Technical Note

Meniscus Allograft Transplantation Augmented With Autologous Bone Marrow Aspirate Concentrate

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Abstract: Meniscus allograft transplantation (MAT) has been shown to be a feasible surgical option for younger patients, below 50 years of age who have meniscal insufficiency and have failed conservative treatment measures. In this technical note, we describe a procedure of harvesting and injecting bone marrow aspirate concentrate in a meniscus allograft during a MAT procedure, which may allow for longer lasting transplants and improve patient outcomes. In this technical note, bone marrow aspirate concentrate is harvested arthroscopically from the intercondylar notch at the surgical site, which prevents additional donor site morbidity, as seen with harvesting from other locations, such as the iliac crest. This also reduces operating time, since harvesting from the iliac crest requires different patient positioning and usually additional anesthesia. The authors of this surgical technique believe that biological augmentation during MATs will assist surgeons in maximizing graft survivorship and, ultimately, lead to better patient outcomes.

Introduction

The menisci function to increase joint stability, distribute load/improve shock absorption, and are chondroprotective. Meniscus allograft transplantation (MAT) has been shown to be a feasible surgical option for patients who present with meniscal discontinuity or loss that is too severe to be fixed with a typical meniscal repair.[1] Loss of meniscal function can stem from patients experiencing unsalvageable tears, commonly occurring in the avascular region, or from previous repair failures.[2-4] Deficiency in meniscal tissue can predispose patients to developing osteoarthritis (OA) due to changes in arthrokinematics and increased tibiofemoral contact forces.[5] MATs are a viable treatment option for younger patients, below 50 years of age,[1,6-9] who have meniscal insufficiency and have failed conservative treatment measures.[10,11] MATs can help prevent premature chondral thinning by restoring joint stability and function, therefore, reducing the risk for the development and progression of knee OA.[12] However, MAT failure rates of up to 30% have been reported.[13] Failure rates may be higher in patients with comorbidities, such as existing OA, infection, biocompatibility, and allograft fixation techniques (e.g., bone plugs used as anchorage).[14-16]

Newer treatment methods for patients with meniscal insufficiency include the use of scaffolds[16-21] and biological augmentation to encourage tissue growth.[22,23] Recently, there has been an increased interest in evaluating biological augmentation procedures, such as the use of bone marrow aspirate concentrate (BMAC) because of its minimal donor site morbidity,[24] significant cellular growth factors,[23] and relative ease of harvest.[25] The authors of this technical note describe a procedure of harvesting and injecting BMAC in a meniscus allograft during a MAT procedure, which may allow for longer lasting transplants and improve patient outcomes.

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The authors report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received October 11, 2022; revised February 2, 2023; accepted February 15, 2023.

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2212-6287/221342
https://doi.org/10.1016/j.eats.2023.02.043

Surgical Technique

Indications for Meniscus Transplant

Indications for MAT surgery are young (age <50),[8,11] active patients with a history of one or more failed meniscectomies or meniscus repair procedures resulting

Table 1. Summary of Procedural Steps: Main Technical Points

Clinical examination for diagnosis, preoperative radiographs, and magnetic resonance imaging, looking at meniscus and osteochondral integrity
Meniscal allograft is prepared in standard fashion with sutures placed in the anterior and posterior roots.
Arthroscopic harvesting of bone marrow aspirate concentrate (BMAC) using cannulated trocar in the central aspect of the intercondylar notch
Infiltration of 2-10 cc of BMAC using tuberculin needle Luer-Lok in a syringe is inserted into the meniscus allograft transplant.
Creation of small arthrotomy from enlarging arthroscopic portals
Insertion of graft by shuttling sutures through the arthrotomy using the inside-out technique to secure and complete fixation of the meniscus graft
Arthroscopic assessment of fixation making sure sizing and anatomic positioning is correct.

Table 2. Pearls and Pitfalls

Pearls	Pitfalls
Because of the density of the meniscal allograft tissue, a significant amount of pressure is required to inject bone marrow aspirate concentrate (BMAC) into the tissue. A Luer-Lok is used to avoid accidental needle removal caused be the excessive pressure.	An additional accessory arthroscopic portal in the central patella is required to view the intercondylar notch and harvest the BMAC, which causes additional, yet minimal, morbidity.

in symptomatic meniscal deficiency or damage. Additionally, patients must be experiencing continuous, unchanging pain over an extended period that disrupts the performance of daily activities to justify further surgical intervention. Contraindications for this surgery are advanced OA, obesity, skeletal immaturity, synovial disease, and radiographic signs of flattening of the femoral condyle.[8,11] All conservative management strategies, including the use of an unloader brace, modified physical activity, and rehabilitative therapy should also be attempted before MAT surgery is considered. Current knee status can be confirmed via MRI of the knee, which may show early degenerative changes for OA. Only after all indications are reviewed by the surgeon can a discussion of further treatment options, including a MAT procedure, take place. The risks and benefits of undergoing MAT should be discussed, and expectations should be carefully managed by the operating surgeon. The following paragraphs outline the specifications for this surgical technique (Video 1). Additional information regarding the technique's advantages and disadvantages can be found in Tables 1-3.

Patient Positioning

The patient is placed under general anesthesia and positioned in a standard knee arthroscopy set up. The patient is placed in a supine position with their nonoperative knee in a padded leg holder, which is abducted and flexed away from the operative field. A well-padded tourniquet is placed on the proximal thigh of the operative extremity. The patient is placed into a circumferential pattern leg holder, and the end of the bed is flexed downward to expose the surgical knee 360° for surgery exposure. Lastly, the operative extremity is prepped and draped into the sterile field in standard fashion.

Preparation of Meniscus Allograft

The meniscal allograft is thawed and prepared on the back table in standard fashion with heavy nonabsorbable reduction sutures placed in the anterior and posterior roots (Fig 1). The tibial plateau of the meniscal allograft is cut into a small block with retention of the anterior and posterior meniscal attachments. A hand-held saw is then used to cut a 7- to 8-mm-width bone block around the meniscal attachment. This is ultimately compressed down to a size 6-mm bone dowel in which a 2.0 or 4.0 drill bit is placed in the central aspect of the anterior and posterior roots to allow for suture passage into the meniscus and through the bone dowel.

While the meniscus allograft is prepared for transplant, another member of the surgical team debrides the native, deficient meniscus. Once the entire meniscus is removed, the anterior fat pad is debrided arthroscopically under direct visualization via the

Table 3. Advantages and Disadvantages

Advantages	Disadvantages
Harvesting and preparation of bone marrow aspirate concentrate (BMAC) are simple and do not significantly lengthen operating time.	Additional costs of BMAC harvesting equipment and preparation systems
BMAC is harvested autologously, so there is minimal risk of immune reaction.	Uncertainty of the concentration of mesenchymal stem cells in the harvested BMAC
May modulate macrophage differentiation and thus delay the development of osteoarthritis	Unclear benefit due to lack of clinical data

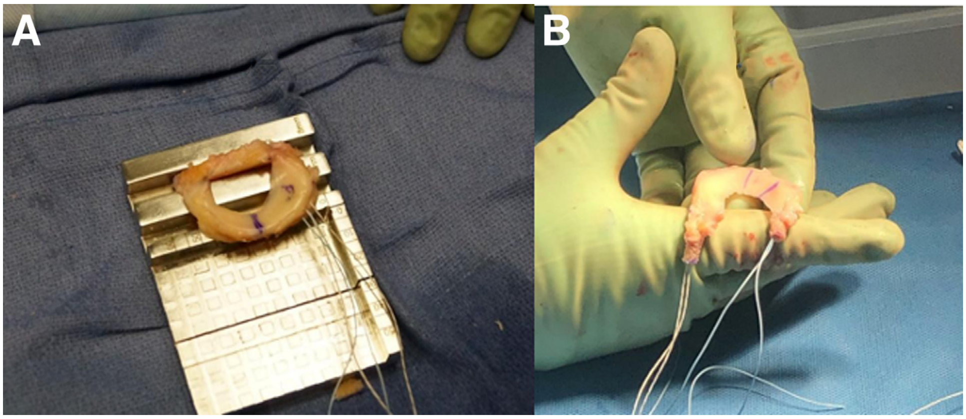

Fig 1. This is a figure depicting the comparison of two meniscal allograft transplant preparation techniques, including the meniscus allograft transplantation (MAT) slot technique and the MAT suture technique. (A) A medial meniscus allograft is being prepared with a bone block and residual attachments of both the anterior and posterior horns used for the MAT slot technique. (B) A lateral meniscus allograft is being prepared with bone plugs at the anterior and posterior horns used for the MAT suture technique.

lateral and medial portals. A threaded guide pin is placed within the posterior aspect of the operative knee, directly into the residual footprint of the posterior horn of the meniscus over which a 6-mm reamer is used to pass and collect sutures using an anterior cannula. This is repeated for the anterior horn attachment, so that the bone blocks can easily be placed into the tibial plateau. A passing stitch is made in each tunnel of the anterior and posterior horns of the graft for passage of the sutures. After, a minimal incision is made over the posterior aspect of the knee centering over the joint line before sharply dissecting the posterior capsule of the knee, exposing the joint. A curved suture passer is then used to pass stitches during the meniscal implantation phase.

Fig 2. From a frontal view, bone marrow aspirate is harvested arthroscopically from the central aspect of the intercondylar notch with assistance of a lateral viewing portal of the surgical limb using a trocar treated with heparin. The bone marrow aspirate is collected in a sterile syringe that is prefilled with anticoagulant citrate dextrose solution A to prevent clotting.

Harvesting of BMAC and Meniscal Injection of BMAC

Bone marrow is aspirated arthroscopically from the central aspect of the intercondylar notch using a non-fenestrated trocar pretreated with heparin (Arthrex, Naples, FL) (Fig 2). During this time, the tourniquet is not inflated, so that approximately 30-60 cc of bone marrow aspirate, depending on patient-specific factors, can be harvested by pulling back on the syringe with maximum suction for 60 seconds. The bone marrow is collected in sterile syringes prefilled with ACDA (anticoagulant citrate dextrose Solution A) to prevent clotting. The harvested bone marrow aspirate is spun down using the Angel system (Arthrex) using the 15% hematocrit protocol for 25 minutes. The MAT is then infiltrated with a total of 2-10 cc of the BMAC with a tuberculin needle Luer-Lok into a syringe (Fig 3). Approximately 0.5 cc of BMAC is injected into multiple locations along the periphery of the meniscus, ~2-4 mm apart (Fig 4). Any residual BMAC can also be injected into the central region of the allograft following a similar spacing pattern. The meniscus transplant is then briefly soaked in the remainder of the BMAC solution mixed with sterile saline (Fig 5) while final preparations are made for graft insertion.

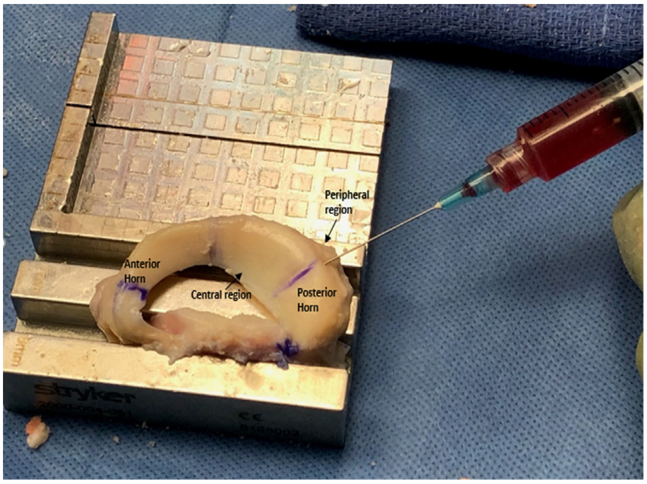

Fig 3. In a superior view, a fully thawed medial meniscus with residual attachments and cut bone block is prepared and measured to fit into a 7-mm-wide tunnel on the graft processing block. Using the syringe containing the harvested bone marrow aspirate concentrate (BMAC), with a Luer-Lok tuberculin needle, 0.5 cc of the total 4 cc of BMAC is slowly infiltrated into the posterior horn of the medial meniscus allograft.

Fig 4. Viewing from the medial side, a medial meniscus allograft that has been infiltrated with bone marrow aspirate concentrate can be observed. The injections are placed along the peripheral circumference of the medial meniscus with ~4-mm spacing patterns between each injection.

Graft Insertion

The meniscus allograft is brought to the operative knee where arthroscopic portals are enlarged to create a small arthrotomy. The sutures placed in the anterior and posterior horn are shuttled through the arthrotomy using the previously prepped passing sutures to provide provisional fixation of the meniscus (Fig 6). The fixation is then checked arthroscopically to ensure the sizing is appropriate and that the transplant is reduced in an anatomic position. The posterior horn sutures are tied outside the posterior capsule to set the tension on the meniscal graft. One horizontal mattress stitch is placed in the posterior horn of the meniscus using an inside-out technique. This inside-out technique is also combined with the usage of 5 more horizontal and vertical mattress sutures to pass through the body of the meniscus. Next, two outside-in sutures are placed through the anterior horn of the meniscus and tied over the anterior capsule using a spinal needle and a PDS suture. The anterior and posterior root sutures are tied over a button on the anterior aspect of the tibia completing fixation of the meniscal graft.

Once the transplant procedure is complete, the knee is extensively irrigated, and a final examination of the fixation, and range of motion is performed. Wound closure is completed in standard fashion with closure of the anterior and lateral arthrotomies using size 0 and 2-0 Vicryl sutures; 2-0 monocryl sutures are used during closure of the skin incision, while prolene is placed along the skin line. A dry sterile dressing is positioned on the knee, and the incisions are all infiltrated with Marcaine with epinephrine. The operative knee is then wrapped in a dressing with the integration of a cryotherapy device and is placed into a hinged knee brace locked in extension. Postoperatively, the hinged knee brace is locked in terminal extension and worn for 4 weeks, allowing for patients to weight bear as tolerated. The expectation after this surgery is for patients to return to all activities, as tolerated, at ~6 months postsurgery.

Discussion

The MAT procedure has been shown to alleviate knee pain and improve physical function in patients with meniscus insufficiency and prevent younger patients from developing chondrosis of the tibiofemoral joint.[26-30] This technique describes biological augmentation of a MAT procedure in an effort to prolong the survivorship of these transplants and improve patient outcomes over time. Undergoing MAT with BMAC augmentation may enhance healing[13] due to the presence of growth factors[5,23,25,31] within the BMAC that is implanted into the allograft. A significant amount of pressure is required to inject the BMAC into the allograft, due to the density of the meniscal allograft tissue. Care should be taken when injecting the BMAC into the allograft. In this scenario, a Luer-Lok is used to avoid accidental needle removal caused by excess pressure.

The influence of BMAC on clinical outcomes is currently unknown. However, the addition of BMAC into the transplant allograft allows for an increased amount of healing as the biologic environment is improved.[25] This may help to modulate macrophage differentiation and, thus, delay the development of osteoarthritis. In the technique above, BMAC is harvested arthroscopically from the intercondylar notch at

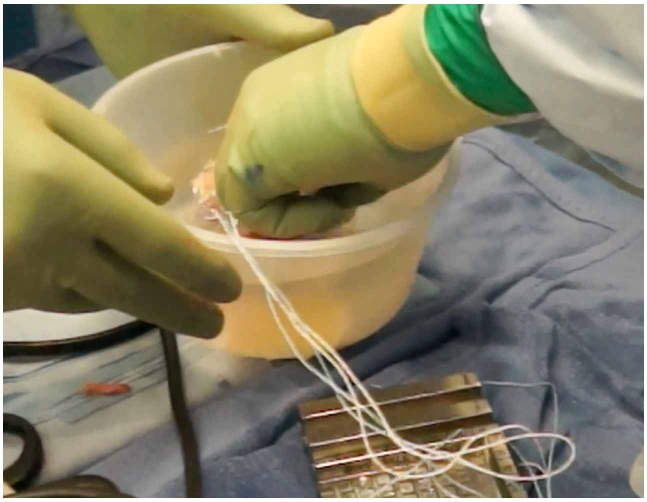

Fig 5. Following injection of the bone marrow aspirate concentrate (BMAC) into the allograft, the medial meniscus allograft is then briefly soaked in the remainder of BMAC mixed with a warm saline solution in a sterile container to thaw out the graft and prevent it from drying out.

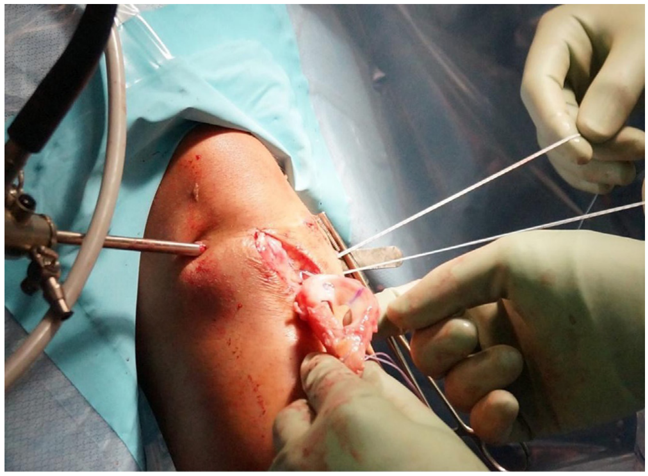

Fig 6. From a superior medial view, a medial compartment arthrotomy is made to pass the meniscus allograft. During the medial compartment arthrotomy the medial collateral ligament capsule is protected using a shovel meniscus boom and sutures are passed using a straight needle passing system with #2 FiberWires (Arthrex, Naples, FL).

the surgical site.[24,32] This harvest and preparation procedures are simple and do not significantly lengthen the operating time. While this technique requires an additional accessory arthroscopic portal in the central patella to view the intercondylar notch and harvest the BMAC, it reduces the need for additional donor site morbidity, as seen with harvesting from other locations, such as the iliac crest. This also reduces operating time, since harvesting from the iliac crest requires different patient positioning and usually additional anesthesia.[31] Further because the BMAC is harvested autologously, there is minimal risk of immune reaction. The authors of this surgical technique believe that biological augmentation during MATs will assist surgeons in maximizing graft survivorship and ultimately lead to better patient outcomes. Future work should evaluate the clinical implications and outcomes of BMAC injected into the meniscal allograft technique to support continued use and integration into surgical practice.

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