Technical Note

Anterior Cruciate Ligament Revision Using Quadriceps Tendon Autograft and Lateral Extra-Articular Tenodesis

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Abstract: Revision of anterior cruciate ligament (ACL) reconstruction presents numerous challenges not encountered in the primary setting and therefore requires thorough preoperative planning. Addressing tunnel widening is the primary concern, and therefore the appropriate graft choice is pivotal. Quadriceps tendon autograft recently has gained popularity for its dimensions and the possibility to harvest a bone block from the patella that can fill potential tunnel bone defects. Adjunctive procedures to isolated ACL reconstruction such as lateral extra-articular tenodesis (LET) may help in sharing the loads with the neoligament, with recent findings recommending LET in the revision setting. The technique presented in this Technical Note describes a 1-stage revision ACL combined with LET using a quadriceps tendon autograft with a bone plug.

Revision of anterior cruciate ligament reconstruction (Rev-ACLR) is a demanding procedure and presents numerous challenges, such as addressing tunnel osteolysis, obtaining a stable fixation, and managing associated lesions that can contribute to knee instability. Recent studies have shown that the scientific literature is now leaning toward a 1-stage over 2-stage revision procedure, which is burdened by greater rates of complications.[1] Patellar tendon autograft often is considered the most suitable graft of choice in revision settings, even though it is associated with a greater risk of donor-site morbidity, including anterior knee pain and extensor mechanism complications such as patellar fractures and patellar tendon rupture. To mitigate these possible complications, alternatives such as quadriceps tendon (QT) autograft with patellar bone block (B-QT) have been proposed. B-QT offers adequate length and thickness, can be fixed using various methods, and growing body of evidence demonstrates excellent patient outcomes and lower donor-site morbidity when compared with bone—patellar tendon—bone (BPTB) with noninferior survival graft rate.[2-4] We describe a simple technique for Rev-ALCR using B-QT associated with lateral extra-articular tenodesis (LET) where the bone block of the graft is used to fill the widened tibial tunnel and obtain adequate tibial fixation that is very often the critical part of the procedure (Fig 1, Video 1).

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Preoperative Planning

Thorough clinical and radiographic evaluation is carried out to obtain accurate preoperative planning. Our preoperative imaging protocol consists of anteroposterior and lateral knee and x-ray scanogram of the lower limb, computed tomography scan with dedicated study protocol of the tunnels' position[5] and diameter, and magnetic resonance imaging (Figs 2 and 3).

Surgical Technique

QT Graft Harvest

A 2- to 3-cm median longitudinal incision is made starting from the superior border of the patella with the knee at 90° of flexion. Subcutaneous fat and the fascia must be dissected to obtain proper visualization of the QT, ensuring optimal graft harvesting. The central third of the QT is incised starting from the

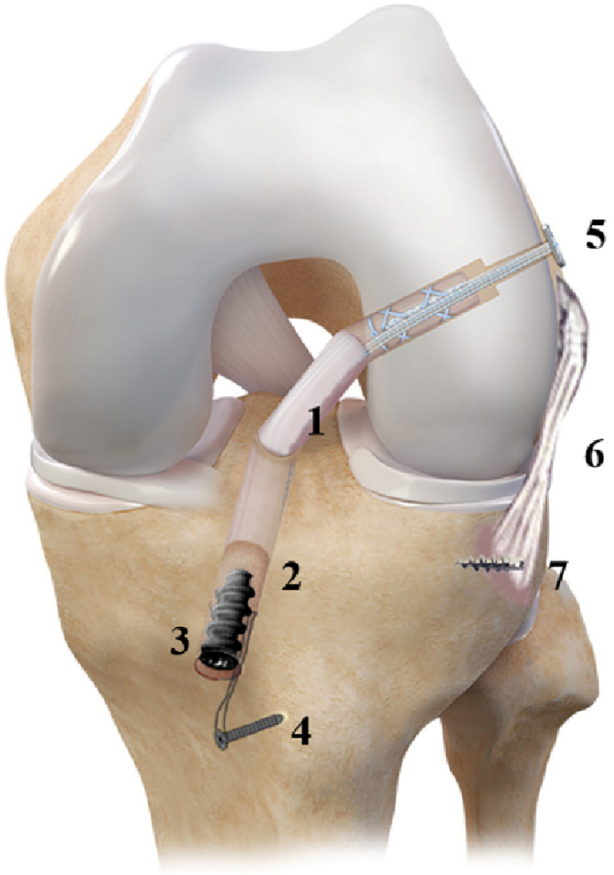

Fig 1. Shown is an illustration of the surgery with all the various essential elements: 1. New anterior cruciate ligament (quadriceps tendon autograft); 2. bone plug; 3. interference screw; 4. cortical screw; 5. FiberTag TightRope Implant (Arthrex); 6. anterolateral ligament; 7. anchor.

superior border of the patella progressing proximally for about 6 cm. The myotendinous junction of the QT is visualized and the graft is incised through a percutaneous incision using a size 11 blade. The tendon is harvested in proximo-distal fashion. The patellar bone block is then harvested using an oscillating saw of 10 mm and an osteotome; the bone block measures 20 mm in length and 10 mm in width. The final harvested graft should be 8 cm in length (2 cm bone block + 6 cm quad tendon). The tendon end of the graft is placed in the femoral socket using an adjustable cortical fixation device; meanwhile, the patellar bone block is introduced into the tibial tunnel to fill the bone defect and address the tibial tunnel widening. The QT is immediately closed with 0 VICRYL sutures (Ethicon, Somerville, NJ). The superior pole of the patella is filled with bone grafting at the end of the procedure and, eventually, cancellous bone allograft can be used to fill the patellar defect before complete wound closure.

QT Graft Preparation

The tendinous end of the graft is prepared using a SpeedWhip rip-stop technique with a No. 2 FiberLoop suture (Arthrex, Naples, FL) and a FiberTag Implant (Arthrex). The bony end of the graft is prepared by drilling 2 perpendicular 1.5-mm holes through the bone. A No. 2 VICRYL suture is passed through the distal hole, and a 0.8-mm K-wire is passed through the distal one and can be used to provide optional double tibial fixation to a monocortical screw (Fig 4). The graft is marked distally at the bone-tendon interface and proximally at 25 mm from the tendinous end. Once the

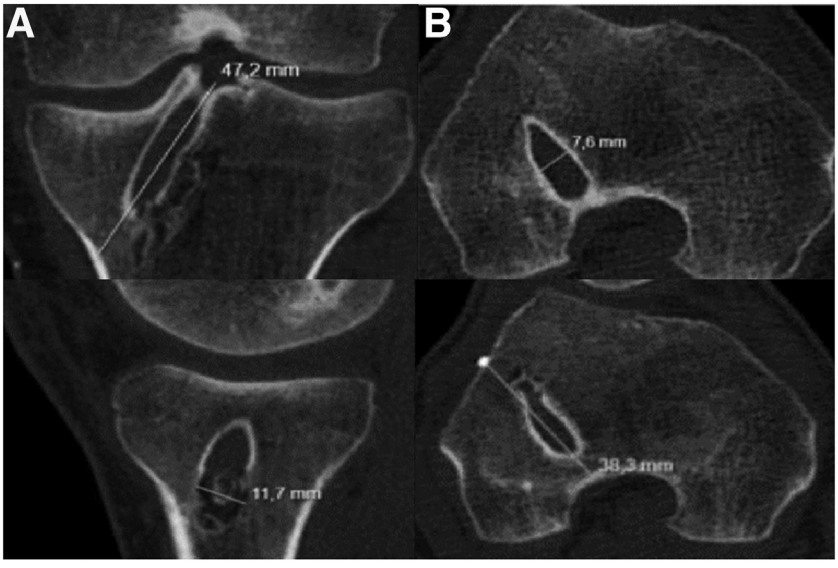

Fig 2. Preoperative computed tomography scans of the right knee of the patient in supine position. (A) Coronal view of the tibia: the image shows the tibial tunnel length (top). Sagittal view of the tibia: the image shows the tibial tunnel width (bottom). (B) Axial view of the femur: the image shows the femoral tunnel width (top) and femoral tunnel length (bottom).

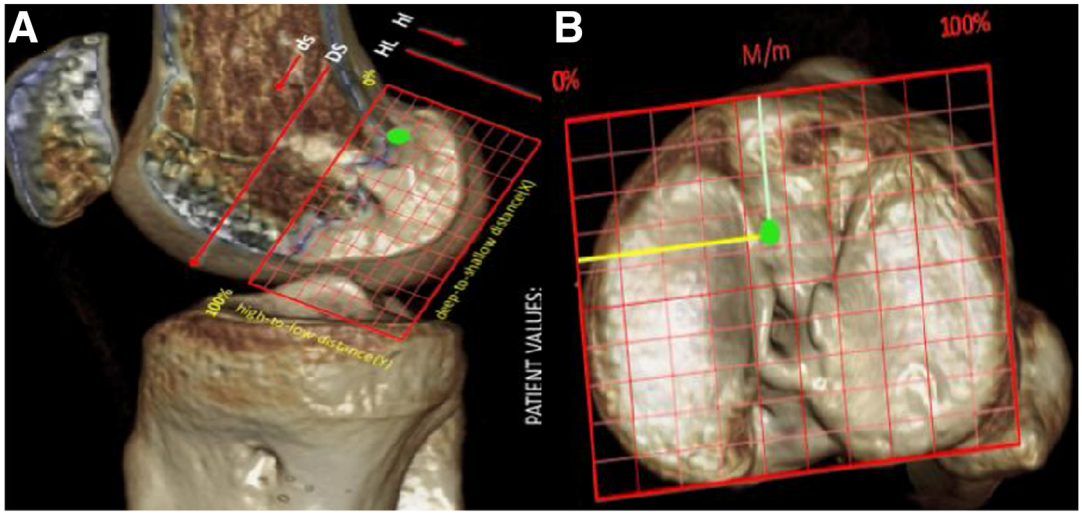

Fig 3. (A) Three-dimensional computed tomography images of a right knee showing femoral tunnel (green dot). The femoral tunnel is too anterior in relation to the anatomic anterior cruciate ligament footprint. The green dot shows the ideal position of the femoral tunnel. (B) Three-dimensional computed tomography images of a right knee showing aperture location of the tibia tunnel (green dot). In this case, it seems too posterior. The green dot shows ideal tibial tunnel position according to the methods of Bernard Hertel.[5]

Fig 4. Graft preparation. The quadriceps tendon is prepared on a separate table: a graft of about 80 mm in length and 10 mm width is obtained with a patellar bone plug of about 20 mm in length and matching the width of the tendon graft.

graft has been prepared, it is wrapped in gauze impregnated with vancomycin until it is introduced into the joint.

Diagnostic Arthroscopy

A diagnostic arthroscopy is performed using standard anterolateral and anteromedial portals with a 30° arthroscope. The remnants of the ACL graft are debrided, and the previous tunnel position is inspected. The medial compartment is inspected with the knee at 20° to 30° of flexion with a valgus force applied and the foot in external rotation to rule out any underlying undiagnosed lesion. The lateral compartment is inspected with the leg in a figure-of-4 position. Any associated meniscal or cartilage lesions are treated simultaneously. Video 1 describes a case with a medial meniscus lesion that was treated with an all-inside suture as a secondary stabilizer of the knee and a functional meniscus will destress the graft.

Tunnel Positioning and Landmarks

The ideal position of the tibial tunnel is obtained with tibial guide aiming toward the native ACL footprint; the anterior horn of the lateral meniscus is a reproducible landmark. The tunnel is angled at around 20° medially in the axial plane and 55° in the sagittal plane (Fig 5). However, in Rev-ACLR the direction of the tibial tunnel should be carefully planned using the preoperative CT scan and in relation to the previous tunnel position. Sometimes it is necessary to compromise and the previous tibial tunnel may be exploited. It's of utmost importance to check with the arthroscope that the walls of the new tibial tunnel are at least debrided of any remnants of the previous graft for at least 75% (Fig 6). The femoral tunnel is created with an outside-in technique combined with a retrograde drill (FlipCutter; Arthrex). A femoral socket of 25 mm in length is created matching the diameter of the graft.

ACL Graft Passage and Fixation

The graft is inserted from the tibial tunnel and shuttled into the femoral sockets via pull-through sutures. Femoral fixation is achieved by tightening the FiberTag TightRope Implant (Arthrex) over a cortical button after checking appropriate position with the scope and using the mark on the tendinous end of the

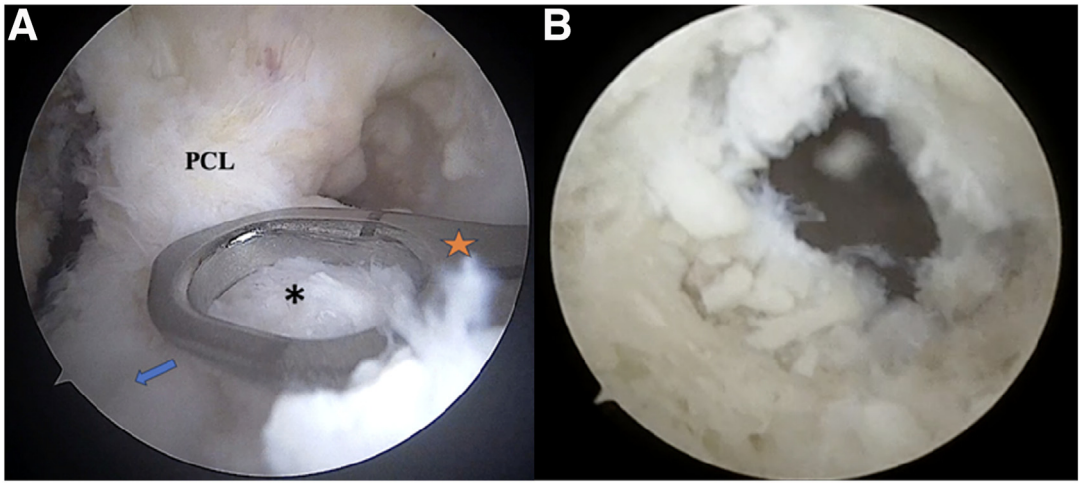

Fig 5. (A) Arthroscopic view of the tibial footprint through the anterolateral portal. The asterisk denotes the previous graft footprint. Yellow star: tibial guide; blue arrow: anterior horn of lateral meniscus. (B) Arthroscopic view of the tibial tunnel because the arthroscope is inserted inside it to check that it is three-fourths debrided from the previous graft and that the tunnel's walls are intact. (PCL, posterior cruciate ligament.) Patient in supine position with the right knee at 90° of flexion

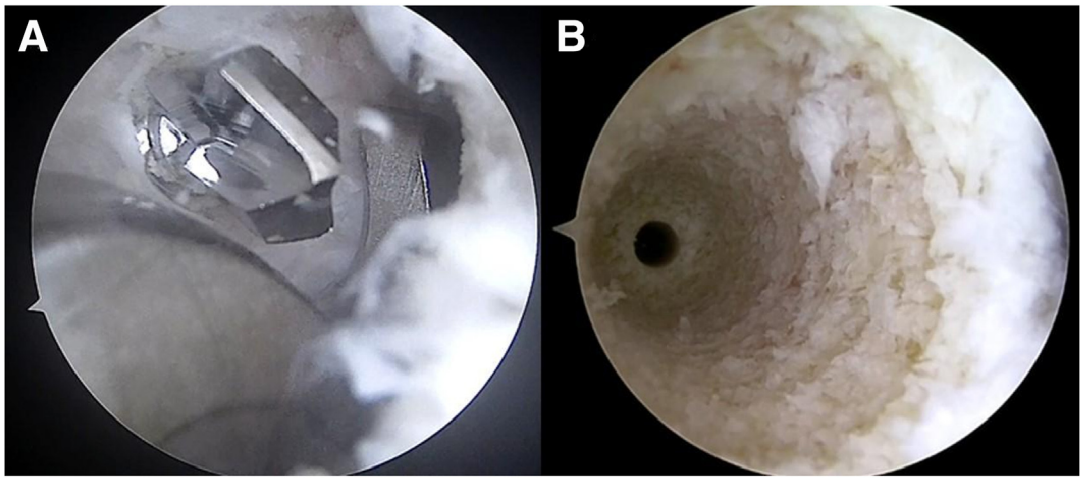

Fig 6. (A) Arthroscopic view of the footprint femoral tunnel through the anteromedial portal. The FlipCutter is used to drill a half tunnel of the appropriate diameter under arthroscopic visualization through the anteromedial portal. The letter "A" denotes the femoral outside-in guide. (B) Arthroscopic view of femoral tunnel under arthroscopic visualization through the anteromedial portal. Patient in supine position with the right knee at 90° of flexion.

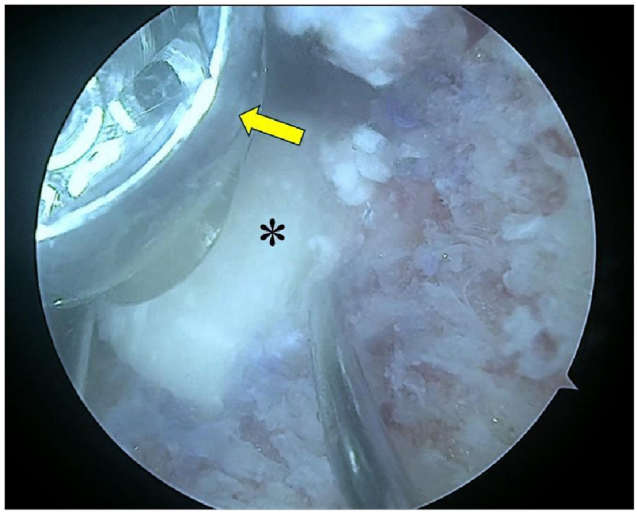

Fig 7. Arthroscopic check of correct placement of the bone plug and metallic screw in the tibial tunnel. Yellow arrow: metallic screw; asterisk: bone plug. Patient in supine position with the right knee at 90° of flexion.

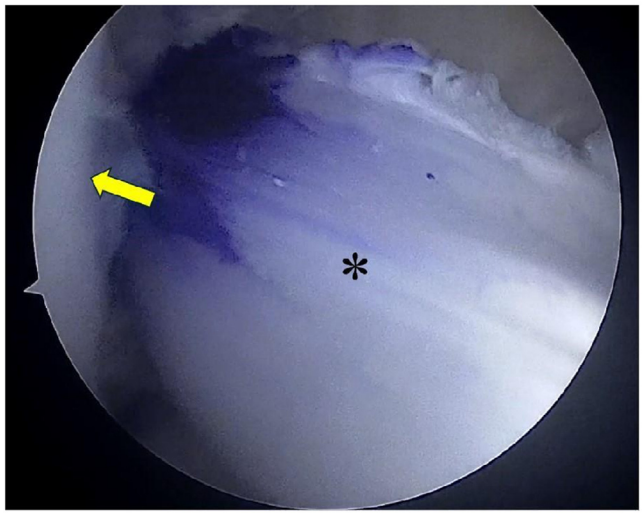

Fig 8. Arthroscopic view of the new anterior cruciate ligament by anteromedial portal. Yellow arrow: lateral condyle; asterisk: new anterior cruciate ligament. Patient in supine position with the right knee at 90° of flexion.

graft as a reference.[6] The knee is cycled through 10 repetitions of flexion-extension, and then a metal screw (DePuy Synthes, West Chester, PA) is used to fix the graft in the tibial tunnel with the knee at 30° of flexion with posterior drawer force is applied to the tibia (Fig 7). Often a screw with the same diameter as the tibial tunnel is chosen, but in some circumstances a screw undersized by 1 mm may be chosen if the bone block passes too tightly through the tunnel or if a weakness of the new tunnel walls is feared, excessive pressure exerted by the screw could cause the walls to collaborate and cause coalescence of the 2 tunnels. Double fixation of the graft on the tibia is obtained if needed by tying the metal wire armed on the bone plug to a monocortical screw placed slightly distally. At the end of the procedure, proper tensioning of the ACL graft is arthroscopically confirmed, and eventually the FiberTag allows retensioning of the quadriceps graft (Fig 8).

Extra-articular Tenodesis and Graft Fixation

LET is performed with the modified Ellison technique, as is shown in Video 1. A lateral incision of approximately 6 cm is centered on the Gerdy tubercle and

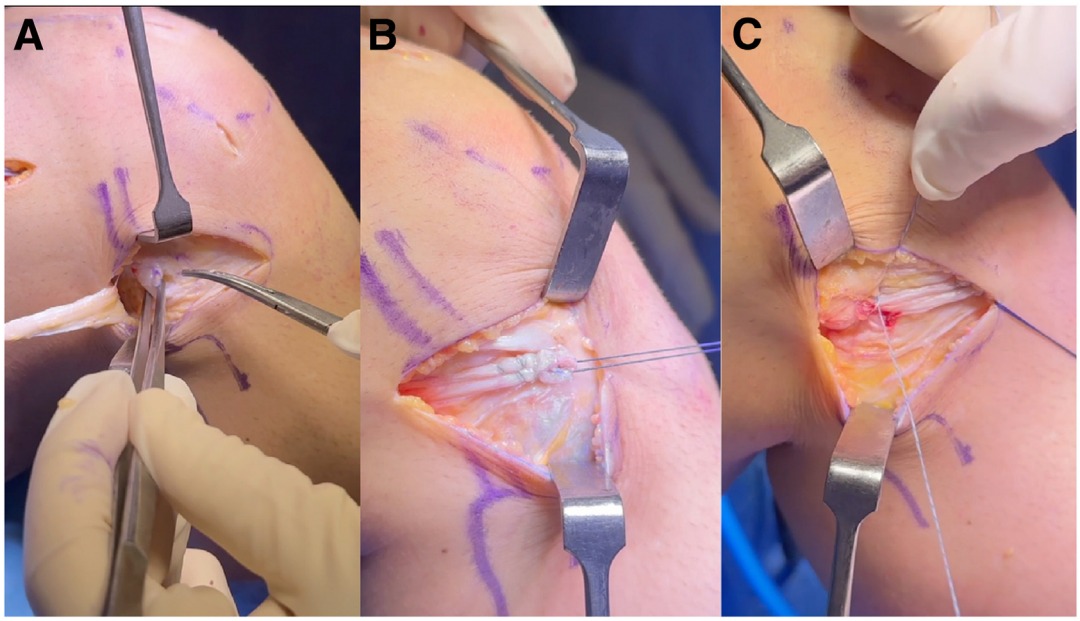

Fig 9. Lateral aspect of the femur: a 6-cm lateral incision is performed centered on the Gerdy tubercle. The distal end of the ITB is then lifted off the Gerdy tubercle with a sleeve of periosteum. The LCL is identified (A) and the ITB graft is then passed underneath the LCL (B). (C) The graft is then sutured to the LCL using a nonabsorbable suture. (ITB, iliotibial band; LCL, lateral collateral ligament.) Patient in supine position with the right knee at 90° of flexion.

Fig 10. Postoperative radiographs of revision of anterior cruciate ligament reconstruction with quadriceps tendon with patellar bone block. (A) Anteroposterior vision. (B) Lateral vision. Final radiographs are taken to check hardware and tunnel positions. Right knee.

continues superoproximal to the lateral collateral ligament (LCL). An approximately 1-cm strip of iliotibial band is isolated and detached distally from the Gerdy tubercle. This is passed below the LCL and refixed with a double-loaded suture anchor 4 mm (REVO; Arthrex), which is inserted just distally to Gerdy tubercle. With the knee flexed at 30° and the foot in neutral rotation, the first suture is used to tie the free end of the graft to the anchor using Krackow suturing technique to tension the graft. The second suture loop is used to tie a knot around the graft to bring the graft towards the anchor. The fixation is reinforced with a nonabsorbable single stitch suturing the fascia lata to the LCL (Fig 9). Final radiographs are then taken (Fig 10).

Ten key points for a correct procedure are listed in Table 1.

Rehabilitation

For the first 4 weeks, the goal is to achieve a range of motion (ROM) 0° to 90° in flexion, and then allowing ROM 0 to 120 for the successive 4 weeks and full ROM afterward. A partial weight-bearing protocol is adopted, followed by progressive and then to complete weight-bearing. Early rehabilitation is focused on isometric strengthening of the quadriceps and extensor-flexor muscles of the hip. In the case of meniscal injuries, the rehabilitation protocol must be adapted.

Discussion

The choice of graft for Rev-ACLR presents a challenge and is influenced by many factors, such as the harvest site, type of graft used during the primary ACLR, and the surgeon's preference. Autografts remain the preferred

Table 1. Ten Key Points for a Correct Procedure

1. AL and AM portals.	Standard portals using 30° arthroscopy. Check for associated intra-articular lesions.
2. Quadriceps tendon graft harvest	Requires a tendon graft with patellar bone block measuring 2 cm in length resoaked in 5 mg/mL vancomycin.
3. Tibial tunnel	Aim toward the anatomic tibial footprint. Tunnel should be angled approximately 20° medially in the axial plane and 55° in the sagittal plane.
4. Femoral tunnel	The guide is directed toward the femoral anatomical footprint, then a half tunnel of approximately 2.5 cm in length and appropriate diameter is made using the FlipCutter (Arthrex) under arthroscopic visualization through the AM portal.
5. Lateral incision	After superficial dissection to the IT band, the LCL is then identified and isolated.
6. ACL passage	The graft is pulled from the femoral side until the bony plug is completely seated on the tibial tunnel.
7. Femoral fixation	Knee 90°, suspension fixation with adjustable loop.
8. Tibial fixation	Then, 30° of flexion with posterior drawer force is applied and metal screw against bone block. A monocortical screw is used for metal wire suture.
9. ALL	The graft passed underneath the IT band and LCL and fixed with an anchor with the knee flexed at 30° and the foot in neutral rotation.
10. Check intra-articular	Check intra articular ACL tension, position and clinically assess the knee's stability.

ACL, anterior cruciate ligament; AL, anterolateral; ALL, anterolateral ligament; AM, anteromedial; IT, iliotibial; LCL, lateral collateral ligament.

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
• One-stage Rev-ACLR with bone loss • An outside-in technique on the femur decreases risk of tunnel convergence • Manage tibial bony defect with proper shaping of patellar bone block • Adjustable loop fixation allows optimal tensioning of the graft • Adequate autograft dimension • Decreased donor-site morbidity compared with BPTB • LEAP gives more stability to the knee with no differences for post-operative rehabilitation protocol	• Not suitable technique in cases of extensive bone loss on both the tibia and the femur • Bone-to-bone healing just on one side

BPTB, bone–patellar tendon–bone; LEAP, lateral extra-articular procedure; Rev-ACLR, revision of anterior cruciate ligament reconstruction.

choice, since they are associated with a re-rupture rate of 2.7 times less compared with allograft when used for Rev-ACLR.[7,8] Historically, the BPTB and hamstring autografts have been commonly used in Rev-ACLR surgery, but as the result of their limited availability, other options must be considered. The QT autograft has emerged as a viable alternative, offering adequate length and size, relatively easy harvest, and low donor-site morbidity.[9] The mean cross-sectional area of QT graft is significantly larger than the patellar tendon,[10] and for this reason it can reproduce the broad anatomic insertion of the native ACL on the tibia and moreover reduce the graft-tunnel mismatch caused by tunnel enlargement encountered during Rev-ACLR.

Another important consideration is donor-site morbidity. A recent systematic review showed that using B-QT for primary ACLR resulted in knee stability and subjective outcomes similar to those achieved with BPTB grafts but with less donor-site morbidity.[2,3] Furthermore, QT autograft can potentially be harvested with a bone plug, providing a solution to tunnel enlargement, especially of the tibial tunnel, which is often encountered when performing an Rev-ACLR, providing an increased compression of the interference fixation. Ultimately, the tendon end of the graft can be fixed with newly designed fixation devices featuring an adjustable loop and cortical button of a different diameter to obtain adequate cortical fixation. The technique we presented provides a solution to manage Rev-ACLR in a one-stage surgery using an autograft with a bone plug to restore bone stock and fill tibial tunnel widening. The unique anatomy of the QT creates a predictable and versatile graft that allows surgeons flexibility in both graft harvest and method of fixation. Advantages and disadvantages of this procedure are listed in Table 2 and pearls and pitfalls are listed in Table 3.

Disclosures

All authors (F.M., J.C., M.C., P.F., Z.A.T., and R.C) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 3. Pearls and Pitfalls

Pearls	Pitfalls
• Harvest quadriceps tendon through longitudinal skin incision and in a proximal-distal fashion. • Patellar bone block should be a trapezoidal transverse section and no more than 2 cm in length to reduce the risk of patellar fracture. • A metallic wire should be placed in the bone block to allow secondary fixation in case of extensive tibial tunnel widening. • Out-in technique for femoral tunnel allow creation of new tunnel with low risk of tunnel convergence. • Direct arthroscope inspection of tibial and femoral tunnel to check cleaning and any convergence with old tunnels. • Anterolateral reconstruction or lateral extra-articular tenodesis can be easily performed, as the incision for graft harvest is away.	• Excessive length or depth in bone plug harvesting could lead to patellar fracture. • Inadequate technique for graft preparation at the tendon extremity (Speed-Whip rip-stop technique) could lead loosening of the tension.

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