Technical Note

Arthroscopic Primary Repair of the Anterior Cruciate Ligament With Single-Bundle Graft Augmentation

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Abstract: Recently, there has been a resurgence of interest in ligament preservation of the anterior cruciate ligament (ACL) that has the advantage of preserving the native tissue and maintaining proprioceptive function. Studies reporting outcomes of remnant-preserving ACL surgery have shown encouraging results with a higher potential for early healing and better functional outcomes compared with remnant-resecting surgery. Over the past decade, several surgical techniques for remnant preservation of the ACL have been proposed. In this technical note, the technique of primary ACL repair with graft augmentation is described. The goal of this technique is to preserve and tension the native tissue, thereby restoring the anatomy as much as possible while avoiding cyclops lesions, whereas the additional graft provides strength to the repaired ligament.

The anterior cruciate ligament (ACL) is the most commonly injured ligament in the knee.[1] In young and active patients, surgical management is considered the gold standard. For those patients, the standard surgical treatment for ACL injuries is reconstruction of the ligament.[2] Although excellent results have been reported with this type of surgery, some disadvantages still exist because of the invasiveness of the operation. Recently, ligament preservation of the ACL has been subject to a resurgence of interest because of potential advantages such as maintaining the native tissues while potentially maintaining proprioceptive function.[3]

Regarding proximal tears, several authors have shown promising outcomes over the past decade after primary repair of proximally avulsed ACL tears.[4] In some cases, however, either the anteromedial (AM) or posterolateral (PL) bundle is noted to be torn proximally and therefore repairable, whereas the other bundle is deemed unrepairable (i.e., because of insufficient remnant length or poor tissue quality) or the tear type does not provide enough length to repair the tissues directly to the bone (Fig 1). In these patients, augmented ACL repair could be performed, allowing the proximally avulsed bundle to be preserved while the other bundle is reconstructed or simply allowing the distal portion to be preserved while the remnant is augmented.

Preserving the fibers of the native ACL has some important advantages. First, whereas the additional graft provides the primary strength to the augmented ACL, especially during the rehabilitation phase, proprioceptive innervation can potentially be maintained.[4] Furthermore, the residual portion of the ACL provides vascular supply and might improve ligamentization and intra-articular graft remodeling, thereby leading to better biological healing of the graft.[5] In light of this improved biological milieu, improved outcomes might be expected after graft augmentation. The purpose of this technical note is to describe the surgical technique for augmented single-bundle ACL repair, therefore providing an extra tool in the armamentarium of the orthopaedic sports medicine surgeon.

Surgical Technique

General Preparation

The patient is placed in the supine position, and the operative leg in prepared and draped in sterile fashion

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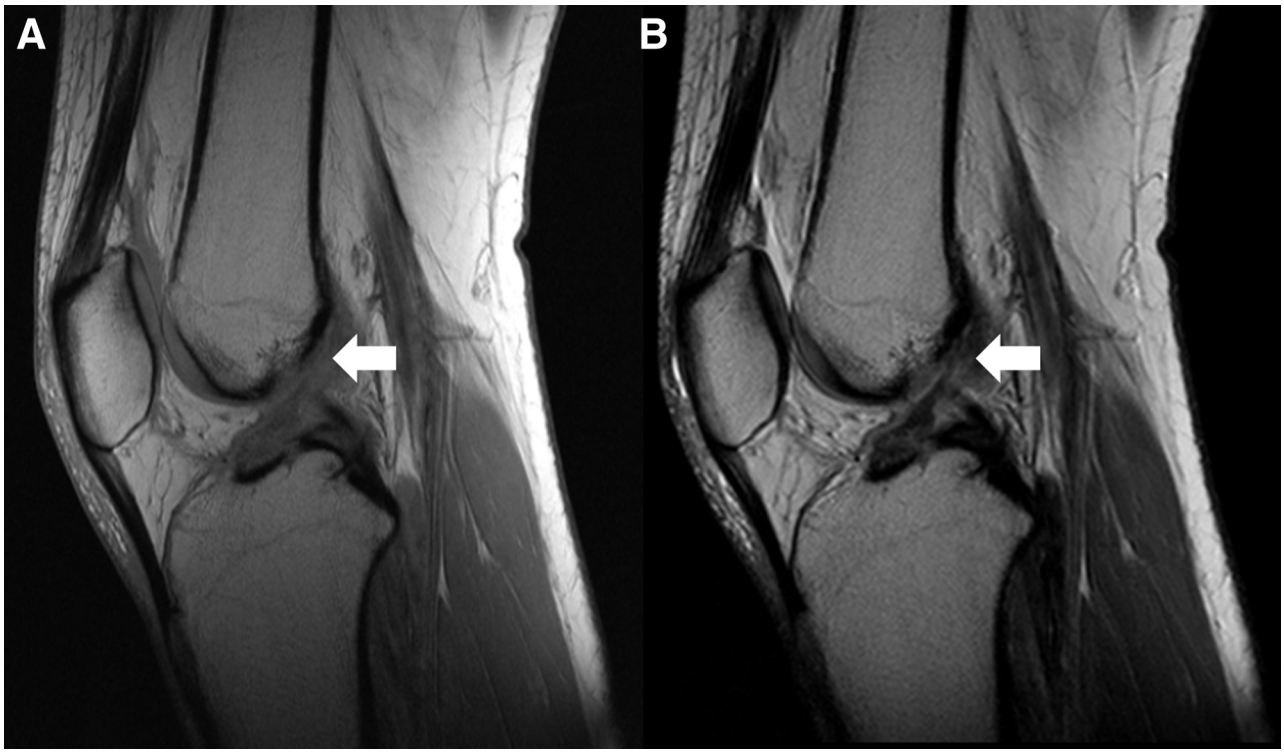

Fig 1. Two sagittal magnetic resonance images (T1 [A] and T2 [B]) of right knee showing partial anterior cruciate ligament tear (arrows).

as for knee arthroscopy (Video 1). In addition to the standard knee arthroscopy equipment and implants, some instruments from the shoulder set are used. Standard anteromedial and anterolateral portals are made. To facilitate suture passage, a malleable Passport cannula (Arthrex, Naples, FL) is placed in the anteromedial portal. Then, with the scope placed in the anterolateral portal, an assessment of tear type and tissue quality is made during a general inspection of the knee (Fig 2). For the purposes of this technique description, we will assume that the AM bundle is amenable to repair (most frequently) and that the PL bundle will be augmented. It should be noted that sometimes (less frequently) the PL bundle is intact and the AM bundle is augmented, whereas still other times both bundles are relatively preserved (less frequently) but are not long enough to reapproximate to the femur and a central augmentation can be performed.

Graft Preparation

Once the pattern of tear and the quality of the remnant tissue are evaluated (again, we will use the AM bundle for this technique description), either a single-tendon (semitendinosus) or 2-tendon (semitendinosus and gracilis) autograft is harvested in standard fashion, or a soft-tissue allograft can be used for the augmentation. The graft is prepared in standard fashion with whipstitches on the ends and is then looped through a TightRope RT (Arthrex) on one end and a TightRope ABS (Arthrex) on the other. Depending on the length of the tendons, the graft can be either tripled or quadrupled as needed. The whipstitches are placed under tension, and cerclage of the graft is performed.

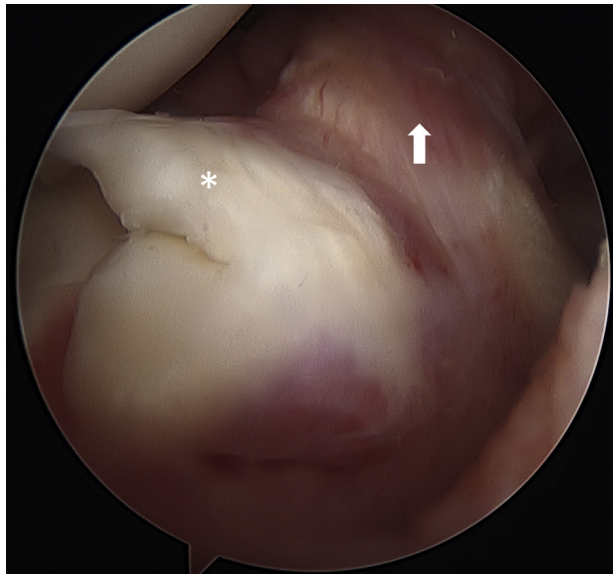

Fig 2. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The anterior cruciate ligament is shown with the posterolateral bundle (asterisk) flipped and shortened; the anteromedial bundle (arrow) is scarred to the femur.

Then, the graft is left under tension on the graft table and wrapped in a sponge moistened with antibiotic solution.

Femoral Tunnel Placement

Before the femoral socket is drilled, the arthroscope is switched to the anteromedial portal, allowing the anterolateral portal to be used for the femoral guide placement. Next, a small incision is made over the lateral side of the femoral condyle through the iliotibial band. With the knee in 90° of flexion, a guidewire is advanced into the center of the femoral origin of the irreparable bundle. The guidewire is then removed, and the appropriately sized FlipCutter (Arthrex) for the graft is introduced down the same hole. The femoral socket is cut in retrograde fashion using the FlipCutter (Fig 3). As mentioned, the tunnel diameter of the FlipCutter is predetermined by the diameter of the graft, although in the recently released version of the FlipCutter, this is adjustable. After removal of bony debris, a passing stitch for later use is placed in the femoral socket and brought out the anteromedial portal.

Tibial Tunnel Placement

Attention is now turned to the tibial side. With the arthroscope in the anterolateral portal, the ACL tibial guide is centered on the ligament footprint of the removed bundle. After a small skin incision is made on the anteromedial side of the proximal tibia, a guide pin is drilled at the appropriate inclination up to the tibial insertion, which is then overdrilled with a barrel reamer with the size determined in advance by the diameter of the graft (Fig 4). In general, a smaller, 6-mm barrel reamer is used for the first pass, and then fine-tuning adjustments are made to the guidewire such that the final diameter of drill is appropriately deployed with great care taken to avoid damage to the ACL insertion fibers that are being preserved. It is important to stop drilling as soon as the proximal tibial cortex is breached to avoid plunging the reamer and destroying the ACL remnant. An arthroscopic shaver is then used to clean up debris around the aperture of the tibial tunnel that might "hang up" the graft during passage.

Suturing of ACL Bundles

After placement of the tunnels, the remnants of the irreparable bundle are debrided with an arthroscopic shaver (Fig 5). Care must be taken not to damage the origin of the intact fibers of the proximally torn (repairable) bundle. Then, the repairable bundle is sutured with a No. 2 TigerWire (Arthrex; Fig 6) in a Bunnell-type pattern using the Scorpion suture passer (Arthrex). This suture can be docked out the medial portal or via an accessory portal that can be made just above the medial portal. Retracting the ligament away allows better visibility of the femoral footprint, and to enhance healing, a small opening notchplasty is performed on the notch wall using a shaver or burr, which induces some bleeding, whereas the femoral footprint is left intact (Fig 7). In general, the repair suture is placed after drilling of the tunnels to avoid damaging the repair suture with the reamers. In some cases, however, the repair suture can be used to retract the ACL remnant and improve visualization while preparing the

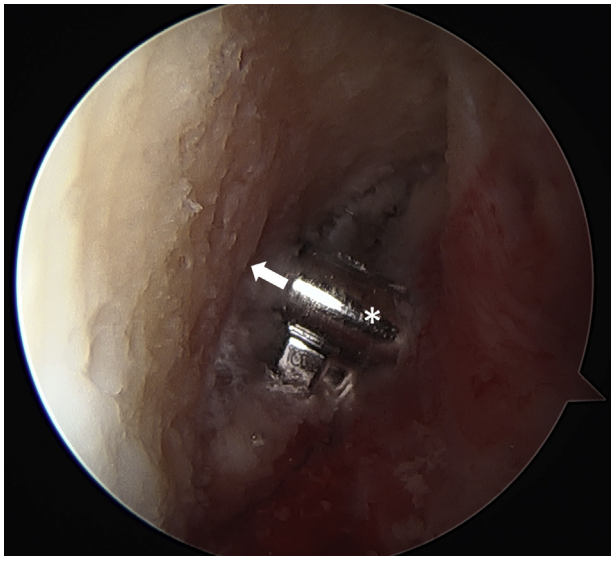

Fig 3. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The femoral socket (asterisk) is drilled in a retrograde manner (arrow) using the FlipCutter.

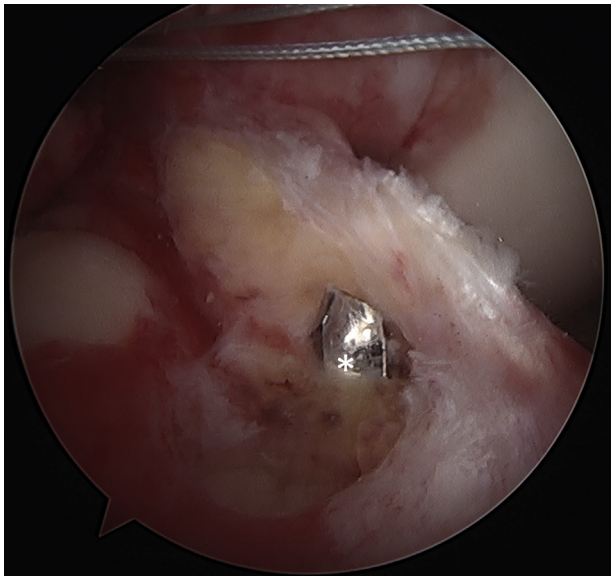

Fig 4. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. Using a guide pin, the tibial socket is drilled (asterisk). Care must be taken not to damage the anterior cruciate ligament fibers at the tibial insertion.

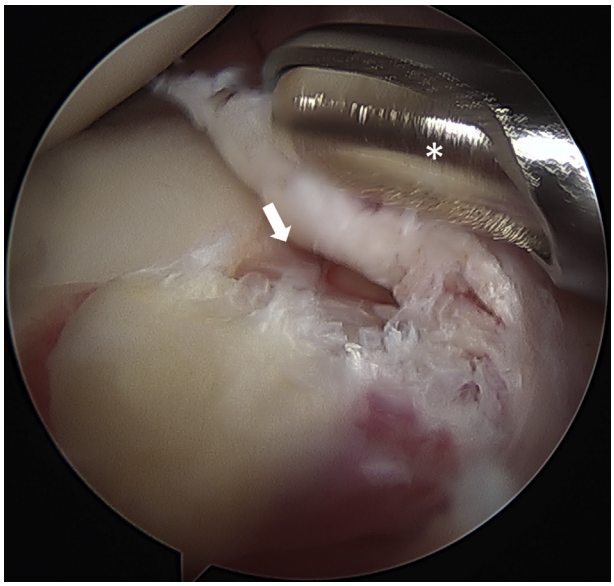

Fig 5. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The remnant of the posteromedial bundle (arrow) is carefully debrided with a shaver (asterisk).

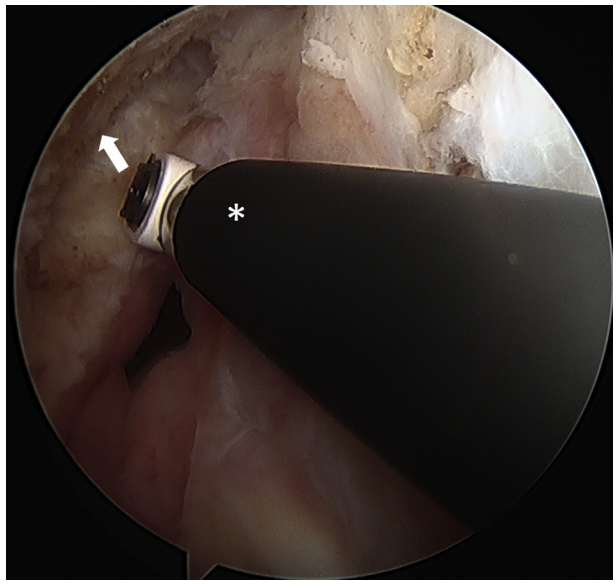

Fig 7. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. A small opening notchplasty is performed on the notch wall (arrow) using a shaver (asterisk) to enhance healing.

tunnels. An intraoperative decision is made for each case to decide on the optimal sequence of events.

Graft Placement

After placement of the tibial and femoral sockets, both the draw sutures and the repair sutures are retrieved down through the ACL and through the tibia. With care taken to avoid tangling or twisting the sutures, the repair stitches are passed through the TightRope (RT) ligament button using one of the straight passing needles that was used to prepare the graft. Close attention must be paid to avoid the TightRope suture when passing the repair stitches because tangling or twisting the sutures will prevent the cinching mechanism from functioning correctly. Then, the previously placed femoral draw suture is used to pass the suture complex for the TightRope RT and the repair stitches up through the tibia, through the femoral socket, and out the lateral femoral cortex (Fig 8). After the TightRope RT button is flipped and the proximal stitches are organized, the TightRope draw suture can be removed. The cinch stitches are then shortened per standard, thus advancing the graft up into the femoral tunnel. Once the graft is advanced, while the ACL remnant is visualized with the arthroscope, the repair stitches of the repairable remnant bundle are gently tensioned, which in turn advances the ACL remnant up close to the femoral wall. The repair stitches are subsequently tied over the RT button using alternating half-hitches. The knee is cycled multiple times, and the graft is tensioned near full extension, with tibial fixation being achieved using a 14-mm contoured ABS button. After cycling of the knee, the cinch stitches on the proximal TightRope RT can be retightened a final time to remove any slack. This can be secured with alternating half-hitches at the surgeon's discretion. Finally, the knee is tested for range of motion (ROM), stability, and stiffness. It is important to assess whether impingement of the graft or repair composite occurs in either flexion or extension and to address this as necessary. Once deemed satisfactory, the wounds are closed in standard layer fashion, and the single-bundle augmented ACL repair is

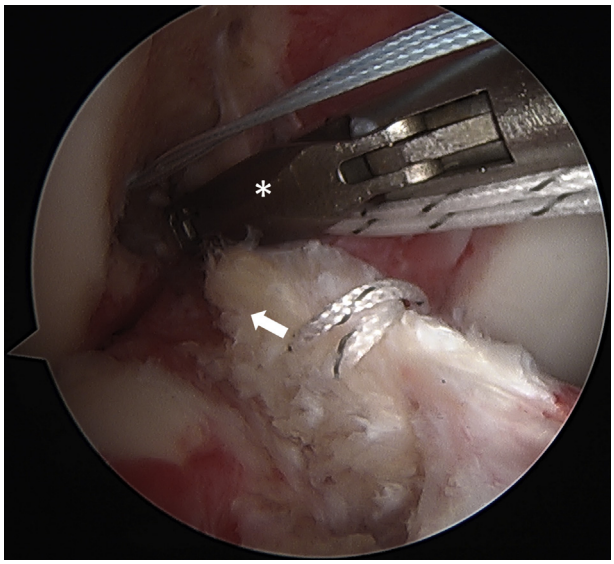

Fig 6. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. A locking stitch is passed through the repairable (anteromedial) bundle in a Bunnell-type pattern (arrow) using the Scorpion suture passer (asterisk).

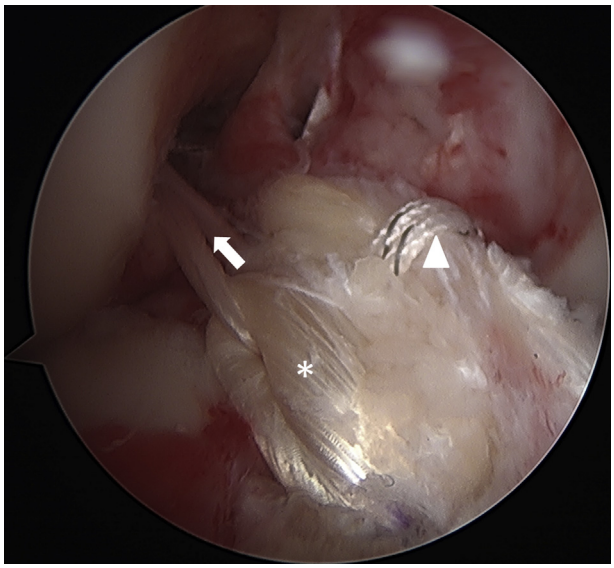

Fig 8. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The draw sutures (arrow) are used to advance the graft (asterisk) through the tibia and the femur. The arrowhead shows the repaired bundle.

completed (Fig 9). Pearls and pitfalls of this technique are shown in Table 1.

Postoperative Management

The rehabilitation protocol focuses on obtaining early ROM and controlling edema. Patients are placed in a hinged brace in the operating room. The brace is locked in extension, and weight bearing is allowed as tolerated by the patient depending on concomitant meniscal work. Within the first several days after surgery, ROM exercises are initiated. At 4 weeks postoperatively, quadriceps control is generally regained and the brace is unlocked for ambulation. Then, formal physical therapy can follow as prescribed by a standardized ACL reconstruction protocol. A gradual return to sports is allowed at approximately 9 months to 1 year postoperatively when muscle strength (90% isokinetic strength compared with the contralateral leg) and ROM are restored and the patient has passed return-to-play standards.

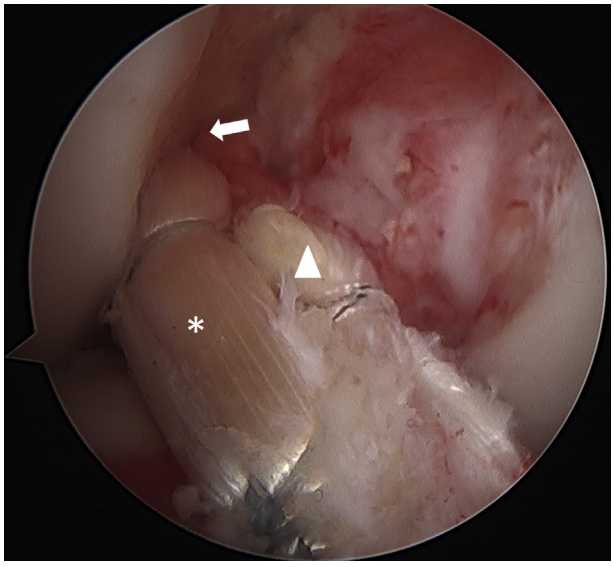

Fig 9. Right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The anterior cruciate ligament repair (arrowhead) with augmentation (asterisk) has been completed. The construct is reattached to the femoral footprint (arrow).

Table 1. Surgical Pearls and Pitfalls of Single-Bundle ACL Repair With Augmentation

Pearls	Pitfalls
Note that MRI can predict the tear type and tissue quality.	Take care not to damage the remnant while drilling the tibial tunnel.
Use a malleable cannula in the working portal.	Use sequential barrel reamers for the tibial tunnel to avoid damaging the remnant.
Assess the remnant to determine the salvageable bundle while resecting poor tissue.	Use a FlipCutter for the femoral tunnel to appropriately localize the tunnel while minimizing damage to the remnant.
Use a self-retrieving suture passer to pass a locking stitch in the repairable bundle.	First, drill the tunnels; then, suture the repairable remnant.
After preparing tunnels, retrieve the draw and repair stitches through the remnant and pass the repair stitches through the TightRope RT button.	Bear in mind that inadequately tensioning the remnant increases the risk of a cyclops lesion.
Pass and tension the graft in standard fashion, but use the repair stitches to tension the remnant.	Be gentle when tensioning the remnant to avoid cutting the repair stitches through the remnant tissue.

ACL, anterior cruciate ligament; MRI, magnetic resonance imaging.

Discussion

Over the past decade, several partial ACL remnant-preserving techniques have been proposed.[2,6] Saving the ligament remnant has the potential advantages of preserving proprioception and preserving vascularity and thus promoting graft healing. Furthermore, some recent studies of ligament preservation have reported promising outcomes in a select group of patients.[5]

The current surgical technique is adapted from a combination of primary ACL repair and reconstructive surgery.[2,4] Review of the literature showed that augmented repair was a commonly used treatment in the 1990s,[7] especially during the transition period from primary repair to reconstruction. At that time, primary repair was performed via an open arthrotomy approach because it was easier to suture the remnant in this fashion and, when combined with hamstring augmentation, yielded excellent results; Sgaglione

et al.[7] reported negative Lachman test findings in 93% of cases whereas 77% returned to the preinjury sport level in their cohort of 72 acute ACL injuries. However, as primary repair slowly fell out of favor and as arthroscopic approaches became the standard, a trend away from the augmented approach was also seen. One cause for concern was that the preserved remnant would occasionally cause cyclops lesions to form and require a second operation because of lack of extension. In addition, it was far easier to control the remnant while the augmentation was being performed when the procedure involved an open approach. As arthroscopic approaches became the standard, surgeons struggled to accomplish the repair with the augmentation approach until the instrumentation gradually improved as the years passed. A final factor that affected this was the trend to perform ACL surgery in a delayed fashion to avoid arthrofibrosis because it was known that the quality of the ACL remnant deteriorates over time.[3] With all of these factors at play, an evolution to removing the remnant led to the widespread adoption of the technique of arthroscopic ACL reconstruction used today, in which the remnant is resected. Owing to advanced technology in current arthroscopic surgery and to other modern-day developments, a resurgence of interest in ligament preservation has been seen over the past decade.[3]

There are several theoretical advantages of the repair-with-augmentation procedure compared with reconstruction. The augmented ACL repair has the benefit of preserving the native tissue, therefore maintaining the blood supply and native biology. Preclinical studies have shown that the preserved fibers have the capacity to improve ligamentization of the graft,[8] whereas preservation of the synovial sheath also appears to play a significant role in vascularization.[9-11] Other experimental studies have shown higher biomechanical strength, lower failure rates, and more anterior stability than with standard ACL reconstruction.[5] Thus, remnant preservation is thought to improve biological healing and enhance cell proliferation and revascularization of the graft and repaired ligament, although clinical studies have not yet shown clinical superiority. It is possible that current objective outcome measurements are not sensitive enough to measure the improvements provided by improved proprioception.

A review of the recent literature showed that some studies have supported these theoretical advantages by reporting excellent outcomes after different preservation techniques. Kondo et al.[12] found significantly improved postoperative knee stability in patients treated with a preservation technique compared with a remnant-resecting technique, whereas Lee et al.[13] showed better proprioceptive function in patients with a remnant greater than 20% of the ACL length compared with those with less than 20% length. On the basis of these studies, single-bundle augmentation could therefore be considered in patients with 1 repairable ACL bundle in an attempt to optimize mechanical and functional outcomes. On the contrary, a recent meta-analysis did not show a true clinically important difference between remnant-preserving and remnant-resecting surgery; therefore, the additional value of remnant preservation is still controversial.[14]

The most common complication of remnant-preserving ACL surgery is the increased risk of reoperation for impingement as a result of cyclops lesions from the remnant sagging distally.[15] One of the main benefits of the currently described technique is that the remaining remnant is tensioned and tied over a ligament button at the lateral femoral cortex, thus preventing cyclops lesions. In the literature, in those studies that have shown high rates of cyclops lesions, preservation of the remnant was performed without tensioning of the remnant, therefore potentially leading to scar-tissue impingement and resultant extension deficits and the need for further surgery.[15] Another disadvantage of this technique is that the potential benefits of the surgical procedure might only be seen in the acute or subacute setting, given that tissue quality tends to decrease over time. In addition, smaller grafts are used with the present surgical technique to avoid excess tissue in the intercondylar notch. After isolated ACL reconstruction, it has been shown that small-diameter grafts (<8 mm) are associated with higher failure rates,[16] but it remains unclear whether this also applies to our technique.

In conclusion, we have presented the surgical technique of single-bundle augmented ACL repair for complete ACL tears in which one of the bundles is torn proximally and the other bundle is torn at the mid-substance level. Historically, the technique was abandoned because of technical difficulties; however, owing to the modern-day technological advances of arthroscopy and suture-passing devices, it is now possible to preserve the remnant in cases in which one of the bundles is proximally torn.

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