# Allograft Meniscus Transplantation

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**Abstract:** Menisci function to manage load transmission, provide secondary mechanical stability as well as nutrition, and lubricate the joint. Meniscus transplantation techniques continue to evolve and include: free soft tissue allograft implantation; separate anterior and posterior bone plugs; and bone bridges including key hole, trough, dovetail, and bridge-in-slot variations. The senior author's preference is for the bridge-in-slot technique for lateral and medial menisci, owing to its simplicity and secure bony fixation, flexibility in allowing concomitant procedures as osteotomy and ligament reconstruction, and the ability to maintain the native anterior and posterior meniscal horn attachments. Meniscal allograft transplantation yields fair to excellent results in almost 85% of patients. Patients demonstrate significant decrease in pain, as well as an increase in activity. Long-term success is encouraging in well-selected patients but is unknown whether transplantation is protective against the progression of degenerative changes.

**Key Words:** meniscus transplantation, meniscal allografts, meniscus

(*Sports Med Arthrosc Rev* 2012;20:106–114)

Over the last few decades, physicians' understanding of meniscal function, as well as the management of meniscal lesions has continued to evolve. Meniscal tears have historically been treated primarily with meniscal excision, but deficiency of the meniscus has been known to alter the biological and biomechanical environment of the knee. The degree of injury and degeneration in the tibiofemoral joint has been shown to be directly proportional to the amount of meniscus removed.[1] Resection of the meniscus has been shown to alter the contact mechanics in the knee.[2] The resulting degenerative change in the involved compartment has prompted a movement away from meniscus removal and toward preservation. Partial meniscectomy and meniscus repair procedures have become the standard of care to preserve meniscal function.[3–7] Patients with severe meniscal pathology may not be candidates for a partial meniscectomy. These patients may become a candidate for meniscal allograft transplantation provided that they have symptomatic meniscal deficiency.

Meniscus transplantation techniques continue to evolve and include: free soft tissue allograft implantation; separate anterior and posterior bone plugs; and bone bridges including key hole, trough, dovetail, and bridge-in-slot variations. The bone bridge is almost always used for lateral meniscus transplantation because of the close proximity between the anterior and posterior horns. The medial meniscus can be anchored with either plugs or a bridge because the anatomy of the anterior horn is variable and plugs may allow for minor modifications. The senior author's preference is for the bridge-in-slot technique for lateral and medial menisci, owing to its simplicity and secure bony fixation, flexibility in allowing concomitant procedures as osteotomy and ligament reconstruction, and the ability to maintain the native anterior and posterior meniscal horn attachments.

## MENISCAL ANATOMY AND BIOMECHANICS

Menisci function to manage load transmission, absorb shock, provide secondary mechanical stability as well as nutrition, and lubricate the joint.[8–10] Both lateral and medial menisci stabilize the tibiofemoral joint, improve joint congruency, as well as enhance rotation of the opposing articular surfaces. Load sharing is achieved by improved tibiofemoral congruency and increased joint contact area.[5]

Seventy percent of meniscal composition is water, whereas collagen type I predominantly makes up 60% to 70% of the dry weight. The high composition of water in the menisci is crucial for optimal force transmission. The menisci are semilunar-shaped fibrocartilaginous disks consisting of coarse cartilage bundles circumferentially arranged to disperse compressive loads and radially resist shear. Meniscal ultrastructure consists of 3 layers of collagen matrix that are organized circumferentially and tangentially to convert loading force into hoop stress. Radially oriented ties weave across the circumferential fibers and provide resistance to shear.[3]

Together, the menisci transmit approximately 50% of the joint load in the extended knee and 90% when flexed.[11,12] Loss of meniscus increases the load on the articular cartilage surfaces and therefore accelerates the development of degenerative changes. The possible biomechanical impact has been evaluated, as studies have shown a correlation in the loss of meniscus to an increase in contact forces.[13] Thus, a minor loss of meniscus may play a significant role in the area of contact that impacts stresses on the articular surfaces. In addition, subtotal losses ranging from 80% to 100% of meniscus are equivalent to total meniscectomies with respect to contact forces and contact areas.[2]

The medial meniscus bears 40% of the tibiofemoral load, whereas the lateral meniscus bears 70% of the load.[11] Thus, a meniscus-deficient knee on the lateral side may lead to faster onset of knee degeneration than one on the medial side.[14] Also notable is that the medial meniscus functions as a secondary restraint to knee instability. This was demonstrated by Papageorgiou and colleagues, in a cadaveric study where increased anterior tibial translation occurred subsequent to medial meniscectomy in an anterior cruciate ligament-deficient knee.[14,15]

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Disclosure: The authors declare no conflict of interests except, Dr Cole with Arthrex, Zimmer.

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## PATIENT EVALUATION

### History

Eliciting a thorough history is important as causative factors, associated injuries, and previous treatments will have an effect on the formulation of the treatment plan. Patients will often present after specific knee injuries with subsequent surgical treatments involving meniscectomy or meniscal repair. Patients usually note a period of pain relief after surgery, but this relief in some may only be temporary and over time, joint line and weight-bearing pain with activity-related swelling may occur. Recent operative reports and imaging are key components in helping to rule out arthritic changes which would otherwise contraindicate meniscal transplantation.

### Physical Examination

Examination begins with observation of the patient's stance. The patient's alignment is assessed for any varus or valgus deformities. In addition, the skin is inspected for any prior incisions that would indicate prior surgical interventions. Next, gait is tested which helps the examiner assess the presence of an antalgic limp, stability, alignment, and baseline functionality of the patient. The patient is instructed to squat, which may be limited with meniscal deficiency. The patient is then asked to lie on the examination table. Joint effusion and joint line tenderness may be present with meniscal deficiency. Range of motion is tested, which is often intact in the chronic setting, but may be limited after an acute reinjury. Crepitus and patellofemoral stability are also observed during ranging of the knee. Ligament stability is tested in all planes. A meniscal compression test, such as the McMurray test, assesses meniscal integrity however, due to its poor sensitivity, joint line tenderness was found to have a greater mean sensitivity (76%) than the McMurray test (53%). Other maneuvers include the Apley compression test, and the medial-lateral grind test.[16] The physical examination along with a thorough history should provide the examiner with an understanding of the primary pathology along with the presence or absence of concomitant injuries.

### Diagnostic Imaging

A complete set of radiographs include weight-bearing anteroposterior (AP) in full extension, weight-bearing posteroanterior in 45-degree flexion, non–weight-bearing 45-degree flexion, axial view of the patellofemoral joint, and a long leg mechanical axis view (Fig. 1). These are used to evaluate the degree of joint space narrowing, limb alignment, and secondary osteoarthritic changes caused by a prior meniscectomy. The Fairbank changes may be seen, which include formation of a ridge on the femoral condyle, joint space narrowing, and flattening of the femoral condyle.[17] Long leg cassette views are taken to evaluate the mechanical alignment. Magnetic resonance imaging (MRI) is reserved for cases that are not as well delineated. MRI may aid in assessing the extent of meniscal deficiency, status of the articular cartilage, and degree of subchondral edema in the involved compartment. However, using MRI for graft size matching often underestimates meniscus length and width. In addition to imaging, a diagnostic arthroscopy may also be useful to obtain a better understanding of the pathology in the patient's knee and would aid in proper surgical planning.[5]

## TREATMENTS

### Indications and Contraindications

Surgery should be considered for symptomatic meniscus-deficient knees only after all nonsurgical treatments have been utilized. Unloading braces, weight loss, encouragement of nonimpact activities and exercises, and pharmacologic measures are some nonsurgical treatments that have been successful in the past. When therapies fail to provide relief of symptoms or joint space narrowing occurs, meniscal transplantation should be considered. Successful meniscal transplantation depends on proper selection and screening for the ideal candidate. Typically patients are relatively young (age below 50 years) and often present with a history of prior total or subtotal functional meniscectomy with persistent pain localized to the meniscus-deficient compartment.[18] The most common indication for meniscal transplantation is in

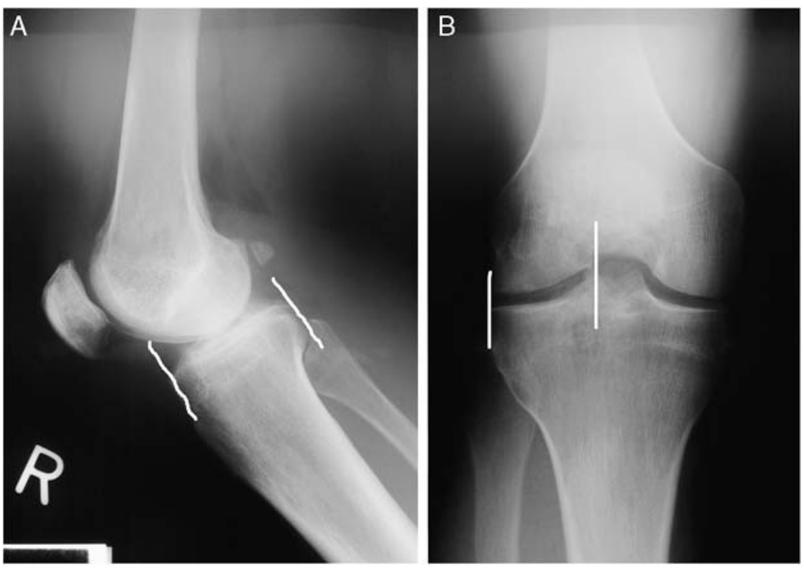


**FIGURE 1.** Lateral (A) and anteroposterior (B) views are essential in evaluation of meniscal sizing and procedural preparation.

 

patients with symptoms referable to a meniscus-deficient tibiofemoral compartment.[4] The knee joint must be stable and have normal alignment, with intact articular surfaces (grade I or II). Any grade III or IV lesions should be focal and require concomitant treatment. Special considerations are required for athletes who desire to return to high-level sports in the absence of problems with activities of daily living. The primary goal of meniscus allograft transplantation is to reduce symptoms of pain and improve function, but patients are educated as to the relative risk of returning to high-level sports that might prematurely jeopardize the implant.

Contraindications for meniscal transplantation include diffuse arthritic changes, squaring or flattening of the femoral condyle or tibial plateau, and significant osteophyte formation in the involved compartment, outerbridge grade IV articular changes, untreated tibiofemoral subluxation, inflammatory arthritis, synovial disease, previous joint infection, skeletal immaturity, or marked obesity. Although not absolute contraindications, chondral defects (often involving the femoral condyle), varus/valgus malalignment, or ligamentous instability all require consideration for concurrent or staged treatment to ensure that all joint pathology is addressed.

In the past, full-thickness chondral defects were considered a contraindication; however, cartilage degeneration is not a significant risk factor for meniscal allograft failure.[19] Outcomes of many concurrent procedures, including meniscal transplantation with concurrent autologous chondrocyte implantation (ACI)[7,20] and osteochondral allograft,[21] have shown excellent results in the carefully selected patient.

Concurrent or staged corrective osteotomy is indicated for patients with malalignment affecting the involved compartment. Axial malalignment can exert abnormal pressure on the newly placed graft, which can lead to loosening, overload, degeneration, and failure.[22–24] Osteotomy is also effective in reducing load in the involved compartment which may independently be responsible for pain relief. ACL-deficient patients who have had a prior medial meniscectomy may benefit from concomitant ACL reconstruction (ACLR) and meniscal transplantation. Studies have shown that meniscectomized ACL-deficient knees lead to worsening degenerative changes. Moreover, combined ACLR and meniscal transplantation has good long-term follow-up as opposed to untreated knees. Also, the posterior horn of the medial meniscus is an important secondary stabilizer to anterior translation and may be important in preventing secondary stretch of the ACL-reconstructed knee[22,23] A similar paradigm exists for the ACL-deficient patient with a history of lateral meniscectomy. The most common indications for this combined procedure are a failed ACLR in the setting of a prior meniscectomy without any other clear etiology of failure, especially in those who present with concomitant joint line pain.

## Nonoperative Management

Patients who have had a prior meniscectomy should have a trial of conservative treatment before consideration of operative measures. Activity modifications, anti-inflammatory medications, and joint injections can help determine which patients can function without surgical intervention. More aggressive management of the relatively young patient after lateral meniscectomy might be considered, especially in female athletes with slight valgus who are at significant risk for the development of progressive lateral compartment arthritis.[14] It must be understood that despite this relative indication with a slightly lower bar for surgical recommendations, meniscus transplantation should not be considered as a prophylactic operation preventing the ultimate onset or progression of osteoarthritis.

# SURGICAL TECHNIQUES

## Preoperative Planning

### Allograft Sizing

Success of meniscal transplantation is highly dependent on accurate size matching of the meniscus allograft to the native meniscus when using bone bridge or plugs.[4,21,24] Meniscal allografts are compartment-specific and side-specific. Pollard et al proposed the most common methods for sizing by radiographic imaging, whereas Haut provided significant contributions for sizing with MRI.[25,26] AP and lateral preoperative radiographs with sizing markers are important for meniscal sizing. Proper sizing is critical because oversized meniscal allografts lead to greater forces across the articular cartilage and may cause extrusion with inadequate transmission of compressive loads across the knee. Alternatively, undersized allografts result in poor congruity with the femoral condyle and lead to excessive load.[24] The meniscus width is determined on the AP radiograph by measuring from the edge of the ipsilateral tibial spine to the edge of the tibial plateau. Meniscal length is determined on the lateral radiograph as determined by the AP dimension of the ipsilateral tibial plateau. These measurements, after correction for magnification, are multiplied by 0.8 for the medial and 0.7 for the lateral meniscus. These measures are compared with the soft tissue measures provided by the tissue bank. Other methods using height and weight have been proposed but are not routinely used.[21,27]

### Meniscal Graft Processing, Selection, and Preservation

Stringent donor selection is practiced by screening donors with comprehensive medical records and social history to procure disease-free allograft tissue. The risk of disease transmission is further reduced by screening for human immunodeficiency virus, human T-cell lymphotropic virus, hepatitis B and C, and syphilis. Blood cultures for aerobic and anaerobic bacteria, as well as lymph node sampling, may be performed. Graft processing, including debridement, ultrasonic pulsatile washing, and use of ethanol to denature proteins, further lowers the risk of disease transmission.[28] Meniscal allografts are harvested using sterile surgical technique ideally within 24 hours after death and frozen to $-80^\circ$C. Four methods of preserving allografts are cryopreserved, fresh-frozen, fresh, and freeze-dried allografts. Of these options, fresh-frozen grafts are the most commonly used. Graft preservation methods have been moved away from cryopreservation as studies have shown that this method is associated with chondrocyte apoptosis.[29]

### Anesthesia

Meniscal transplantation can be performed under regional, spinal, or general anesthesia based on surgeon and anesthesia preferences. Patient age, comorbidities, and adverse events with previous anesthesia are important in the decision-making process.

## Positioning

The patient is positioned supine on a standard operating room table. A tourniquet is placed as high as possible around the thigh, and the extremity is placed in a standard leg holder allowing full knee flexion. It is important that the posterolateral or posteromedial corner be freely accessible for inside-out suturing of the meniscus.

## Surgical Anatomy, Incisions, and Portals

Important surgical landmarks to be identified are the patella, patellar tendon, tibial plateau, and fibular head. Portals and incisions include inferomedial and inferolateral arthroscopy portals, an accessory outflow portal, a posterolateral or posteromedial incision, and a miniarthrotomy adjacent to or splitting the patellar tendon on the transplant side.

Caution should be taken while making incisions because many structures are at risk, depending on the approach. These include the peroneal nerve and lateral collateral ligament with the posterolateral approach, the saphenous nerve and medial collateral ligament with the posteromedial approach, and the patellar tendon with the anterior miniarthrotomy. In addition, the posterior neurovascular bundle can be damaged during needle passage when suturing the meniscus in place, especially on the lateral side.

## Examination Under Anesthesia and Diagnostic Arthroscopy

Examination under anesthesia evaluates range of motion and ligamentous stability. Diagnostic arthroscopy is performed to confirm the preoperative diagnosis and evaluate any changes in articular cartilage (Fig. 2). Diagnostic arthroscopy should confirm any arthrosis in the affected compartment; grade I or II cartilage damage is acceptable at the time of meniscal transplantation. Grade IV chondral damage should be treated with concomitant allografting of the femoral condyle.

## Arthroscopic Preparation

The initial steps for medial and lateral meniscal transplantation are similar. The remaining meniscus is arthroscopically debrided to a 1 to 2 mm peripheral rim until punctate bleeding occurs. The most anterior part of the meniscus can be excised with a no. 11 scalpel through the respective anterior portal followed by the use of an aggressive arthroscopic shaver. The anterior and posterior horn insertion sites should be maintained, because they are helpful markers during preparation of the slot. In addition, limited notchplasty along the posterior and inferior femoral condyle allows for improved visualization of the posterior horn during passage of the graft.

## Exposure

A miniarthrotomy is performed directly adjacent to or through the patellar tendon on the affected side, in line with the patellar tendon fibers. To achieve correct orientation of slot and introduction of the graft, the arthrotomy is performed in line with the insertion sites of the anterior and posterior horns of the involved meniscus. Prior localization with a spinal needle to determine the proper trajectory is helpful to ensure proper incision location. The incision should extend approximately one third above the joint line and two thirds below the joint line. An ipsilateral (posteromedial or posterolateral) approach is required for meniscal repair.

For lateral meniscal transplantations, a second posterolateral incision is made at the interval between posterior edge of the iliotibial band and the anterior edge of the biceps femoris tendon. The gastrocnemius muscle tendon junction is elevated off the posterior capsule at the joint line, and the meniscal retractor is placed anterior to the muscle. Proper retraction allows suture tying beneath these structures to minimize the chances of soft tissue tethering with flexion or extension of the knee.

For medial meniscal transplants, a second posteromedial incision is made just anterior to the semitendinosus and semimembranosus tendons. The sartorial fascia is incised and the hamstring tendons are retracted posteriorly. The interval is opened between the posteromedial aspect of the capsule just anterior to the gastrocnemius and semitendinosus tendons. Proper retraction facilitates retrieval and suturing of meniscal sutures.

## Slot Preparation

Slot orientation follows the normal anatomy of the meniscal attachment sites. Electrocautery is used to establish a line connecting the center of the anterior and posterior horn attachment sites. Using this line as a guide, a 4 mm burr is used to make a straight anterior to posterior reference slot in the tibial plateau. Slot height and width will equal the dimensions of the burr, and its alignment in the sagittal plane should parallel the slope on the tibial plateau. Slot measurements, such as the AP length of the tibial plateau, will be verified by placement of a depth gauge in the reference slot. With the drill guide, a guide pin will be placed just distal and parallel to the reference slot. This guide pin may be placed with the knee in flexion and under

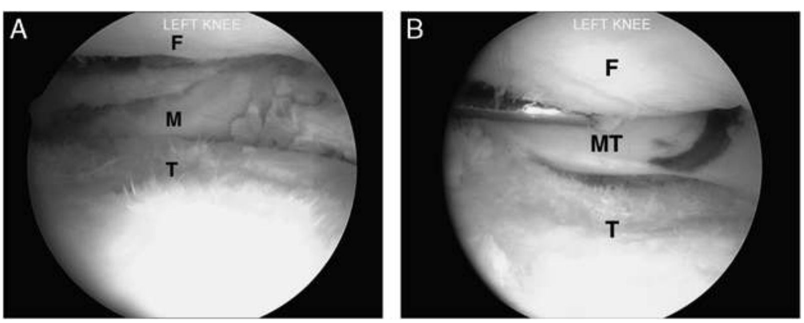


**FIGURE 2.** Arthroscopic evaluation provides information on preoperative (A) as well as postoperative (B) condition of meniscus (M) and meniscal transplant (MT). The relative condition of femoral (F) and tibial surfaces (T) may also be assessed by arthroscopic evaluation.

**FIGURE 3.** A box-cutter osteotome is used to widen the tibial trough. Arthroscopic imaging (inset photo) may confirm the path which will hold bone bridge and meniscal transplant.

fluoroscopic guidance to help avoid violating the posterior cortex. The drill guide is advanced to but not through the posterior cortex. The pin is subsequently overreamed with a 7 or 8 mm cannulated drill bit, while stopping short of the posterior cortex. A box-cutter osteotome is then used to widen the trough to 7 to 8 mm and deepened to 10 mm. Ensure that the box-cutting osteotome is in line with the path made by the burr (Fig. 3). The slot may be refined with a 7 to 8 mm rasp to ensure smooth integration of the bone bridge of the allograft.

## Meniscal Allograft Preparation

Our preferred technique utilizes a bone bridge to secure graft to the tibial plateau. The meniscus allograft tissue arrives as a hemiplateau with an attached meniscus. All nonmeniscal soft tissue is removed. Attachment sites of the meniscus are identified on the bone block, and the accessory attachments are debrided, leaving only true attachment sites (approximately 5 to 6 mm wide). The meniscus is then prepared to achieve the desired width and length, as determined by the slot preparation. The width of the bone bridge is intentionally undersized by 1 mm to facilitate graft passage into the slot and reduce inadvertent bridge fracture during insertion. The bone bridge is then cut to a width of 7 mm and a height of 10 mm (Fig. 4). Bone extending beyond the posterior horn attachment is removed so that the posterior wall of the bone bridge will be aligned with the most posterior edge of the prepared slot. Bone extending to the anterior horn, however should be preserved to maintain graft integrity and ease in graft insertion. A vertical mattress traction suture (no. 0 polydioxanone) is placed at the junction of the posterior horn and middle thirds of the meniscus.

If the anterior horn attachment is larger (up to 9 mm wide), the attachment should be left intact and the width of the bone bridge should be increased accordingly in the area of the anterior horn insertion only, and the remainder of the bone bridge should be trimmed to the intended 7 mm. The corresponding area of the recipient slot should be widened to accommodate the increased width. All soft tissue should be removed from the meniscal graft and bone block to help with visualization during insertion. Care must be taken to not damage the meniscal insertion sites while cutting the bone block.

## Meniscus Insertion and Fixation

Using a single barrel, zone-specific meniscal repair cannula placed through the contralateral portal, a Nitinol suture passing pin is placed through the capsular attachment site of the posterior and middle thirds of the meniscus. The proximal end of the Nitinol pin is withdrawn from the anterior arthrotomy site, the allograft traction sutures are passed through the loop of the Nitinol pin, and the pin and traction sutures are withdrawn through the accessory incision. With the aid of the traction sutures, the meniscal allograft is pulled through into the joint through the anterior arthrotomy, whereas the bone bridge is advanced into the tibial slot. Choi and colleagues examined 33 patients utilizing MRI to determine that placement of the center of the bony bridge to 50% of tibial plateau resulted in less extrusion. Proper placement of the bony bridge is vital to

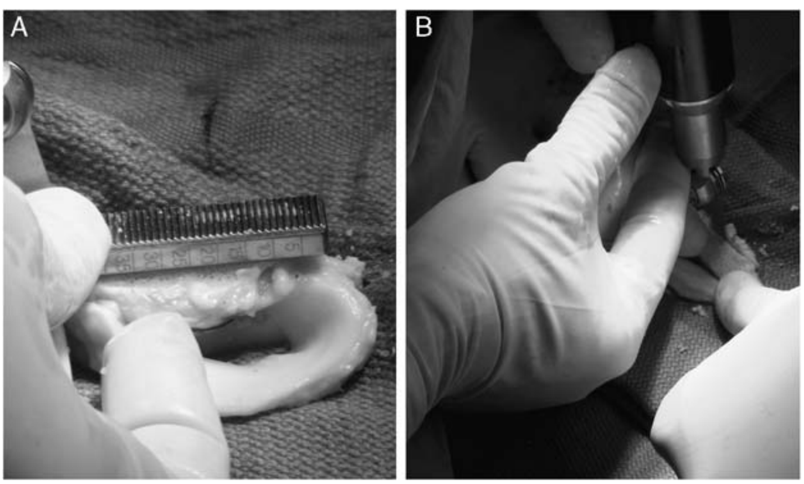


**FIGURE 4.** Sizing of meniscal allograft bone block ensures successful reduction into the trough (A). Assistance as well as caution is necessary while trimming the allograft for proper size (B).

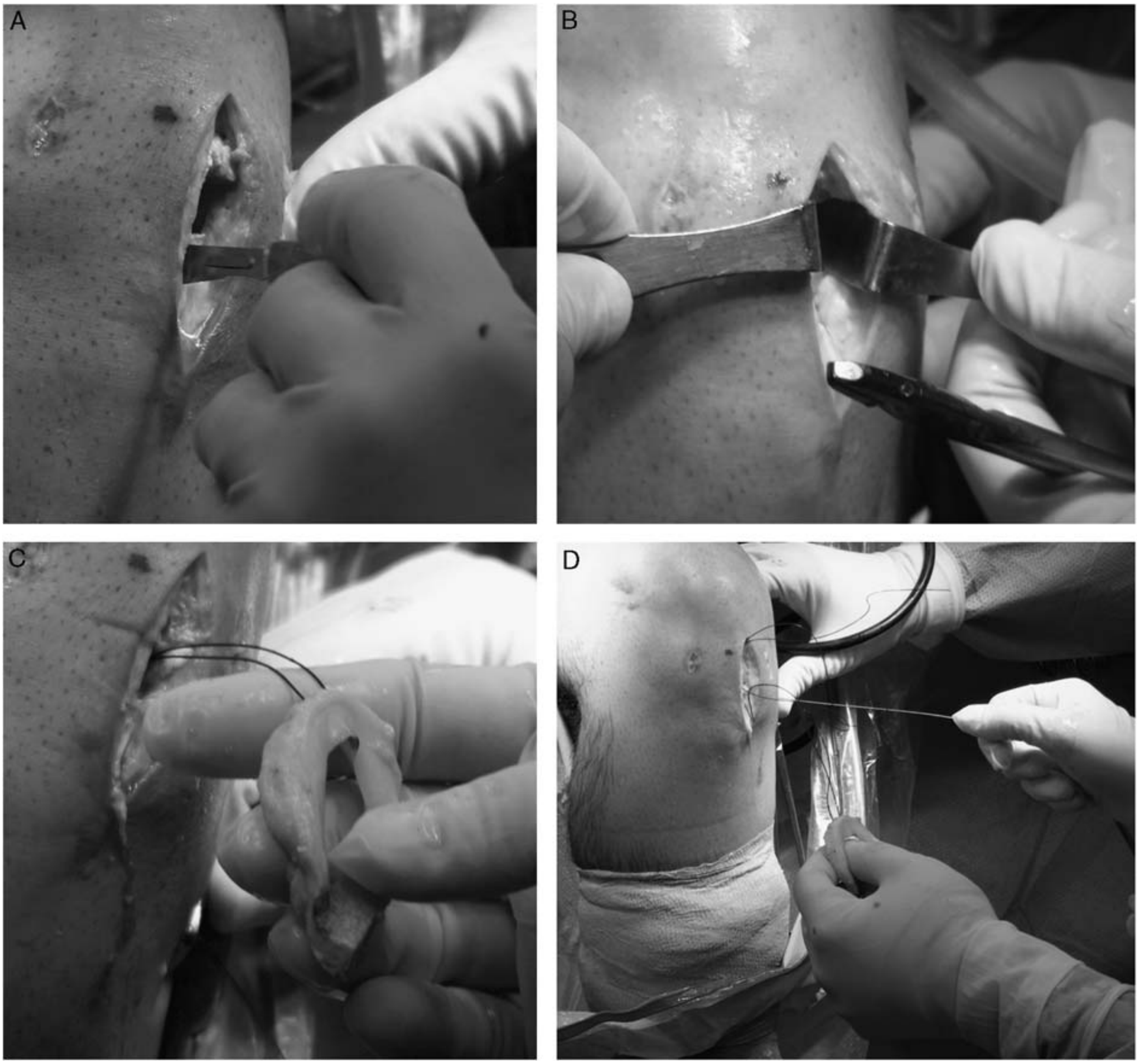


**FIGURE 5.** The anterior arthrotomy site may be appropriately adjusted to allow passage of allograft. A and B, Traction sutures attached to meniscus allow for passage of the meniscus with manual reduction and appropriate placement of transplant (C, D).

maintain anatomical alignment of the meniscus and to avoid possible cause of failure after transplantation.[30] The meniscus is manually reduced under the condyle with a finger placed through the arthrotomy (Fig. 5). Appropriate varus or valgus stress is needed to open the ipsilateral compartment as well as knee flexion-extension to aid in graft introduction and reduction. Once the meniscus is reduced, the knee is cycled to ensure proper placement and capturing by the tibiofemoral articulation. A guidewire is inserted between the bone bridge and the medial eminence side of the slot. A tap is inserted over the guidewire to create a path for the interference screw, with the bone bridge held in place manually. The bone bridge is then secured within the tibial slot with a $7 \times 25$ mm bioabsorbable cortical interference screw. This step is typically done in flexion under direct visualization (Fig. 6).

Finally, the graft is attached to the capsule with 8 to 10 standard inside-out vertical mattress sutures (2-0 Ethibond) placed, equally on the superior and inferior meniscal surfaces. Sutures should be placed peripherally on the meniscus, because sutures placed in the middle or inner third of the meniscus can weaken the implant. For medial transplants, this fixation can be modified with the use of appropriate all-inside fixation devices placed most posteriorly and outside-in sutures placed most anteriorly. If the slot is off slightly medially or laterally to the desired position, it is possible to realign the bone trough by placing the interference screw on the opposite side. Meniscal stitches are started at the site of the traction sutures and placed sequentially anteriorly and posteriorly to ensure correct tension.

## Closure

Standard closure of the arthrotomy and accessory portal incisions is performed.

**FIGURE 6.** To secure the graft, a bioabsorbable cortical interference screw (inset photo) will be placed under direct visualization. Care should be taken not to apply excessive force during insertion.

## CONCURRENT PROCEDURES

### Anterior Cruciate Ligament and Medial Meniscal Transplantation

Concomitant ACL and medical meniscus deficiency with significant anteromedial rotatory instability warrants early surgical intervention. Medial menisci of patients with chronic ruptures sustain higher loads and exposed to increased risk of rupture during activities of daily living.[15] Sekiya and colleagues, retrospectively, reviewed 28 patients who underwent ACLR with meniscal transplantation followed postoperatively for 2.8 years, as results suggested that combined meniscal allograft transplantation with ACLR was beneficial for specific patients with chronic ACL insufficiency or failed ACL surgery. On the International Knee Documentation Committee subjective assessment, 85% had normal scores and 90% had normal Lachman and pivot shift test scores.[31] Shelbourne and Gray[22] in a large study with objective follow-up of 482 patients with a mean of 7.6 years postoperatively, patients with more meniscus and articular cartilage damage at the time of ACLR displayed subjective symptoms and arthritic changes over time. This study recommended ACLR be performed before meniscus and articular cartilage damage occurs, and revealed that patients with partial or total meniscectomy may have lower subjective scores 10 years postoperatively. For combined medial meniscal transplantation and ACLR, a modified bridge-in-slot technique with 2 smaller bone blocks is utilized.

A soft tissue graft (hamstring graft, Achilles allograft, tibialis anterior allograft, or hamstring allograft) is recommended because this allows for a smaller diameter tibial tunnel. The ACL tibial tunnel is drilled as obliquely as possible, entering the lateral aspect of the tibial footprint. Then the femoral tunnel is drilled. After tunnel placement, the meniscal slot should be prepared, as described earlier. Graft placement occurs in a sequential order: femoral fixation is completed first, followed by meniscal transplantation, and lastly tibial fixation of the ACL graft. The meniscus is secured with an interference screw between the ACL and the most lateral aspect of the bridge. Tibial ACL fixation as the final step allows maximum separation of the tibiofemoral joint during meniscal transplantation. Drill the tibial tunnel first before making the trough for the meniscal transplantation. Soft tissue graft is preferred to make passing the graft easier with a meniscal transplant in place. Notch the bone bridge at the site of ACL tibial tunnel to reduce intersection pressure of the ACL graft against the bone bridge. With inadequate fixation from an interference screw, consider placing 2 transosseous sutures through the bone block anteriorly and posteriorly as described when the block inadvertently fractures during preparation or insertion. Remove a small segment of bone between the 2 bone blocks to accommodate the ACL as it courses from the tibia to the femur. Alternatively, a standard transosseous technique or “retro-grade,” drilling with a flip cutter, or retrocutting reamer (Arthrex, Naples, FL) of the anterior and posterior horn tunnels can facilitate easy graft placement.

### High Tibial Osteotomy and Medial Meniscal Transplantation

All aspects of the meniscal transplantation are performed first. Varus or valgus stresses are needed to place the meniscus graft and if not completed first, could jeopardize fixation of the osteotomy. The open wedge osteotomy is performed as distally as possible with the osteotomy wedge passing at least 1.5 cm below the bottom of the tibial slot. Two Steinmann pins can be placed above the osteotomy site but below the slot to prevent propagation of the osteotomy into the slot.

### Cartilage Restoration and Meniscal Transplantation

If ACI or osteochondral allografting is preformed simultaneously, it is usually safer and easier to perform all steps of the meniscal transplantation and then proceed onto the cartilage restoration procedure. Care should be taken, however, to avoid damage to the anterior horn of the transplanted mensicus with the arthrotomy and while placing osteochondral grafts. Perform meniscal transplantation before the cartilage procedure. All the meniscal sutures except the anterior horn can be placed as noted above. The anterior horn can be stitched through the anterior arthrotomy at the end. Avoid damage to the meniscus graft by flexing the knee and using a retractor while performing the cartilage procedure.

### Biologics/Stem Cells/Synthetic Transplants

Allograft tissue as meniscal replacement is probably the best surgical option currently available for the selective patient population. Tissue engineering techniques to grow new replacement host tissue for individual patients have surfaced. Studies attempting to examine the utilization of scaffold seeded with host cells synthesized in bioreactors that provide an environment for cell induction of a new meniscus substitute.[32,33] Kon and colleagues investigated tissue regeneration with the use of biomaterials for meniscal tissue engineering along with augmentation of implant with expanded autologous chondrocytes. Although longer term animal studies were recommended, Kon showed that cell-seeded constructs significantly formed more cartilaginous tissue.[34] Grafts may also carry specific growth factors to encourage rapid biological incorporation into recipient tissues. Collagen meniscus implantation is a scaffold that has been used in the clinical setting for partial meniscus substitution. Martinek and colleagues showed that collagen meniscus implants in sheep seeded with meniscal fibrochondroyctes in comparison with cell-free implants, showed better macroscopic and histologic results. However, the tissue-engineered implant size decreased over a 3-month observation period and was biomechanically unstable.[35] A pivotal prospective randomized study by Rodkey and colleagues following 311 patients of which 160 patients were treated with collagen meniscus of a mean follow-up of 59 months. In 141 repeat arthroscopies performed after a year, the collagen meniscus implants had significantly increased meniscal tissue compared with that seen after partial meniscectomy. The collagen meniscus implants appeared safe, formed biomechanically stable meniscus-like tissue, and could possibly replace lost or damaged tissue in patients with chronic meniscal injury.[36]

### Postoperative Rehabilitation Protocol

Immediate partial weight-bearing is allowed in a hinged knee brace, with range of motion limited to 0 to 60 degrees of flexion for the first 2 weeks and to 90 degrees at 4 weeks. Non–weight-bearing flexion beyond 90 degrees is also allowed immediately, progression to full weight-bearing and range of motion as well as strengthening exercises are achieved at 4 weeks postoperatively. Squatting and pivoting are avoided until 16 weeks, at which time in-line running is permitted. Return to full activity is permitted after 6 months as long as strength is 80% that of the contralateral leg. Success of meniscal allograft transplantation may be judged on improvement in short-term symptoms of pain, improvement in function, and whether the onset or progression of degenerative changes often seen with partial or total meniscectomy is prevented.[18]

## COMPLICATIONS

Complications include those similar to those of meniscal repair, consisting of infection, arthrofibrosis, incomplete healing of the meniscocapsular repair, and saphenous or peroneal nerve injury. Meniscal retears can occur as a transplanted meniscus is at a higher rate for reinjury.

## CONCLUSIONS

Meniscal allograft transplantation yields good to excellent results in almost 85% of patients. Patients demonstrate significant decrease in pain, as well as an increase in activity. Long-term success is encouraging in well-selected patients but it is unknown whether meniscal transplantation is protective against the progression of degenerative changes.

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