Technical Note

Modified Lemaire Lateral Tenodesis Associated With an Intra-articular Reconstruction Technique With Bone-Tendon-Bone Graft Using an Adjustable Fixation Mechanism

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Abstract: The goal of this study was to report a surgical technique used in a revision anterior cruciate ligament (ACL) reconstruction case, consisting of an adaptation of the anterolateral iliotibial band tenodesis technique (modified Lemaire technique) combined with ACL reconstruction using an adjustable fixation mechanism. Rotational overload was one of the most likely hypotheses for failure of primary surgery, despite correct positioning and secure fixation. We performed a review of the most pertinent factors related to ACL reconstruction failure, as well as surgical strategies for its treatment. After this, we described, step by step, a combination of the 2 forms of surgical intervention that were already presented isolated with good clinical results, correcting the common anterior and rotational instabilities found in these cases. Knowing new techniques for intra- and extra-articular ligament reconstruction is imperative in the present day, when more patients are seeking a full return to their preinjury recreational, labor, and sports activities. We believe that the combination of these surgical techniques is able to achieve these goals effectively and reproducibly.

Although widely performed by orthopaedic surgeons all over the world, anterior cruciate ligament reconstruction (ACLR) surgery has a failure rate as high as 20%.[1,2] Usually, the best option to treat this complication is revision surgery, which is a technically challenging procedure, the outcome of which depends on the surgeon's ability to correctly identify and treat the possible causes of failure of the primary operation.[1,2]

Multiple aspects may be related to the failure of an ACLR, including technical errors, biological failure, and traumatic injuries. The most common technical error related to failure is inadequate positioning of the femoral tunnel.[2] Infection, poor incorporation of the graft, and errors during the ligamentization process represent the main biological causes. New traumatic injuries represent 5% to 10% of failures.[1,2]

To improve the results of anterior cruciate ligament (ACL) surgery, several research trends have been observed in the medical literature, among which the biomechanical importance of the anterolateral (AL) structures of the knee represents one of the main theories.[3] Although there is no consensus regarding the individual function of each AL structure of the knee, the overlook of this anatomy may be related to some cases of isolated ACLR failure, especially when it is associated with great rotational instability.[3-5]

The aim of this article was to report a surgical technique for ACL revision surgery combining intra-articular reconstruction of the ligament with autologous patellar tendon graft using an adjustable fixation mechanism with an extra-articular lateral tenodesis technique (modified Lemaire technique). Although the use of adjustable fixation devices for graft fixation in ACLR is well known with the flexor tendons, their use with bone-tendon-bone graft has some particularities that are not

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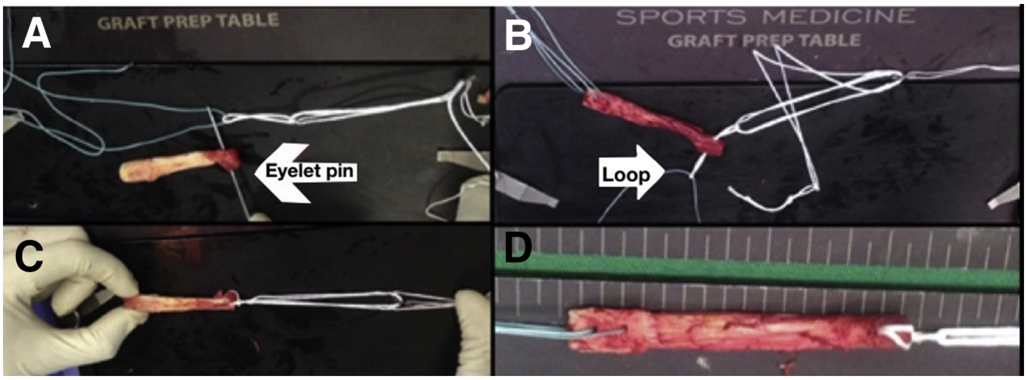

Fig 1. (A) Preparation of the patellar tendon graft for the anterior cruciate ligament revision procedure. Initially, an eyelet pin loaded with a No. 2 Ethibond suture, used as a relay suture for the fixation device, is advanced through the hole in the bone block. (B) The loop of the fixation device is pulled through the bone plug. (C) The whole construct is advanced through the small loop until it cinches around the bone block. (D) Two No. 2 Ethibond sutures are advanced through the holes drilled in the distal bone block for further traction of the graft during tibial fixation.

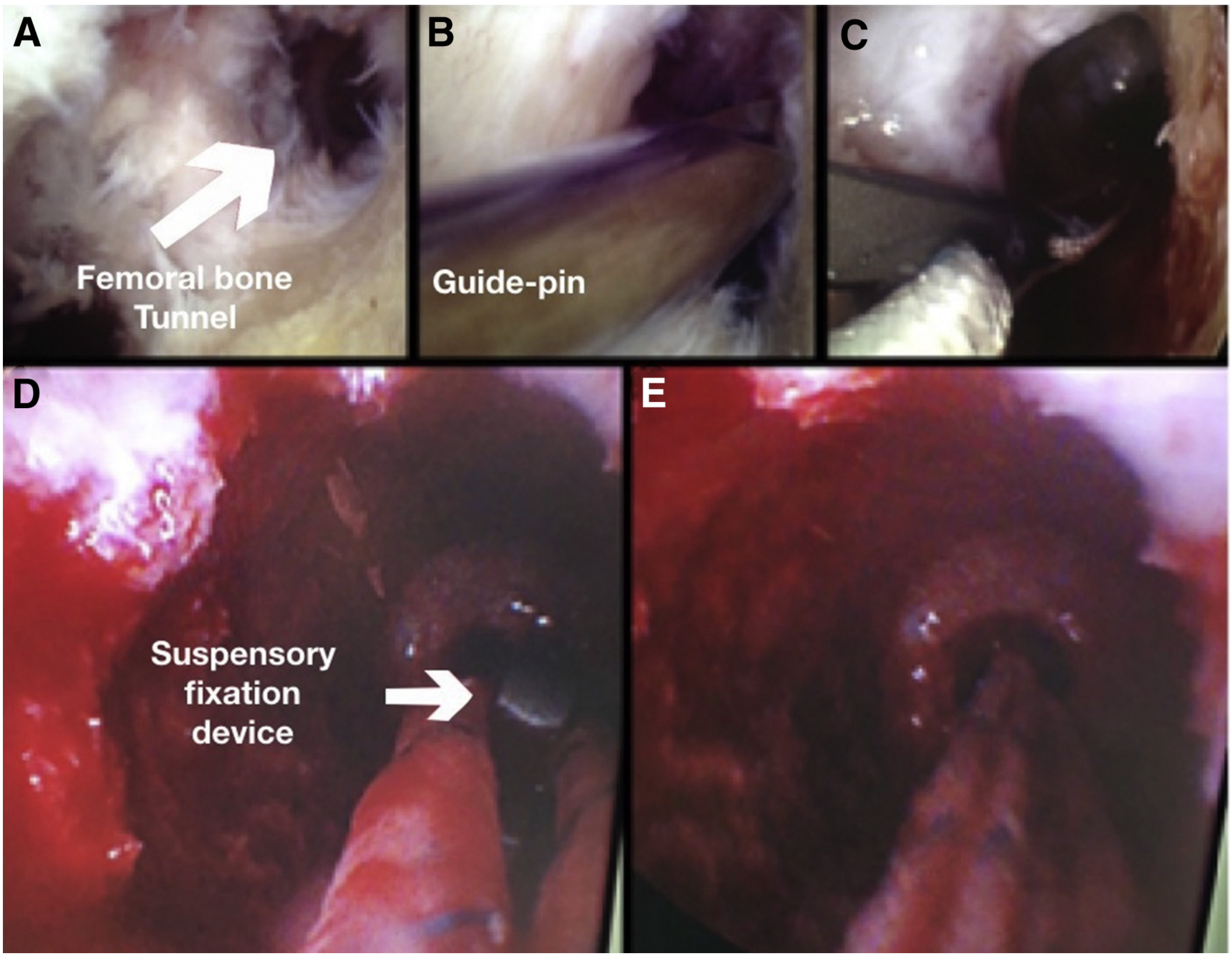

Fig 2. Anchoring of the ligament fixation device in the femur in a left knee. (A) Femoral bone tunnel. (B) Passage of the guide pin entering the femoral tunnel through the anteromedial portal. (C) Entry of the suspensory fixation device through the femoral tunnel as visualized through the anterolateral portal. (D) View of the fixation device through the accessory anteromedial portal, just before it crosses the lateral femoral cortex. (E) Same view showing the traction sutures after the fixation device was flipped over the lateral cortex of the femur.

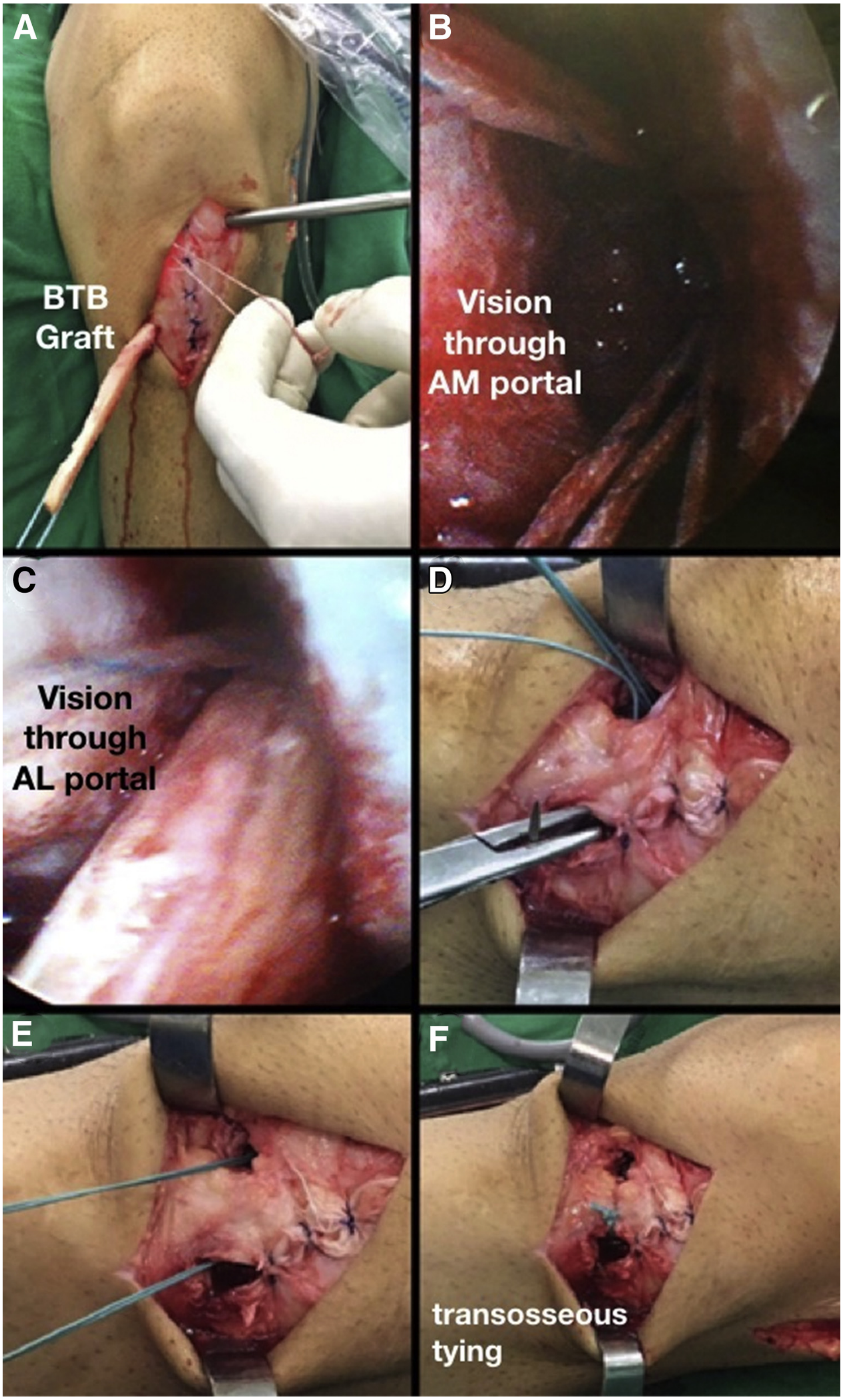

Fig 3. Mechanism of graft ascension through the bone tunnels and tibial backup fixation in a left knee. (A) Extra-articular view of the graft traction sutures being pulled through the anteromedial (AM) portal while the graft penetrates the tibial tunnel. (B) Intra-articular view of the graft traction sutures going toward the anteromedial portal and the tibial tunnel. (C) View through the anterolateral (AL) portal of the graft after having penetrated the tunnels. (D) Transosseous suture between the tibial tunnel and the donor area of the tibial bone plug. (E) One of the graft suture loops attached to the tibial plug is drawn through the bone bridge, whereas the other remains tensioned through the tibial tunnel. (F) Tibial fixation by transosseous tying. (BTB, bone-tendon-bone.)

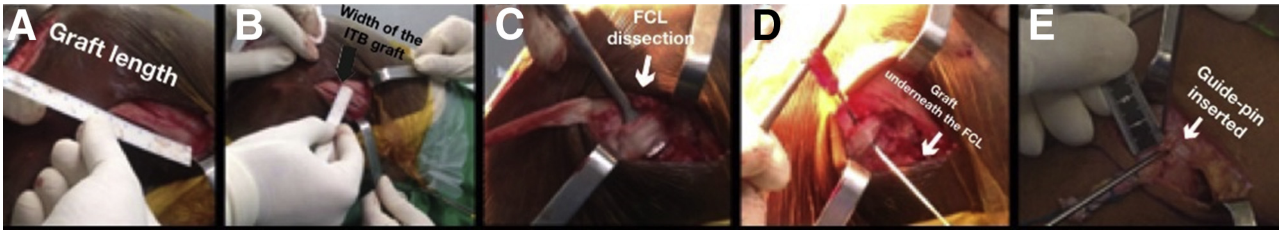

Fig 4. Preparation of iliotibial band (ITB) graft for lateral tenodesis in a left knee. (A) After skin incision, the ITB is identified and the graft length is measured from the Gerdy tubercle. (B) Next, the width of the ITB graft is measured, starting 1.0 cm above its lower edge. (C) After preparation of the ITB graft, blunt dissection of the fibular collateral ligament (FCL) is performed. (D) The ITB graft is passed underneath the FCL. (E) A guide pin is inserted 3.0 mm posteriorly and proximally to the lateral femoral epicondyle.

yet well detailed. The same applies to lateral reinforcement techniques that in selected cases have been increasingly important. Although the modified Lemaire technique has shown good results in the literature, we believe that a detailed step-by-step description may help make the technique more reproducible.

Operative Technique

The patient is placed in the supine position on the operating table after receiving spinal anesthesia. The limb is then exsanguinated, and the tourniquet is inflated to 300 mm Hg.

ACL Reconstruction

An anterior longitudinal incision is made over the patellar tendon. The central third of the patellar tendon is removed with a standard technique, including 20 × 10—mm bone plugs and a 10-mm-wide tendon to be used as an ACL graft, as shown in Video 1.

For graft preparation, a 2.5-mm drill bit is used to make 2 holes at the tibial bone plug, through which 2 No. 2 Ethibond sutures (Ethicon, Somerville, NJ) will be passed. The same drill bit is then used to make a hole in the patellar bone plug, through which the loop of the adjustable button will be inserted (Fig 1). Through the same incision previously used to remove the graft, arthroscopic portals are created as follows: an AL portal (for visualization) at the level of the inferior pole of the patella, adjacent to the patellar tendon; an anteromedial (AM) portal at the same level as the AL portal, near the medial border of the tendon; and an accessory anteromedial (aAM) portal (for instrumentation), closer to the articular line (lower and medial to the AM portal).

By AL visualization, a guide pin is inserted through the aAM portal toward the femoral footprint, according to anatomic reconstruction concepts.[5] The knee is then flexed to 120° to avoid blowout of the posterior cortex and to have a longer tunnel. A 10-mm drill bit is used to ream a 25-mm-deep tunnel; then, through the same guide pin, a 4.5-mm drill bit is used to over-ream the opposite cortex to allow for the passage of the suspensory device to secure the graft (Fig 2).

The tibial tunnel is made by positioning the guide pin at the level of the posterior margin of the anterior horn of the lateral meniscus, as close as possible to the base of the medial tibial eminence. A complete 10-mm tunnel is reamed.

An eyelet pin loaded with a looped No. 2 Ethibond suture is passed through the femoral tunnel through the aAM portal, allowing the capture of its free ends on the lateral side of the thigh. The Ethibond loop remains intra-articular, being captured out of the joint through the tibial tunnel to be used as a transport suture for the cortical fixation device (ToggleLoc; Zimmer Biomet, Warsaw, IN) along with the graft.

After the device sutures are transported through both tunnels, they are then pulled through the lateral femoral cortex and, by direct visualization (aAM portal), the cortical fixation device is locked by pulling the distal end of the graft as soon as the device overlaps the lateral femoral cortex. Once fixed, the 2 adjustable sutures are symmetrically pulled through the AM portal, causing the graft to progressively ascend until the proximal bone plug fully enters its tunnel. The knee is then cycled 30 times, and the tibial end is secured at 30° of flexion with a bioabsorbable interference screw (10 × 30 or 11 × 30 mm, depending on bone quality). If needed, this system also allows extra tensioning, up to 5 mm, by pulling the adjustable graft suspension sutures. In addition, transosseous tying of the distal sutures can be performed as a reinforcement to this fixation (Fig 3).

Lateral Tenodesis

A 6-cm incision, centered in the joint line, is made on the lateral side of the knee, in line with the iliotibial band (ITB), toward the Gerdy tubercle. A 9 × 1—cm ITB strip is excised from its inferior border, keeping the distal attachment intact (Fig 4). A whipstitch suture is applied to the proximal end of the graft, using a No. 2 Ethibond suture, allowing it to be subsequently pulled

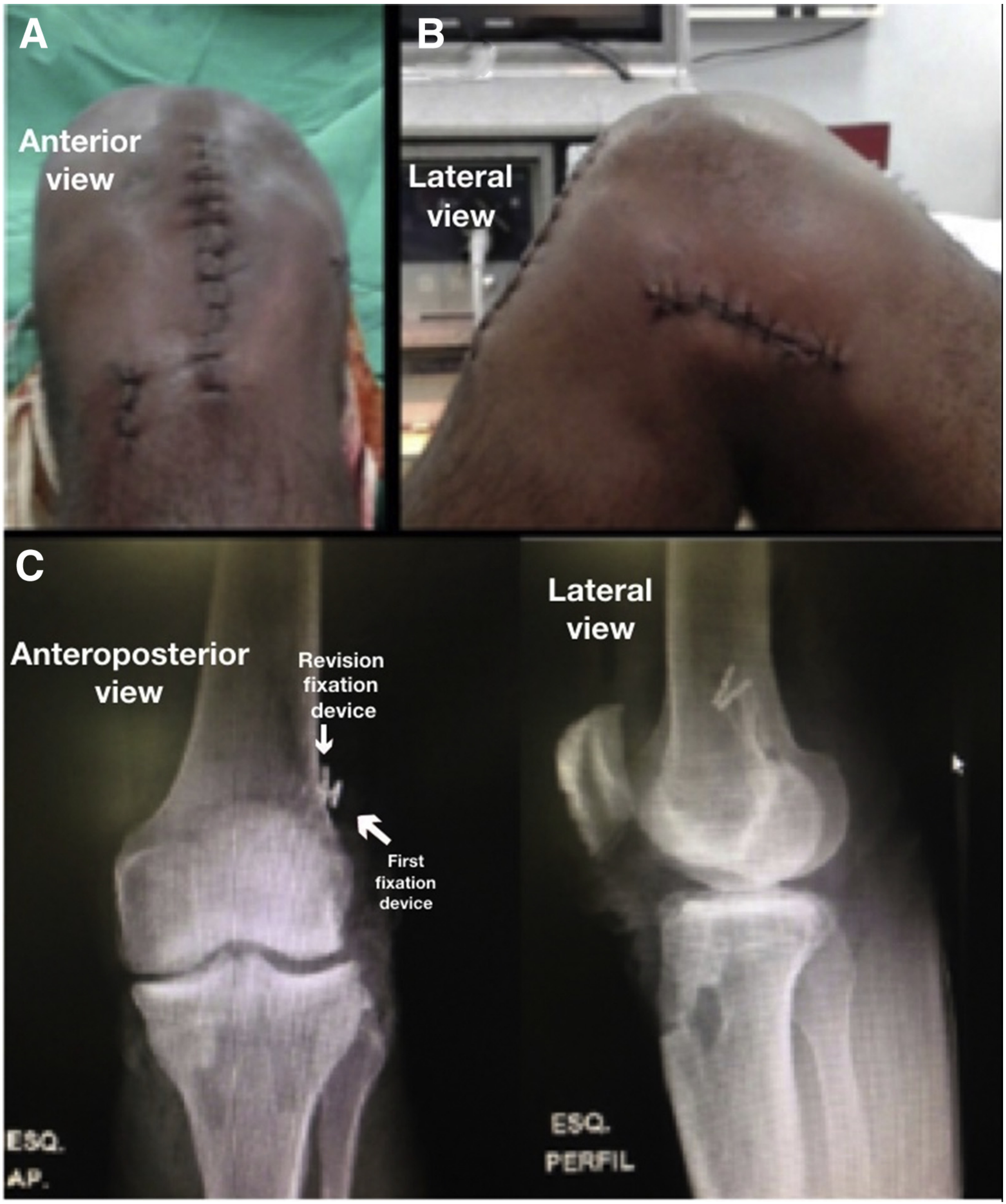

Fig 5. Final aspect of procedure in a left knee. (A) Anterior view of the patient's knee with surgical incisions already sutured. (B) Lateral view showing the lateral tenodesis incision after closure. (C) Postoperative radiographs: anteroposterior (AP) and lateral views. One should observe the fixation device of the primary reconstruction (which was not removed) and fixation device for revision surgery over the lateral femoral cortex.

by the femoral tunnel. For the femoral tunnel, a guide pin is introduced into the lateral aspect of the lateral femoral condyle, 3 mm proximal and posterior to the lateral femoral epicondyle (LFE), aiming proximally and anteriorly, to exit the AM aspect of the distal femur. A 7-mm cannulated bit is then used to over-ream a 30-mm-deep tunnel, through which the graft will be drawn. After careful dissection, the ITB strip is passed under the fibular collateral ligament (FCL), and by use of an eyelet pin, the suture previously whipstitched to the free edge of the graft is passed through the femoral tunnel. By pulling this suture through the medial aspect of the distal femur, the graft is tensioned and fixed using an 8-mm bioabsorbable screw, with the knee positioned at 30° of flexion and neutral rotation. The final aspect of the surgical procedure and the immediate postoperative radiographs are shown in Figure 5.

Postoperative Rehabilitation

Regarding the rehabilitation program, there are no differences from the usual postoperative care applied after primary surgical procedures.

Table 1. Pearls and Pitfalls

Pearls	
	Especially in obese or very strong patients, it is important to draw the anatomic landmarks before beginning surgery to avoid loss of references during the procedure.
	When positioning the patient, it is important to check for adequate range of motion and freedom to mobilize the knee during instrumentation to avoid difficulties in achieving correct drilling of the tunnels.
	Using a long needle to determine the best positioning of the accessory anteromedial portal guarantees the passage of the instruments for a well-tuned femoral tunnel perforation.
	Because the cortical fixation device is adjustable, it is possible to visualize the "flip" of the device through the accessory anteromedial portal without obstruction of vision by the graft.
	To ensure the femoral tunnel for tenodesis is deep enough to allow adequate tensioning of the graft, it is important to mark the distance from its free end to the femur's entry and make sure the tunnel length is greater than this distance.
Pitfalls or complications and how to avoid them	
	Breakage of the graft's bone plug: During the preparation of the patellar tendon graft, it is important to apply a small traction suture on the tendinous part of the graft (similar to a soft-tissue graft), close to the bone plug, besides drilling the classic hole to pass the traction suture. This ensures traction of the graft even in cases of block breakage.
	Postoperative graft loosening: Cycling the knee shortly after femoral fixation and re-tightening the device after tibial fixation may reduce the chance of loosening.
	Posterior cortex blowout: Before the femoral tunnel is fully pierced, it is important to mark its entrance by inserting only the tip of the drill and then to introduce the arthroscope through the anteromedial portal to better estimate the remaining posterior wall, before proceeding with complete drilling.
	Confluence of tunnels in lateral femoral condyle: The exit of the tenodesis guide pin should be planned slightly proximal and anterior to the adductor tubercle, moving this tunnel away from the anatomic positioning of the ACL.
	Internal rotation overconstraint: To avoid restriction of this movement, the lateral tenodesis should be fixed with the knee positioned at 30° of flexion and neutral rotation.

ACL, anterior cruciate ligament.

Discussion

It is known that knees with increased anterior translation—especially those associated with great rotational laxity—are at higher risk of failure after ACLR.[2,4,5] Therefore, it is paramount that the reconstruction strategy satisfactorily contemplate both components of instability.[1,2,4,5]

To avoid possible enlargement of the previous femoral tunnel to impair the mechanism of fixation, we advocate the use of a suspensory device as a viable and advantageous alternative to this condition because it does not depend on the compression forces inside the tunnel.[1] Although the first suspension fixation devices were related to tunnel widening due to the "windshield-wiper" effect,[1] the most modern devices, such as the ToggleLoc and TightRope (Arthrex, Naples, FL), have the advantage over the first devices by allowing tension adjustments in the graft after the initial fixation, letting the tunnel almost be filled by the bone plug and thus minimizing the risk of enlargement.[6]

This technique, however, has the disadvantage of being more expensive, owing to the use of more fixation devices. The risks related to the suspensory device include drilling beyond the desired femoral tunnel and rupturing the cortex at the exit of the tunnel, preventing the use of this device. As a limitation, it cannot be used in revision cases in which the primary reconstruction had violated the lateral cortex of the femur.

Tibial fixation should be performed with special attention because it is a metaphyseal bone and will counteract forces that are collinear to the graft's orientation, representing a usual site of failure.[7] Accordingly, it is important to add some type of backup fixation, such as a bicortical screw, as a post.[1] In the reported technique, we placed a transosseous suture in the tibia with the graft's own traction as backup fixation. This would be a practical and effective backup technique, without the need to use any additional implants.

Recent studies on the anatomy and function of the anterolateral ligament (ALL) have gained prominence in the literature,[2,4,5] while the understanding of the elements responsible for rotatory stability has progressively increased. Although the indications for ALL reconstruction remain controversial, most authors agree that it is biomechanically important to improve AL rotational stability in cases in which there is a high-grade pivot shift, in patients with anterior

Table 2. Advantages and Disadvantages

	Advantages	Disadvantages
Suspensory device	Allows its use with good fixation even in cases of posterior cortical blowout Minimizes risk of tunnel enlargement	Is technically more demanding
Modified Lemaire technique	Allows ACL and ITB grafts to be fixed at independent times and at different degrees of flexion Minimizes risk of mistaking positioning of each tunnel	Needs lateral incision
Combined technique	Is reproducible and effective technique	Is more expensive because more fixation devices are needed

ACL, anterior cruciate ligament; ITB, iliotibial band.

Table 3. Risks and Limitations

	Risks	Limitations
Suspensory device	Rupture of cortex at exit of tunnel, preventing use of device	Cannot be used in revision cases in which primary reconstruction violated lateral cortex of femur
Modified Lemaire technique	Injury to fibular collateral ligament Overconstraint of lateral compartment Limitations in range of motion in cases of non-isometric placement of graft	Inadequate biomechanics in cases of insufficient fibular collateral ligament
Combined technique	Overconstraint of lateral compartment and predisposition to osteoarthritis in future Loss of some degree of flexion	

tibial translation greater than 10 mm, in athletes involved in sports with high rotational demand, and in revision surgical procedures.[5]

In 2018, Geeslin et al.[8] performed a robotic biomechanical study to evaluate the role of the ALL and the ITB Kaplan fibers in extra-articular stabilization of the knee. Twenty cadaveric specimens were evaluated. The authors found that the ALL and the ITB Kaplan fibers were both restrictors of internal rotation in knees with ACL injury. The Kaplan fibers, when sectioned alone, further increased the internal rotation of the knee compared with the isolated section of the ALL, with the authors concluding that the ALL and the ITB Kaplan fibers contribute to the pivot-shift restriction and anterior tibial translation in knees with injured ACLs.[8]

In 1967, Lemaire[9] proposed a complex lateral tenodesis technique, which was modified by Christel and Djain[10] in 2002. These authors, to perform a simpler operation, with less surgical exposure, used an ITB graft 75 mm long by 12 mm wide, keeping its distal insertion, passing over the FCL, and fixing it proximal and posterior to the LFE.[4]

Kernkamp et al.[3] observed that a graft that originates near the Gerdy tubercle and is fixed proximally to the LFE is able to provide rotatory stability without compressing the lateral compartment or stretching during joint movement because it passes underneath the FCL. Magnussen et al.[11] described an ACLR technique associated with AL stabilization using the same modified Lemaire principles but using the hamstrings as grafts and passing underneath the FCL, with good results. In 2015, Dejour et al.[2] described a similar technique in revision cases, associated with tibial slope correction, with good results; they used an 80 × 12—mm strip of the ITB, keeping its distal attachment, and fixing it at an isometric point proximal and posterior to the LFE, passing underneath the FCL, to guarantee an isometric reconstruction.

The technique presented in this article is a modification of that proposed by the previous authors. The main differences are related to the method used to create the femoral tunnel (anatomic inside-out technique rather than outside-in technique) and the method of fixation (we secure the ACL graft with an adjustable suspensory method rather than screws). We do not necessarily consider this technical variation to be superior to the first, but it is certainly different and has particular technical details that need to be known and observed.

Our lateral tenodesis is similar to the technique described by Dejour et al.,[2] except that we used an anatomic point as a reference for our femoral tunnel, as recommended by Lutz et al.,[12] 3 mm proximal and posterior to the LFE, instead of an isometric point. Another important difference is that we performed placement of an independent tunnel for ALL fixation and did not use the same tunnel used for ACL reconstruction, as advocated by Dejour et al. We believe this makes the technique more reproducible because it is based on an anatomic framework. Establishing different tunnels for ACL and ITB grafts allows their fixation at independent moments and at different degrees of flexion, and making independent tunnels minimizes the risk of mistaking the positioning of each tunnel.

The risks regarding the modified Lemaire technique include injury to the FCL; overconstraint of the lateral compartment of the knee, if fixed in external rather than neutral rotation; and limitations in range of motion in cases of non-isometric placement of the graft.[12] Pearls and pitfalls related to the described surgical technique are depicted in Table 1. The advantages and disadvantages, as well as risks and limitations, are summarized in Tables 2 and 3.

One concern regarding extra-articular tenodesis is the theoretical risk of osteoarthritis development in patients undergoing such techniques. In opposition to this idea, Devitt et al.[13] published a systematic review, in 2017, reporting that extra-articular tenodesis of the ITB associated with ACLR did not increase the incidence of osteoarthritis in the knee in the first 11 years postoperatively. Lee et al.[14] published a retrospective study comparing the clinical outcomes of revision ACLR in isolation or in combination with anatomic ALL reconstruction and observed significantly reduced rotational laxity and a higher rate of return to the same level of sports activity in the combined group.

We understand that evaluation of a large number of patients is necessary to validate the described technique, although the results have been encouraging so far. Knowledge of new techniques of intra- and extra-articular ligament reconstruction is imperative in the present day, when more and more patients are seeking a full return to their preinjury recreational, labor, and sports activities. We believe that the combination of these surgical techniques is able to achieve these goals effectively and reproducibly.

References

1. Di Benedetto P, Di Benedetto E, Fiocchi A, Beltrame A, Causero A. Causes of failure of anterior cruciate ligament reconstruction and revision surgical strategies. *Knee Surg Relat Res* 2016;28:319-324.
2. Dejour D, Saffarine M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2846-2852.
3. Kernkamp WA, van de Velde SK, Bakker EW, Van Arkel ER. Anterolateral extra-articular soft tissue reconstruction in anterolateral rotatory instability of the knee. *Arthrosc Tech* 2015;4:863-867.
4. Duthon VB, Magnussen RA, Servien E, Neyret P. ACL reconstruction and extra-articular tenodesis. *Clin Sports Med* 2013;32:141-153.
5. Luzo MV, Franciozi CE, Rezende FC, Gracitelli GC, Debieux P, Cohen M. Anterior cruciate ligament—Updating article. *Rev Bras Ortop* 2016;51:385-395.
6. Firat A, Catma F, Tunc B, Hacihafizoglu C, Altay M, Bozkurt M. The attic of the femoral tunnel in anterior cruciate ligament reconstruction: A comparison of outcomes of two suspensory femoral fixation systems. *Knee Surg Sports Traumatol Arthrosc* 2014;22:1097-1105.
7. West RV, Harner CD. Graft selection in anterior cruciate ligament reconstruction. *J Am Acad Orthop Surg* 2005;13:197-207.
8. Geeslin AG, Chahla J, Moatshe G, et al. Anterolateral knee extra-articular stabilizers: A robotic sectioning study of the anterolateral ligament and distal iliotibial band Kaplan fibers. *Am J Sports Med* 2018;46:1352-1361.
9. Lemaire M, Combelles F. Plastic repair with fascia lata for old tears of the anterior cruciate ligament (author's transl). *Rev Chir Orthop Reparatrice Appar Mot* 1980;66:523-525.
10. Christel P, Djian P. Anterio-lateral extra-articular tenodesis of the knee using a short strip of fascia lata. *Rev Chir Orthop Reparatrice Appar Mot* 2002;88:508-513.
11. Magnussen RA, Jacobi M, Demey G, Lustig S, Servien E, Neyret P. Lateral extra-articular augmentation of ACL reconstruction. *Tech Knee Surg* 2011;10:224-230.
12. Lutz C, Sonnery-Cottet B, Imbert P, Barbosa NC, Tuteja S, Jaeger J. Combined anterior and anterolateral stabilization of the knee with the iliotibial band. *Arthrosc Tech* 2016;5:251-256.
13. Devitt BM, Bouguennec N, Barfod KW, Porter T, Webster KE, Feller JA. Combined anterior cruciate ligament reconstruction and lateral extra-articular tenodesis does not result in an increased rate of osteoarthritis: A systematic review and best evidence synthesis. *Knee Surg Sports Traumatol Arthrosc* 2017;25:1149-1160.
14. Lee DW, Kim JG, Cho SI, Kim DH. Clinical outcomes of isolated revision anterior cruciate ligament reconstruction or in combination with anatomic anterolateral ligament reconstruction. *Am J Sports Med* 2019;47:324-333.