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Technical Note

Hybrid Remnant-Sparing Anterior Cruciate Ligament Repair-Reconstruction

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Abstract: In anterior cruciate ligament (ACL) reconstruction, the remnant ACL is often debrided in an effort to improve visualization of patient anatomy and reduce surgical difficulty. However, retention of the tibial remnant of a torn ACL theoretically portends several advantages. These include preservation of knee proprioception and mechanoreceptors, an enhanced biological environment for healing, and accelerated revascularization and ligamentization of the graft. Despite these advantages, it is not a widely adopted practice and the optimal technique is still subject to debate. The purpose of this technical note is to describe our preferred technique for performing hybrid ACL reconstruction with remnant incorporation.

The incidence of anterior cruciate ligament (ACL) tears is increasing.[1] More than 200,000 ACL reconstructions (ACLRs) are performed every year, with the goal of restoring knee kinematics and stability. Restoring the biomechanics of the knee minimizes damage to menisci and cartilage.[2] A successful outcome after ACLR is often defined as anatomic graft placement, secure fixation, graft vascularization or reinnervation, and graft incorporation. Despite the 80% to 90% success rate of contemporary ACLR techniques, further improvements can be made.[3]

A significant number of ACL tears occur at the femoral origin. In these tears, the tibial remnant is often debrided in an effort to improve visualization of patient anatomy and reduce surgical difficulty. However, retention of the tibial remnant of a torn ACL theoretically portends several advantages. These include preservation of knee proprioception and mechanoreceptors, an enhanced biological environment for healing, and accelerated revascularization and ligamentization of the graft.[4,5] Although retention and incorporation of the ACL remnant portend several advantages, it is not a widely adopted practice and the optimal technique is still subject to debate.

The purpose of this technical note and Video 1 is to describe our preferred method of hybrid remnant-sparing ACLR. This technical note provides important pearls for performing hybrid ACLR with remnant incorporation using all types of grafts. This technique offers several advantages over other methods, such as additional scaffolding, augmentation, and protection of the reconstructed graft; preservation of native mechanoreceptors; restoration of the native ACL size; and an enhanced biological environment (Table 1).

Surgical Technique

Patient Positioning and Anesthesia

Preoperatively, the patient receives an adductor canal block. The patient is positioned supine with the surgical limb secured in an arthroscopic leg holder and the contralateral leg in a foam well-leg holder. After the induction of general anesthesia, an examination under anesthesia is performed to assess knee stability and range of motion. A nonsterile tourniquet is placed high on the leg and is set to 300 mm Hg.

Graft Harvest and Preparation and Arthroscopy

At case initiation, graft harvest and preparation occur based on surgeon preference and patient factors.

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Table 1. Pearls and Pitfalls of Hybrid Remnant-Sparing ACL Reconstruction

Pearls
Preservation of remnant serves as scaffolding and augments ACL reconstruction
Protection of reconstructed graft
Enhanced biological environment for healing and accelerated revascularization and ligamentization of graft
Preservation of native mechanoreceptors and improved proprioception
Restoration of native ACL size (33 mm × 11 mm)
Adds minimal surgical time to current practice
Pitfalls
Considerable technical difficulty in preserving ACL remnant without damaging native tissue
Implications on terminal knee motion have not been elucidated

ACL, anterior cruciate ligament.

Diagnostic arthroscopy and assessment are performed using standard anteromedial and anterolateral portals.

ACL Remnant Assessment and Tunnel Preparation

ACL tears occurring at the femoral origin with little scar formation are ideal candidates. It is important to assess bundle preservation (anteromedial vs posterolateral). Adjacent scar (often occurring at the posterolateral bundle) and thickening are carefully debrided, with preservation of the tibial insertion (Fig 1).

The tibial insertion is undermined just posterior to the native tibial insertion of the ACL, from lateral to medial, using an ablation device (Video 1). This allows for most of the tibial insertion of the ACL fibers to be preserved for later incorporation. By use of an ACL tibial guide with an open circular aim tip, a guide pin is drilled, with careful consideration not to advance past the proximal tibial cortex, and care is taken to prevent penetration of the ACL remnant (Fig 2). The open circular aim tip allows for protection of the remnant. A curette can be used to protect the guide pin from advancement. An appropriately sized reamer is used to create the tibial tunnel, drilling to the proximal tibial cortex, without plunging into the notch. A 12-mm Passport cannula (Arthrex, Naples, FL) is placed in the medial portal. Three throws of cored suture are passed in the proximal portion of the ACL from distal to proximal in a cinch fashion (Fig 3). This allows for complete security of the ACL remnant and full control of later fixation. The suture is placed through the Passport cannula to ensure protection from later drilling.

Attention is turned to the femoral tunnel, which is prepared using an anteromedial-portal technique in maximal knee hyperflexion. Any femoral tunnel drilling technique can be used including an outside-in technique or a FlipCutter device (Arthrex). We recommend the placement of an appropriate offset over-the-top guide to ensure proper femoral tunnel placement and back wall preservation. A Beath pin is drilled through the guide. An appropriately sized low-profile cannulated reamer is drilled over the guide pin (Fig 4). Care is taken to protect the cored suture tape and ACL remnant. The drill is removed and excess bone is shaved. We recommend the use of an Arthrex GraftNet collector connected to the shaver to collect excess bone for bone–patellar tendon–bone (BPTB) grafts.

Two cored sutures of different colors are loaded into the Beath pin, with tails first. The Beath pin is pulled through the lateral side of the knee, and the sutures are separately snapped to the operative drape. One loop is pulled through the tibial tunnel, used for graft passage, and the other loop remains in the anteromedial portal, used for remnant fixation. The graft is pulled through the tibial tunnel and appropriately positioned in the knee joint.

Fixation: Soft-Tissue and BPTB Grafts

For BPTB grafts, the femoral bone block is guided into the femoral tunnel. Cored suture that was previously passed through the remnant is loaded through the previously placed anteromedial-portal suture loop and pulled through the femoral tunnel. A probe is used to guide the cored suture tape over the reconstructed graft to allow the remnant to serve as a supportive scaffold to the graft. The remnant suture is integrated into the aperture fixation of the femoral tunnel.

The femoral tunnel is fixed using suspensory fixation for soft-tissue grafts. The remnant cored suture is placed through the central holes in an EndoButton (Smith & Nephew, Andover, MA). An incision is made on the lateral thigh adjacent to the Beath pin, and dissection is carried to the lateral femoral cortex. The cored suture tape is tied to the cored suture in the button, affixed to the lateral femoral cortex.

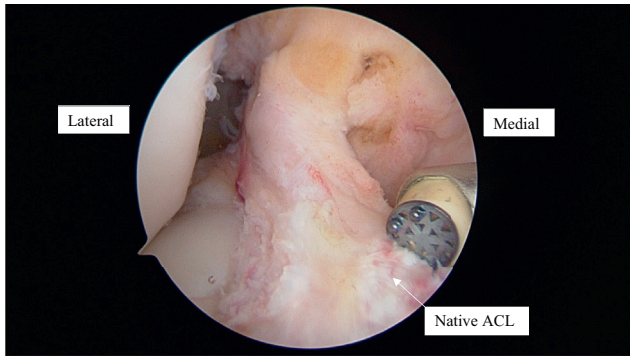

Fig 1. Intraoperative arthroscopic image of right knee from anterolateral viewing portal. An anterior cruciate ligament (ACL) tear occurring at the femoral origin is shown. It is important to assess bundle preservation (anteromedial vs posterolateral). In this patient, both bundles were intact. Adjacent scar (often occurring at the posterolateral bundle) and thickening are carefully debrided, with preservation of the tibial insertion.

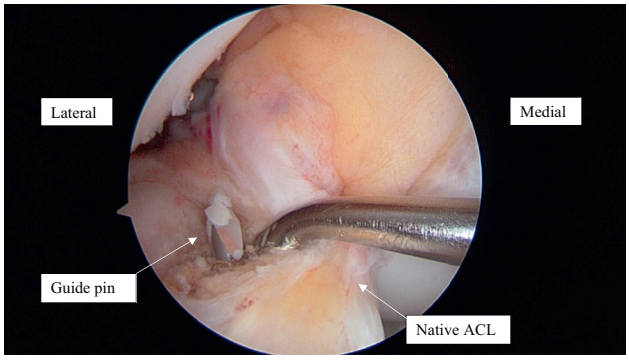

Fig 2. Intraoperative arthroscopic image of right knee from anterolateral viewing portal. The tibial insertion of the native anterior cruciate ligament (ACL) is undermined just posterior to the native tibial insertion of the ACL, from lateral to medial, using an ablation device. A guide pin is drilled using an Arthrex Tibial Guide with an open circular aim tip. Careful consideration is taken not to advance past the proximal tibial cortex, and care is taken to prevent penetration of the ACL remnant.

Graft Tensioning and Fixation

The tibial tunnel is fixed using interference screw fixation with backup. The femoral tunnel is fixed, and the knee is passed through the full range of motion for 20 repetitions. While under tension, a Bio-Interference screw (Arthrex) is applied to secure the graft in 20° to 30° of flexion, and backup fixation is applied with the use of a 4.75-mm BioComposite SwiveLock anchor (Arthrex). The knee is assessed to confirm full range of motion to ensure no graft or remnant impingement in extension (Fig 5), and an anterior drawer or Lachman test is performed to confirm stability. The wounds are copiously irrigated.

Postoperative Care

In the first 2 weeks after surgery, the patient is allowed weight bearing as tolerated with crutches and a brace. The hinged knee brace is kept locked in full extension during walking or sleeping. Surgeon preference on further physical therapy can be followed.

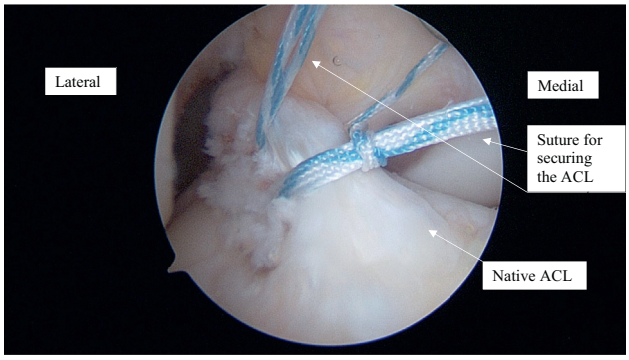

Fig 3. Intraoperative arthroscopic image of right knee from anterolateral viewing portal. Three throws of FiberTape suture (Arthrex) are passed in the proximal portion of the anterior cruciate ligament (ACL) from distal to proximal in a cinch fashion. This allows for complete security of the ACL remnant and full control of later fixation.

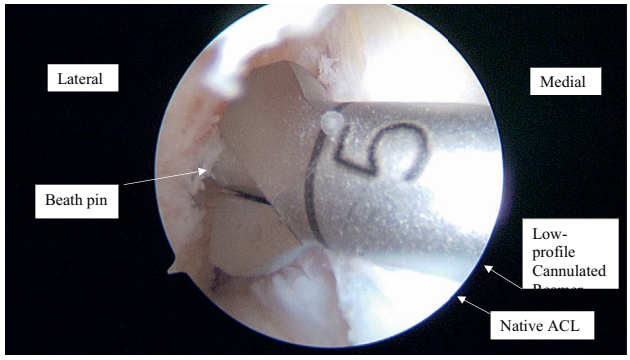

Fig 4. Intraoperative arthroscopic image of right knee from anterolateral viewing portal. A Beath pin is drilled through an appropriate offset over-the-top femoral guide. An appropriately sized low-profile Arthrex cannulated reamer is used to drill over the pin. Care is taken to protect the FiberTape and anterior cruciate ligament (ACL) remnant.

Discussion

This technical note details the surgical technique for performing hybrid ACLR with remnant incorporation. This technical note is applicable for all types of ACL grafts. Advantages include preservation of knee proprioception and mechanoreceptors, an enhanced biological environment for healing, and accelerated revascularization and ligamentization of the graft.

Gait alteration in ACL-deficient or -reconstructed knees has been attributed to the loss of normal proprioception.[4] The native ACL is rich in proprioceptive nerve fibers such as Pacinian corpuscles, Ruffini endings, and Golgi tendon organs.[5] These receptors mediate joint position sense and motion, as well as

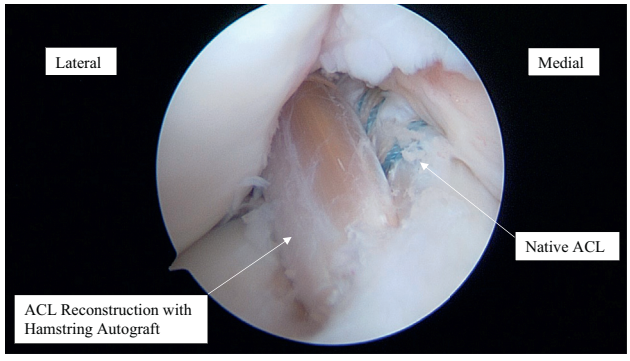

Fig 5. Intraoperative arthroscopic image of right knee from anterolateral viewing portal. Hybrid remnant-sparing anterior cruciate ligament (ACL) repair-reconstruction using hamstring autograft is shown at case completion. A probe is used to guide the cored suture tape and the patient's native ACL over the reconstructed graft to allow the remnant to serve as a supportive scaffold to the reconstructed graft.

important reflex arcs used for muscular stabilization. It has been shown that a vast majority of these receptors are found in the tibial insertion of the native ACL.[6] Moreover, Adachi et al.[7] found sensory nerve and receptor retention in the tibial stump of the injured ligament. Restoration of normal proprioception may play a pivotal role in improved functional outcomes and reduced reinjury rates in reconstructed ACLs. In a laboratory study of 42 sheep undergoing remnant-retaining ACLR with semitendinosus autograft, Takahashi et al.[8] found that superficial mechanoreceptors were comparable to the native ACL after 12 weeks; however, they were not able to detect the existence of deep mechanoreceptors in their study time frame. The present method of hybrid ACLR with remnant incorporation allows for concurrent healing of the native ACL and the reconstructive graft and may provide a source for reinnervation of the graft, allowing for retention of proprioceptive receptors, an internal scaffolding that integrates into the reconstruction, and potentially improved patient outcomes and rerupture rates.

The blood supply of the native ACL originates from the tibial and femoral insertions, which form a vascular plexus imbedded in the synovial membrane covering the ligament. This periligamentous network provides little vascular supply in the midsubstance of the ligament. The reconstructed graft is avascular and lacks a synovial membrane. Studies have found that ACL remnant attachments have been shown to maintain the native vascular system, and there is a suggestion of improved tendon vascularity and healing after incorporation of the native ACL remnant.[9,10] In a study of 36 sheep undergoing ACLR, Unterhauser et al.[11] showed that capillary vessels, which originate from the synovial envelope of the tibial ligament remnant, invaded the avascular graft tissue from the surface toward the center zone. The previously discussed work by Takahashi et al.[8] found that preserved remnant tissue adhered to the graft surface and underwent a remodeling process, accelerated graft revascularization, and increased the number of graft mechanoreceptors in the ACL-reconstructed knee by 12 weeks. The present method of hybrid ACLR with remnant incorporation allows for improved vascularity and expedited healing of the reconstructed graft.

There is a suggestion in the literature that preservation of the ACL remnant may portend stability to the knee joint. A case series of 40 patients undergoing ACLR with remnant preservation by Adachi et al.[7] found that patients in the remnant-preserved group had significantly improved anteroposterior stability as measured by a KT-1000 device (MEDmetric, San Diego, CA) (0.7 ± 1.8 mm vs 1.8 ± 2.1 mm, $P < .05$). The findings of Takahashi et al.[8] echoed these findings, in that remnant tissue preservation significantly improved anteroposterior translation and initial joint stiffness of the ACL-reconstructed knee on drawer testing at 12 weeks. Our method of hybrid ACLR allows for native remnant tissue to serve as a robust supplemental reinforcement of the reconstructed graft and an additional point of fixation, mitigating graft stress and possible rerupture.

This technique is not without limitations. Appropriate tibial tunnel positioning is imperative for achieving stability after ACLR. Owing to retention of the tibial insertion of the ACL, it may be difficult to identify the correct anatomic insertion of the ACL. A cohort study examining the tunnel position of 44 ACLRs without a remnant versus 47 ACLRs with a remnant using computed tomography scans by Naraoka et al.[12] found no significant between-group differences in tibial tunnel position. Next, retention of the ACL remnant may portend a theoretical risk of cyclops lesions and loss of terminal extension; however, recent studies have shown equivalent recurrence rates of cyclops lesions between remnant-sparing and non—remnant-sparing procedures.[13] Last, the volume of the ACL "remnant" lacks consensus; however, a recent systematic review of ACLR with remnant preservation found that larger remnant tissue volumes corresponded with improved measures of objective knee stability.[14] In conclusion, although the retention of the tibial remnant of a torn ACL theoretically portends several advantages, further studies are needed to evaluate the outcomes and validate the suggested benefits of using the hybrid repair-reconstruction technique, which remains an underused and promising option for ACLR.

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