Technical Note

# Anterior Cruciate Ligament Allograft Reconstruction Augmented With a Reinforced, Bioinductive Collagen Scaffold in the Setting of Multiligamentous Knee Injury

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**Abstract:** The gold standard for surgical treatment of anterior cruciate ligament (ACL) injuries is reconstruction. There are a variety of graft options, from autograft to allograft, using bone–patellar tendon–bone (BTB), hamstrings, quadriceps, or Achilles, and, in the case of a multiligamentous knee injury (MLKI), allograft may be preferred to decrease operative time and graft harvest morbidity. The BioBrace (ConMed, New Haven, CT) is a bioinductive collagen scaffold designed to provide an environment for soft tissue remodeling with time zero biomechanical support and can be used to augment graft reconstructions in the case of concerns for allograft strength, healing, or width. The purpose of this Technical Note is to describe the technique for performing an ACL reconstruction with BioBrace-augmented allograft in the setting of a MLKI, with special consideration for 2 methods of graft preparation (BTB and soft tissue).

The BioBrace (ConMed, New Haven, CT) is a bioinductive collagen scaffold designed to provide an environment for soft tissue remodeling with time zero biomechanical support and can be used to augment graft reconstructions in the case of concerns for allograft strength, healing, or size.[1,2] It is an off-the-shelf implant that comes in ligamentous (5 × 250 mm) and patch form (23 × 30 mm), composed of highly porous type I collagen (20 μm average pore size) and bio-resorbable poly (L-lactide) microfilaments (15 μm diameter), which provides a cited load sharing strength of 141 N at time zero of implantation.[3] This provides a useful mechanical and biological augmentation, especially in procedures requiring allografts or harvested autografts with less than desired size, such as in anterior cruciate ligament (ACL) reconstruction.

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The purpose of this Technical Note is to describe the technique for performing an ACL reconstruction with a BioBrace-augmented allograft in the setting of a multiligamentous knee injury (MLKI), with special consideration for 2 methods of graft preparation (bone–patellar tendon–bone [BTB] and soft-tissue). To demonstrate the procedure in a reproducible method, we have provided a list of necessary equipment, intraoperative positioning, pearls and pitfalls, and a technical video (Tables 1-3, Video 1). Informed consent was obtained, and patient privacy was maintained throughout this video.

## Surgical Technique

### Equipment/Implants Required

Table 1 lists the necessary equipment, implants, and grafts required for preparation of this operative technique.

### Preoperative Planning/Positioning

The patient is induced under general anesthesia. The large C-arm should be positioned on the ipsilateral side of the surgery for medial collateral ligament (MCL) repair work. An examination with the patient under anesthesia is performed, demonstrating a 2B Lachman, positive anterior drawer and pivot shift, valgus stress with grade 3 laxity at 0° and 30° of flexion, and varus

**Table 1.** Equipment Necessary to Perform the Proposed Technique

| Equipment | Specific Examples in Operative Technique |
|---|---|
| Required | |
| Large C-arm | N/A |
| Arthroscopy tower, arthroscopic electrocautery, shaver, burr/bone cutter | Surgeon preference |
| Leg holder | Acufex leg holder (Smith & Nephew, London, UK) |
| ACL allograft | Bone-patellar tendon-bone allograft (JRF Ortho, Centennial, CO) |
| Reinforced, bio-inductive collagen scaffold augment | BioBrace (ConMed, New Haven, CT) in 5 × 250 mm ligamentous form |
| BTB allograft preparation | Microsagittal saw, bone crimpers, graft sizing tubes, 2.0-mm drill bit, #2 and 2-0 high-tensile, braided, non-absorbable suture |
| Quadriceps allograft preparation | FiberTag (Arthrex, Naples, FL) × 2<br>TightRope BTB Implant (Arthrex)<br>Graft sizing tubes |
| Tunnel reamers per surgeon preference<br>Flexible reamer for femur | Stryker Versatomic 7 mm over the top flexible reamer system (Stryker, Kalamazoo, MI) |
| Tibial guide | Arthrex Constant Tibial Guide (Arthrex) |
| Interference screw fixation | Milagro Advance Interference Screw (Johnson & Johnson, New Brunswick, NJ) 7 × 23 mm, 9 × 30 mm |
| Available in room | |
| MCL reconstruction graft if MCL is irreparable | Achilles allograft with or without bone graft<br>Hamstring allograft<br>Tendon strippers if hamstring autograft preferred |
| Second reinforced bioinductive collagen scaffold if MCL is irreparable | BioBrace (ConMed) in 5 × 250 mm ligamentous form |

ACL, anterior cruciate ligament; BTB, bone–patellar tendon–bone; MCL, medial collateral ligament; N/A, not available.

stress stable at 0° and 30° of flexion. A well-padded high-thigh tourniquet is placed on the operative leg, which is then placed in the Acufex leg-holder (Smith & Nephew, London, UK), with the contralateral leg in a well-leg holder positioned in hip and knee flexion and hip abduction to clear room for intraoperative fluoroscopy.

Depending on institutional policies, number of assistants, and surgeon preference, graft preparation can be performed before the above positioning or concurrently. Given the MLKI, the senior author's preference is to have the graft preparation completed before exsanguination of the limb to limit tourniquet time.

**Table 2.** Advantages and Disadvantages of Proposed Technique

| |
|---|
| Advantages |
| Minimal increase in graft preparation time |
| Ability to supplement mechanical strength of allograft at time zero |
| Ability to increase graft diameter when necessary with an off-the-shelf implant |
| Decreased surgical morbidity of an additional soft-tissue autograft harvest |
| The potential for biologic remodeling of the bioinductive collagen reinforced scaffold augmentation to avoid late stress-shielding of static augmentation implants |
| Disadvantages |
| Limited long-term clinical or radiologic outcomes |
| Cost |

## Graft Preparation

The described operative technique was performed with a BTB allograft, but the graft augmentation can be performed on soft tissue (quadriceps or hamstring tendon) allograft or autograft, of which the video technique also demonstrates quadriceps allograft augmentation with BioBrace. With a BTB allograft, the soft tissue patellar tendon component of the graft is often smaller in diameter than the bone blocks, and with soft tissue hamstring grafts the available sizes can be less than 9 mm. In these cases the BioBrace is used to augment the soft tissue component of the allograft.

The senior author's preferred technique for quadriceps allograft preparation is as follows. If less than the surgeon's preferred size or concerns remain over allograft integrity, the ligamentous 5 × 250 mm bioinductive scaffold can be used to augment the graft (Fig 1A). For quadriceps grafts the senior author prefers 65 to 70 mm of graft length to avoid inadequate graft-tunnel interface. The BioBrace is overlaid over the graft from end-to-end and trimmed to match the graft length (Fig 1B). One end of the quadriceps graft and overlaid scaffold is then clamped using the FiberTag (Arthrex, Naples, FL) clamp, and the FiberTag suture implant is then passed through both, taking care to lay the FiberTag implant on the opposite side of the graft of the BioBrace scaffold, which allows the graft to tubularize optimally as well as provide a "sandwich"

**Table 3.** Pearls and Pitfalls of the Proposed Technique

| |
|---|
| Pearls, Pearls |
| Practice graft preparation on cadaver ligament prior to patient use, particularly soft tissue graft augmentation using the FiberTag (Arthrex, Naples, FL) implant |
| For soft tissue augmentation using the FiberTag, lay the BioBrace (ConMed, New Haven, CT) on the opposite side of the graft as the suture augmentation of the FiberTag implant to optimize compressive structural integrity and graft tubularization |
| For BTB allograft augmentation, secure only the ends of the BioBrace to the soft tissue portion of the graft, to avoid (1) bone tunnel-soft tissue diameter mismatch and (2) over-tethering the length of the soft tissue portion of the graft with multiple sutures |
| Use of a small-bore, non-cutting needle (i.e., CT-2) and 2-0 heavy, braided, non-absorbable suture for optimal strength while minimizing suture/needle cutout of the scaffold during suturing of BioBrace to BTB allograft |
| If surgical center and assistants allow, begin allograft preparation before surgical procedure to decrease surgical time |
| Pitfalls |
| Not having all available assistants, instruments, or implants ready at beginning of procedure |
| Relying solely on BioBrace for graft, because it was developed and indicated solely for ligament, tendon, or graft augmentation |
| Augmenting an already large-diameter graft, because the scaffold adds approximately 1-2 mm of graft width, which could lead to notch impingement or a risk for postoperative cyclops lesions |
| Failing to ensure flush, tapered ends of the scaffold when augmenting soft-tissue grafts, or failing to ensure a smooth transition from bone block to soft tissue–augmented graft when augmenting a bone–patellar tendon–bone allograft |
| Sizing the allograft and using corresponding tunnel reamers before augmenting with the bioinductive scaffold will make graft passage difficult if not impossible |

augment (Fig 1 C and D). This is then repeated for the tibial end of the quadriceps graft, with the option for a variety of cortical fixation methods on the tibial side. The final graft construct is then remeasured and placed on tension until ready for implantation (Fig 1E).

Graft preparation for the BTB allograft involves standard preparation, tubularizing the bone plugs, sizing the femoral side to 10 × 20 mm, and the tibial side to 10 × 25 mm. A single 2.0 mm drill hole is made in the femoral bone plug and a no. 2 nonabsorbable suture is passed, and two 2.0 mm drill holes are made in the tibial bone plug, and 2 sutures are passed. At this point the ligamentous form (5 × 250 mm) of BioBrace (Fig 2A) is overlaid over the soft tissue component of the BTB allograft, aligning the edge with the end of the femoral bone plug. This is then sutured in place with figure-of-eight 2-0 nonabsorbable braided sutures to secure both corners. Care should be taken to pass the needle through the scaffold at least 2 mm from its border, because although it is highly structural, passing the needle too close to the edge could lead to suture cutout. A second key point is to use a small-bore, non-cutting needle such as a CT-2 to avoid scaffold cutout (Fig 2 B-D). Twenty millimeters is then marked on the graft from the end of the femoral bone plug. This is repeated over the tibial end (Fig 2E). A remnant scaffold is then cut and can be used again if needed (i.e., if augmenting the MCL repair or reconstruction).

### ACL Reconstruction

A sterile esmarch bandage is applied and the limb is exsanguinated to 250 mm Hg. A diagnostic scope is performed with a 30° 4 mm arthroscope, demonstrating a complete ACL rupture, which is debrided followed by a notchplasty with a 5.5 mm bone cutter.

For the femoral tunnel the knee is flexed to 95°, and with the anteromedial portal, a 7 mm over-the-top flexible guide (Stryker Versatomic, Kalamazoo, MI) is used to drill a flexible beath pin and over-reamed with a 10 mm flexible reamer to 22 mm, passing a looped suture for later graft passage. Next with the anteromedial portal, a tibial guide set at 60° is used to place a guidepin for a cannulated 10 mm fully fluted reamer. Bony debris is removed, and the passing suture is pulled through the tibial tunnel. The BTB allograft with accompanying reinforced, bioinductive collagen scaffold is then passed into the femoral socket, taking care to bring the edge of the BioBrace to the femoral aperture (Fig 3A). Femoral fixation is achieved with a 7 × 23 mm biocomposite (Mitek Milagro Advance, Depuy Synthes, Warsaw, IN) interference screw (Fig 3B). The graft is then cycled to reduce creep and fully extended under arthroscopic visualization to carefully ensure no graft-roof impingement. A 9 × 30 mm biocomposite Milagro interference screw is then placed for tibial fixation (Fig 3C) with repeat arthroscopic visualization of range of motion demonstrating no impingement and excellent graft and scaffold tension (Fig 4 A and B). At this point open collateral ligament repair or reconstruction can be performed.

### Postoperative Protocol

After surgery, the patient's extremity is placed in a hinged knee brace and allowed to be weightbearing as tolerated while locked in extension. The brace is set from 0° to 90°, and the patient is encouraged to perform straight leg raises, knee extension, and flexion exercises daily. Aspirin 81 mg is given twice daily for deep vein thrombosis prophylaxis for 1 month without antibiotic prophylaxis. The patient returns in 1 week for suture removal and initiation of formal physical therapy, with advancement to full ROM at 6 weeks.

## Discussion

This Technical Note describes an ACL reconstruction with a bio-inductive, reinforced, collagen scaffold-augmented BTB allograft in the setting of a MLKI,

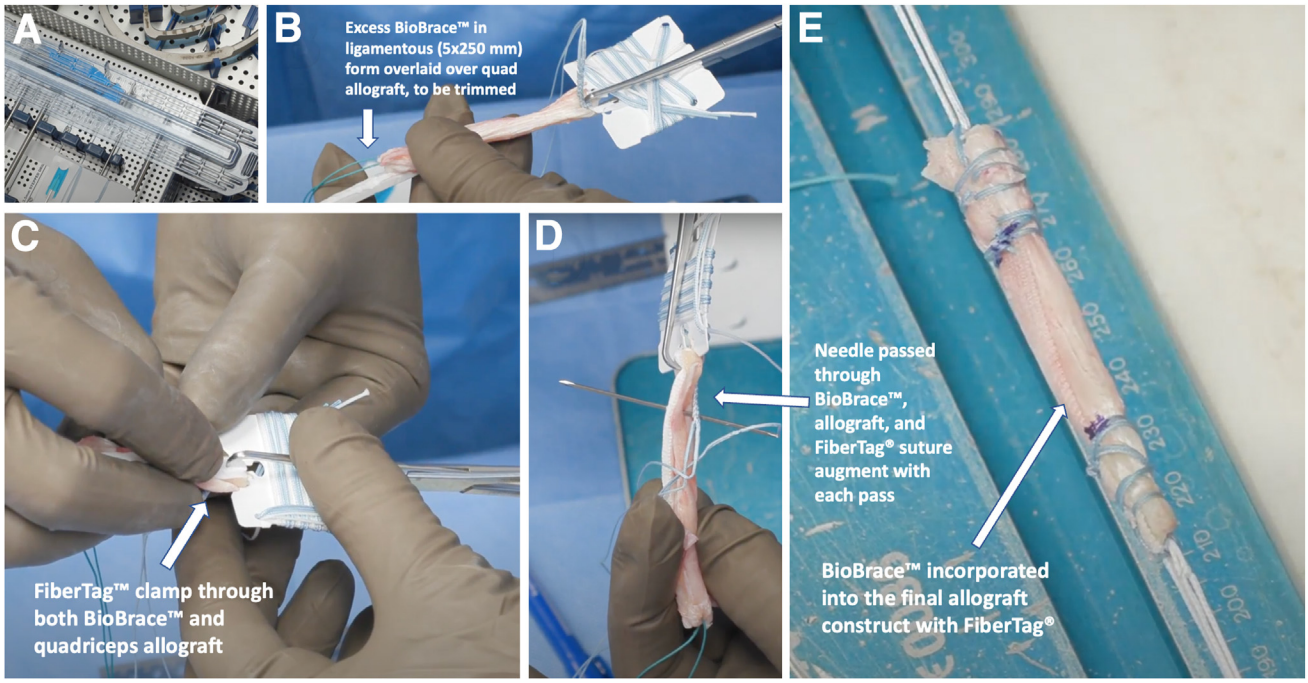


**Fig 1.** (A) The BioBrace (ConMed, New Haven, CT) in ligamentous 5 × 250 mm form. (B-D) Modified preparation of quadriceps allograft using the FiberTag (Arthrex, Naples, FL) implant, with care taken to lay the suture tape on the opposite side as the BioBrace for maximal graft tubularization and reinforcement. The sutures are then passed through both the suture tape and scaffold augments in the same steps as with the FiberTag alone. (E) Final quadriceps allograft prepped and augmented with the FiberTag and BioBrace, for a diameter of 10.5 and 9.5 mm, 70 mm in length, with markings 20 mm from the ends. Each end is attached to a tensionable cortical button implant.

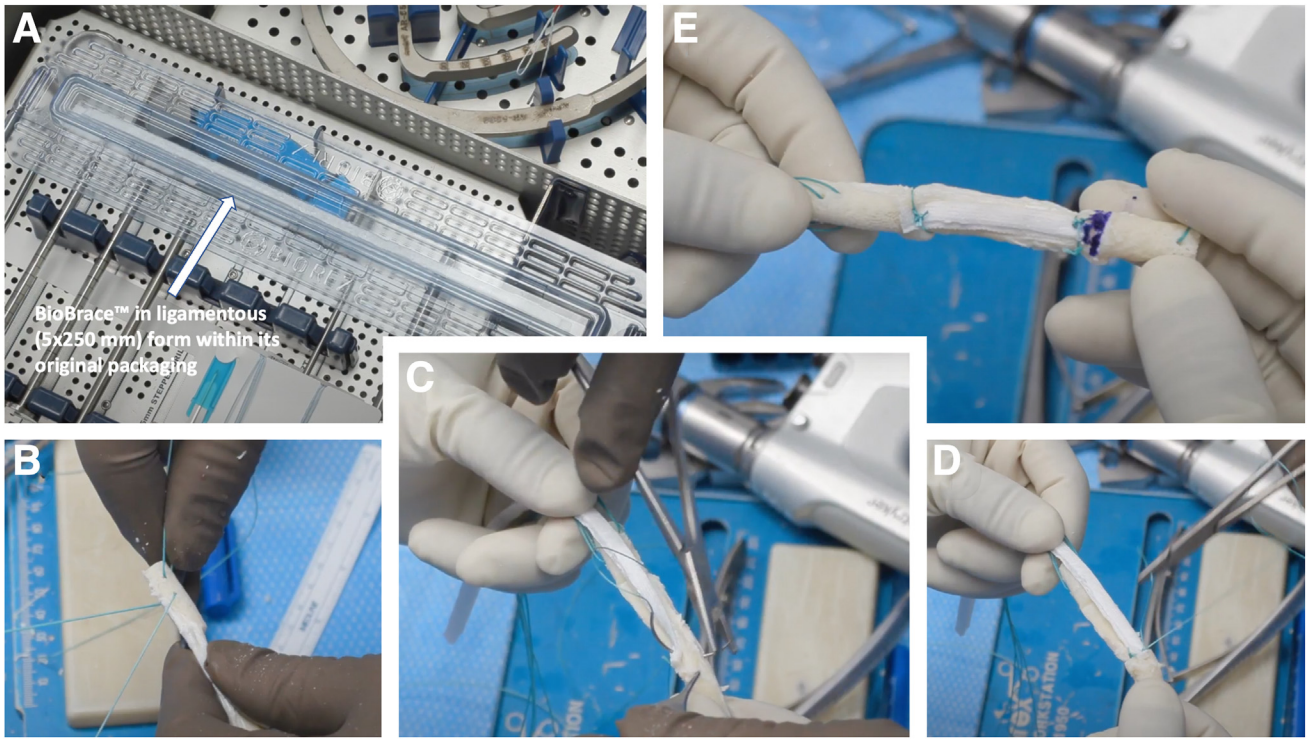


**Fig 2.** (A) The BioBrace (ConMed, New Haven, CT) in ligamentous 5 × 250 mm form. (B) Standard bone—patellar tendon—bone (BTB) allograft bone block preparation per surgeon preference. (C, D) Use of a small-bore, non-cutting needle (i.e., CT-2) and 2-0 high-strength, braided, nonabsorbable suture to secure the ends of the BioBrace to the soft tissue portion of the BTB allograft in figure-of-8 fashion. (E) Final BTB allograft augmented with BioBrace, with smooth transitions from bone block to soft tissue-augmented segment. Marking pen is used to mark 20 mm from the end of the femoral bone plug.

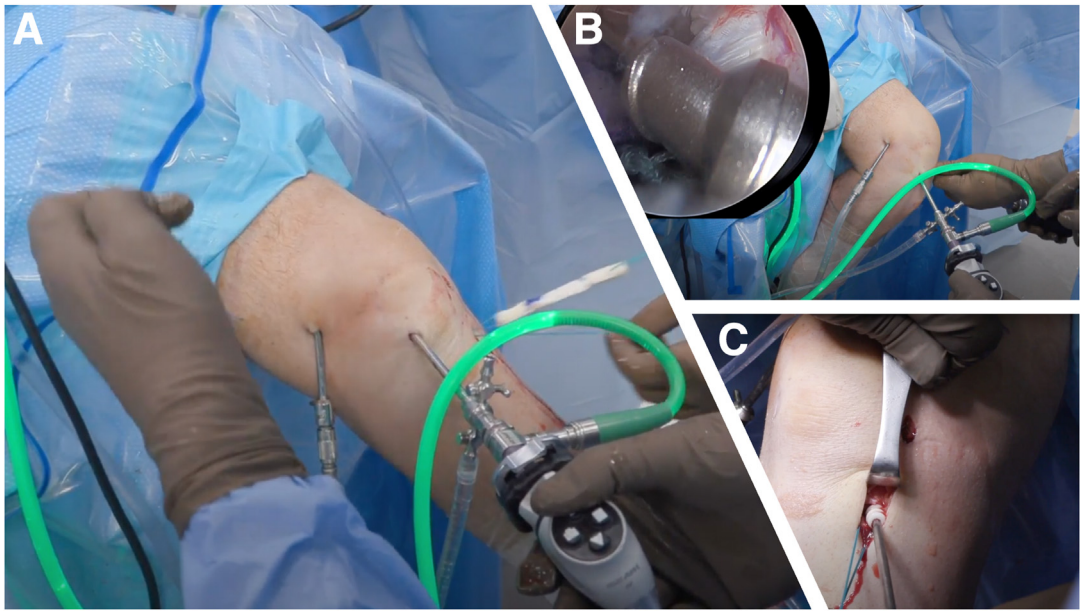


**Fig 3.** (A) Standard graft passage of the augmented BTB allograft through the tibial tunnel. (B) Standard anteromedial portal interference screw fixation of the femoral bone plug while viewing from the anterolateral portal in a right knee. (C) Standard tibial-sided interference screw fixation of the tibial bone plug (after graft cycling).

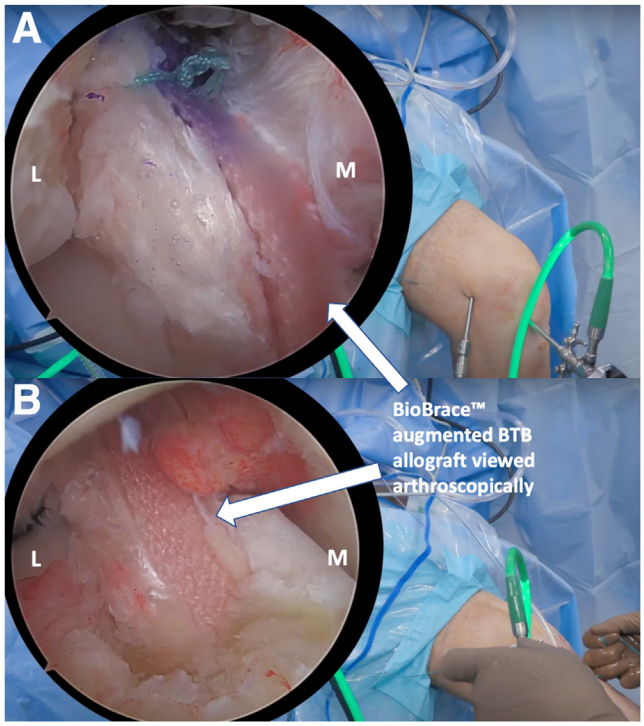


**Fig 4.** Arthroscopic evaluation of the right knee from the anterolateral portal (with fluid) of the passed bone–patellar tendon–bone allograft augmented with BioBrace (ConMed, New Haven, CT) after femoral sided fixation, cycling the graft and ensuring no impingement at extremes of motion in (A) flexion and (B) extension. Medial and lateral in arthroscopic images are marked with "M" and L," respectively.

with special consideration for two methods of graft preparation (BTB and soft-tissue/quadriceps). The BioBrace (ConMed) has had approval from the Food and Drug Administration since 2021, with various clinical applications for tendon or ligament reinforcement in cases of poor quality tissue, insufficient tissue, or need for mechanical strength augmentation. Although the senior author has initially found it to be most helpful in ACL reconstruction augmentation, augmentation of rotator cuff repair and collateral ligament surgery have been describe in the literature.[1,2]

There is controversy over autograft versus allograft choice for ACL reconstruction in the setting of MLKI, with higher graft failure rates demonstrated in primary isolated ACL reconstruction when using allograft in younger patients or with small diameter grafts, which can often occur with soft-tissue hamstring autograft.[4,5] Even with good to excellent outcomes demonstrated using allograft in ACL reconstruction in patients aged 40 and older, augmentation using a biocomposite collagen-reinforced scaffold, adding time zero mechanical strength while providing the potential for future biologic remodeling is beneficial. In cases when hamstring autografts yield diameters less than 9 mm, the ability for an off-the-shelf augment to increase the diameter of the graft and resultant strength is needed.[3,6] An additional proposed benefit includes decreased risk for stress-shielding of the ACL graft compared to static suture-based augmentations.

Although this patient had excellent valgus stability at both 0° and 30° after the MCL repair, if any concern remains about valgus stability or tissue quality, the remnant BioBrace could be used to augment the MCL repair, with the possible advantage over static suture augmentation of biologic remodeling over time given the type I collagen and bio-resorbable poly (l-lactide) structural scaffold.[2]

## Conclusions

With our technique, we hope to present multiple graft preparation options using a bioinductive, collagen-reinforced scaffold for ACL reconstruction in the setting of a MLKI. These graft preparation techniques can be applied in primary or revision isolated ACL reconstruction procedures or in other cruciate or collateral ligament reconstructions.

## Disclosure

The authors report the following potential conflicts of interest or sources of funding: R.J.M. reports a consulting or advisory relationship with DePuy Mitek, Arthrex, and CONMED Corp. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

## References

1. Cheesman QT, Szukics PF, Stark M, Kramer SC, McMillan S. Arthroscopic rotator cuff repair technique using a bio-composite scaffold for tissue augmentation. *Arthrosc Tech* 2022;11:e517-e522.
2. LeVasseur MR, Uyeki CL, Garvin P, McMillan S, Arciero RA. Knee medial collateral ligament augmentation with bioinductive scaffold: surgical technique and indications. *Arthrosc Tech* 2022;11:e583-e589.
3. Carter A, Lovric V, Morberg P, et al. Characterization of a novel bio-inductive biocomposite scaffold for tendon and ligament healing. *In: Orthopaedic Research Society 2021 Annual Meeting* 2021:12-16.
4. Helito CP, da Silva AGM, Sobrado MF, Guimarães TM, Gobbi RG, Pécora JR. Small hamstring tendon graft for anterior cruciate ligament reconstruction combined with anterolateral ligament reconstruction results in the same failure rate as larger hamstring tendon graft reconstruction alone. *Arthroscopy* 2023;39:1671-1679.
5. MARS Group, Wright RW, Huston LJ, et al. Association between graft choice and 6-year outcomes of revision anterior cruciate ligament reconstruction in the MARS Cohort. *Am J Sports Med* 2021;49:2589-2598.
6. Sylvia SM, Perrone GS, Stone JA, et al. The majority of patients aged 40 and older having allograft anterior cruciate ligament reconstruction achieve a patient acceptable symptomatic state. *Arthroscopy* 2022;38:1537-1543.