Technical Note

Revision Anterior Cruciate Ligament Reconstruction: Tibial Tunnel-First Graft-Sizing Technique

Joo Yeon Kim, B.A., Juho Park, B.A., Dong Hyeon Kim, B.A.,
Brandon Gardner, M.D., Ph.D., Sarah Jenkins, M.D., Patrick McGahan, M.D., and
James L. Chen, M.D., M.P.H.

Abstract: Revision anterior cruciate ligament reconstruction (R-ACLR) has become more common as the number of failed primary ACLRs increase. Although increasingly common, R-ACLR has a greater failure rate than a primary reconstruction. Technical errors, particularly in tunnel placement, account for a large proportion of graft failure in R-ACLR as well as re-revision cases. Tunnel placement and trajectory is particularly important in R-ACLR and becomes more challenging with each additional revision attempt. This is in part because any tunnels created for revision may converge with formerly drilled tunnels or face interference hardware creating, complicating proper graft fixation. While there are many approaches to revision ACL surgery, our technique describes a simple, tibial tunnel-first graft-sizing method initially reaming tunnels with very small diameters and sequentially working your way up to more anatomic diameters.

Anterior cruciate ligament reconstructions (ACLRs) are one of the most common surgical procedures but still have a 3% to 25% failure rate, with little improvement over recent years.[1-3] In addition to graft failure, postoperative complications include limited range of motion, recurrent instability, pain, and reduced proprioception and function.[4,5] Multiple studies have found that technical errors in ACLR surgery account for the vast majority of graft failures and are related to 52% of all complications in general.[6-8] Specifically, these technical errors include nonanatomic tunnel placement of either tibial or femoral tunnels, inadequate graft fixation or tensioning, and graft impingement.[4,9] Tunnel malposition comprises 70% to 80% of the technical complications and is the primary cause of technical failure after ACL reconstruction.[5]

Revision ACLR (R-ACLR) is becoming an increasingly viable option to treat primary ACLR failure, especially in young active patients.[2,10,11] That said, the technical difficulty of R-ACLR is substantially greater than primary reconstruction and is reflected by greater rates of failure, complications, and reduced return to sport of R-ACLR compared with primary reconstruction. Specifically, a recent study showed 60% of patients who undergo R-ACLR return to sport compared with 82% of patients who undergo ACLR and thus argued that R-ACLR should be viewed as a "salvage" procedure aimed at alleviating pain while allowing normal gait rather than a tool for consistent return to sport.[8,12-14] Gifstad et al.[15] found that at 90 months postoperatively for both R-ACLR and ACLR, the R-ACLR group exhibited greater graft failure and greater re-revision rates in addition to reduced range of motion, reduced activity levels, increased radiologic osteoarthritis, and greater rates of chondral and meniscal lesions. However, R-ACLR is able to provide substantial improvement in subjective stability in addition to recover some range of motion compared with those who do not undergo revision.[12] Careful consideration of all the potential causes of primary ACLR failure and proper preoperative evaluation using physical examination, imaging, and patient consultation are crucial for a successful treatment plan.[16]

R-ACLR procedures suffer a relatively high reoperation rate, with roughly 11% requiring reoperation in

From Advanced Orthopaedics and Sports Medicine, San Francisco, California, U.S.A.

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Address correspondence to Joo Yeon Kim, Advanced Orthopaedics and Sports Medicine, 450 Sutter St, Ste 400, San Francisco, CA 94108. E-mail: jooyeon.john.kim@gmail.com

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less than 2 years.[11,16] The purpose of this Technical Note is to address the technical challenges that come with a single-stage revision ACL reconstruction for tibial tunnel placement and sizing. Our technique and accompanying Video 1 describe the usage of a tibial guide and sequentially sized reamers to create and size an anatomically appropriate tibial tunnel in a simple and convenient manner.

Surgical Technique (With Video Illustration)

Preoperative Considerations

Preoperative assessment is conducted with magnetic resonance imaging, which is particularly important for localizing the trajectory and landmarks surrounding previous tunnels, in addition to identifying the make and material of any implanted interference hardware (Fig 1).[4,16]

Patient Positioning and Diagnostic Arthroscopy

The patient is positioned supine on the operating table with the left knee marked as the correct operative site. The head and bony prominences are well padded and a lateral post attached to the bed. The left leg is then prepped and draped in the usual sterile fashion.

An anterolateral portal is established in a standard fashion with a vertical incision using a No. 11 blade just lateral to the patellar tendon. The intra-articular space is entered with a blunt trocar and scope sheath and once the trocar is removed, a 30° 4.0-mm arthroscope is inserted to conduct the diagnostic arthroscopy. With arthroscopic visualization, meniscus and cartilage lesions and degenerative changes are addressed before R-ACLR. An anteromedial portal is then created at the joint line medial to the patellar tendon.

Tibial-Tunnel Sizing Technique

The remnant, ruptured ACL graft is debrided at the tibial and femoral footprints using a shaver and electrocautery (Fig 2). Particular attention is then given to the position and size of the previous femoral and tibial tunnels. The position and widening of the previous tibial tunnels. The tibial guide is inserted into the anteromedial portal and set to 60°; its placement is confirmed posterior to the anterior horn of the lateral meniscus above the anatomically positioned tibial tunnel (Fig 3). A straight clamp secures the position and trajectory of the guide pin, enabling removal of the drill guide and insertion of the appropriate reamer over the properly placed guide pin (Fig 4).

Once guide pin placement is satisfactory, the smallest reamer available of 6 mm is used to initially ream a "scout" tunnel to check for convergence and interference prior to full-bore reaming (Fig 5). Once the scout

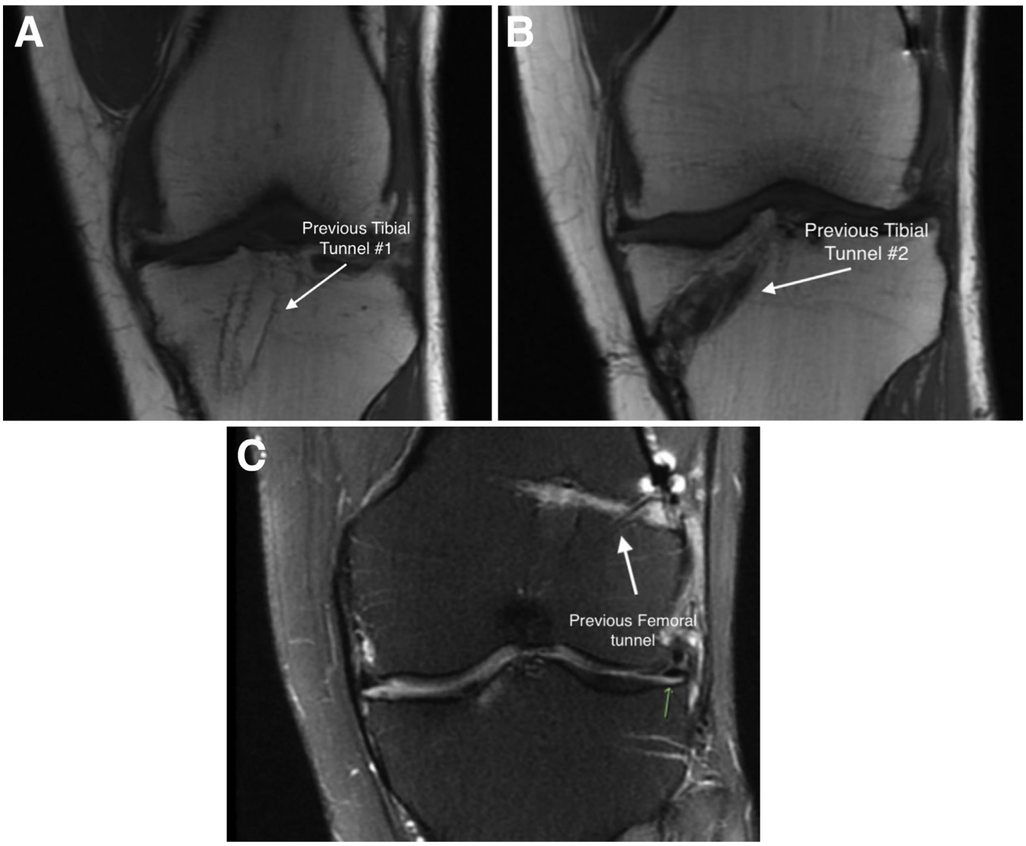

Fig 1. Preoperative magnetic resonance imaging of 3 previous tunnels of the left knee. Our patient displayed 2 previously formed tibial tunnels with interference hardware in place. One relevant unicortical femoral tunnel is identified without any luminal interference hardware and is fixed at the femoral side with a single cortical button. (A) Coronal T1 view of the tibial tunnel no. 1, which shows previous hardware present. (B) Coronal T1 view of the tibial tunnel no. 2, which shows the tunnel is older and has significant scarring. (C) Coronal fat-suppressed view of the previous femoral tunnel.

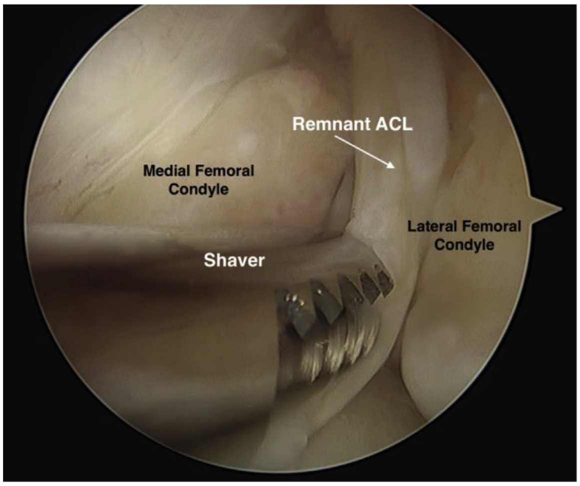

Fig 2. The patient is positioned in the supine position. Intraoperative arthroscopic image of the ruptured graft in the left knee as seen through the anteromedial portal with a 30° 4.0-mm arthroscope. This remnant ACL is debrided at the tibial and femoral footprints using a shaver and electrocautery. (ACL, anterior cruciate ligament.)

tunnel is inspected arthroscopically for obstruction, the tunnel is expanded using sequentially larger readers until the appropriate size for your graft is reached. A camera is placed into the proximal and distal meatus of the tibial tunnel, confirming that the tunnel has a bony circumferential wall after each reaming (Fig 6).

Graft Preparation

An Achilles allograft is prepared on the back table. A No. 15 blade is used to cut away the calcaneal bone

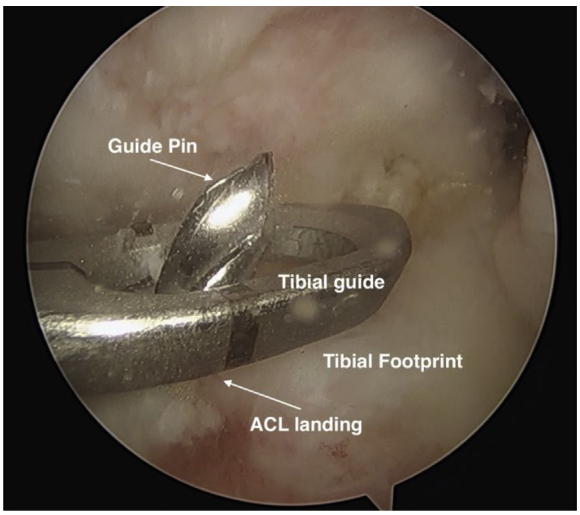

Fig 3. The patient is positioned in the supine position. Intraoperative arthroscopic image at the tibial notch of the tibial guide placed 60° and posterior to the anterior horn of the lateral meniscus as seen through anteromedial portal with a 30° 4.0-mm arthroscope. The guide pin is inserted through the ACL landing of the tibial footprint. (ACL, anterior cruciate ligament.)

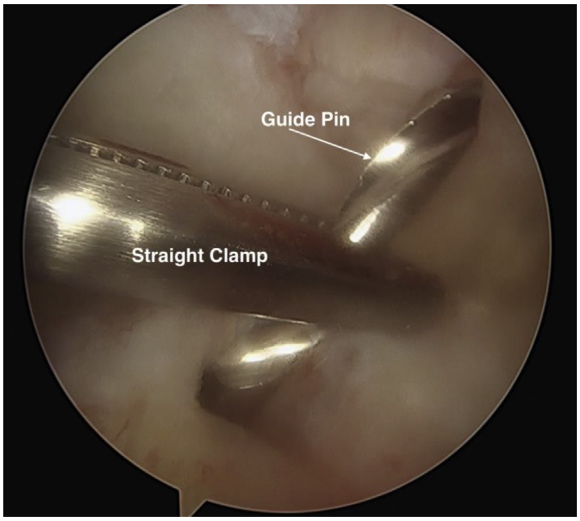

Fig 4. The patient is positioned in the supine position. Intraoperative arthroscopic image at the tibial notch of the guide pin inserting as seen through the anteromedial portal with a 30° 4.0-mm arthroscope. The straight clamp secures the position of the guide pin, allowing the surgeon to remove the drill guide and eventually insert the appropriate reamer through the properly placed guide pin.

and shape the graft, then each end of the graft is whipstitched with No. 2 ETHIBOND (Ethicon, Somerville, NJ) and the tendon is prepared for implant. The

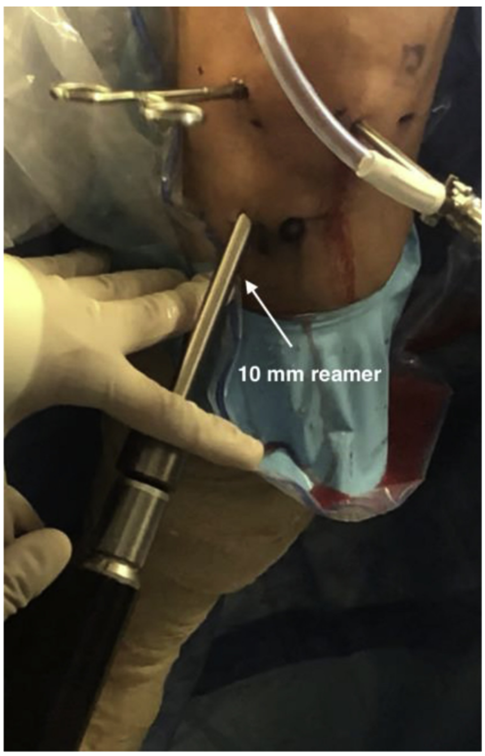

Fig 5. The patient is positioned in the supine position. Intraoperative photograph of the 10-mm reamer following through the guide pin and inserting through the tibial footprint.

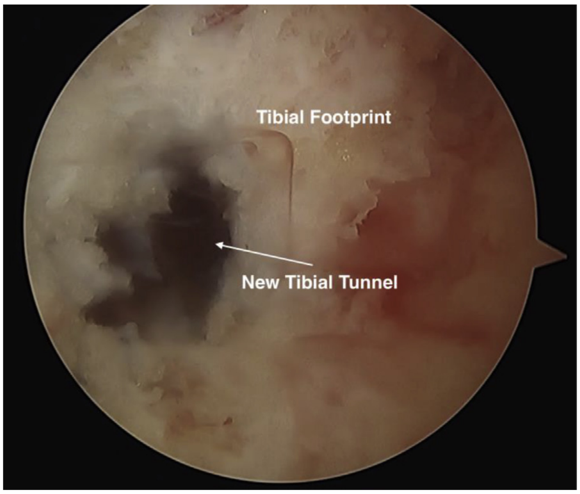

Fig 6. The patient is positioned in the supine position. Intraoperative arthroscopic image at the tibial notch of the new tibial tunnel formed as seen through the anteromedial portal with a 30° 4.0-mm arthroscope. The tibial tunnel does not converge, is adequately sized at 10 mm with a sufficient bony circumferential wall.

graft is measured to 10 mm on the femoral side and tibial side (Fig 7). The allograft is loaded onto an ACL TightRope RT (Arthrex, Naples, FL) and sized with a graft sizing block.

Drilling of the Femoral Tunnel and ACL Graft Positioning

A No. 7 over-the-top guide is inserted into the anteromedial portal and hyperflexed the knee up to 120° (Fig 8). Once the position of the over-the-top guide in the intercondylar notch is clear, a spade tip pin is fired bicortically through the lateral femoral

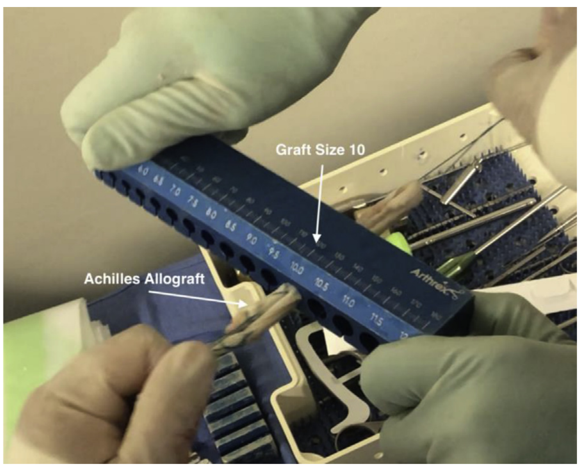

Fig 7. The patient is positioned in the supine position. Intraoperative photograph of the Achilles allograft loaded onto ACL TightRope RT (Arthrex) measured to 10 mm on the femoral side and tibial side. The allograft is sized with a graft sizing block.

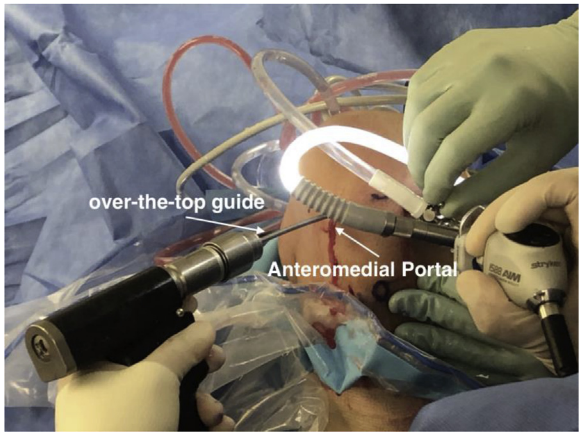

Fig 8. The patient is positioned in the supine position. Intraoperative photograph of the 10-mm low-profile reamer following the guide pin in the intercondylar notch and through the lateral femoral cortex for producing a new femoral tunnel.

cortex and the femoral condylar width is measured to be 40 mm. Then, a size 10-mm low-profile reamer is reamed over the Beath pin to create a femoral socket of approximately 35 mm (Fig 9). A No. 0 VICRYL suture (Arthrex) is placed at the end of the spade-tip pin and shuttled through the femoral tunnel and out of the lateral thigh. The suture is clamped to the side to be used later to pass the graft. Pearls and pitfalls of the procedure are listed in Table 1. A standard allograft ACL reconstruction with femoral suspension using an ENDOBUTTON and tibial screw fixation is performed.

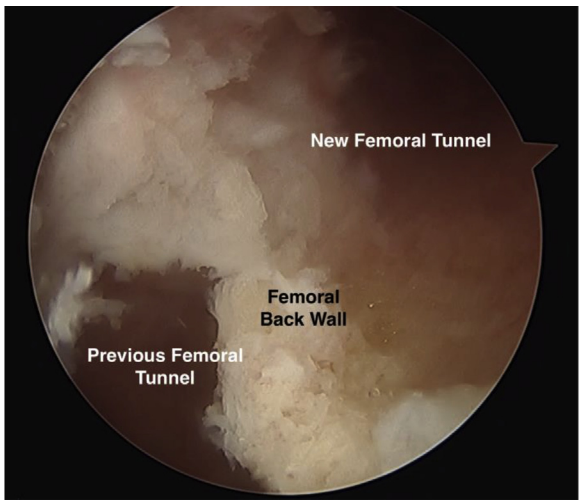

Fig 9. The patient is positioned in the supine position. Intraoperative arthroscopic image at the intercondylar notch of the new femoral tunnel formed as seen through the anteromedial portal with a 30° 4.0-mm arthroscope. The femoral back wall is 2 mm thick, patent, continuous, and without convergence.

Table 1. Pearls and Pitfalls

Pearls	
	Start reaming with small diameters, 5-6 mm initially, working your way up serially to larger sizes. This prevents the expansion of any converging tunnels you may encounter.
	High-quality, up-to-date, MRI is critical to tunnel planning and assigning correct orientation to each.
	The tibial tunnel is reamed first.
Pitfalls	
	Failing to immediately recognize convergence of tibial or femoral tunnels
	Reaming the femoral or tibial tunnels in a standard order that does not take into account which has more or less bone to spare
	Creating a femoral tunnel orientation that is more vertical than anticipated

MRI, magnetic resonance imaging.

Table 2. Advantages and Disadvantages

Advantages	
	Allows graft to be customized or cut down to size
	Ensures avoidance of convergence with previous tibial tunnel(s) while achieving anatomic tibial tunnel position
	Addresses sizing uncertainties that come with revision ACL reconstruction tibial tunnel drilling
	Helps minimize bone stock used for tunnels on tibial footprint
	Establishes a secure trajectory for tibial tunnel to avoid tunnel malalignment
Disadvantages	
	Repetitive and slight time inconvenience
	Variable in approach depending on previous tunnel placements and operation

ACL, anterior cruciate ligament.

Final Examination and Postoperative Care

Successful R-ACLR is examined through a tibial tug test on the sutures exiting the tibial tunnel and confirmed that the entire tibia is moving with the graft. Final fluoroscopic images verify the ACL button sits flush on the lateral femoral cortex (Fig 10). A No. 11 blade is used to remove the excess graft. The incision site is irrigated and excess fluid is suctioned and the arthroscopic incision portals are closed with 3-0 nylon. The patient is placed in a knee extension brace locked in full extension. Postoperative care is similar to primary ACL reconstruction rehabilitation but should avoid accelerated rehabilitation.[1,11,17]

Discussion

There are several different approaches to R-ACLR depending on preoperative assessment and placement of the previous tibial tunnels. In some cases, R-ACLR may require more than one surgery. If tunnel widening greater than 10 to 15 mm, tunnel malalignment, or active infection are present, a 2-staged approach involving a bone grafting procedure followed by the new tunnel creation may be necessary for improved outcomes.[11,18-21] A single-stage approach either reuses a previously placed tunnel or produces a new anatomically placed tunnel. This decision is contingent on the degree of malalignment, graft size, and surrounding pathology of the original tunnel.[20-22] Since outcomes are not significantly different between single- and 2-staged procedures, a single-stage approach is preferable due to the faster recovery and fewer operations.[17,23] In cases in which tunnel positioning is satisfactory, reusing the same tunnel is sufficient if patent and sized correctly for the new graft.[2,19,23,24] However, tunnel malalignment in the previous ACLR requires the surgeon to create a new tibial and femoral tunnel.[9,16,20,21]

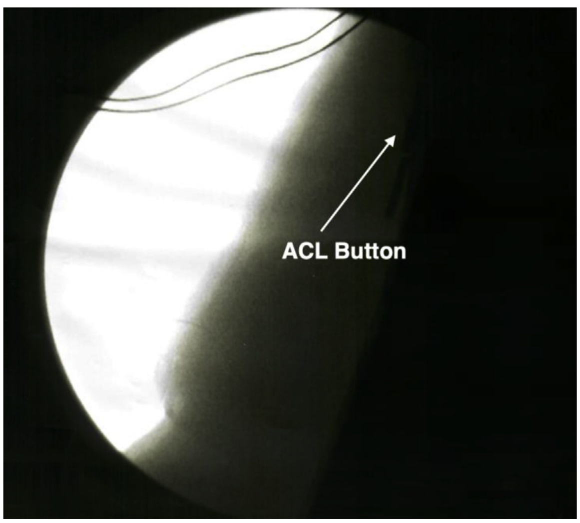

Fig 10. The patient is positioned in the supine position. Intraoperative radiograph verifies the ACL button sits flush on the lateral femoral cortex and confirms successful revision ACL reconstruction. (ACL, anterior cruciate ligament.)

Since it is difficult to perfect the trajectory and size of the tibial tunnel in the limited surface area of the tibial footprint when previous tunnels are present, technical errors unsurprisingly account for the majority of R-ACLR failures.[6,7] Kamath et al.[4] describes the necessity of precise tibial tunnel placement and found excessive anterior, medial, or lateral tunnel placement can result in impingement against the intercondylar notch whereas excessive posterior placement lends to impingement against the posterior cruciate ligament. Any of these inaccuracies can contribute to excessive graft extension or strain and eventual loss of fixation.

Accordingly, in cases in which tunnel malalignment is present in the previous ACLR, the surgeon is required to create a new tibial tunnel.[9,16,20,21,25] The concern then becomes avoiding convergence with the previous tibial tunnel while obtaining the ideal anatomic position of the new tunnel.[4,25-27] This proves to be a difficult task for many surgeons as tunnel malposition becomes increasingly common with each additional revision procedure.[13,22] However, if tunnel positioning is satisfactory, reusing the same tunnel is sufficient.[2,19,23,24,26] Future studies should explore patient outcomes and re-revision rates when using methods for technical improvements including the method described here.

Our technique describes a method for graft and tibial tunnel sizing to alleviate the technical challenges of R-ACLR.[9,25,27] Specifically, this Technical Note presents a tibial tunnel first graft sizing method using a previous anatomically positioned tibial tunnel during R-ACLR. Accurate trajectory and sizing of the reamer will help overcome the narrow margin of error in establishing an anatomic positioning of the tibial tunnel and sufficient bony circumferential wall. Knowing the angle, placement, and quantity of previous tunnels for both the femoral and tibial side through magnetic resonance imaging and diagnostic arthroscopy are essential for producing an appropriate plan and application of this technique. A potential disadvantage of our approach is that the technique varies depending on the mentioned qualities of tunnels from previous operations. As a result, the standard order of operation of primary ACLR for tunnel creation does not need to be followed for this revision technique. Advantages and disadvantages of the procedure are listed in Table 2.

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