

Knee Medial Collateral Ligament Augmentation With Bioinductive Scaffold: Surgical Technique and Indications



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Abstract: The medial collateral ligament (MCL) is the most commonly injured ligament of the knee; however, only a minority of cases require surgical intervention. Classically, isolated grade I and II MCL injuries are treated nonoperatively whereas isolated grade III injuries may be treated with surgery. High-grade MCL injuries are frequently associated with concomitant knee ligamentous injuries, particularly the anterior cruciate ligament. Nonetheless, MCL repair or reconstruction is generally reserved for patients with persistent valgus instability after failed nonoperative management. Synthetic and biological implants are increasing in popularity to augment repairs and reconstructions for biomechanical reinforcement and promotion of the native healing response to hasten rehabilitation. The BioBrace (Biorez, New Haven, CT) is a bioinductive scaffold composed of highly porous type I collagen and bioresorbable poly(L-lactide) microfilaments, providing an environment for soft-tissue regeneration and mechanical support. The purpose of this article is to describe the surgical technique and relative indications for the BioBrace in knee MCL ligament repairs and reconstructions.

The medial collateral ligament (MCL) of the knee is the primary restraint to valgus load and the most frequently injured ligament of the knee.¹⁻³ Most isolated MCL tears may be treated nonoperatively, with excellent outcomes seen in grade I and II injuries.⁴⁻⁶ However, grade III injuries may heal less predictably.⁷ Moreover, the treatment of grade III injuries with concomitant ligamentous injury is

controversial, with many surgeons favoring nonoperative management and reservation of surgery for patients with continued valgus instability.⁸⁻¹¹

A variety of repair and reconstruction techniques have been described in the literature.^{12,13} Recently, interest has grown in biological and synthetic implants as augmentations in the treatment of MCL tears. The proposed benefits of these augmentations include improved biological ligamentous healing and biomechanical strength.^{8,14-16} Biological and synthetic augmentation can hasten recovery by enhancing the native healing process and by providing load sharing to the repair or reconstruction. This can be particularly important in the early postoperative period.^{8,14-16}

The BioBrace (Biorez, New Haven, CT) is a bioinductive scaffold composed of both biological and synthetic materials—a highly porous type I collagen matrix and bioresorbable poly(L-lactide) microfilaments—providing an environment for soft-tissue regeneration and mechanical support. The implant is 80% porous, having a median pore diameter of approximately 20 μm and a void volume of 4.2 cm^3/g to allow for native soft-tissue ingrowth, with strength retention up to 24 months to support full healing without the concerns of a permanent synthetic material.¹⁷

The purpose of this article is to describe the surgical technique and indications for the BioBrace in knee MCL ligament repairs and reconstructions. In this

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article, we discuss open MCL repair, mini-open MCL repair, and open MCL reconstruction with allograft, all with BioBrace augmentation.

Surgical Technique

Surgical Indications

There is significant controversy regarding the treatment of high-grade MCL tears in the anterior cruciate ligament (ACL)-injured knee.⁹⁻¹¹ The relative indications for MCL repair or reconstruction with augmentation include (1) multiligamentous knee injury involving the MCL and both the ACL and posterior cruciate ligament; (2) ACL and MCL injury in an elite athlete who has valgus laxity in extension indicating a complete medial-sided injury; and (3) chronic, isolated MCL injury with persistent grade III laxity.

In the senior author's practice (R.A.A.), most MCL tears, both isolated and in the setting of concomitant knee ligamentous injuries, are treated nonoperatively. Patients with high-grade MCL injuries are indicated for surgery following continued valgus instability after at least 6 to 8 weeks of nonoperative treatment of the MCL, particularly midsubstance tears, in which the BioBrace can be incorporated in the healing MCL tissue to augment repair. In chronic MCL injuries, the BioBrace can be added to the reconstruction to provoke a more robust healing response and offer some additional strength to the construct. Additionally, high-level athletes, in the setting of concomitant knee ligamentous injury, who require significant cutting and pivoting during sports may be indicated for MCL repair or reconstruction.

Preoperative Evaluation

Prior to surgical intervention, a complete knee ligamentous examination is performed, including the Lachman test, anterior and posterior drawer tests, pivot-shift test, and dial test, as well as varus-valgus testing at 0° and 30° of knee flexion. A standard radiographic series including anteroposterior, lateral, and Rosenberg views should be performed. Lower-extremity limb alignment films should also be obtained. Magnetic resonance imaging of the knee can be used to identify the location of the MCL injury.^{9,15} Because most MCL ruptures occur on the femoral side, the following techniques will focus on treatment of these injuries.^{9,15} However, it should be noted that these techniques may be used in a similar fashion for tibial insertion ruptures.

Patient Positioning

The following is the lead author's preferred technique. After successful induction of general anesthesia and a femoral nerve and/or posterior capsular block,

the patient is placed supine on the operating room table and a thigh tourniquet is placed. An examination of the knee under anesthesia is performed, particularly assessing for valgus laxity at 0° and 30° of flexion. The operative extremity is prepared and draped in a standard fashion for routine knee arthroscopy. The thigh is stabilized with a leg holder, and the foot of the bed can be raised or lowered depending on whether other associated pathologies need to be addressed. To aid in visualization of the medial aspect of the knee, the operative extremity is externally rotated, and the knee is placed in 20° to 30° of flexion.

Open MCL Repair

A longitudinal, anteromedial incision with full-thickness skin flaps along the course of the superficial MCL is used. This exposure will allow for inspection and treatment of other medial-sided injuries including posterior oblique ligament and posteromedial capsule injuries. The incision should extend from the anteromedial tibia, approximately 1 cm medial to the tibial tubercle, to just proximal to the medial epicondyle. The

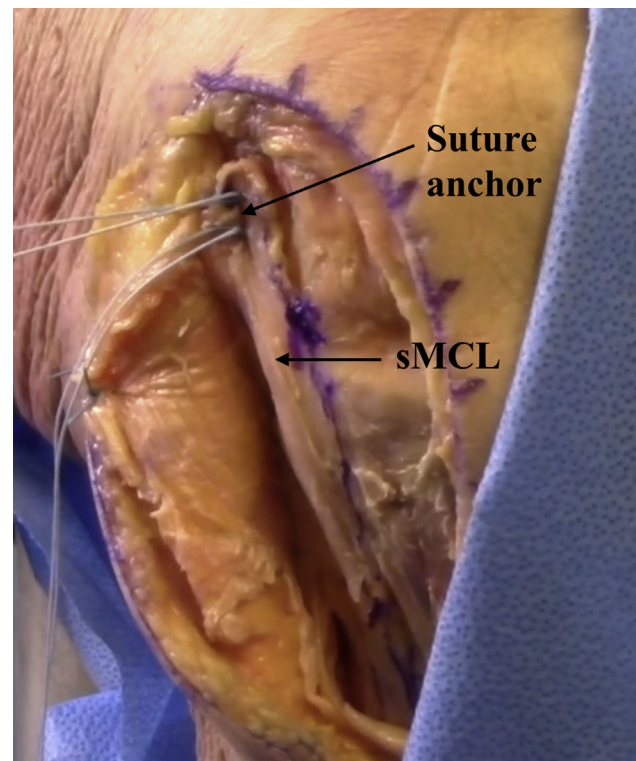
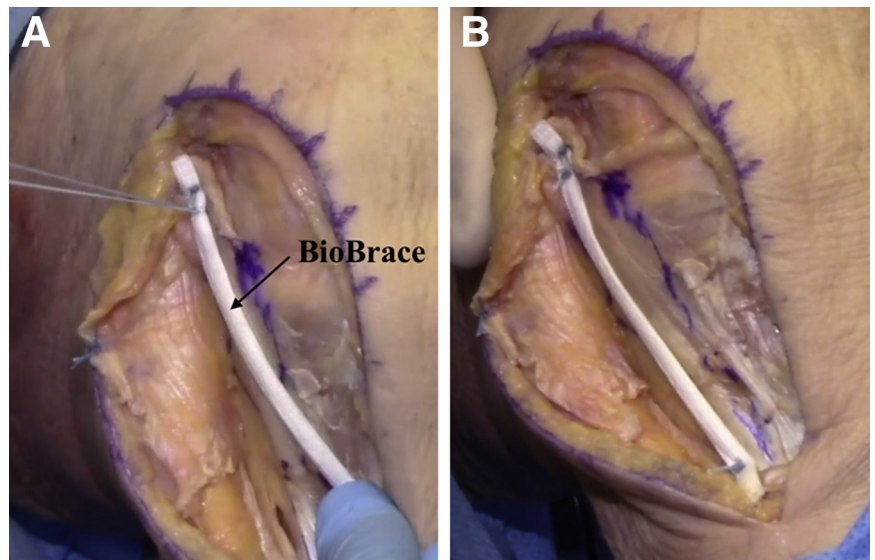


Fig 1. Two double-loaded suture anchors are placed in the femur proximal and posterior to the medial epicondyle to repair and advance the medial collateral ligament femoral-sided tear in this left knee with the patient in the supine position. The ligament is repaired using a horizontal mattress suture pattern at 30° of knee flexion and with a varus moment applied. (sMCL, superficial medial collateral ligament.)

Fig 2. (A) The BioBrace is sewn into the proximal repair using the suture tails from the previously placed suture anchors for the medial collateral ligament (MCL) repair and a free needle, shown in a left knee. (B) Two additional suture anchors are placed distally in the tibia at the superficial MCL insertion and sewn into place with the knee in 30° of flexion and varus. Additional tacking sutures can be added along the length of the BioBrace to increase its security to the underlying deep MCL and joint capsule.



sartorial fascia is incised, and the pes tendons are retracted posteriorly to expose the superficial MCL. Care is taken to prevent injury to the saphenous nerve.

In chronic injuries, the superficial MCL may be attenuated and scarred. The superficial MCL femoral origin can be elevated using a scalpel and periosteal

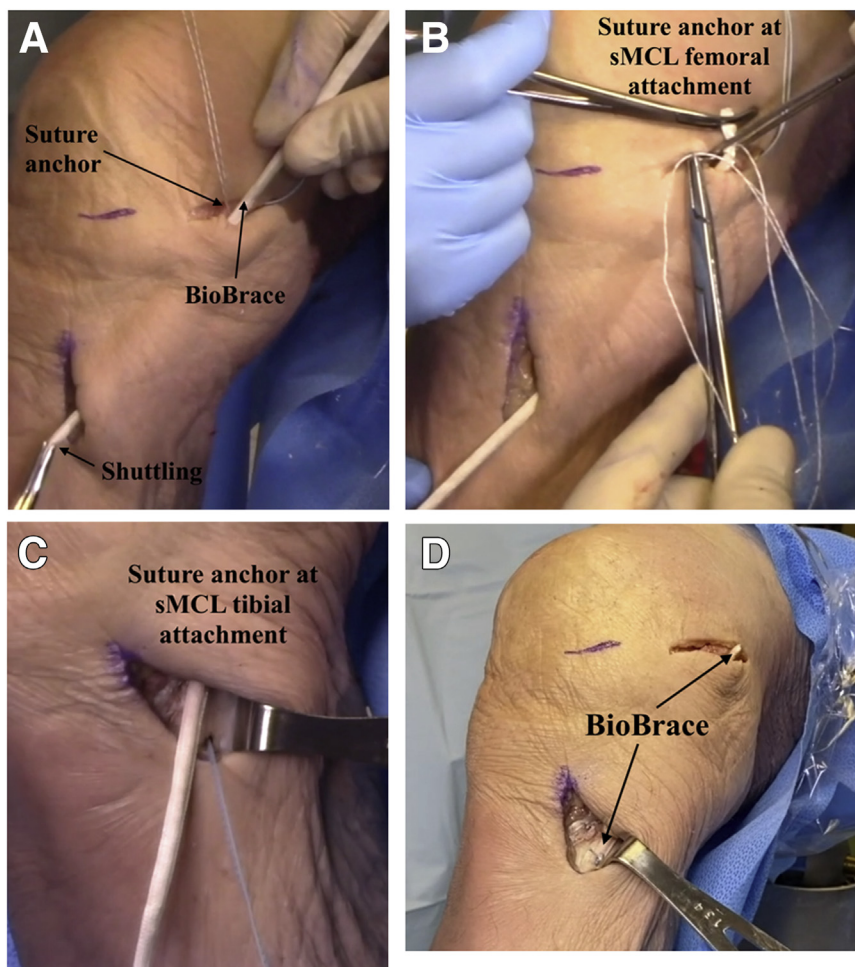


Fig 3. The mini-open medial collateral ligament repair with augmentation uses 2 smaller incisions at the location of the femoral and tibial attachments of the superficial medial collateral ligament (sMCL), shown in a right knee with the patient in the supine position. The femoral-based medial collateral ligament tear is repaired using 2 suture anchors. (A) The BioBrace is shuttled from proximal to distal using a tonsil forceps. (B) The BioBrace is sewn proximally using the anchor sutures. (C, D) The BioBrace is secured distally using 2 additional suture anchors to complete the augmentation.

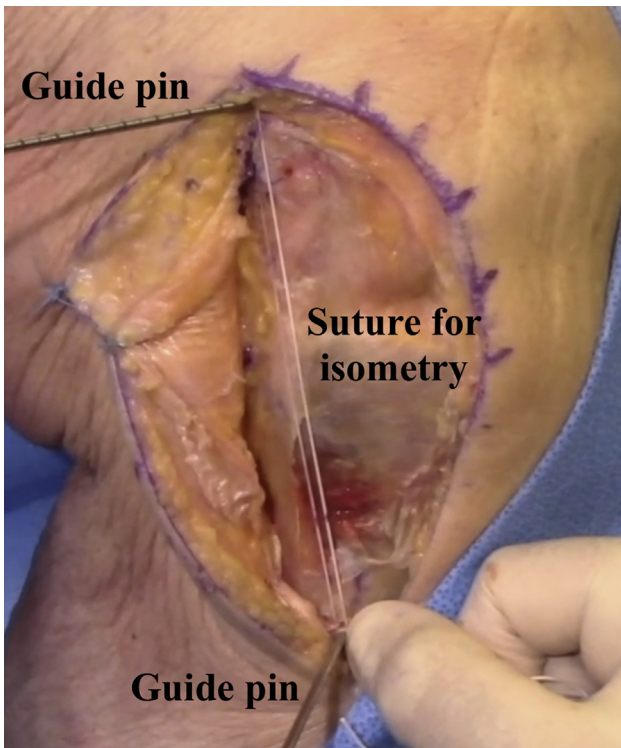


Fig 4. Medial collateral ligament reconstruction requires the surgeon to determine the isometric point of the graft. This can be executed using 2 guide pins and a suture. Isometry is obtained when the length of the suture does not change throughout the knee flexion and extension arc. A left knee is shown.

elevator. Two tagging stitches can be placed into the ligament to aid in repair and soft-tissue handling. The pes fascia distally can be opened and is useful for identifying and assessing the tibial attachment of the MCL. It is important to remember that the superficial MCL attaches 3.2 mm proximal and 4.8 mm posterior to the medial epicondyle.^{18,19} For femoral-based superficial MCL tears, 2 double-loaded suture anchors (3.0-mm Gryphon PEEK [polyether ether ketone] Suture Anchors; DePuy Mitek, Raynham, MA) with a braided, high-strength No. 2 suture (Orthocord; DePuy Mitek) are placed just proximal and posterior to the medial epicondyle for anatomic repair and advancement of the MCL (Fig 1). The anchor sites are first drilled, and the anchors are then tapped into place with a mallet. The avulsed superficial MCL is repaired with a horizontal mattress suture pattern with the knee in 30° of flexion while a varus stress is applied.

We recommend not cutting the suture tails because they can be used to secure the 5-mm BioBrace proximally. Alternatively, additional suture anchors could be placed in the femur to complete this task. By use of a free tapered needle, the BioBrace is secured proximally using 2 figure-of-8 suture patterns (Fig 2). If additional security is required, additional anchors can be used.

Next, the tibial insertion is exposed and identified. The distal end of the BioBrace can be held with a tagging suture or Alice clamp to tension the device. Two suture anchors are placed approximately 1 cm apart in the posteromedial tibia 6 cm distal to the joint line.²⁰ The BioBrace is then sutured into place in a figure-of-8 fashion with the knee in 30° of flexion and a varus knee moment. All sutures can now be cut, and any excess BioBrace can be trimmed, leaving a short tail. Finally, tacking sutures (No. 0 Vicryl; Ethicon [Johnson & Johnson], New Brunswick, NJ) can be added to secure the length of the BioBrace to the underlying deep MCL and joint capsule.

Prior to closure, the knee is evaluated for signs of valgus instability at 0° and 30° of flexion. Then, using absorbable suture, the sartorial fascia is repaired, followed by a layered skin closure.

Mini-Open MCL Repair

To treat isolated, acute MCL tears, a mini-open technique can be used for femoral- or tibial-based tears seen on preoperative magnetic resonance imaging. Two smaller incisions are made at the location of the femoral and tibial superficial MCL attachments. The sartorial fascia is similarly incised, and the hamstring tendons and saphenous nerve are retracted and protected posteriorly. Similarly to the open approach, the avulsed ligament is repaired with 2 double-loaded suture anchors. The BioBrace can be shuttled from the proximal incision to the distal incision using a tonsil forceps. The BioBrace is then sewn into place proximally using the available suture limbs from the anchors and a free needle (Fig 3). Finally, the BioBrace is secured distally using 2 double-loaded suture anchors akin to the open technique.

Open MCL Reconstruction

Chronic MCL injuries with attenuated and atrophied tissue typically require soft-tissue reconstruction. Hamstring tendons are frequently used for MCL reconstruction and augmentation.^{14,21} A 2-limbed semitendinosus allograft in conjunction with the BioBrace can be used in these instances to increase load sharing and biological incorporation of the hamstring allograft. Although hamstring autograft can be used, the senior author is reluctant to use medial hamstring autografts because of their role in dynamic valgus stability.^{22,23}

A similar exposure to the open repair technique is performed. Attention can now be directed to the open MCL reconstruction as shown in Video 1. The remaining superficial MCL may be difficult to identify owing to chronic scarring and attenuation. First, a 2.4-mm guide pin is placed at the femoral origin of the superficial MCL, located 3.2 mm proximal and 4.8 mm posterior to the medial epicondyle.^{18,19} Next, a second

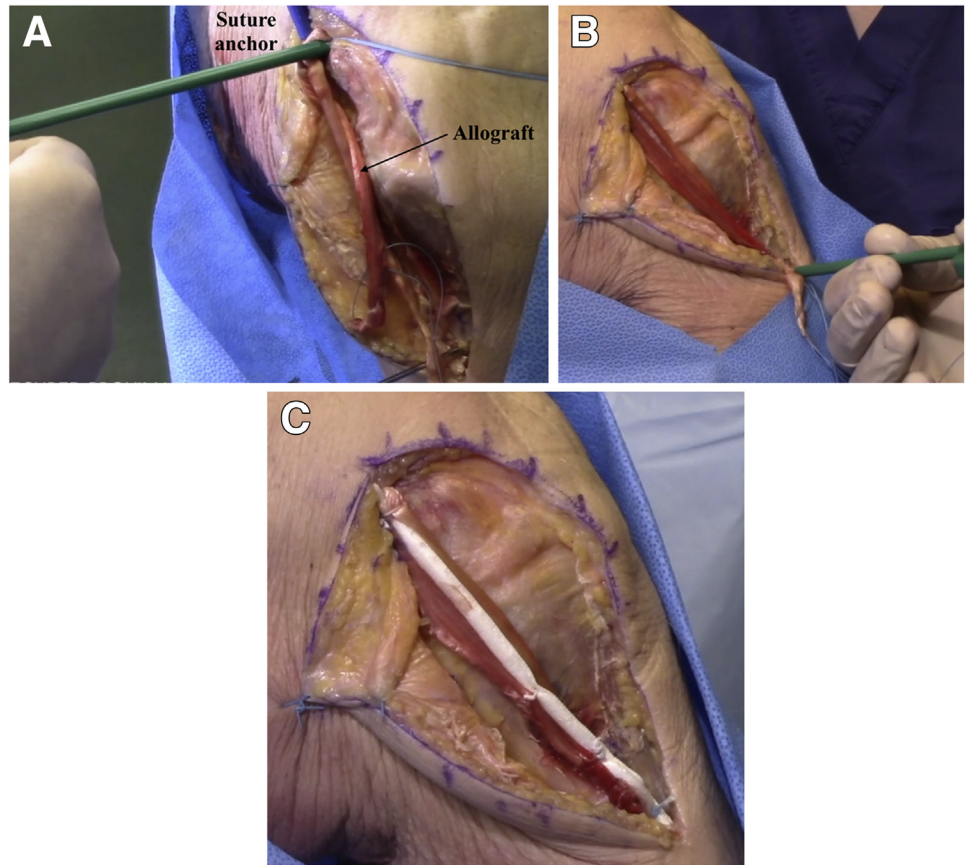


Fig 5. The medial collateral ligament reconstruction with allograft hamstring tendon is secured proximally (A) and distally (B) using SwiveLock anchors at the isometric guide pin locations. Care is taken to secure the graft with the knee in 30° of flexion and varus to limit graft laxity. (C) By use of the remaining suture limbs from the SwiveLock anchors, the BioBrace is sewn into place. A left knee is shown.

guide pin is placed at the tibial insertion located approximately 6 cm distal to the joint line and just off the edge of the posteromedial tibia. A high-tensile suture is wrapped around the 2 pins to assist in locating the isometric point. The pin locations are marked on the suture with a marking pen, and the knee is taken through a complete knee range of motion. Either pin can be adjusted until the suture markings no longer move throughout the flexion-extension arc, indicating an appropriate determination of isometry. Thereafter, these guide pin locations will mark the locations of the anchor sites (Fig 4).

The hamstring allograft is folded into 2 equal limbs, and the free ends are sutured together with a simple stitch, with care taken to ensure there is no laxity in either limb. The femoral guide pin is removed. At the same location, an anchor tunnel is drilled and tapped. By use of a 4.75-mm PEEK SwiveLock suture anchor (Arthrex, Naples, FL) double loaded with No. 2 FiberWire (Arthrex), the graft is secured proximally and hand tied into place. Next, the distal guide pin is removed and a similar SwiveLock anchor is placed for tibial insertion, with care taken to ensure that the knee is in 30° of flexion and in varus to limit graft laxity (Fig 5). Alternatively, a large tibial hole can be drilled, and the graft can be secured using an interference screw.

Finally, the BioBrace is secured over the top of the allograft tendon using the sutures from the previously placed SwiveLock anchors or additional adjacent anchors using a figure-of-8 suture (Fig 5). The allograft and BioBrace can be further approximated along the length of the reconstruction using No. 0 Vicryl suture so that they function in a cohesive manner. We recommend looping the suture around the BioBrace rather than penetrating the augmentation with a needle so as

Table 1. Advantages and Disadvantages of MCL Repair or Reconstruction With BioBrace

Advantages	
	Acute or chronic setting
	MCL repair or reconstruction
	Readily available; no need for special instruments or implants
	Easy to use
	Protects repair, allowing early ROM to prevent stiffness
	Bioinductive scaffold that incites native healing
	Spares autograft harvest; minimizes allograft use
Disadvantages	
	Application in patients still early
	Long-term outcomes not yet acquired
	PLLA portion of graft requires more prolonged time for resorption
	Cost (but very favorable compared with allograft)

MCL, medial collateral ligament; PLLA, poly(L-lactide); ROM, range of motion.

Table 2. Surgical Pearls and Pitfalls of MCL Repair or Reconstruction With BioBrace

Pearls	
Anchor the graft at the origin and insertion sites with anchors or interference screws.	
Tension the repair or reconstruction and the BioBrace with the knee at 30° of flexion and varus stress applied to prevent residual laxity.	
Once the BioBrace is sewn into the repair or reconstruction construct, perform tensioning simultaneously distally with either anchors or a screw and soft-tissue washer device.	
Place the BioBrace as close as possible to the point of isometry to avoid laxity.	
Immerse the graft in saline solution or blood, making it easier to manipulate the graft and pass sutures.	
Use tapered or cutting needles to easily pass sutures through the BioBrace into native tissue or allograft; typically, use a No. 2 ultrahigh-strength suture.	
Pitfalls	
Address other pathologies to prevent failure.	
Cut the ends closely to prevent skin irritation.	

MCL, medial collateral ligament.

to maintain uninterrupted longitudinal integrity of the device along its midsubstance.

Postoperative Rehabilitation

Postoperatively, the patient is placed in a hinged knee brace. After an isolated MCL repair or reconstruction, range of motion is restricted to 20° to 90° of flexion for the first 2 weeks. Thereafter, full range of motion in the brace to provide coronal-plane control is initiated. The patient is restricted to partial weight bearing for the first 4 weeks and then transitions to full weight bearing in the brace. The brace is discontinued at 6 to 8 weeks postoperatively.

Discussion

MCL injuries are common, and most injuries can be treated nonoperatively. However, there is controversy regarding the treatment of grade III MCL injuries, with current options including conservative care with functional rehabilitation, primary repair with or without augmentation, and reconstruction.^{21,24} In the acute setting, anatomic repair can be performed. However, in chronic cases, reconstruction may be a better option. In a systematic review, DeLong and Waterman¹² cautioned that inferior results may be seen in chronic MCL injuries that undergo primary repair. Nonetheless, when injuries are treated acutely or in a delayed fashion, satisfactory results can be seen for both repairs and reconstructions.²⁵ Moreover, owing to the abundance of techniques and heterogeneity of patient injuries, it is difficult to demonstrate superiority between repair and reconstruction. As such, in this article, we have presented our repair and reconstruction techniques with BioBrace augmentation for MCL injuries.

Biological and synthetic augmentation of ligamentous injuries is advantageous for its ability to enable early weight bearing, range of motion, and strengthening.¹⁶ Moreover, augmentation serves as a secondary stabilizer to protect the repaired or reconstructed ligament, as well as to provide tensile strength for the prevention of construct elongation.^{26,27}

An abundance of surgical techniques exist for medial knee injuries. Van der List and DiFelice¹⁶ reported their technique of primary MCL repair with internal bracing using 2 mini-open skin incisions. Lubowitz et al.¹⁵ reported a similar technique performed in an open fashion with a single longitudinal incision and suture anchors. Golden et al.⁸ reported a double-row suture repair technique with suture tape augmentation. Unfortunately, these repair techniques cannot be used to treat chronic injuries, for which reconstruction techniques are preferable. Accordingly, we have presented MCL allograft reconstruction with the BioBrace to show the utility of augmentation in the chronic setting. The BioBrace may be advantageous for its biological and synthetic composition, which can provide a scaffold for native healing, as well as supplementary tensile strength.

The innovation of synthetic and biological augmentation of soft-tissue repairs and reconstructions has become a focus in orthopaedics in recent years. The ability of these augmentations to allow for increased healing potential and reinforcement of surgically treated tendon and ligamentous injuries holds appeal for many surgeons. The BioBrace has been shown to incite a robust native healing response and the formation of regularly oriented connective tissue fibers in large-animal models.^{17,28} These characteristics may lend themselves to enhanced graft and/or repair healing incorporation. In turn, this can potentially lead to enhanced rehabilitation protocols and, ultimately, decreased failures. The advantages and disadvantages of the described technique are listed in Table 1. Important surgical pearls are listed in Table 2. We recognize that further outcome studies will be needed to better assess the efficacy of the BioBrace device.

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