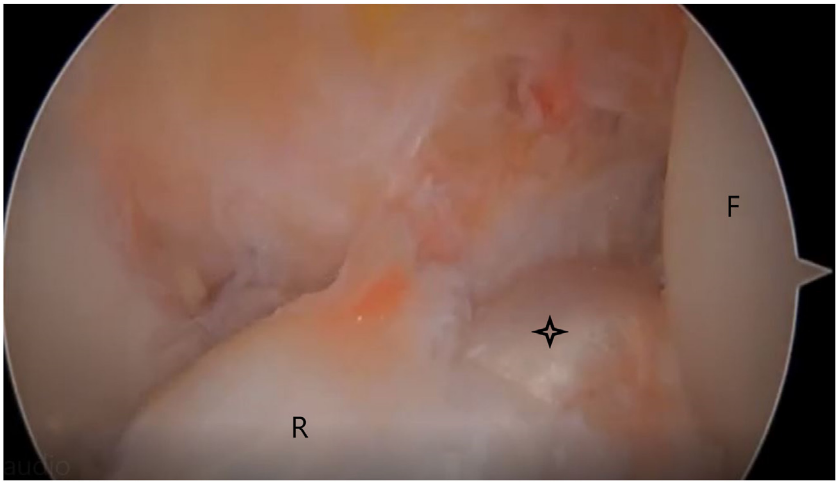

Fig 10. Arthroscopic view showing passage of anterior cruciate ligament graft (star) through tibial tunnel and through native anterior cruciate ligament remnant (R) to femoral tunnel in left knee. (F, lateral femoral condyle.)

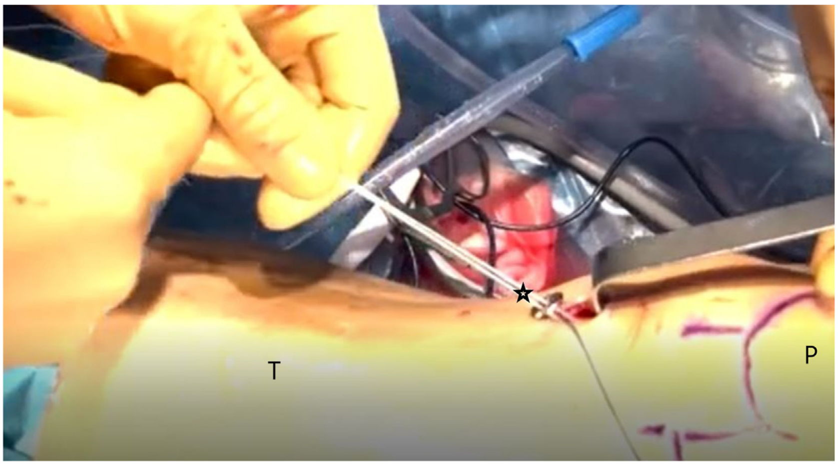

Fig 11. Superolateral view of left knee showing tibial fixation (star) of anterior cruciate ligament graft using Attachable Button System button (diameter, 14 mm) inserted onto anterior cruciate ligament TightRope. The graft is tensioned at 20° of knee flexion. (P, patella; T, tibia.)

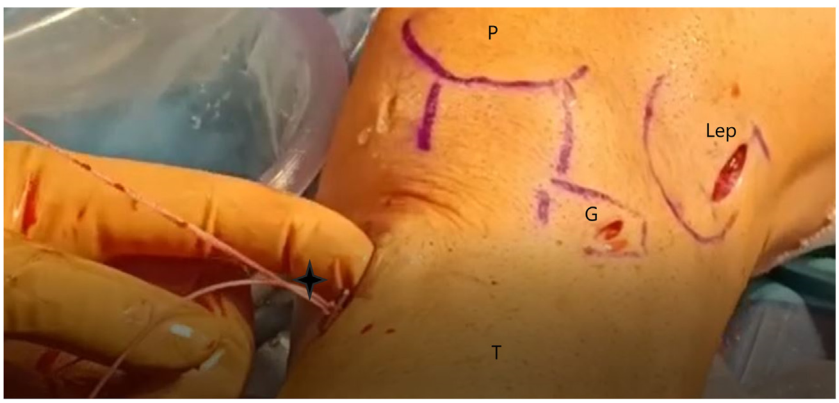

Fig 12. Anterolateral view of left knee showing tibial fixation of gracilis graft achieved by successively pulling TightRope shortening strands (star). During fixation, it is crucial to maintain the knee at full extension with neutral rotation to ensure optimal tensioning. (G, Gerdy tubercle; Lep, lateral epicondyle; P, patella; T, tibia.)

Table 1. Tips and Pearls

1. During initiation of the drilling of the guide pin for the ALL femoral tunnel, it is essential to direct the drilling proximally and anteriorly. This orientation facilitates the creation of a vertical tunnel that diverges as much as possible from the femoral tunnel of the ACL, minimizing the potential for overlap.
2. During the drilling of the guide pin for the ACL femoral tunnel, once the pin penetrates the lateral cortex, it is recommended to perform 3 back-and-forth motions through this cortex before extending beyond the skin. These back-and-forth movements aid in facilitating the subsequent passage of the TightRope system through the lateral cortex, ensuring smooth and efficient advancement of the graft fixation apparatus.
3. Before the reaming of the ACL femoral tunnel is started, it is advised to manually introduce the reamer and ensure that the tip of the reamer aligns flush with the medial aspect of the lateral femoral condyle. This precautionary measure safeguards the integrity of the medial condyle during the reaming process.
4. During the introduction of the ACL graft, when passing the TightRope system through the femoral tunnel, the surgeon should exert a downward pull to carefully monitor the optimal positioning of the button on the lateral cortex. This prevents the button from remaining in the spongy bone, potentially leading to postoperative complications, and from conflicting with the fascia lata, causing lateral pain.
5. During enlargement of the tibial tunnel, it is crucial to ensure that the entire tip of the drill has passed through the intra-articular cortex. By use of a low reaming speed, the ACL remnant should exhibit rhythmic movement (samba dancing) as the reamer gently rotates inside it. This technique helps in the controlled enlargement of the tunnel.
6. The ACL graft should be securely fixed at a knee flexion angle of 20°, while the ALL graft should be tensioned at full knee extension and neutral rotation. Maintaining these specific angles during graft fixation optimizes the stability and functional outcomes of the reconstructed knee joint.

ACL, anterior cruciate ligament; ALL, anterolateral ligament.

achieved, with an emphasis on preserving the remnant (Fig 9). The tibial tunnel entry point is cleared using a scalpel. Subsequently, the shaver is introduced through the tibial entry point to effectively eliminate debris, establish a pathway through the ACL remnant, and retrieve the suture loop by using a grasper. The femoral loop of the graft is then passed through the tibial tunnel, and the graft is pulled into the joint under arthroscopic guidance (Fig 10) until reaching the aforementioned reference mark (20 mm away from the femoral end of the graft). The progression of the graft within the femoral tunnel can be controlled by the surgeon owing to the adjustable feature of the button. Subsequently, the TightRope shortening strands are pulled successively. On the tibial side, an ABS button (diameter, 14 mm; Arthrex) is inserted onto the ACL TightRope. Finally, the graft is tensioned at 20° of knee flexion (Fig 11).

ALL Reconstruction

ALL reconstruction involves the insertion and fixation of the GT graft within the previously created femoral tunnel. The graft is secured using a 7 × 20-mm interference screw (FastThread; Arthrex). Subsequently, the GT graft is drawn through the distal lateral skin incision and guided through the horizontal tibial tunnel using the suture loops that were previously passed. Tibial fixation is achieved by successively pulling the TightRope shortening strands. During fixation of the GT graft, it is crucial to maintain the knee at full extension with neutral rotation to ensure optimal tensioning (Fig 12). Table 1 provides tips and pearls for surgeons intending to implement the surgical technique delineated in this technical note.

Table 2. Advantages and Disadvantages or Risks

Advantages
The described technique is indicated for patients at high risk of ACL graft rupture, including the following:
Young patients
High-demand athletes
Patients who participate in pivoting sports
Patients with high-grade pivot shift on clinical examination
Patients in whom a Segond fracture or the lateral femoral notch sign is present on preoperative knee radiographs
Patients with a history of revision ACL reconstruction
Patients with chronic ACL injury
The associated ALL reconstruction reduces the likelihood of graft failure compared with isolated ACL reconstruction.
ALL reconstruction offers a protective effect on the meniscal repair.
Combined ACL-ALL reconstruction shows superior outcomes in comparison to isolated ACL reconstruction or associated LET. Improved outcomes include the following:
Reduction in residual pivot shift
Lesser anterior tibial translation
Higher IKDC subjective scores
Preservation of ACL remnants provides several advantages, such as
Enhanced vascularity
Synovial coverage of the graft
Preservation of proprioception
Disadvantages or risks
Using the described technique with a graft diameter < 7 mm increases the risk of ACL graft failure.
Insufficient knowledge about ALL and LCL anatomy might impede safe procedure execution, potentially impacting outcomes negatively.
Established lateral femorotibial compartment osteoarthritis may be considered a relative contraindication to ALL reconstruction.
Harvesting an inadequate length of the semitendinosus or gracilis tendon might result in insufficient material for achieving an adequate ACL and ALL graft diameter.
Percutaneous ALL reconstruction performed by a surgeon in the learning phase carries a risk of LCL injury. Preventative measures include making a small longitudinal femoral incision to identify and safeguard the LCL, ensuring the femoral tunnel does not encroach on it.
Securing the ALL graft in non-neutral rotation or with knee flexion may lead to potential gait disturbance or overconstraint.

ACL, anterior cruciate ligament; ALL, anterolateral ligament; IKDC, International Knee Documentation Committee; LCL, lateral collateral ligament; LET, lateral extra-articular tenodesis.

Discussion

The described technique encompasses the integration of HT ACLR using quadrupled ST graft, as well as reconstruction of the ALL. Furthermore, it adheres to the preservation of the ACL remnants in accordance with the single anteromedial bundle biological augmentation (SAMBBA) technique.[9] The use of the 4-stranded ST graft endows it with robust biomechanical properties,[10] whereas the preservation of the ACL remnants offers several advantages, including enhanced vascularity, synovial coverage of the graft, and preservation of proprioception.[9] Concerning the ALL reconstruction, its incorporation with ACLR has a protective effect on the ACL graft and meniscal repair as reported in the literature.[6] This can be attributed to a more comprehensive restoration of native knee stability in terms of not only anterior translation but also internal rotation, in contrast to isolated ACLR.[6] The application of this technique proves beneficial for patients identified as having a high risk of ACL graft failure, notably encompassing individuals of young age (<20 years), high-demand athletes or those engaged in pivoting sports, and patients exhibiting a high-grade pivot shift during clinical examination, among other predisposing factors for rerupture. Additionally, Park et al.,[11] in a network meta-analysis, showed superior outcomes associated with combined ACL-ALL reconstruction, particularly in mitigating residual pivot shift, reducing anterior tibial translation, and enhancing International Knee Documentation Committee (IKDC) subjective scores. However, limitations of this technique are evident, notably regarding instances with insufficient graft diameter (<7 mm), increasing the likelihood of ACL graft failure.[12] Furthermore, inadequate knowledge pertaining to the anatomy of the lateral collateral ligament and ALL, alongside structures around the LEp, poses risks in the safe and precise execution of this procedure. Finally, the presence of established lateral femorotibial compartment osteoarthritis may warrant consideration as a relative contraindication to the application of this technique.[12] Table 2 summarizes the main advantages and risks or limitations of the technique.

Disclosures

Both authors (I.S., A.H.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Castle JP, Khalil LS, Tramer JS, et al. Indications for surgery, activities after surgery, and pain are the most commonly asked questions in anterior cruciate ligament injury and reconstruction. *Arthrosc Sport Med Rehabil* 2023;5, 100805.
2. Murgier J, Powell A, Young S, Clatworthy M. Effectiveness of thicker hamstring or patella tendon grafts to reduce graft failure rate in anterior cruciate ligament reconstruction in young patients. *Knee Surg Sports Traumatol Arthrosc* 2021;29:725-731.
3. Greif DN, Shallop BJ, Allegra PR, et al. A comparison of two-year anterior cruciate ligament reconstruction clinical outcomes using all-soft tissue quadriceps tendon autograft with femoral/tibial cortical suspensory fixation versus tibial interference screw fixation. *Arthroscopy* 2022;38:881-891.
4. Frank RM, Hamamoto JT, Bernardoni E, et al. ACL reconstruction basics: Quadruple (4-strand) hamstring autograft harvest. *Arthrosc Tech* 2017;6:e1309-e1313.
5. Lawrence KW, Okewunmi JO, Chakrani Z, Cordero JK, Li X, Parisien RL. Randomized controlled trials comparing bone−patellar tendon−bone versus hamstring tendon autografts in anterior cruciate ligament reconstruction surgery are statistically fragile: A systematic review. *Arthroscopy* 2024;40:998-1005.
6. Sonnery-Cottet B, Haidar I, Rayes J, et al. Long-term graft rupture rates after combined ACL and anterolateral ligament reconstruction versus isolated ACL reconstruction: A matched-pair analysis from the SANTI study group. *Am J Sports Med* 2021;49:2889-2897.
7. Stordeur A, Grange S, Servien E, et al. Optimal combination of femoral tunnel orientation in anterior cruciate ligament reconstruction using an inside-out femoral technique combined with an anterolateral extra-articular reconstruction. *Am J Sports Med* 2022;50:1205-1214.
8. Pearle AD, McAllister D, Howell SM. Rationale for strategic graft placement in anterior cruciate ligament reconstruction: I.D.E.A.L. femoral tunnel position. *Am J Orthop (Belle Mead NJ)* 2015;44:253-258.
9. Sonnery-Cottet B, Freychet B, Murphy CG, Pupim BHB, Thaunat M. Anterior cruciate ligament reconstruction and preservation: The single-anteromedial bundle biological augmentation (SAMBBA) technique. *Arthrosc Tech* 2014;3:e689-e693.
10. Brzezinski A, Nasra M, Pfaff W, et al. Five-strand hamstring grafts are biomechanically comparable to four-strand grafts and offer greater diameter for anterior cruciate ligament reconstruction. *Arthrosc Sport Med Rehabil* 2022;4:e1731-e1738.
11. Park YB, Lee HJ, Cho HC, Pujol N, Kim SH. Combined lateral extra-articular tenodesis or combined anterolateral ligament reconstruction and anterior cruciate ligament reconstruction improves outcomes compared to isolated reconstruction for anterior cruciate ligament tear: A network meta-analysis of randomized controlled trials. *Arthroscopy* 2023;39:758-776.e10.
12. Saithna A, Thaunat M, Delaloye JR, Ouanezar H, Fayard JM, Sonnery-Cottet B. Combined ACL and anterolateral ligament reconstruction. *JBJS Essent Surg Tech* 2018;8:e2.