Technical Note

Anatomic Arthroscopic Primary Repair of Proximal Anterior Cruciate Ligament Tears

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Abstract: Within the last decade, various highly diverse anterior cruciate ligament (ACL) preservation techniques have been proposed, as contemporary selective arthroscopic ACL preservation experienced a resurgence. Among surgical techniques, there are a variety of suturing, fixation, and augmentation methods, whereas a common thread, considering essential anatomic and biomechanical properties, is missing. This technique aims to anatomically reapproximate both the anteromedial (AM) and posterolateral (PL) bundles to their respective femoral footprints. Additionally, a PL compression stitch is performed to increase the ligament-bone contact area and recreate the anatomic vectors of the native bundles, therefore, creating a more anatomic and biomechanical construct. This technique is a minimally invasive procedure, with no graft harvesting nor tunnel drilling, which leads to decreased pain levels, earlier return of full range motion (ROM), and faster rehabilitation, while failure rates seem to be comparable to that of ACL reconstruction. We present an updated surgical technique of anatomic arthroscopic primary repair with suture anchor fixation for patients with proximal ACL tears.

Introduction

Arthroscopic Contemporary selective arthroscopic anterior cruciate ligament (ACL) preservation has seen a general resurgence of interest worldwide,[1-3] and an increasing number of surgeons are using various techniques to preserve the native ACL and its proprioceptive function in patients with proximal ACL tears.[4] Recent systematic reviews and meta-analyses of short to mid-term follow-up,[4-6] and comparative trials comparing ACL preservation versus ACL reconstruction,[7-9] indicate that ACL preservation shows comparable or better functional outcomes, as compared to ACL reconstruction, with similar or slightly higher failure rates.

Over the last decade, multiple ACL preservation techniques have been proposed, with a vast variety of fixation and augmentation methods, including single or double bundle fixation, dynamic intraligamentary stabilization, and bridge-enhanced techniques.[5] The term "ACL repair" has previously been generalized to include highly diverse techniques, which distinguish themselves by specific indications and their surgical and rehabilitative approaches.[10] The same is true for ACL reconstruction,[11] although in the last two decades, a common opinion has been formed, and there is a clear consensus that ACL reconstruction implies anatomic techniques using grafts to recreate the ACL to its native dimensions, collagen orientation, and insertion site.[12] This common thread is missing when considering techniques for ACL preservation.[5,10]

In this surgical technique article, we describe the surgical technique of anatomic arthroscopic primary ACL repair with suture augmentation (SA) using suture anchor fixation (SAF). This technique is an evolution of previously published techniques,[13,14] in that an additional

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Fig 1. Schematic figure of anatomic arthroscopic primary anterior cruciate ligament repair technique (Arthrex, Naples, FL).

core stitch is added to improve the vector of the repaired ACL without increasing the morbidity of the technique.

Surgical Technique

Indications

The indication for anatomic arthroscopic primary ACL repair (Fig 1) is defined through the classification and treatment algorithm published by van der List et al. (Fig 2),[15] where a proximal tear (Type I-II: upper 25% of ligament), and good to excellent tissue quality must be present to proceed with repair. Patients are preferably treated in the acute setting (<4 weeks), although performing ACL primary repair (ACLPR) in chronic tears, in which the ACL has been scarred to the posterior cruciate ligament (PCL), has also been shown to be effective.[16] No restrictions are given regarding activity level[17] and age, although patients >21 years of age demonstrate lower reinjury rates compared to younger patients.[7,18] An overview of all indications and absolute contraindications for this technique is displayed in Table 1.

Arthroscopic Preparation and Tear Type Classification

The patient is prepped and draped in supine position in a standardized fashion for arthroscopic ACL surgery. In addition to standard arthroscopic devices, the SwiveLock ACL Repair Kit (Arthrex, Naples, FL) is used. Anteromedial and anterolateral portals are created, and a passport canula is inserted at the anteromedial portal for suture management. Then, an arthroscopic inspection and determination of the ACL tear type and tissue quality are performed (Fig 3, Video 1). In the case of a chronic tear, where the ACL may be scarred to the PCL, the ACL can be gently separated using an arthroscopic scissor. Prior to starting the repair procedure, the feasibility of the refixation to the femoral footprint is tested by gently pulling the ligament to the native footprint using an arthroscopic grasper.

Anteromedial and Posterolateral Bundle Stitching

A FastPass Scorpion Suture Passer (Arthrex) and a No. 2 FiberWire suture (Arthrex) is used to stitch the anteromedial bundle (AM) first. This is performed in an alternating, interlocking Bunnell-type pattern from as far distally as possible to the proximal avulsed end with three to four passes, depending on the tissue quality; proximally the repair sutures exit on either side of the ligament (Fig 4, A-C). Each bite through the bundle is performed while holding the FiberWire suture tails (anteromedial portal) gently with a little bit of tension, so that the ligament will not splay apart. Caution must be taken, and resistance is monitored when passing the Scorpion's needle through the ligament, so that previously placed repair sutures are not transected (Table 2).

Next, an inferior-medial portal is created to reach the ACL's femoral footprint for the placement of the SwiveLock anchors (Arthrex) at a later stage, as well as to now dock and retract the FiberWire repair sutures out of harm's way and clear out the intra-articular work area to stitch the posterolateral (PL) bundle. Prior to retrieving the repair sutures out through the inferior-medial portal, a grasper is used (anteromedial portal) to pass the sutures into the knee to create slack; this allows the surgeon to retrieve the sutures without causing extra tension on the ligament at this stage.

The PL bundle is then stitched using a no. 2 TigerWire applying the same technique as for the AM bundle, with usually 2-3 passes. At the proximal aspect of the bundle, the PL repair sutures, in contrast to the AM sutures, both exit laterally toward the femoral wall (Fig 4, D-F). Caution must be taken to avoid impacting the Scorpion's needle into the lateral condyle, causing a potential break, by twisting the hand holding the Scorpion downward when placing the stitches. The PL TigerWire is now also retrieved through the inferior-medial portal, while the FiberWire is retrieved out the anteromedial portal.

Femoral Suture Anchor Placement

The femoral notch is slightly decorticated anteriorly to the femoral footprint using a shaver to induce bleeding,

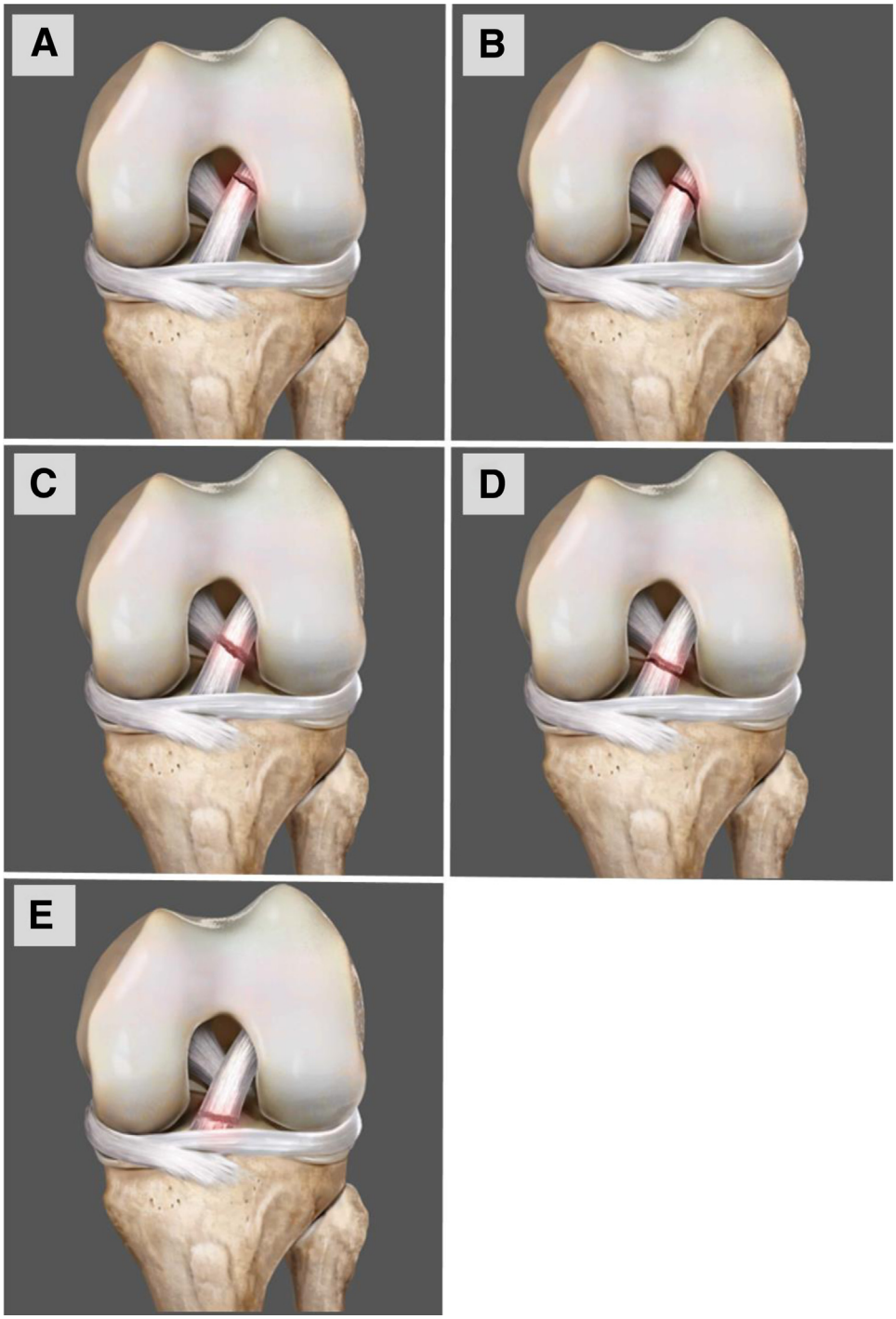

Fig 2. ACL tear type classification[15]: (A) Type 1: proximal avulsion, >90%. (B) Type 2: proximal tear, 75-90%. (C) Type 3: midsubstance, 25-75%. (D) Type 4: distal, 10-25%. (E) Type 5: Distal (bony) avulsion, <10.

whereas the footprint is left in its native state. With the knee at 115° flexion, a drill sleeve is placed at the native PL femoral footprint, and a 4.5 × 20 mm hole is drilled and tapped (Fig 5, A and B). The TigerWire repair suture is passed through the eyelet of a 4.75-mm Vented BioComposite SwiveLock suture anchor (Arthrex). Using the inferior-medial portal, the surgeon deploys the loaded suture anchor at 115° knee flexion into the predrilled and tapped hole in the femoral PL footprint, while tensioning the ACL remnant to the wall (Fig 5C). The SwiveLock handle is removed, core stitches are left in place, and the free ends of the TigerWire PL repair sutures are cut short with an open-end suture cutter (Arthrex). The core stitch of the PL anchor is then retrieved out the anteromedial (AM) portal. Each limb is then sequentially passed from lateral to medial through the proximal aspect of the PL bundle using the Scorpion Suture Passer. These sutures are parked at the

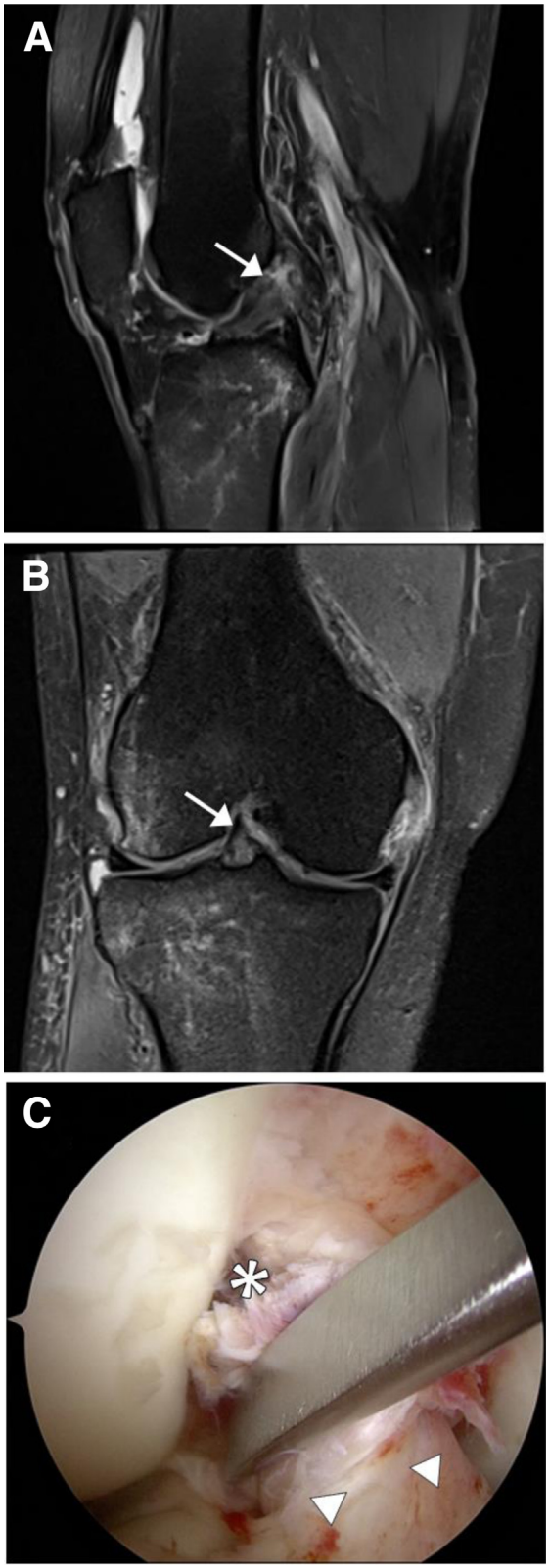

Fig 3. Preoperative magnetic resonance imaging images (right knee), sagittal (A) and coronal (B) view, displaying a tear of the anterior cruciate ligament (ACL) in a 30-year-old woman. (C) Arthroscopic view from the anterolateral portal of the right knee: confirming the proximal ACL tear using an arthroscopic probe in the same patient. A type I avulsion tear (asterisk) with an intact midportion and a distal insertion with excellent tissue quality and vascularity (triangles) are presented.

Table 1. Indications and Absolute Contraindications of Anatomic Arthroscopic Primary ACL Repair

Indications	Absolute Contraindications
1) Proximal type I and type II tears[15]	1) Midsubstance tears
2) Good to excellent tissue quality	2) Poor and fair tissue quality (depending on surgical experience)
3) Acute and chronic tears (ACL reattached to PCL)	
4) Patients of all age groups	
5) Isolated ACL injuries and ACL injuries in multiligamentous knees	

ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

AM portal for later use, and the FiberWire sutures are retrieved out of the inferior-medial portal. With the knee at 90°, the same procedure is then repeated for the AM bundle using FiberWire repair sutures, and a vented BioComposite 4.75-mm SwiveLock preloaded with a FiberTape (Arthrex) to serve as the suture augmentation (Fig 5, D-F). Once the anchors are deployed and flush with the femoral footprint, the handle is removed, and the free ends of the FiberWire repair suture are cut short, whereas the SwiveLock core stitches from this anchor are removed. The additional PL compression stitch is performed laterally to medially (Fig 6), and a knot pusher is used to compress the ligament with 3 alternating half hitches from medially to laterally to its native femoral footprint, to achieve maximal wall contact and reestablish the native anatomic ligament vector (Fig 7B). The free ends of the core stitch are cut short to finish the femoral refixation (Fig 7C).

Tibial Suture Augmentation Fixation

To establish tibial fixation of the FiberTape suture augmentation, a tibial ACL drill guide is placed at the anterior one-third of the tibial ACL footprint. A 2.4-mm cannulated pin is drilled from the proximal anteromedial cortex of the tibia up and exiting at the anterior one-third of the tibial ligamental insertion. An arthroscopic probe is used to apply counterpressure and stabilize the ligament when drilling through the tibial insertion (Fig 8A). The cannulated pin is removed, and a nitinol wire lasso is passed through the pin and into the knee. The wire is used to shuttle the FiberTape down through the tibia to create the suture augmentation (Fig 8, B and C). With the knee in full extension, the FiberTape is lightly tensioned and fixed using another 4.75-mm BioComposite SwiveLock perpendicular to the tibial cortex (Fig 8D). To avoid hardware

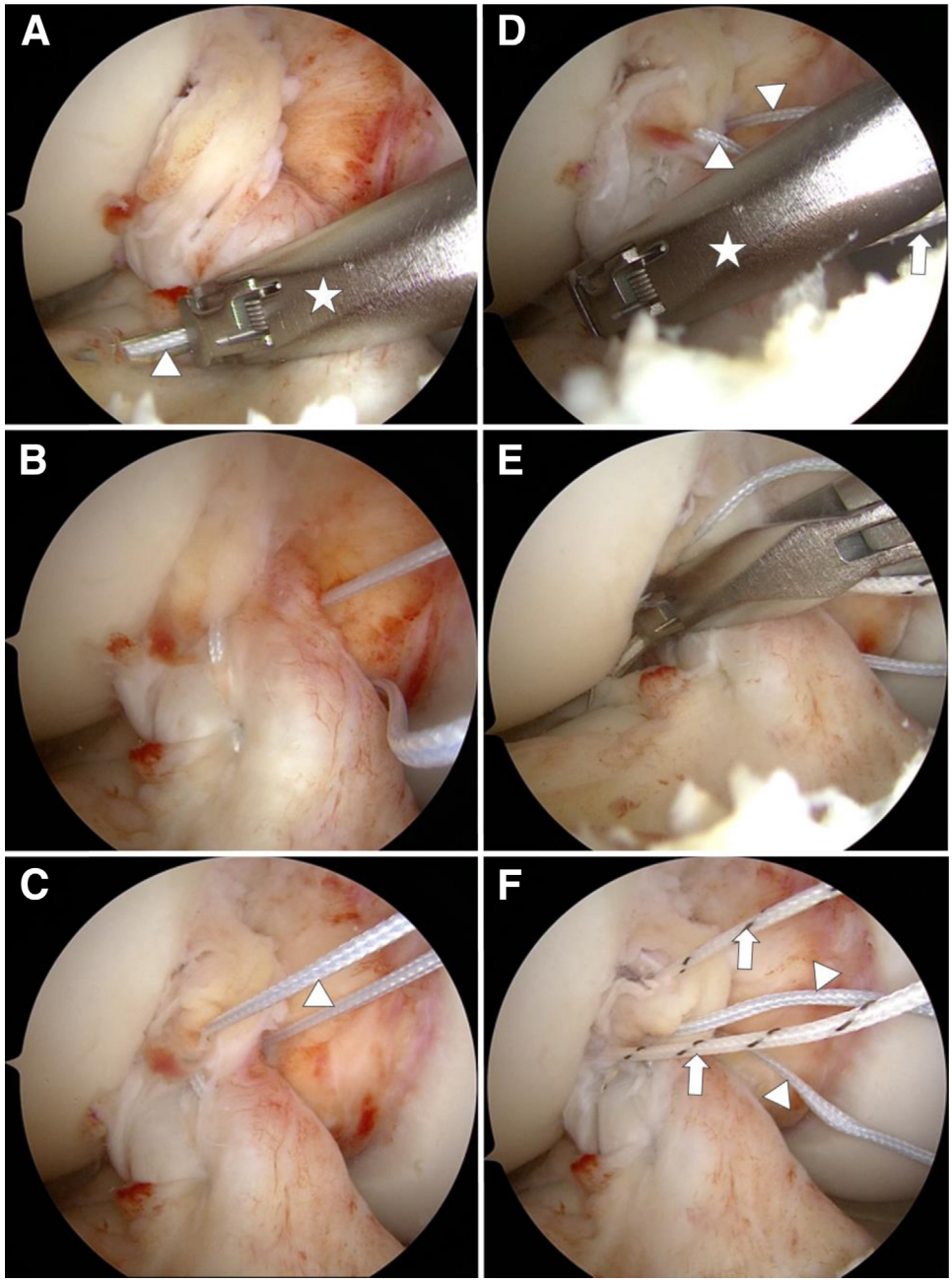

Fig 4. Arthroscopic view from the anterolateral portal of the right knee. Placement of the anteromedial (AM) (A-C) and posterolateral (PL) bundle's (D-F) repair sutures using a FastPass Scorpion Suture Passer (star) from distally to proximal in an interlocking Bunnell-type pattern. A no. 2 FiberWire (triangles) is used for the AM and a no. 2 TigerWire (arrows) for the PL bundle.

irritation, the suture anchor should be flush with the tibial cortex, and the FiberTape is cut short.

To end the procedure, the ligament is tested for tension using a probe. Range of motion (ROM) and anatomic positioning should be visualized without graft impingement. It should be noted that the suture augmentation is usually a little loose in flexion after final fixation. Intraoperative Lachman testing should be performed to test stability and will usually reveal minimal anteroposterior translation with a firm endpoint (Fig 9).

Rehabilitation

Postoperatively, the patient is provided with a brace that is locked in extension while ambulating until protective quadriceps function is present. At this point, the patient can unlock the brace and ambulate normally. Weight-bearing clearance is given from day 1 if there is no meniscal work, but will be limited for up to 4 weeks postoperatively if a meniscal repair is done concomitantly. ROM exercises can be performed immediately without the use of the brace. As

Table 2. Pitfalls and Pearls of Anatomic Arthroscopic Primary ACL Repair

Pitfalls	Pearls
1) Transecting previously placed repair sutures	1) Monitor resistance when placing sutures.
2) Poor suture management	2) Create a low inferior-medial portal and use a cannula in the anteromedial portal.
3) Breaking the Scorpion needle by impacting the lateral femoral condyle	3) Rotate hand holding the scorpion device downward to avoid impacting the needle.
4) Posterior femoral condyle perforation with the anchors	4) Optimize angle for suture anchor placement by using the inferior-medial portal and deploy anchors in 90° flexion for the AM and 115° in case of the PL.
5) Overconstraint of the knee through FiberTape fixation in flexion	5) Cycle the knee first before tensioning and fixing the FiberTape near full extension.

ACL, anterior cruciate ligament; AM, anteromedial; PL, posterolateral.

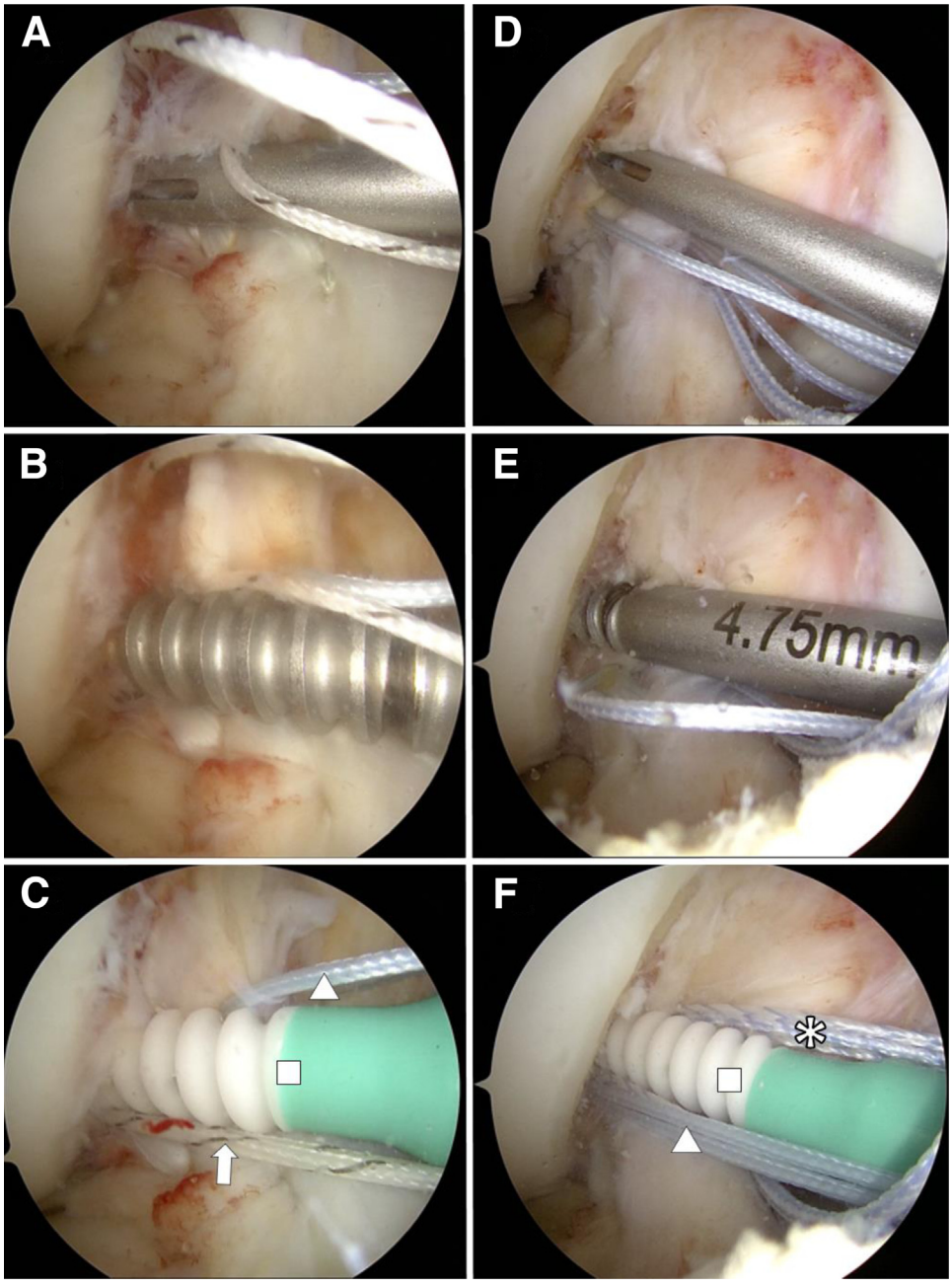

Fig 5. Arthroscopic view from the anterolateral portal of the right knee. Femoral suture anchor placement: A hole for the posterolateral (A and B) and anteromedial (AM) suture anchor (D and E) is drilled and taped into the respective bundle's femoral footprint. The suture anchors (square) of the posterolateral and AM bundle are deployed into their respective region within the femoral footprint. (F) The asterisk shows the FiberTape suture augmentation loaded in the AM suture anchor. The repair sutures are marked with an arrow (no. 2 TigerWire) and a triangle (no. 2 FiberWire).

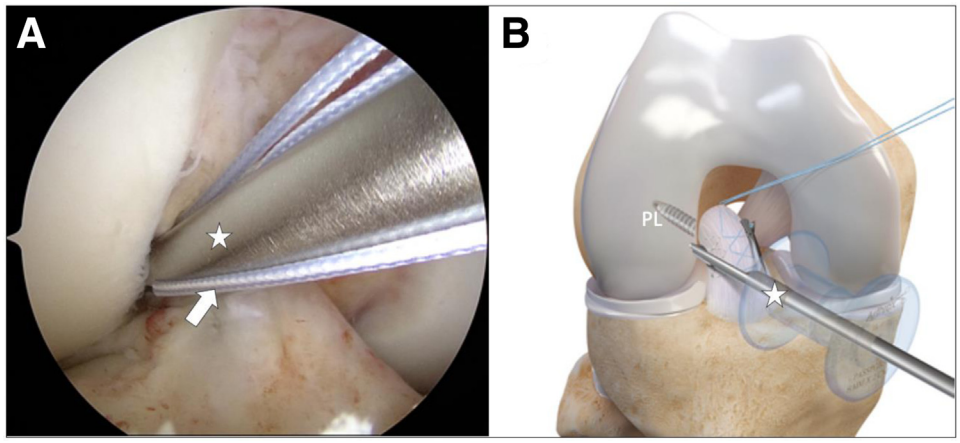

Fig 6. (A and B) Arthroscopic view from the anterolateral portal of the right knee. Using the Fast-Pass Scorpion Suture Passer (star) and the SwivelLock's core stitch (arrow), the surgeon performs an additional posterolateral compression stitch laterally to medially (Arthrex, FL).

mentioned, as soon as active quadriceps contraction has returned, the brace can be unlocked for the rest of the first 4 postoperative weeks.

With regard to physical therapy, a milestone-based approach, rather than a timeline-based approach, is used and started in the first week after surgery.

Discussion

Taking a closer look at important anatomical properties, it must be pointed out that the ACL is the major kinematic stabilizer of the knee joint as a result of an interplay of its anatomic landmarks. The twist of the ACL's fibers results from the orientation of the tibial and femoral footprint. Hence, the ACL cannot just be seen as a band of connective tissue linking the femoral condyle with the tibial plateau.[19] The AM and PL bundle each should be considered on their own and together as a synergistic functional unit, as they both play a specific and important role to stabilize the knee joint against anteromedial tibial and rotatory forces.[20] As the knee is being moved from extension to flexion and the femoral insertion moves horizontally, the PL bundle loosens up, whereas the AM bundle synergistically tightens up. Hence, the AM bundle is a strong protector against anterior-tibial translation, and the PL bundle stabilizes the knee near full extension and is the primary restraint against rotatory forces.[20,21]

In the past decade, a resurgence in contemporary selective ACL preservation has been noted.[1] Several techniques to preserve the ACL have been proposed, including suture anchor and cortical button fixation, additional suture augmentation (SA) or dynamic intraligamentary stabilization (DIS), and bridge-enhanced ACL restoration (BEAR).[5] However, a common thread toward the restoration of important anatomical properties is missing when analyzing available techniques.[5,10]

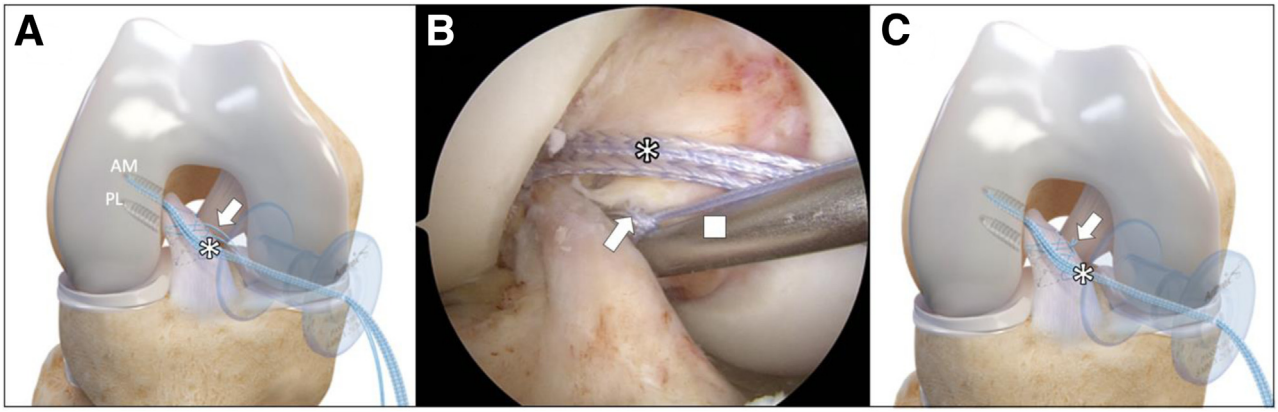

Fig 7. (A) After the core stitch has been placed from laterally to medially (B) (arthroscopic view, anterolateral portal, right knee) a knot pusher (square) is used to compress the ligament with three alternating half hitches from medially to laterally to its native femoral footprint, to achieve maximal wall contact and reestablish the native anatomic ligament vector. (C) The core stitch (arrow) is cut short after the alternating half hitches have been placed. The FiberTape is marked using an asterisk (Arthrex, FL).

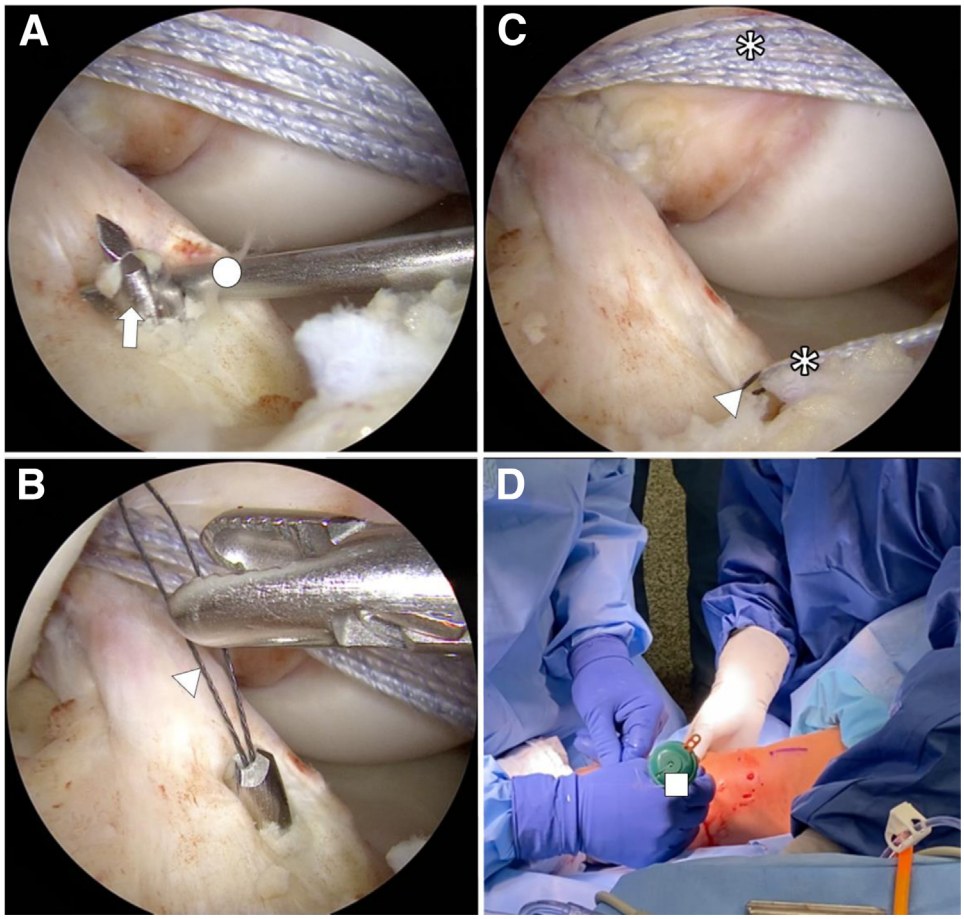

Fig 8. (A) Arthroscopic view from the anterolateral portal of the right knee: The tibial tunnel is drilled into the anterior one-third of the tibial insertion for internal brace augmentation fixation using a 2.4-mm cannulated pin (arrow). To protect and stabilize the ligament while drilling, a probe (circle) is used to apply counterpressure. (B and C) The FiberTape (asterisk) is retrieved through the tibial tunnel using a nitinol wire lasso (triangle). (D) Cortical fixation of the FiberTape suture augmentation, with the knee in full extension, is achieved using a 4.75-mm BioComposite SwiveLock (square) perpendicular to the tibial cortex.

This arthroscopic ACL primary repair (ACLPR) technique considers essential anatomical and biomechanical proprieties of the knee joint (Table 3). The anatomic reapproximation of both the AM and PL bundle to their respective femoral footprints, and utilization of an extra PL compression stitch, is viewed as highly critical as it increases the ligament-bone contact area and creates a more anatomical and biomechanical native construct. It is believed that this separate 2-bundle repair technique with an extra PL bundle core stitch better recreates the anatomic vectors of the native ACL, compared to using techniques with only a single repair-stitch mechanism, cortical button fixation, or a single anchor. Addressing these anatomic factors are considered to be critical, given the essential contribution of both bundles to the knee's biomechanics.[20] Furthermore, this technique is a minimally invasive procedure with no graft harvesting or tunnel drilling, which explains the reported decreased pain levels, earlier ROM return, and faster rehabilitation,[9] while failure rates are similar or slightly higher (especially in patients <21 years of age) to that of ACL reconstruction.[7,18] See Table 4 for further advantages of the presented technique.

Highlighting the importance of these anatomical and biomechanical properties, it can be stated that, when comparing ACL primary repair using a separate anchor bundle fixation with suture augmentation[14] versus ACL reconstruction with bone-patellar tendon-bone (BTB) autograft in a biomechanical trial,[22] both techniques restore initial functionality. In terms of the different types of ACL repair augmentation, a recent meta-analysis comparing nonaugmented, static, and dynamic augmented techniques, reported that static augmentation shows the lowest failure and complication rates.[5]

Conclusion

With this updated technique, we want to highlight the importance to consider essential anatomical and biomechanical factors when performing primary ACL repair. We present an evolved procedure, performing separate anatomical reapproximation of both bundles

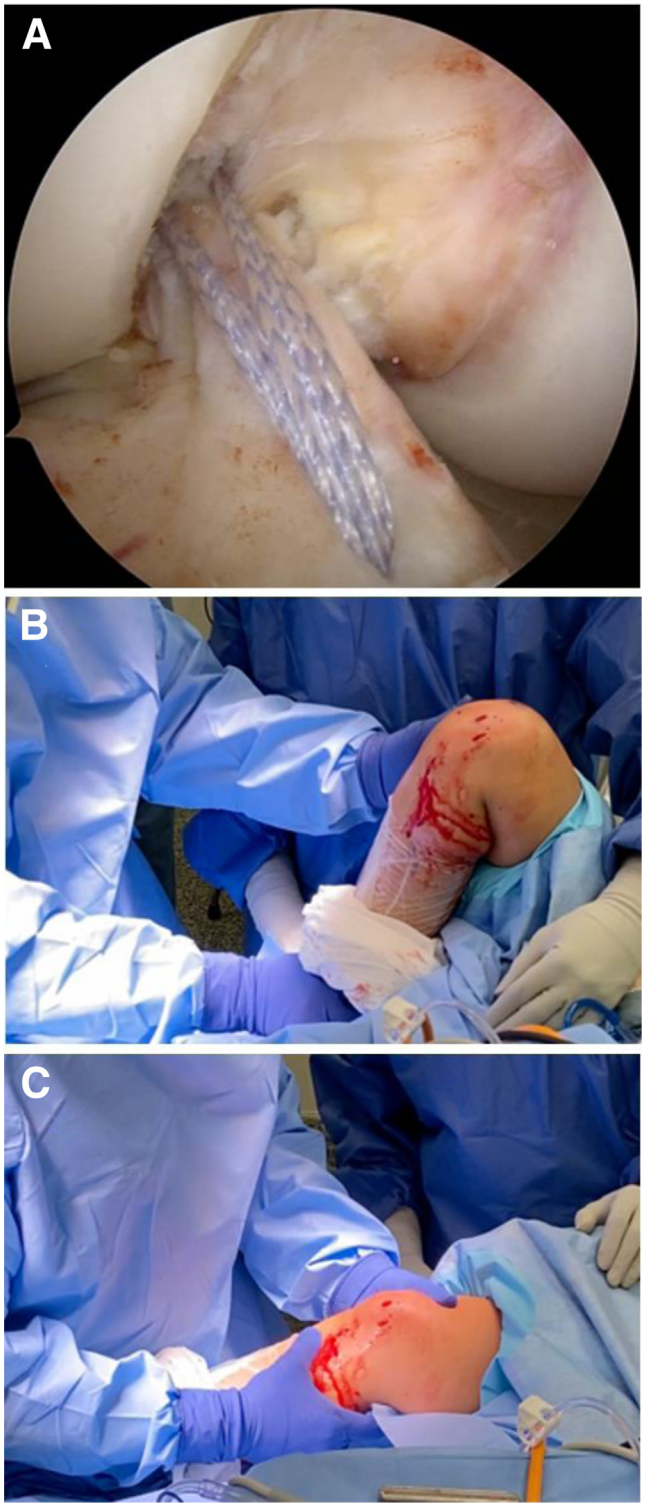

Fig 9. (A) Arthroscopic view from the anterolateral portal of the right knee. Finished anatomic repair of the anterior cruciate ligament (ACL), with the suture augmentation channeled and placed at the anterior one-third of the tibial ACL footprint. Range of motion (B) and Lachman testing (C) should be performed before ending the procedure.

Table 3. Anatomic Characteristics of Anatomic Arthroscopic Primary Repair of Proximal ACL Tears

Characteristics
Separate and individualized AM and PL bundle repair (= more anatomic and biomechanical construct)
■ AM bundle stitching with repair sutures exiting either side to create vertical traction
■ PL bundle repair suture limbs both exit laterally to create traction toward the wall
Anatomic restoration of the femoral footprint
■ Increased ligament-bone contact area through anatomic reapproximation of both bundles
■ Anatomic suture anchor placement recreates native AM and PL bundle reinsertion.
■ Full-footprint contact through extra PL bundle compression stitch
ACL vasculature preservation through Interlocking Bunnell-type suture stitching technique
■ No embracing suture technique to risk potential strangulation of vasculature

ACL, anterior cruciate ligament; AM, anteromedial; PL, posterolateral.

Table 4. Advantages and Disadvantages of Anatomic Arthroscopic Primary ACL Repair

Advantages	Disadvantages
■ Relatively short duration procedure	■ Technique limited to tear type (proximal) and good to excellent tissue quality
■ Minimally invasive: no tunnel drill or graft harvesting	■ Potential higher failure rate in younger patients
■ No graft harvesting complications	
■ Early ROM with ligament protection	
■ Faster rehabilitation	
■ Few bridges burned if later ACL reconstruction necessary	
■ Reduced osteoarthritis risk in experimental studies	
■ Preserves proprioception and native biomechanical properties	
■ Restoration of native knee biomechanics through restoration of the ACL's anatomic properties	

to their respective femoral footprints, with an additional PL compression stitch. This technique increases the ligament-bone contact area and recreates the anatomic vectors of the native ligament, aiming to restore native biomechanical properties of the knee joint.

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