Technical Note

Bridge-Enhanced Anterior Cruciate Ligament Repair for Mid-Substance Tear With Concomitant Lateral Meniscus Radial Repair

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Abstract: In recent years, repair of the injured anterior cruciate ligament (ACL) has been subject to a renewed interest as novel arthroscopic techniques have been developed. Specifically, the bridge-enhanced ACL repair is a technique composed of a resorbable protein-based implant combined with autologous blood that is used to bridge the gap between 2 torn edges of a mid-substance ACL tear. This implant is believed to help facilitate healing of a primary suture repair and suture cinch and has since demonstrated noninferiority to ACL reconstruction with autograft at 2-year follow-up. The purpose of this Technical Note is to describe a step-by-step surgical technique of a mid-substance ACL repair using the bridge-enhanced ACL repair system in a case with a concomitant lateral meniscus radial repair

Isolated anterior cruciate ligament (ACL) tears are relatively common injuries in young, active individuals and have a reported incidence of 68.6 per 100,000 person-years.[1] Individuals who suffer ACL tears experience functional loss of stabilization of anterior and rotational forces at the tibiofemoral joint. It is also common to experience time away from sport and inability to return to preinjury activity level.[2,3] ACL deficiency also impairs proprioception in the knee joint,[4,5] increasing the risk of meniscal and chondral injuries[6] and ultimately resulting in increased risk of developing premature osteoarthritis.[7,8] As such, the ACL is cited as the most commonly injured ligament in the knee that requires surgical intervention, yielding clinically stable results in most patients.[7,9,10]

Historically, until the mid-1980s, tears of the ACL were treated with primary repair of the ligament.[11] However, failure rates as high as 50% were reported with primary repairs and led to the widespread adoption of ACL reconstruction with a tendon graft, which remains the gold standard to date.[12,13] In a 21-year population-based study, the rate of ACL reconstructions was found to increase significantly over time across all age groups.[1] More specifically, Buller et al.[14] reported that the rate of ACL reconstructions from 1994 to 2006 increased by 37%. Consequently, a plethora of literature exists regarding different ACL reconstruction techniques and graft preferences, including large population-based registries such as the Multicenter Orthopedic Outcomes Network and the Multicenter ACL Revision Study.[14-16]

In recent years, repair of the injured ACL has been subject to a renewed interest as novel arthroscopic techniques have been developed. Traditionally, ACL repairs are reserved for proximal tears in which the ligament can be reattached to the femoral insertion point.[17-19] Some studies have reported success of ACL repairs in older patients with these specific proximal

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tears; however, these studies are retrospective in nature and report outcomes in patient populations that have shown nonoperative treatment of ACL tears to be equally as effective.[20,21] In the last decade, investigations have been underway to develop a method of effectively repairing mid-substance ACL tears. Specifically, the bridge-enhanced anterior cruciate ligament repair (BEAR) is a technique composed of a resorbable protein-based implant combined with autologous blood that is used to bridge the gap between 2 torn edges of a mid-substance ACL tear.[11] This implant is believed to help facilitate healing of a primary suture repair and suture cinch and has since demonstrated noninferiority to ACL reconstruction with autograft at 2-year follow-up.[11]

The purpose of this Technical Note is to describe a step-by-step surgical technique of a mid-substance ACL repair using the BEAR system, in a case with a concomitant lateral meniscus radial repair.

Surgical Technique (With Video Illustration)

Patient Positioning and Anesthesia

The patient is placed under general anesthesia and positioned supine on an operating table with the leg of the bed down to allow circumferential access and hyperflexion of the knee. An ACL leg holder is applied. The leg is prepared and draped in standard surgical fashion for knee arthroscopy. The limb is exsanguinated and a tourniquet is inflated.

Surgical Technique

The surgical technique is demonstrated in Video 1, and the advantages and disadvantages are summarized in Table 1. A high and tight anterolateral portal and standard anteromedial parapatellar portal is created. A comprehensive diagnostic arthroscopy is performed, assessing cartilage, meniscus, and ligament status. A mid-substance tear of the ACL is confirmed (Fig 1), as is a radial tear of the lateral meniscus next to its posterior root insertion (Fig 2).

We first proceed with the meniscus repair (Fig 2). The anatomic location of the root is identified and a curved ring curette is used to prepare a healing surface. Two transtibial tunnels are subsequently drilled to the root footprint using 2.4-mm cannulas separated by approximately 5 mm and employing a root-specific aiming device (Smith & Nephew, London, UK). The pins are removed from the cannulas, allowing for subsequent suture passage.

A 6-mm × 7-cm twist in cannula (Arthrex, Naples, FL) is placed into the anteromedial portal and, subsequently, a self-retrieving suture passage device (FIRSTPASS; Smith & Nephew) is used to pass a #2 suture in a simple fashion from tibial to femoral side and then shuttled down the posterior tunnel with a looped passing wire. The steps are repeated with a second suture in the mid-portion of the meniscus root, anterior to the first suture. This is then pulled down through the anterior cannula (Fig 2). Sutures are tagged for final reduction and fixation following ACL repair.

Attention is then turned to ACL repair using the BEAR technique. We ensure that the ACL is of satisfactory tissue quality and length for repair using reduction with a manual grasper (Fig 1). The lateral wall of the femur is debrided and a notchplasty is performed using a 5.0-mm BoneCutter (Arthrex). The location of the anatomic femoral footprint of the ACL is located and a 2.4-mm guide pin is placed through the footprint in standard inside out fashion (Fig 3). This is over-reamed with a 4.5-mm cannulated drill, and a #2 nonabsorbable suture is passed through the femur using the previously placed guide pin. This is secured in place for future use for suture passage.

A tibial aimer (ACUFEX DIRECTOR; Smith & Nephew) is then used to place a 2.4-mm guide pin just anterior to the tibial attachment of the ACL (Fig 3B).

Table 1. Advantages and Disadvantages

Advantages	Disadvantages
Reduces risk of donor-site morbidity, as harvesting an autograft is not required	Learning curve for the technique that must be overcome by surgeons
Expands the indication for repair by including mid-substance ACL tears	Increased surgical time
Can be used in young, athletic patient populations	Recommendation to avoid knee flexion or to irrigate the joint immediately following BEAR fixation (preventing arthroscopic visualization postfixation)
Absolute reapproximation of the torn edges of the ACL is not required for healing as the scaffold bridges the gap	Immediate postoperative period requires immobilization in extension
Potentially decreases the risk of developing premature osteoarthritis as compared to reconstruction	Lacking in large-population, high-quality studies relative to reconstruction
May result in better postoperative hamstring strength than those undergoing reconstruction with ST-G autograft	

ACL, anterior cruciate ligament; BEAR, bridge-enhanced anterior cruciate ligament repair; ST-G, semitendinosus−gracilis.

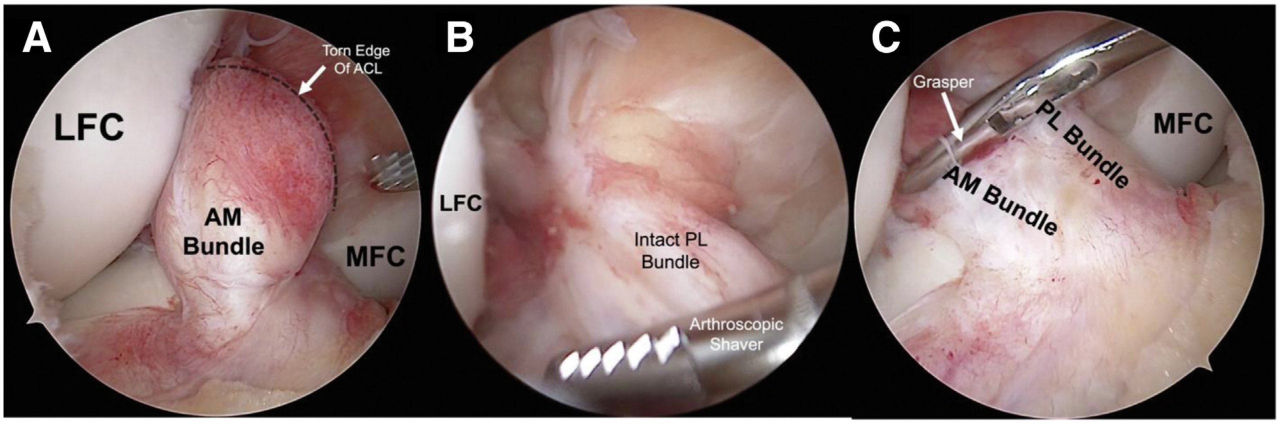

Fig 1. Arthroscopic scope footage of the right knee from the anterolateral portal. (A) Demonstration of the mid-substance tear of the right anterior cruciate ligament (ACL). (B) Close-up view of the posterolateral ACL bundle including the arthroscopic shaver. (C) Use of arthroscopic grasper to reduce the torn ACL back to its native insertion site. (AM, anteromedial; LFC, lateral femoral condyle; MFC, medial femoral condyle; PL, posterolateral.)

The self-retrieving suture passage device is then used to place #2 absorbable suture (VICRYL, Ethicon, Somerville, NJ) into the stump of the torn ACL using a Bunnell type, cross-locking suture configuration, moving from distal to proximal along the ACL stump (Fig 3C).

The 2 ends of the VICRYL suture are then brought out through an anteromedial cannula together with the

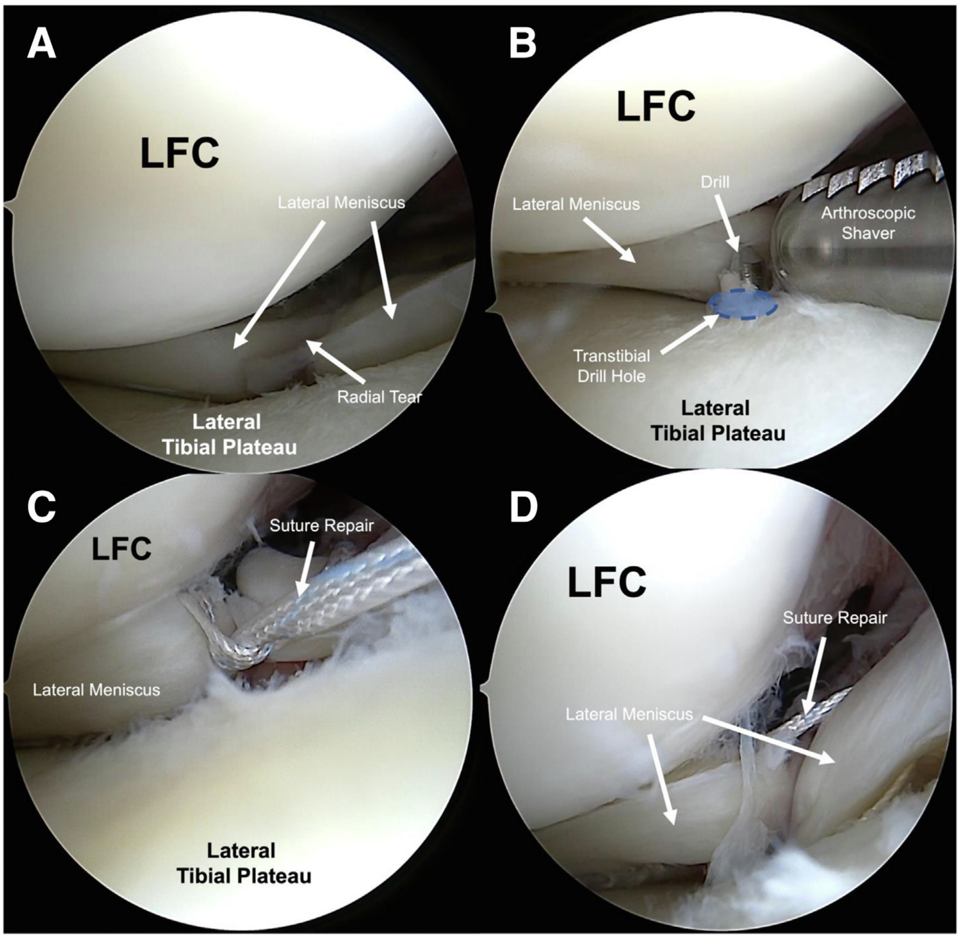

Fig 2. Arthroscopic scope footage of the right knee from the anterolateral portal focusing on the lateral meniscus. (A) Confirming radial tear of the lateral meniscus. (B) Drilling of the transtibial drill hole to facilitate meniscus repair. (C) #2 suture inserted through radial tear to facilitate repair construct. (D) Final meniscus repair construct after sutures are pulled through the transtibial tunnels. (LFC, lateral femoral condyle.)

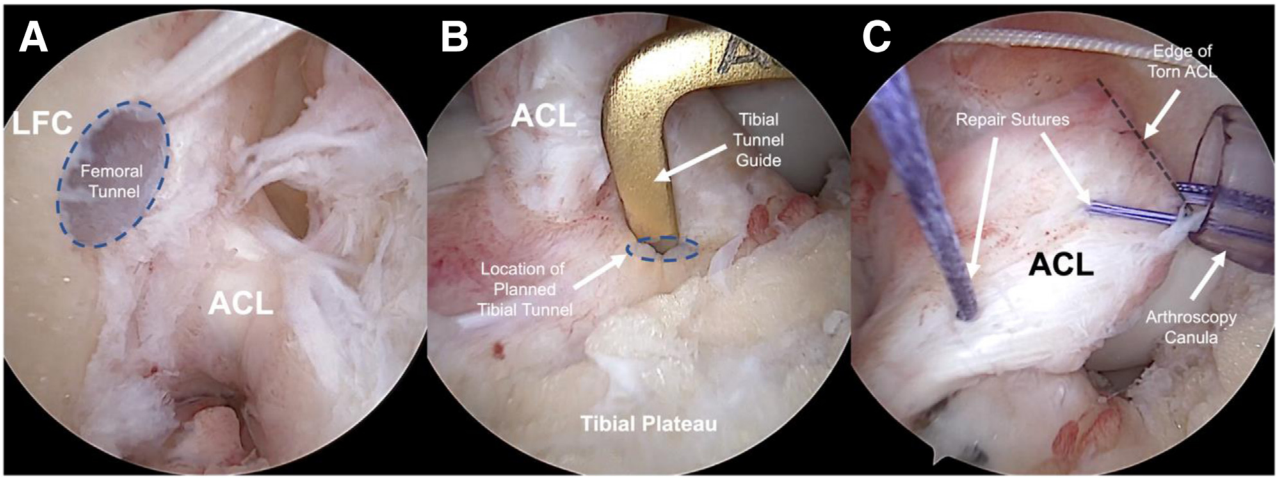

Fig 3. Arthroscopic scope footage of the right knee from the anterolateral portal focusing on the anterior cruciate ligament (ACL). (A) Demonstrating the location of the drilled femoral tunnel on the lateral femoral condyle (LFC). (B) Demonstrating the location of the planned tibial tunnel just anterior to the native tibial insertion of the ACL using a tibial aimer. (C) #2 absorbable sutures placed through the stump of the torn ACL.

previously placed femoral passing suture. Two nonabsorbable, high tensile strength #2 sutures are then looped through the center holes of a cortical button (ENDOBUTTON, Smith & Nephew) and the free ends of the VICRYL suture from the tibial stump are also passed through the cortical button (Fig 4). Subsequently, the button carrying the 2 ends of the VICRYL suture as well as the 2 nonabsorbable sutures is passed through the femoral tunnel and engaged outside the lateral femoral cortex. Location of the button is confirmed with fluoroscopy (Fig 4C).

The cannula is removed and the anteromedial portal is enlarged to approximately 50 mm to allow for passage of the BEAR graft (Miach Orthopaedics, Westborough, MA) (Fig 5). The 2 nonabsorbable sutures from the cortical button are then passed out the enlarged anteromedial portal and both ends of each nonabsorbable suture are passed through the BEAR graft (Miach Orthopaedics) sequentially using a free needle (Fig 5D). A passing suture is shuttled up the previously drilled tibial tunnel in preparation for graft placement and associated suture passage.

The 4 ends of the 2 nonabsorbable sutures that have been passed through the graft are passed through the tibial tunnel. Then, 20 mL of previously harvested autologous blood is used to presoak the BEAR graft

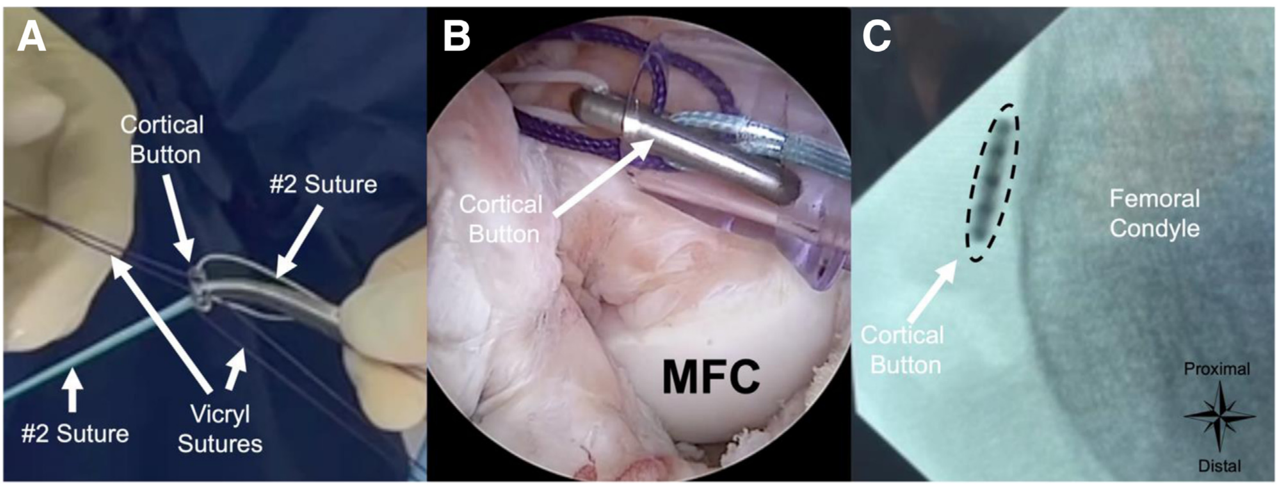

Fig 4. Footage demonstrating application of the cortical button. (A) Outside photograph of the VICRYL sutures (from the tibial stump) being fed through the cortical button. (B) Scope footage of the right knee from the anterolateral portal showing the medial femoral condyle (MFC) and the cortical button as it passes through the cannula and into the lateral femoral condyle tunnel. (C) Intraoperative fluoroscopy lateral view of the right knee demonstrating correct placement of the cortical button overlying the cortex of the lateral femoral condyle.

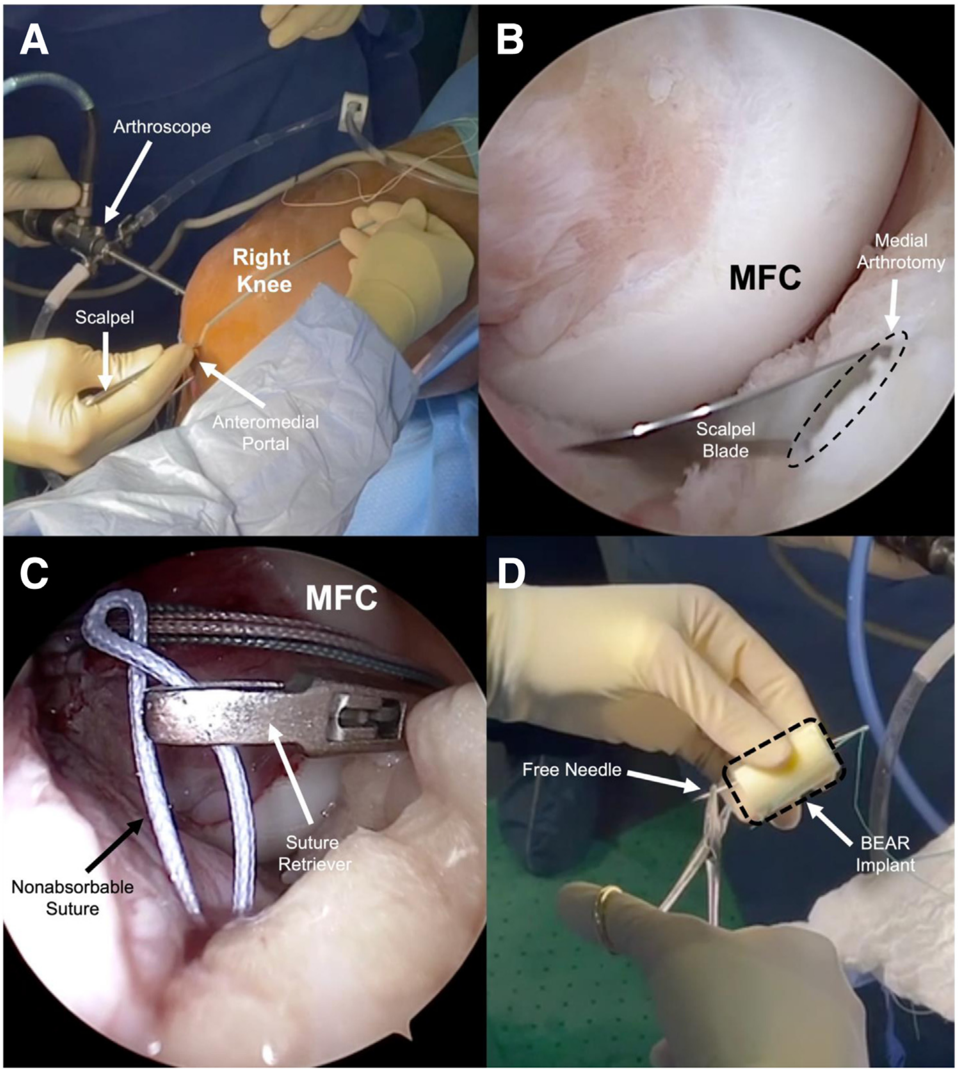

Fig 5. Outside and arthroscopic scope footage of the right knee. (A) Outside footage showing the arthroscope in the anterolateral portal while a scalpel is used to enlarge the anteromedial portal. (B) Scope footage from the anterolateral portal showing the medial femoral condyle (MFC) as the scalpel blade creates the medial arthrotomy. (C) Scope footage from the anterolateral portal showing the MFC as a suture retriever is used to shuttle the nonabsorbable suture out of the anteromedial portal. (D) Outside footage demonstrating the first pass of the nonabsorbable suture through the BEAR implant using a free needle. (BEAR, bridge-enhanced anterior cruciate ligament repair.)

(Miach Orthopaedics) (Fig 6). The graft is gently introduced through the enlarged medial portal while applying gentle traction to the passing suture (Fig 6C). These nonabsorbable sutures are tensioned with the knee in full extension and tied over a cortical button on the anterior tibial cortex. Subsequently, the lateral meniscus repair is also fixed using an anchor on the anteromedial tibia.

Incisions are then closed in standard fashion, using 2-0 MONOCRYL (Ethicon) followed by running 3-0 MONOCRYL for the anteromedial and distal tibial incisions and simple 3-0 MONOCRYL sutures for the anterolateral portal. Sterile dressings are applied. The patient is placed in a hinged knee brace locked in full knee extension.

Discussion

Repair of the ACL traditionally has been reserved for proximal ligament tears; however, there has been growing interest in the use of repair techniques for mid-substance ACL tears. To expand the scope of repair techniques, there have been substantial preclinical efforts to evaluate the causes of failed mid-substance repair as well as to identify augmentation strategies to overcome these challenges.[11] In ligaments like the medial collateral ligament, which heal nonoperatively, it has been observed that the torn ligament ends are bridged by a fibrin clot, serving as a biologic scaffold to facilitate ligament repair and allow the torn edges to unite.[22] However, in ACL injuries, the intra-articular location of the ACL limits the ability of a fibrin clot to serve as this scaffold, and an expedited dissolution of the fibrin clot may contribute to the poor gap healing observed in mid-substance ACL tears.[11]

Subsequent preclinical studies have been designed in an effort to augment this fibrin clot and help create a scaffold to bridge mid-substance ACL tears. This involves both the development of orthobiologic

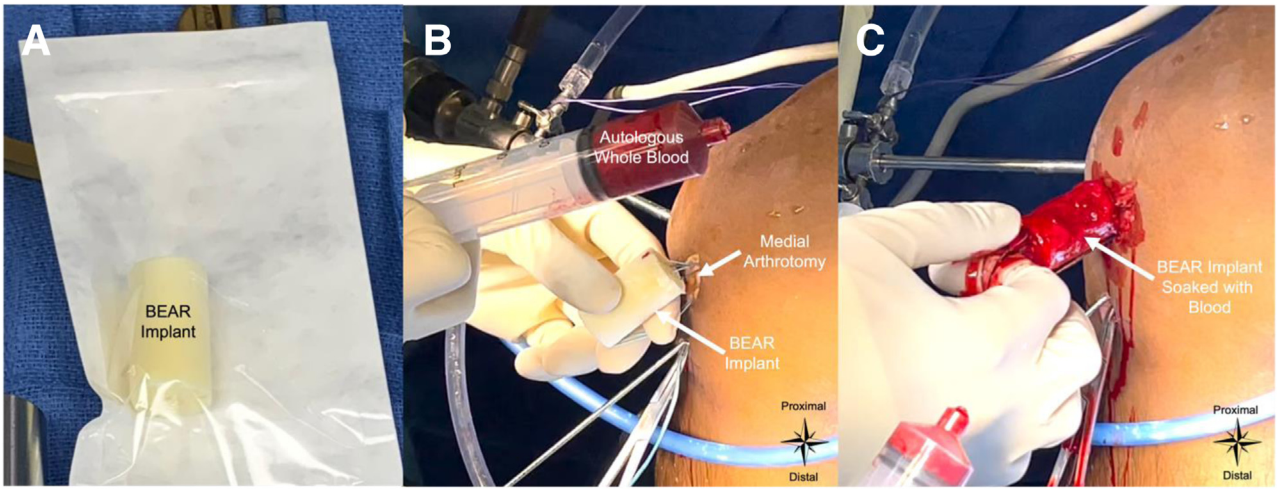

Fig 6. Outside photographs of the bridge-enhanced anterior cruciate ligament repair (BEAR) implant. (A) BEAR implant in its sterile packaging prior to implantation. (B) Demonstrating the right knee with the BEAR implant after it has been sutured longitudinally and prior to being soaked with autologous whole blood. (C) Demonstrating the BEAR implant after it has been soaked with autologous whole blood and just before insertion through the enlarged medial portal of the right knee.

constructs as well as suture configurations to augment the repair.[23] As such, the BEAR implant was developed as a resorbable protein-based implant containing autologous blood. It is designed to be sutured to the torn ends of a mid-substance ACL tear such that the ends do not require absolute re-approximation to adequately heal.[22] A recent systematic review on ACL arthroscopic repair techniques by Cao et al.[24] demonstrated that biologically enhanced repair is superior to primary repair alone in terms of postoperative side-to-side difference and patient-reported outcomes at a mean follow-up of 36 months.

Preliminary animal studies have demonstrated that the BEAR technique resulted in comparable mechanical properties to gold standard reconstructive techniques as well as reduced posttraumatic osteoarthritis relative to the animal controls undergoing reconstruction.[25,26] More specifically, Karamchedu et al.[27] examined 36 minipigs and randomized them to receive either ACL reconstruction or the BEAR technique. The authors demonstrated reduced macroscopic cartilage damage at 52 weeks in the BEAR group relative to the ACL reconstruction group. However, it is still unclear whether the chondroprotection stems from the release of growth factors or from retained proprioception, which more closely mimics joint loading and kinematics to that of an uninjured knee. Proprioception often is cited as a shortcoming of ACL reconstruction, and there is substantial evidence demonstrating that positional sense, although improved after reconstruction, is not restored to normal.[28] Beyond potential benefits related to reduced post-traumatic arthritis, an additional theoretical benefit of the repair technique relative to autograft reconstructive techniques is the lack of donor site morbidity.[11] Consequently, these potential benefits have led to clinical interest in the development of the BEAR technique as an alternative to autograft reconstruction for complete mid-substance ACL tears.

Historically, ACL repairs have been studied in older, less-active patient populations in whom nonoperative

Table 2. Relative Indications for BEAR Technique

Inclusion	Exclusion
Ages 13-35 with closed physes	History of ipsilateral knee surgery
Complete ACL tear	Previous knee infection
<45 days from injury to surgery	Nicotine/tobacco use
At least 50% of the length of ACL attached to the tibia on MRI	Use of corticosteroid within past 6 months
	History of diabetes, chemotherapy, or inflammatory arthritis
	Displaced bucket-handle tear of medial meniscus requiring repair
	Full-thickness chondral injury
	Grade III MCL injury
	Concurrent complete patellar dislocation or posterolateral corner injury requiring surgery
	Known allergy to bovine, beef, or cow products

ACL, anterior cruciate ligament; BEAR, bridge-enhanced anterior cruciate ligament repair; MCL, medial collateral ligament; MRI, magnetic resonance imaging.

treatment also may be an effective treatment option.[20,21] Thus, despite the promising theoretical benefits of BEAR, there are concerns over its utility in younger patient populations, where the graft would be subject to greater levels of strain. In 2020, Murray et al.[11] sought to investigate the clinical efficacy of BEAR relative to ACL reconstruction in young, active patients. The authors conducted a randomized controlled trial (RCT) of 100 patients with a median age of 17 years and randomized subjects to receive either the BEAR technique (n = 65) or autograft ACL reconstruction (n = 33 quadrupled semitendinosus—gracilis; n = 2 bone—patellar tendon—bone). The relative indications for the BEAR technique were defined by the inclusion/exclusion criteria of this RCT and are defined in Table 2. The results demonstrated no significant differences in International Knee Documentation Committee subjective scores, International Knee Documentation Committee objective outcomes, or anteroposterior laxity between the 2 groups at 2 years' follow-up. Furthermore, the authors observed improved hamstring strength in the BEAR group relative to the reconstruction control group. Nine patients (14%) who underwent BEAR were converted to a subsequent ACLR, whereas 2 patients (6%) within the ACL reconstruction group underwent a subsequent ipsilateral revision ACL reconstruction. The subset of patients receiving BEAR who underwent a subsequent procedure had similar outcomes to those who underwent a single ACL reconstruction. The results of this RCT support the clinical viability of the BEAR technique in a subset of eligible, correctly indicated patients.

The results from Li's[29] recent systematic review and meta-analysis of RCTs comparing ACL repair to reconstruction were consistent with these findings. The quantitative assessment of 7 eligible RCTs showed no statistically significant differences between arthroscopic repair and reconstruction for Tegner score, Lysholm score, objective side-to-side difference in anterior translation (Lachman and KT-1000), range of motion, or reoperation rates.[30]

While these initial data are promising, future well-designed studies are needed to further determine the relative clinical efficacy of the BEAR technique, particularly with reference to a bone—patellar tendon—bone autograft ACL reconstruction technique. In addition, future studies reporting long-term follow-up outcomes of the BEAR technique are required to analyze how its promising chondroprotective properties found in animal studies translate to the clinical setting, as well as potential benefits related to retained proprioception.

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