Technical Note

Suture Anchor Technique for Bridge Enhanced Anterior Cruciate Ligament Restoration

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Abstract: Anterior cruciate ligament (ACL) injuries are common in the athletic population. ACL repair with bridge enhancement is an emerging technology with promising clinical outcomes in patients with a proximal to midsubstance ACL tears. Currently, there are a variety of fixation methods described for isolated ACL repair, including suspensory and anchor techniques. This Technical Note describes a bridge enhanced ACL restoration procedure technique, using suture anchors for the femoral fixation. Advantages of this technique include more rigid fixation and avoiding need for accessory over-the-top incision. Additionally, the surgical workflow is more similar to an ACL reconstruction with intra-articular screw fixation, which may be more readily adopted by some surgeons.

Anterior cruciate ligament (ACL) repair was originally described around the turn of the 19th century using catgut ligature.[1] Throughout the decades, various ACL repair techniques were reported but with poor midterm clinical results.[2,3] Randomized controls in the early 1990s demonstrated superior outcomes with ACL reconstruction to repair and shifted the paradigm for ACL reconstruction as the gold standard.[4,5] Renewed interest in ACL repair has been ongoing in the 2010s with primary repair with suture augmentation with variable outcomes.[6-9]

The first cohort of biological augmentation with bridge enhanced ACL repair (BEAR) was first published in 2016 with promising 2-year midterm outcomes.[10,11] The BEAR implant (Miach Orthopaedics, Westborough, MA) is a decellularized, bovine-derived type I collagen implant that facilitates repair of a patient's native ACL tissue. The implant is thought to facilitate the body's own healing response by supporting cell migration and proliferation to allow reconstitution of native cells and collagen and provide tissue strengthening. Benefits include avoiding the morbidity and prolonged rehabilitation of an autograft harvest (hamstring, patellar tendon, or quadriceps tendon) with the potential benefit of accelerated strength recovery.

The original surgical technique by the manufacturer described an ACL repair technique using dual suspensory fixation with cortical buttons on both the femur and tibia. A recently published randomized control trial of 100 patients demonstrated noninferior patient-reported outcomes and similar laxity when compared to ACL reconstruction with autograft.[12] This Technical Note describes our preferred technique for bridge enhanced ACL restoration (BEAR) using suture anchor fixation at the anatomic femoral footprint. Advantages of this technique include direct fixation into the anatomic ACL footprint, decreased potential for gap formation,[13] and avoidance of making an accessory, over the top incision.

Surgical Technique (With Video Illustration)

Prior to surgery, the magnetic resonance imaging is scrutinized to assess the location of the ACL tear. In our opinion, most favorable candidates are those with a proximal avulsion (Type I or II tears) with homogenous remaining tissue quality on sagittal T1 and T2 sequences.[14] The inclusion criteria for the original BEAR study include patient's age 13-35, complete ACL injury, less than 45 days from injury, closed physis, and at least 50% length ACL attached to the tibia. During the

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informed consent process, we discuss with the patient the option to proceed with the BEAR procedure based upon tissue quality and the possibility that the ACL stump may not be repairable. An available backup ACL graft option is agreed upon preoperatively, which would include an autograft from either patellar tendon, quadriceps tendon, hamstring tendon, or allograft tissue.

Patient Positioning

Either prior to or following induction of anesthesia, the patient may undergo a single shot abductor canal regional anesthetic for postoperative pain control. The patient is then positioned supine with the foot at the edge of the bed and a heel bump to maintain the knee at 90° of flexion. A lateral side post helps maintain stability of the limb, as well as to provide a lateral restraint for valgus force during knee arthroscopy.

Arthroscopic Examination

Standard anteromedial and anterolateral portals are created. Initial visualization and assessment of the ACL stump are performed. This includes both visual and tactile assessment using a grasper to assess quality of tissue, ability to hold a suture, as well as location of tear (Fig 1A). At this time, the decision is made whether to proceed with a BEAR procedure or convert to an ACL reconstruction. An ideal BEAR candidate has at least 50% of the tibial stump remaining with the majority of the ACL fibers intact in a parallel orientation. Probing of the stump tissue should show some firmness and resistance.

After the decision to proceed with the BEAR procedure has been made, the remainder of a standard arthroscopic assessment of the knee is performed. This includes evaluation of articular surfaces throughout the

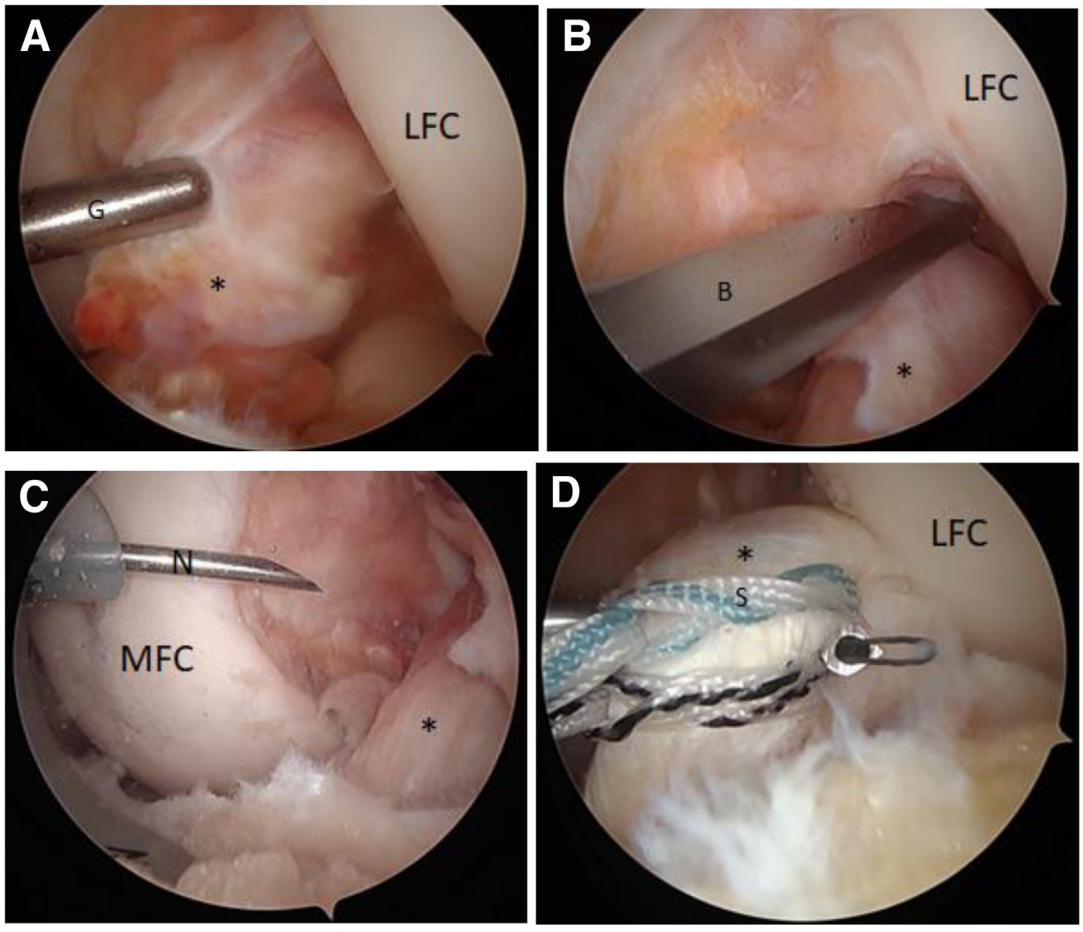

Fig 1. Intraoperative views of a left knee viewing from the anterolateral portal. (A) Tactile assessment of anterior cruciate ligament (ACL) stump using grasper. (B) Using a hip arthroscopy scalpel to sharply release the ACL off the femoral wall. (C) Percutaneous needle placement to establish accessory anteromedial portal needle just superior to anteromedial soft cannula. (D) Placement of suture lasso through ACL stump. The asterisk (*) denotes ACL stump. B, hip arthroscopy scalpel; G, grasper; LFC, lateral femoral condyle; N, spinal needle. S, suture.

knee, inspection of the meniscal tissue, and concomitant treatment, as necessary.

Femoral Preparation for BEAR

Attention is then turned back to the notch for assessment and repair of the ACL tissue. In our opinion, release of the proximal attachment of the ACL off the lateral femoral condyle allows for precise identification for repair site, as well as the ability to prepare the bone bed for optimal healing.

A flexible cannula (Arthrex PassPort, Naples, FL) is placed in the anteromedial portal while an arthroscope is used to view from anterolaterally. Following this, a rigid hip arthroscopy scalpel is used to elevate the ACL from inferior to superior to release the remaining attachments from bone (Fig 1B). The ACL tissue is then protected with a metallic sled retractor, and a bone-cutting shaver is used to decorticate the bone off the native ACL attachment, as well as expose the optimal repair site.

In order to streamline suture passage, an accessory percutaneous anteromedial portal is made in line and just superior to the standard anteromedial portal. This is first localized with a spinal needle, such that the trajectory in the joint is just above the location of the flexible cannula (Fig 1C). Stab incision is made, and an arthroscopic suture grasper is used to help shuttle suture during passage with an arthroscopic lasso device.

Passing Sutures into ACL Stump

Attention is then turned toward suture placement for repair of the ACL. A total of 4 closed-loop, high-strength sutures (Arthrex FiberLink Suturetape, Naples, FL) are passed through the distal stump of the ACL and secured in luggage tag fashion. A curved arthroscopic suture lasso is used to pass the sutures throughout the ACL stump (Fig 1D). In our opinion, use of a suture lasso allows improved precision compared to an auto-capturing suture and allows for control of the most distal ACL fibers. Great care is taken to obtain relatively full-thickness, posterior bites, to allow for maximal capture of the ACL tissue. Suture passing sequence proceeds from distal to proximal in the tibial stump to minimize risk for suture tangle.

Femoral Suture Anchor Fixation

Following this, the suture anchor repair site on the lateral notch is identified. The knee is hyperflexed. A metallic sled retractor is used to protect the ACL tissue and suture, and a 2.4-mm drill pin is placed slightly higher than the native ACL footprint (1:00 position for a left knee using the clock face analogy), as the ACL repair tissue will reduce slightly lower on the wall to where the anchor is placed (Fig 2). This pin is drilled ~25 mm and then exchanged for a tap for preparation of anchor placement. Finally, the 4 limbs of suture are loaded into a knotless suture anchor (Arthrex, 4.75-mm Swivelock, Naples, FL) and inserted under standard technique, taking care not to overtension the tissue (Fig 3). In our opinion, slight undertension is optimal than overtensioning to prevent risk of arthrofibrosis and anisometry. The free limbs of high-strength suture will be retained for usage as the internal brace support, as well as shuttle for the BEAR implant. Potential pearls and pitfalls of this technique are listed in Table 1.

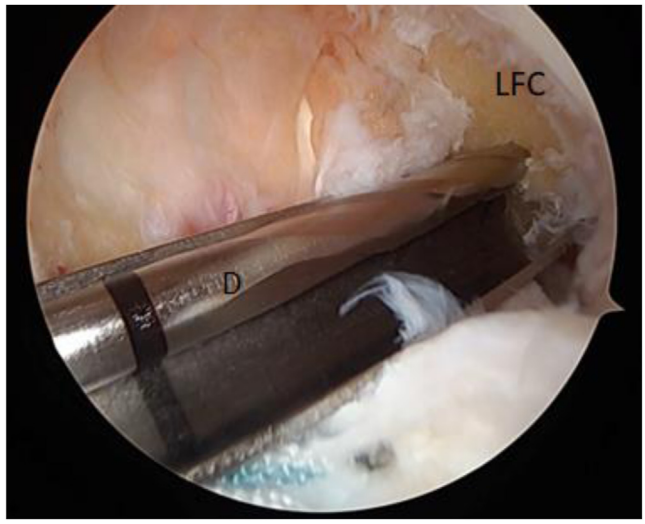

Fig 2. Arthroscopic view of the left knee from the anterolateral portal showing pin placement for the femoral anchor at the 1 o'clock position. *D denotes the 2.4-mm drill pin.

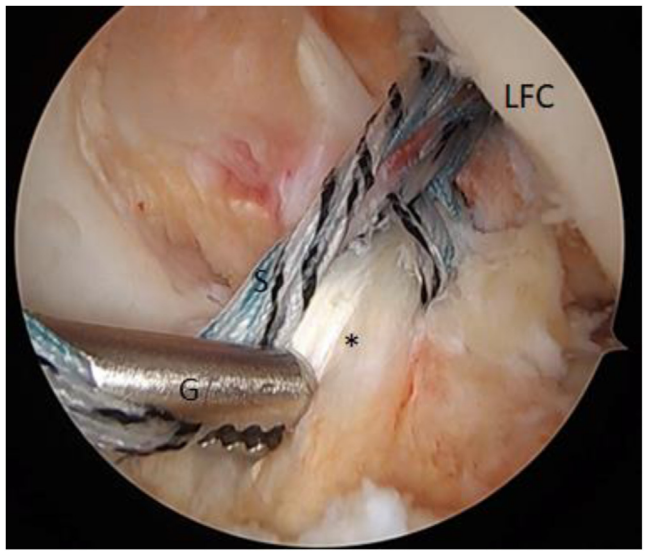

Fig 3. Arthroscopic view of the left knee from the anterolateral portal showing final repair of anterior cruciate ligament (ACL) tissue after femoral anchor placement. The excess suture from the anchor is grasped to demonstrate the location of the internal brace component. An asterisk (*) denotes ACL stump. G, grasper; LFC, lateral femoral condyle; S, suture.

Table 1. Potential Pearls and Pitfalls When Performing Bridge-Enhanced ACL Restoration (BEAR) Procedure With a Suture Anchor Technique

Pearls	Arthroscopic evaluation of the ACL stump with direct observation and tactile probing is important for decision making in proceeding with a bridge enhanced ACL repair (BEAR).
	We recommend having a backup reconstruction plan available if the tear is not amenable to repair.
	Usage of accessory anteromedial portal in-line and just superior to the standard anteromedial portal to 1) aid in suture passage and 2) aid in passage of the BEAR implant by connecting to the anteromedial portal inferiorly)
Pitfalls	Placement of the femoral anchor at the original anatomic footprint is incorrect for a BEAR repair as it is too low and distal. The repaired ligament will need to be "brought up", and the recommended anchor position is slightly higher and proximal to the native ACL footprint.
	Overtensioning repair by pulling too much tension on the repair sutures when inserting the femoral anchor

ACL, anterior cruciate ligament.

Tibial Tunnel Drilling

Once the anchor is placed and provisional stability is confirmed, attention is turned toward creation of the tibial tunnel for suture passage. A tibial ACL guide is placed through the medial portal and aimed at the native ACL footprint (Fig 4). A small incision is made along the proximal medial tibial metaphysis and a 2.4-mm cannulated drill pin is fired. A passing suture is exchanged through the pin and shuttled through the proximal tibia.

Preparation and Delivery of BEAR Implant

Finally, preparation of the BEAR implant (Miach Orthopaedics, Westborough, MA) and delivery are performed. The soft flexible cannula is removed and cut to preserve the sutures. Sutures are protected, and the medial portal is enlarged to incorporate the accessory anteromedial portal to allow for passage of the implant. Portal should be large enough to easily fit a finger through the arthrotomy. Using a straight Keith needle, the surgeon uses the 4 limbs of suture to perform the ACL repair, which emanating from the anchor and are passed through the BEAR implant through 4 quadrants (Fig 5A). The free ends of the suture are then shuttled through the tibial tunnel using the previously passed transtibial shuttle suture.

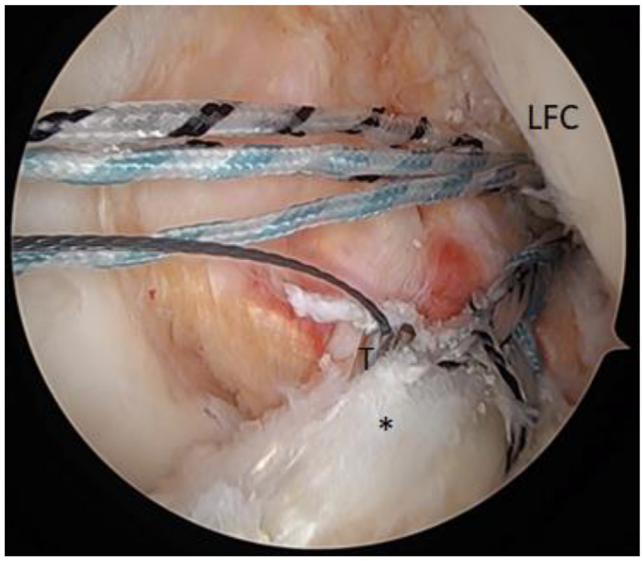

Fig 4. Arthroscopic view of the left knee from the anterolateral portal showing tibial pin placement location through tibial anterior cruciate ligament (ACL) footprint with a passing suture. An asterisk (*) denotes the ACL stump. LFC, lateral femoral condyle; T, tibial pin.

Up to 10 cc of peripheral blood is used to hydrate the implant, and this is inserted through the medial arthrotomy by finger pressure (Fig 5B). Once this is confirmed to be delivered into the notch, distal tension is pulled on the tibial sutures, and the knee is brought into full extension. This will construct the internal brace for reinforcement. Finally, these 4 limbs of suture are tied over a small circular metallic button (Arthrex TightRope ABS, Naples, FL) at the tibial metaphysis. Great care is taken to ensure that there is no soft tissue interposed between the button and proximal tibia. Note that after the BEAR implant is placed into the knee, no further arthroscopy fluid should be run into the knee to avoid disrupting the initial fibrin clot. Final assessment of gentle Lachman test is performed to confirm adequate restoration of stability. Incisions are closed using standard technique, sterile dressings applied, and patient placed in a hinged knee brace locked in full extension.

Postoperative Care

Patients are placed in a hinged knee brace after surgery locked in extension for the first 24 hours. They are made partial weight bearing 50% body weight for 2 weeks with the knee locked in extension. Range of motion (ROM) for physical therapy is allowed with 0-90° for 4 weeks. Patients are transitioned to weight bearing and ROM as tolerated after 4 weeks.

Discussion

Bridge Enhanced ACL Repair (BEAR) is a new technology developed by the Murray et al., starting with basic science work demonstrating fibroblast proliferation in the ACL stump after injury and potential for ACL healing.[15] However, plasmin within the synovial fluid degrades the fibrin clot and prevents full healing of

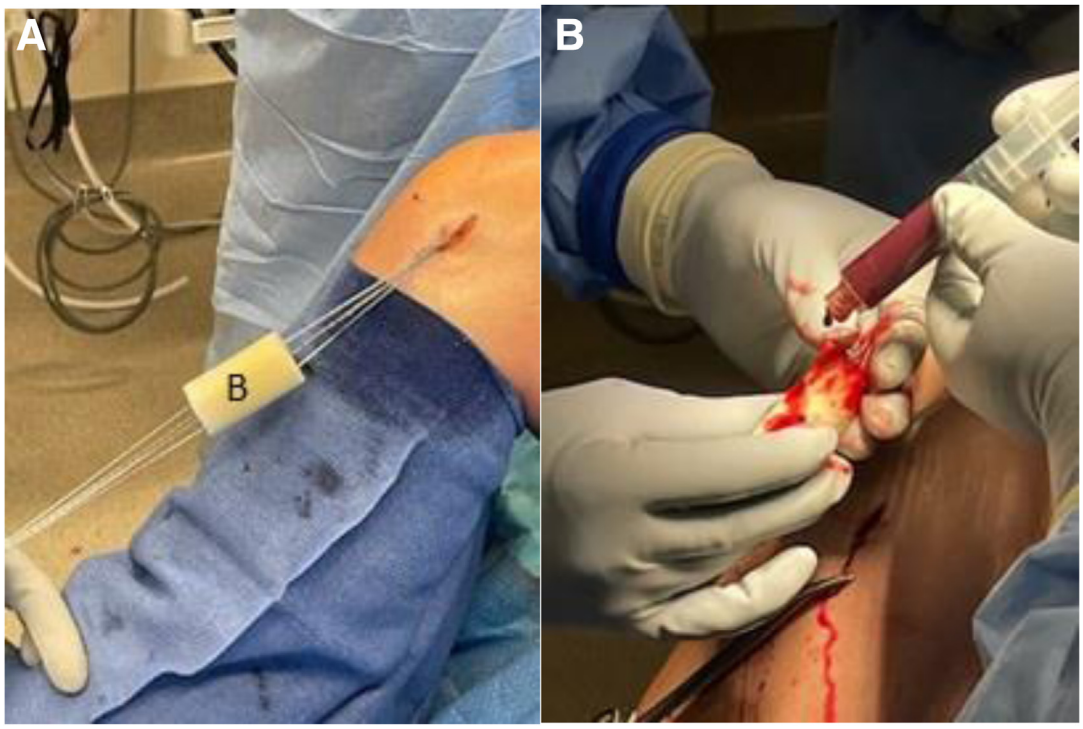

Fig 5. (A) Clinical view of left knee with placement sutures through bridge enhanced ACL repair (BEAR) implant outside of the knee. (B) Clinical view of the BEAR implant being hydrated with autologous patient blood.

the ACL. In 2011, they found that a collagen scaffold could prevent the fibrin degradation, which then became the basis of the BEAR implant.[16]

The first BEAR clinical trial comparing 10 BEAR patients and 10 hamstring reconstructions was published in 2016 showing no adverse reactions to the BEAR and intact implant at the 3-month follow-up.[10] Their 2-year outcome data on this cohort of 20 patients showed no difference in patient-reported outcomes measures (PROMS), laxity on KT 1000, or implant failure between the 2 groups.[11] In 2020, a prospective randomized trial with 65 BEAR patients and 35 hamstring reconstructions found no difference in PROMS or laxity on KT 1000 testing at 2-year follow- up.[12] The hamstring reconstruction group had weaker hamstring strength compared to the BEAR. Although the rerupture rate was 14% in the BEAR group compared to 6% in the hamstring reconstruction, this did not reach statistical significance ($P = .32$).

Despite these promising clinical results, many surgeons may express hesitancy on adopting the BEAR procedure often citing a historical high failure rate for ACL repair alone. A recently published study reported young patient age, contact injury, and increased medial tibial slope found as predictive risk factors for early failure of following the BEAR procedure.[17] Odds for revision within 2 years decreased by 32% for each 1-year increase in patient age up to age 22, with no failures occurring older than this age. We believe that patient selection is vital for success and recommend caution when considering the BEAR for young, high-demand patients. Our institutional experience, thus far, has yielded promising short term (1-year postoperative) outcomes in terms of stability, postoperative imaging, and PROMs.

The original study inclusion criterion for the ACL quality was having at least 50% of the ACL to be attached to the tibia.[12] Proximal avulsions are relatively straightforward to identify on MRI scans, but the quality of midsubstance ruptures may be difficult to predict on imaging alone. Intraoperative evaluation of the tissue length and quality is vital in intraoperative decision making.

When first adopting the BEAR procedure, surgeons may find the technical aspect of the procedure to be challenging. Our technique using suture anchor fixation offers a similar surgical steps to that of a patellar tendon autograft reconstruction. Advantages of this technique include technical ease and efficiency, direct reduction, fixation into the anatomic ACL footprint, decreased potential for gap formation, and tunnel widening,[13,18] and avoidance of making an accessory, over the top incision (Table 2). Additionally, a suture anchor allows the use of four separate independent repair sutures for repair compared to one running suture for a suspensory technique.

A risk for our femoral suture anchor technique may be in the revision setting where it is slightly more

Table 2. Advantages and Disadvantages of a Suture Anchor Repair Technique When Compared to Traditional Suspensory Fixation for Bridge Enhanced ACL Restoration Procedure

	Suture Anchor Repair	Femoral Suspensory Repair
Number of repair sutures	Allows usage of 4 independent sutures for repair	Only allows for 1 running suture for repair
Overall Workflow	Similar workflow to ACL reconstruction with BTB and interference fixation	Requires familiarity with suspensory fixation
Gap Formation[13]	Decreased potential for gap formation	Increase potential for gap formation
Tunnel Widening[18]	Decreased tunnel widening	Increased tunnel widening
Time Zero Stability[19]	No difference	No difference
Ease of Revision	Slightly more challenging revision with creating new femoral tunnel	Easier revision if no tunnel widening
Incisions	No additional incision required	Accessory over the top incision required

ACL, anterior cruciate ligament; BEAR, bridge enhanced ACL repair; BTB, bone-tendon-bone.

difficult to drill a new femoral tunnel through an existing anchor compared to a small femoral tunnel used in suspensory fixation.

Currently, there are only a few biomechanical studies examining the use of suture anchors versus suspensory fixation. Disadvantages of a suspensory technique include potential for tunnel widening and increased loosening.[18] In a quadriceps tendon repair model, suture anchors have been shown to have decreased gap formation during cyclic loading but similar ultimate load to failure when compared to transosseous tunnels.[13] In a cadaver model of ACL repair, suture anchor repair with tape augmentation showed similar time 0 anteroposterior translation to suture repair with suspensory fixation and BTB reconstruction.[19] Further clinical studies are needed to determine the effect that fixation method has on ACL repair outcomes.

In conclusion, we present a reproducible and safe technique for BEAR ACL repair using femoral suture anchor fixation.

Disclosures

The authors report the following potential conflicts of interest or sources of funding: T.W. reports PI research report from Miach and stock in Overture Resurfacing, outside the submitted work. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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