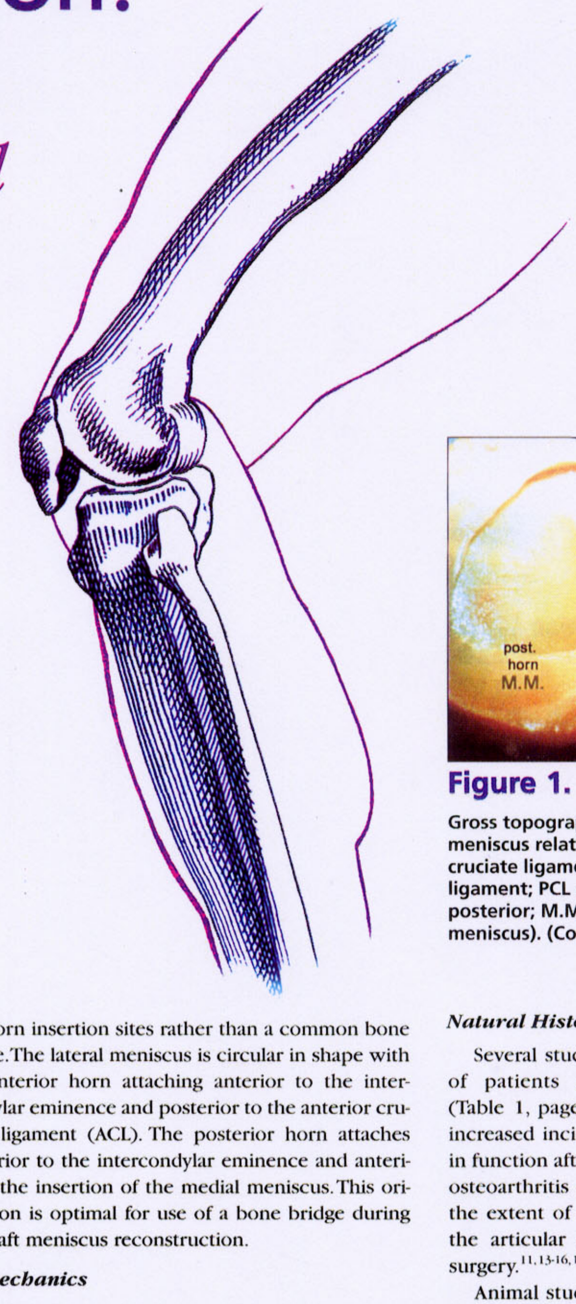
Allograft Meniscus Transplantation:

Background, Techniques, and Results



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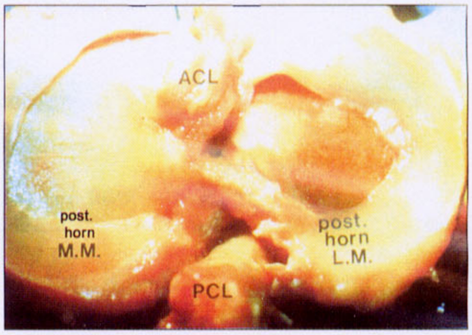


Figure 1.

Gross topography of the medial and lateral meniscus relative to the anterior and posterior cruciate ligaments. (ACL = anterior cruciate ligament; PCL = posterior cruciate ligament; post. = posterior; M.M. = medial meniscus; L.M. = lateral meniscus). (Courtesy of Chris Harner, MD)

Background

History

Contemporary understanding of the natural history and biomechanical consequences of the meniscectomized knee has led to a commitment to meniscal preservation.[1] However, there remains a population of patients who have undergone subtotal meniscectomy, and there are instances where meniscal preservation is not possible. In these patients, knee function is adversely affected with concomitant disruption of important meniscus functions including load sharing, shock absorption, joint stability, joint nutrition, and overall protection of the articular cartilage. In an effort to restore normal knee anatomy and biomechanics, meniscal allografts are used to replace the native meniscus in selected symptomatic patients. Excellent pain relief and improved function can be achieved with rigid adherence to surgical indications.

Relevant Anatomic Considerations

The medial meniscus is semicircular in shape with the posterior horn wider than the anterior horn (Figure 1). This disparity provides the rationale for a surgical technique that uses bone plugs attached to the horn insertion sites rather than a common bone bridge. The lateral meniscus is circular in shape with the anterior horn attaching anterior to the intercondylar eminence and posterior to the anterior cruciate ligament (ACL). The posterior horn attaches posterior to the intercondylar eminence and anterior to the insertion of the medial meniscus. This orientation is optimal for use of a bone bridge during allograft meniscus reconstruction.

Biomechanics

Menisci function mainly in load distribution, shock absorption, and joint lubrication. The circumferential and radially oriented collagen fibers reflect the tensile (hoop) stresses generated within the meniscal ultrastructure. Menisci transmit 50% of joint force in extension and 85% of joint force in flexion. Contact area is decreased by 50% to 70% with medial meniscectomy. Partial and subtotal meniscectomy increase joint stress from 40% to 70%.[2] After allograft reconstruction in the meniscectomized knee, significant reductions occur in maximum pressure, mean pressure, and contact area.[3-6] The posterior horn of the medial meniscus is an important secondary stabilizer to anterior tibial translation in the ACL-deficient knee.[7-9]

Natural History of the Meniscectomized Knee

Several studies demonstrate the poor prognosis of patients after even partial meniscectomy (Table 1, page 21). These reports demonstrate an increased incidence of osteoarthritis and decrease in function after meniscectomy with the severity of osteoarthritis related to the time that has passed, the extent of meniscectomy, and the condition of the articular cartilage at the time of the index surgery.[11,13-16,18]

Animal studies demonstrate that meniscus allografts heal to the capsule, are revascularized, and are repopulated with host cells.[19-22] Additional reports demonstrate that areas of articular cartilage covered by meniscal allografts have appreciably fewer arthritic changes compared to uncovered areas, with associated reductions in contact pressures.[23-25]

Immunology

It is hypothesized that cartilage tissues including meniscal allografts are protected by an extracellular matrix rendering them "immunologically privileged."[26] No systemic responses to meniscal allografts have been reported.

Table 1. Long-Term Results of Partial Meniscectomy

Author	Follow-up	Patients	Results	Findings
Higuchi et al[10]	12 years	67	79% satisfied	Medial meniscectomy associated with cartilage degeneration
Schimmer et al[11]	12 years	119	78% G/E	Increasing symptoms after 5 years
Dai et al[12]	16 years	24	63% G/E	After meniscectomy, 87% developed DJD
Rockborn and Gillquist[13]	12-15 years	60	62% with DJD	Subtotal meniscectomy with higher DJD rate than in partial meniscectomy
Rangger et al[14]	4.5 years	284	Age >40 worse	DJD in 38% after medial and 24% after lateral meniscectomy
Dai et al[15]	10-33 years	60	58% G/E	DJD in 87.5%
Rockborn and Gillquist[16]	13 years	43	84% satisfied	Subtotal meniscectomy with higher DJD rate than partial meniscectomy
Bolano and Grana[17]	5 years	50	82% satisfied	Grade III and IV changes in 30%

DJD, degenerative joint disease; G/E, good to excellent

Table 2. Comparisons Between Fresh-Frozen And Cryopreserved Meniscus Allografts

Steps	Fresh-Frozen	Cryopreserved
Recovery and handling	Aseptic and maintained at 4°C	Aseptic and maintained at 4°C
Processing, preservation, and storage	Without solution and stored at −40° to −130°C	With cryoprotectant and frozen at controlled rate in liquid nitrogen at −135°C
Cell viability	Negligible	10%-50%

Table 3. Allograft Preservation Technique and Charge By Allograft Source

Source	Charge per Allograft*	Preservation Technique
University of Miami Tissue Banks; Miami, Fla	$1,500	Cryopreserved
CryoLife, Inc; Kennesaw, Ga (instrumentation and allograft)	$4,900	Cryopreserved
AlloSource; Centennial, Colo	$2,900	Fresh-frozen
Regeneration Technologies, Inc; Alachua, Fla	$3,000	Fresh-frozen
Northwest Tissue Center; Seattle, Wash	$750	Cryopreserved
Musculoskeletal Transplant Foundation; Edison, NJ	$1,375-$2,058	Fresh-frozen
Arthrex Tissue Systems, Inc; Naples, Fla (instrumentation and allograft)†	$3,950	Fresh-frozen

* All charges subject to verification by allograft source.

† Arthrex receives most menisci from Musculoskeletal Tissue Foundation.

Figure 2.

Physical examination of a 38-year-old male with a history of chronic anterior cruciate ligament insufficiency (ie, positive Lachman) and prior open medial meniscectomy (ie, medial incision) with complaints of recurrent instability and medial joint line pain.

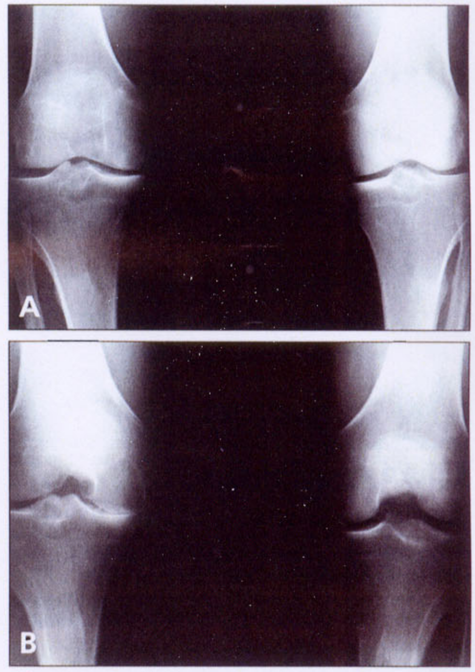


Figure 3.

Radiographs of a 32-year-old male with a history of medial meniscectomy of the right knee. (A) Extension weight-bearing anteroposterior radiograph demonstrating intact medial joint space. (B) 45° flexion weight-bearing posteroanterior radiograph of the same patient demonstrating complete medial compartment joint space loss. Based upon this view, the patient was excluded as a candidate for meniscus allograft transplantation.

Allograft Preservation

Unlike fresh osteochondral grafts, cell viability in meniscal allografts does not seem to improve the morphologic or biochemical characteristics of the graft; therefore, the most commonly implanted grafts are either fresh-frozen or cryopreserved (Tables 2 and 3). Experimental studies in goats suggest that there are no significant differences between cryopreserved and fresh-frozen grafts.[27,28]

Disease Transmission

Because of rigid donor screening criteria as well as aseptic graft harvest and packaging techniques, secondary sterilization methods are generally not required with meniscal allografts. The risk of HIV after screening and cleansing is at most 1:1,667,000.[29] To date, most major tissue banks use polymerase chain reaction testing (an analysis for viral RNA). The use of these tests has reduced the risk of HIV transmission even further. To date, there have been no documented cases of disease transmission with the use of these contemporary screening measures.

Patient Evaluation

It is not uncommon for patients to report a history of nearly immediate and complete symptom resolution after open or arthroscopic meniscectomy, followed by a gradual increase over time of ipsilateral joint line pain, activity-related swelling, generalized achiness (affected by changes in ambient barometric pressure) and occasionally, complaints of "giving way" and crepitus. A thorough history should include the mechanism of injury, associated injuries, and previous treatments such as ligament reconstruction or management of articular cartilage lesions.

A complete physical examination is necessary to evaluate concomitant pathology (ie, malalignment, ligament deficiency) that may modify treatment recommendations. The location of previous incisions should be noted and may provide evidence of prior meniscectomy (Figure 2). Typically, patients are tender along the ipsilateral joint line and may have palpable bony change along the edges of the femoral or tibial condyle. Motion should be normal because only a mild degree of arthritis is considered acceptable in a candidate for meniscal transplantation.

Diagnostic imaging is required and should begin with a standard weight-bearing, anteroposterior (AP) radiograph of both knees in full extension, a non–weight-bearing 45° flexion lateral view and an axial view of the patellofemoral joint. Additionally, a 45° flexion weight-bearing posteroanterior (PA) radi-

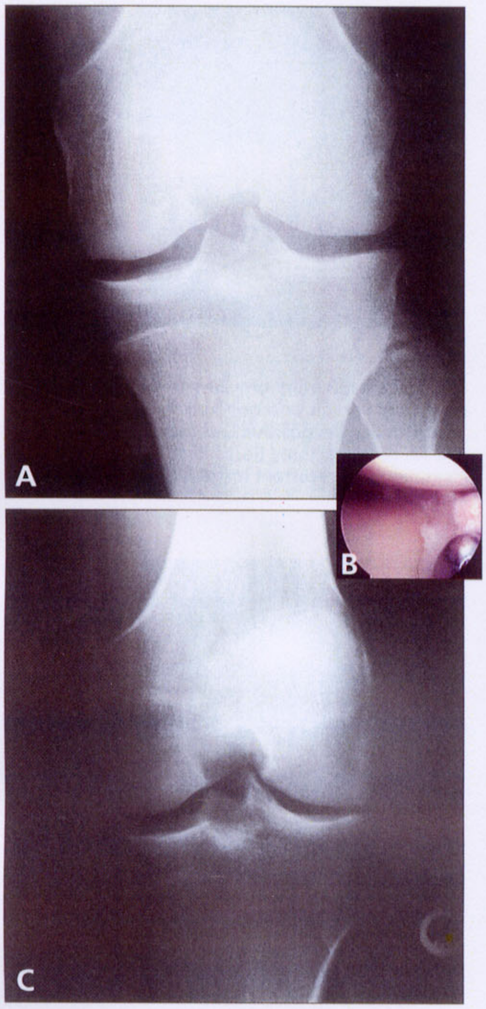


Figure 4.

Clinical example of a 28-year-old female with preserved lateral compartment joint space on (A) 45° flexion weight-bearing posteroanterior radiograph who underwent (B) arthroscopic lateral meniscectomy leading to (C) very rapid lateral joint space narrowing within 12 months demonstrated by follow-up 45° flexion weight-bearing posteroanterior radiograph.

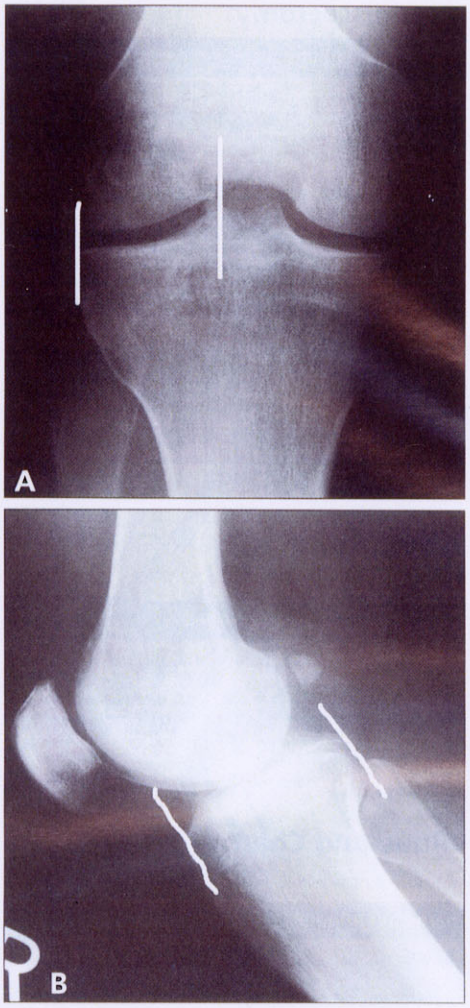


Figure 5.

Meniscus sizing is performed by first correcting for magnification and then (A) calculating the meniscus width (coronal plan) on the anteroposterior radiograph by measuring the distance from the peak of the tibial eminence (medial or lateral) to the tibial metaphyseal margin, ignoring marginal osteophytes. (B) Meniscus length (sagittal plane) is determined on the lateral radiograph with the medial meniscal length 80% and the lateral mensical length 70% of the sagittal tibial plateau distance measured at the joint line between a line parallel to the anterior tibia and 1 tangent to the posterior plateau margin perpendicular to the joint line.

ograph is recommended to help identify subtle joint space narrowing that traditional extension views may fail to identify (Figure 3, page 21).[30] Special studies such as a long-cassette mechanical axis view or magnetic resonance imaging (MRI) should be ordered given any degree of clinical malalignment or suspicion of chondral injury. If joint space narrowing is present on the 45° flexion weight-bearing PA radiograph, an MRI is rarely necessary. Generally, MRI examination should be reserved for difficult cases in which the diagnosis remains unknown, especially when radiographs are completely normal or when previous operative notes are unavailable to determine the extent of prior meniscectomy or the status of articular cartilage. Techniques include 2-dimensional fast spin echo and 3-dimensional fat suppression with and without intra-articular gadolinium.[31] When questions regarding the source of a patient's symptoms still remain after use of these techniques, a 3-phase technetium bone scan may be useful.

Indications

General Considerations

Ideally, allograft meniscus transplantation is indicated in symptomatic patients with prior meniscectomy, persistent pain in the involved compartment with intact articular cartilage (ie, less than Outerbridge classification grade III), normal alignment, and a stable joint.[32] There is no upper age limit, but generally patients aged 50 or older have developed a degree of arthritis that contraindicates the procedure. Simultaneous or staged ligament reconstruction or realignment procedures are performed as indicated. Even a few degrees of deviation toward the involved compartment compared with the alignment of the contralateral limb is an indication for osteotomy. Significant articular disease (ie, late grade III or IV) and radiographic femoral condyle flattening or marked osteophyte formation are generally associated with inferior results and are considered the most common contraindications. Localized chondral defects should be treated concomitantly. Additional contraindications include inflammatory arthritis, obesity, and previous infection.

Specific Clinical Scenarios

Patients commonly present with more rapid and earlier degeneration after lateral meniscectomy than after medial meniscectomy, because the lateral meniscus provides a relatively greater contribution to load sharing than does the medial meniscus (Figure 4). This is especially true for females normally in valgus alignment.

Patients who have chronic ACL insufficiency with prior medial meniscectomy may demonstrate excessive sagittal plane or rotational laxity due to loss of the stabilizing effects of the posterior horn of the medial meniscus. These patients often present with ipsilateral joint line pain and complaints of "giving way" (Figure 2). Additionally, a high index of suspicion is required in evaluating the ACL-reconstructed patient presenting with progressive graft elongation and a prior medial meniscectomy. These patients may respond favorably to allograft meniscus transplantation and will occasionally require revision of their ACL reconstruction.

Patients with a history of meniscectomy who develop secondary varus or valgus deformity can be treated with staged or concomitant high tibial or distal femoral osteotomy, respectively. The order of these procedures will depend on the surgeon and the patient, but meniscal transplantation should not be performed without correction of the malalignment. Typically, patients aged 40 to 45 or older will have an osteotomy first and then have a meniscal transplant should the osteotomy fail to provide sufficient pain relief. Alternatively, patients may respond favorably to a concomitant osteotomy and allograft transplant; patient age, degree of malalignment, and severity of symptoms may be considerations here.

Patients with ipsilateral chondral injury typically have their defects treated simultaneously depending on the size, location, depth, and previous treatment of the defects.[33-36] Untreated focal chondral or osteochondral defects may lead to early meniscus failure or to persistent symptoms unrelated to the meniscus implant.[37] Rehabilitation after these combined procedures is usually guided by the more conservative cartilage restoration regimen (ie, continuous passive motion, non–weight-bearing status) rather than the protocol for meniscus transplant.

Management of patients who remain asymptomatic but have a history of meniscectomy remains controversial. Typically, these patients are educated about the symptoms associated with secondary arthrosis and are followed annually for progression of joint space narrowing by 45° PA radiographs (and occasionally, by 3-phase technetium bone scans). The timing of allograft transplantation in these patients is typically related to the onset of clinical signs and symptoms.

Allograft Sizing

Meniscus allografts are side- and compartment-specific. Preoperatively, precise measurements are obtained from AP and lateral radiographs with magnification markers placed on the skin at the level of the proximal tibia. Surgeons should be familiar with the sizing techniques used by their tissue providers to minimize the chance for size mismatch. At the authors' institution, Pollard's technique for meniscal sizing has been successful (Figure 5).[38] The meniscus width is determined on an AP radiograph after correction for

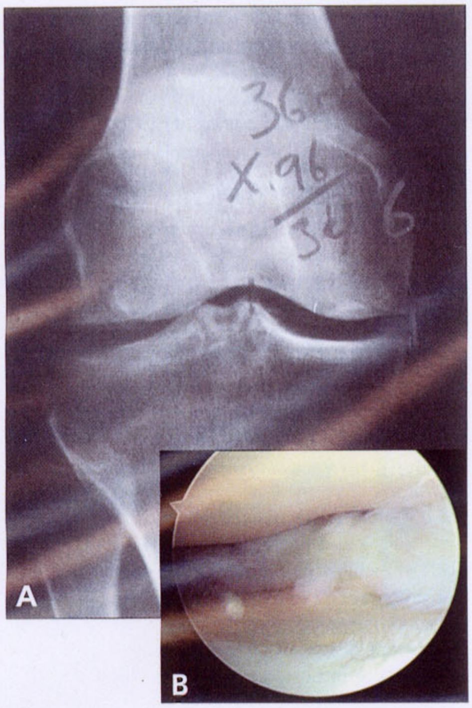


Figure 6.

(A) Anteroposterior radiograph of a prospective patient for medial meniscus allograft transplantation demonstrating mild flattening of the medial femoral condyle with early marginal osteophytes excluded as a candidate for meniscus allograft transplantation because of (B) bipolar arthritis appreciated at the time of arthroscopy.

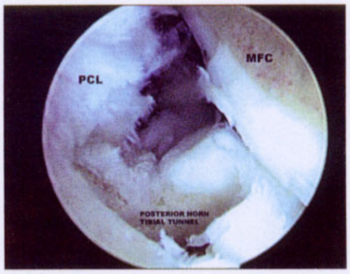


Figure 7.

Arthroscopic view of the medial meniscus posterior horn tibial tunnel created after performing a limited notchplasty along the most inferior and posterior aspect of the medial femoral condyle (MFC) adjacent to the posterior cruciate ligament (PCL).

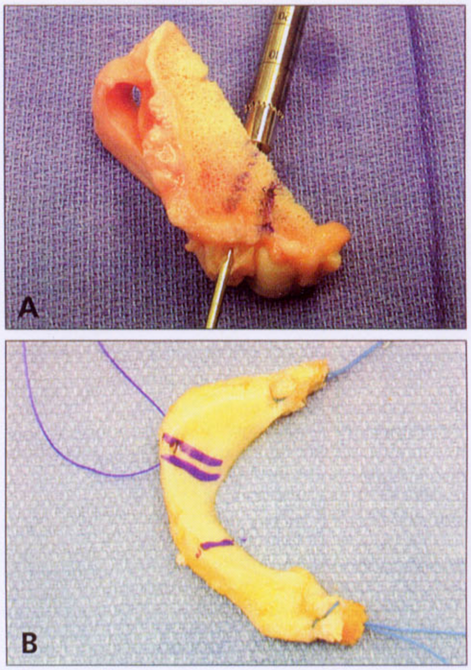


Figure 8.

Double bone-plug configuration created using (A) a commercially available 8-mm coring reamer (Arthrex Corp; Naples, Fla) with (B) final preparation with traction sutures (#2 nonabsorbable through bone plug and #1 PDS at junction of middle and posterior horns) in place.

magnification, on the basis of a 1:1 relationship to the distance from the center of the respective tibial eminence to the periphery of the tibial plateau.[39] Meniscal length is calculated on the lateral radiograph based on the sagittal length of the tibial plateau. After correction for magnification, this number is multiplied by 0.8 for the medial and 0.7 for the lateral meniscus. For example, if the tibial plateau measures 38 mm from the medial tibial eminence to the periphery of the tibia on the AP radiograph with 5% magnification, then the width of the required meniscus is 36 mm (ie, 38 × 0.95). If the sagittal length of the tibial plateau from anterior to posterior is 50 mm with 5% magnification, then the length of the required medial meniscus is 38 mm (50 × 0.95 × 0.8). With this technique, size mismatch occurs less than 5% of the time.

Technique

General Considerations

The clinical success of meniscus transplantation is largely dependent on appropriate patient selection. In addition, a preponderance of evidence suggests that maintaining the bony insertions of the anterior and posterior horns is critical to re-establishing normal function of the transplanted meniscus.[4-6] The authors currently use a double-bone plug configuration on the medial side and a bone bridge configuration (ie, keyhole method) on the lateral side. Modifications of the keyhole method for a slot may make it an acceptable method for the medial side as well.

The authors' preferred technique is an all-arthroscopic procedure requiring only a small arthrotomy to introduce the meniscus. A standard diagnostic arthroscopy is performed using 2 parapatellar tendon portals placed at the level of the distal tip of the inferior pole of the patella. (The medial or lateral portal will ultimately be extended just beyond the tibial plateau for introduction of the medial or lateral meniscus, respectively). A routine diagnostic arthroscopy is performed to determine the extent of prior meniscectomy, the extent and location of articular cartilage damage, and the status of the ACL and posterior cruciate ligament (PCL). There are no current recommendations regarding the degree of prior meniscectomy required for transplantation. In general, patients with only partial meniscectomy (<20% to 30%) would not be considered candidates for the procedure. Similarly, unsuspected ipsilateral bipolar grade III or IV chondral damage would contraindicate a patient for meniscus allograft transplantation (Figure 6). Focal chondral defects discovered at transplant should be characterized by size, depth, and location and can be managed at the time of operation (eg, microfracture, osteochondral autograft) or deferred until definitive treatment is possible (eg, osteochondral allograft, autologous chondrocyte transplantation) in conjunction with allograft meniscus transplantation. The management of focal chondral disease is discussed in detail elsewhere.[33-36]

Preliminary Preparation

The initial steps for medial and lateral meniscus transplantation are similar to one another and are performed in the ipsilateral compartment only. The host meniscus is arthroscopically debrided to a 1- to 2-mm peripheral rim until punctate bleeding occurs. A remnant of the anterior and posterior meniscal horns is maintained to provide a guide for subsequent allograft placement. Performing a limited notchplasty along the most inferior and posterior aspects of the femoral condyle, next to the cruciate ligaments, is helpful for visualizing the posterior horn and passing the meniscus into the recipient socket or slot (Figure 7). This will often require limited debridement of the synovium near the ACL or PCL. A standard meniscus repair exposure positioned in line with the respective femoral epicondyle—situated one third above the joint line and two thirds below the joint line—is required to protect the neurovascular structures during inside-out meniscus repair.

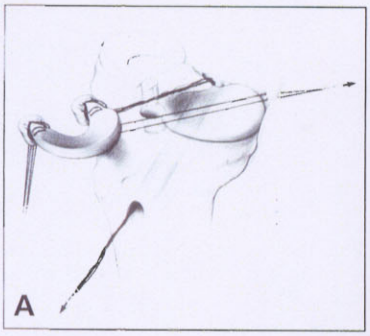
Meniscus Preparation

The meniscus is carefully opened and properly thawed. Fresh-frozen allografts must be thoroughly thawed in normal saline, eliminating all crystalline water content, to prevent tissue injury during manipulation. Cryopreserved menisci should be thawed and maintained in lactated Ringer's solution to preserve cellular viability. All menisci should be maintained on a bed of ice if there is any significant delay (ie, 30 minutes) between thawing and insertion. All nonmeniscal soft tissue is sharply excised from the periphery of the meniscus and from around the insertion sites allowing clear delineation of the entire footprint of the anterior and posterior horns. A #1 polydioxanone suture (PDS) is placed at the junction of the middle and posterior third of the meniscus to facilitate intra-articular positioning of the meniscus.

Medial Meniscus Allograft

Shelton and Dukes[40] popularized the double-bone plug technique to secure the meniscal horn attachments; this is currently the most commonly used method to implant a medial meniscus. Advantages of the double-bone plug technique include the ability first to seat the posterior horn in its recipient socket—placed within the anatomic footprint of the host—and subsequently to adjust the anterior horn insertion, based on the length and width remaining in the meniscus allograft after initial suture placement. This is especially beneficial when slight graft-host size mismatch exists. Additional advantages include the ability to more easily perform concomitant high tibial osteotomy surgery or ACL surgery where the tibial tunnel might otherwise disrupt a meniscus bone bridge. Newer techniques are being developed to minimize the size of the meniscus slot, which may increase the use of a bone bridge technique on the medial side.

A bone plug approximately 8 mm in width by 8 to 10 mm in length, with soft tissue insertion of the



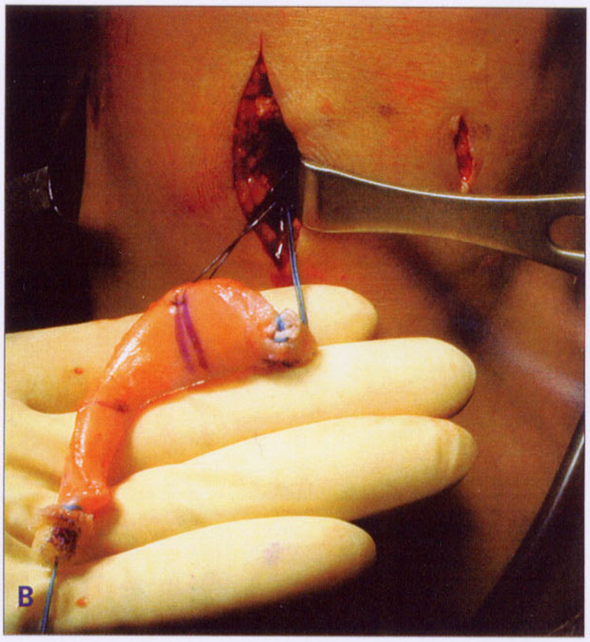
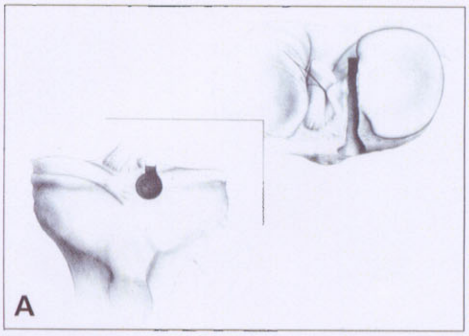


Figure 9.

(A) Schematic of medial meniscus being introduced into the joint guided by traction sutures exiting the posterior medial aspect of the knee (#1 PDS) and posterior horn tibial tunnel (#2 nonabsorbable) (Courtesy of CryoLife, Inc; Kennesaw, Ga). (B) Clinical example of meniscus about to be introduced into the joint through a limited medial arthrotomy with traction sutures in place.



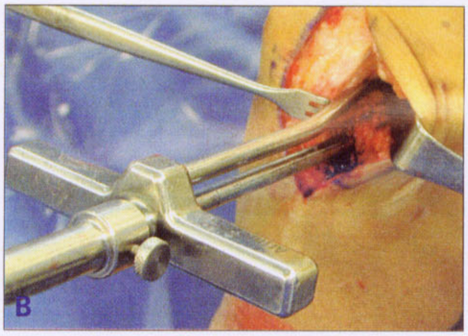


Figure 10.

(A) Schematic of tibial preparation for lateral meniscus keyhole technique (Courtesy of CryoLife, Inc; Kennesaw, Ga). (B) Commercially available keyhole guide (Arthrex Corp; Naples, Fla) positioned to establish keyhole configuration in tibial plateau.

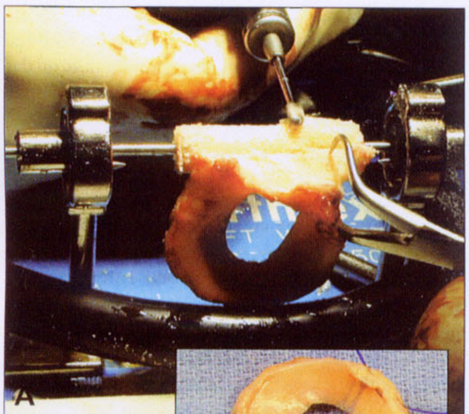


Figure 11.

(A) Preparation of lateral meniscus with fine tuning using a power burr leading to (B) the final configuration ready for implantation.

meniscal horn maximally preserved, is fashioned by hand instrumentation. Alternatively, a commercially available 8-mm coring reamer is used (Arthrex Corp; Naples, Fla). A #2 nonabsorbable traction suture (Ethibond, Ethicon, Inc; Somerville, NJ) is placed in figure-8 orientation through the base of the meniscus horn and then passed through the center of the bony plug (Figure 8, page 23).

An ACL guide system set at approximately 60° placed through the inferomedial portal is used to ream a recipient 9-mm tunnel originating at the anteromedial—and exiting into the most central—aspect of the posterior horn footprint. The #1 PDS traction suture is passed using a nitinol wire guided through a zone-specific cannula positioned intra-articularly at the junction of the middle and posterior third of the meniscal remnant, exiting the medial incision into a meniscus retractor (ie, Henning). The #2 nonabsorbable traction suture attached to the posterior horn and plug is retrieved from within the arthrotomy and pulled out of the tibial tunnel using a suture retriever. The inferomedial portal is extended to allow passage of the posterior horn bone plug and meniscus into the interval established between the ACL and the medial femoral condyle, gently guided by the traction sutures in order to seat the bone plug under direct visualization (Figure 9). Eight to 10 vertically placed 2-0 nonabsorbable mattress sutures are placed from posterior to anterior using standard inside-out meniscus repair techniques. The anterior horn bone plug is press-fit into a blind tunnel ideally reamed in the center of the host anterior horn footprint. Minor adjustments in position are made as required.

Lateral Meniscus Allograft

The anterior and posterior horns are approximately 1 cm apart in the lateral meniscus. Thus, use of a double-bone plug technique requiring 2 tibial tunnels creates a significant risk that the tunnels may become confluent and compromise bone fixation. For this reason, a bone bridge (or keyhole) technique has been devised that maintains the anatomic relationship between the anterior and posterior horns through a connecting bone bridge. Additional advantages of a bone bridge include the reproducibility of the technique and the ability to more precisely maintain the relationship between the anterior and posterior horns. The technique is made possible by commercially available keyhole instrumentation (Arthrex).

An 11-mm recipient socket is established, beginning 7 mm below the articular surface and passing from anterior to posterior in line with meniscal horn remnants. Fluoroscopic guidance is helpful to avoid inadvertent penetration of the posterior tibial cortex. The "key" is actually a 6-mm slot in the articular surface centered over the 11-mm recipient socket (Figure 10). The keyhole technique requires that the tibia be prepared before the meniscus because specific depth measurements are transferred to the meniscus allograft during preparation, which is performed with a slotted coring reamer, an oscillating saw, and a burr (Figure 11). Newer instrumentation soon to be available from Regeneration Technologies, Inc (Alachua, Fla) will allow a slot to be created with minimal tibial bone loss. This technique will permit simultaneous preparation of the tibia and meniscus (Figure 12). With both techniques, the meniscus is inserted in a manner that is similar to the double-bone plug technique using the #1 PDS traction suture for positioning, and is repaired using vertically placed 2-0 nonabsorbable mattress sutures from posterior to anterior.

Advanced Techniques

High tibial osteotomy. All soft tissue and bony portions of the meniscus transplant technique are performed first, followed by the osteotomy. Osteotomies should be performed as far distally as possible. Rigid fixation is required to tolerate meniscus introduction and repair following the osteotomy.

ACL reconstruction. With the medial double-bone plug technique, all soft tissue and bony portions of the meniscus transplant technique are performed first. The ACL tibial tunnel is then drilled slightly more medially than usual to avoid confluence between it and the posterior horn meniscus tunnel. The remaining portions of the ACL reconstruction are performed as usual. With a lateral bone bridge technique, similar to that performed on the medial side, the authors prefer to ream the ACL tibial tunnel after placement of the meniscus allograft. The meniscus bone bridge may be partially compromised without untoward effects during creation of the tibial tunnel.

Occasionally, patients may have combined varus alignment, ACL deficiency, and an absent medial meniscus with relatively intact articular cartilage. These cases are typically managed with ACL reconstruction at the time of high tibia osteotomy. The meniscus transplant (Figure 13) is performed simultaneously only in

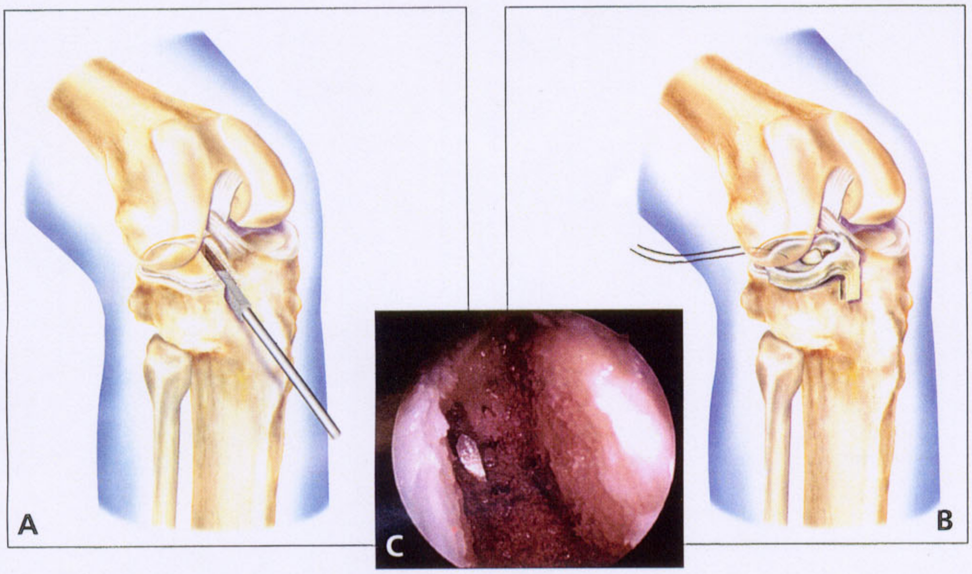


Figure 12.

(A and B) new cannulated instrumentation designed to create (C) a small recipient slot in the proximal tibia as seen arthroscopically (Courtesy of Regeneration Technologies, Inc; Alachua, Fla).

rare situations, such as in very young patients. More commonly, meniscus allograft reconstruction occurs only with persistent symptoms after recovery from this procedure.

Autologous chondrocyte transplantation and osteochondral grafting. It is typically easier and safer for chondral procedures to be performed after all steps of the meniscus transplant are completed; this helps avoid inadvertent damage to the periosteal patch or osteochondral graft during meniscus instrumentation or suture repair (Figures 14 and 15, page 26).

Rehabilitation

There is no universal agreement regarding the parameters of the postoperative rehabilitation protocol for patients after allograft meniscus transplantation. The senior author's protocol includes a progression from partial to full weight bearing with crutches over the first 4 postoperative weeks. Motion from 0° to 90° during weight bearing in a hinged knee immobilizer begins immediately. Occasional passive non-weight bearing motion beyond 90° is permitted in the first 4 weeks. At 4 weeks, full range of motion is allowed and activities such as bicycling, swimming, and active strengthening are begun. Most surgeons recommend a program that allows running at 4 to 6 months and return to full activities at 6 to 9 months, provided that strength is at least 80% to 85% of the nonoperated leg.

Complications

Complications are rare and include the need for graft removal, which is often associated with inappropriate patient selection. Other complications are similar to those of meniscus repair and include incomplete healing, persistent symptoms, infection, arthrofibrosis, and neurovascular injury related to meniscus repair techniques.

Results

Literature overview. The body of relevant peer-reviewed literature suggests that with appropriate indications, results after allograft meniscus transplantation approach 85% "good" to "excellent" ratings, with patients overall demonstrating a measurable decrease in pain and increase in activity levels. Second-look arthroscopies demonstrate early peripheral healing with revascularization and cell repopulation (Figure 16, page 26). Failures are typically due to graft shrinkage and posterior horn rupture. The risk of graft failure appears to be greater with irradiated grafts and in patients with grade III or IV osteoarthritic change. In many series, concomitant surgery (ie, ACL reconstruction, osteotomy) has been performed.

Results summary (Table 4, page 27). In 1989, Milachowski et al[20] reported on 22 patients (with a total of 6 fresh and 16 freeze-dried grafts) at average follow-up of 14 months. Two patients reported occasional knee pain and only 3 failures occurred. Second-look arthroscopy in 9 patients demonstrated only 1 nonhealed meniscal rim. The fresh grafts demonstrated improved appearance (eg, less shrinkage) compared to the freeze-dried grafts. In 2002, Milachowski's long-term results have been published with a mean follow-up of 14 years (range, 12-15 years). Patients receiving meniscus transplantation demonstrated only a slight deterioration in clinical performance from the 3-year follow-up time point to the 14-year follow-up time point. Patients with deep-frozen meniscus transplants generally performed better than patients with lyophilized meniscus transplants by subjective and objective measures.[40]

In 1990, Zukor et al[41] reported on a series of 33 fresh meniscal and osteochondral allografts. At 1 year after surgery, 26 were considered successful; no failures were attributable to meniscal pathology. Second-look arthroscopies in 10 revealed that all menisci were stable at their peripheral attachment.

In 1993, Garrett[42] reported on 43 open allograft transplants (16 fresh and 27 cryopreserved) with 2- to 7- year follow-up. Only 7 were isolated meniscus allografts; the remaining were combined with ACL reconstruction, osteotomies, and osteochondral allografts. A total of 28 second-look arthroscopies at 2-year minimum follow-up demonstrated a well-healed meniscal rim without significant shrinkage in 20 patients. In all, 15 of the patients who did not undergo arthroscopic re-evaluation remained asymptomatic. Poor results (6 of 11) were seen in patients with preoperative grade IV arthrosis. This study demonstrated that excellent results could be obtained, even with combined procedures, provided that patients with grade IV arthrosis are excluded.

In 1995, Noyes[43] presented a series of 96 fresh-frozen irradiated meniscal allografts in 83 patients. Follow-up at a mean of 30 months postoperatively demonstrated that 44% failed, 34% partially healed, and 22% healed. Failures were typically due to incomplete peripheral healing, degeneration of the meniscus, or meniscal tearing with removal required at a mean of 14 months. The significant facts of this study are that patient selection was critical to success (ie, a high rate of failure in patients with grade IV arthrosis) and that irradiated menisci should not be used because of compromised biomechanical properties.

Also in 1995, van Arkel and deBoer[44] reported prospectively on a group of 23 patients with cryopreserved meniscus transplants, with 2- to 5-year follow-up. Satisfactory results occurred in 20

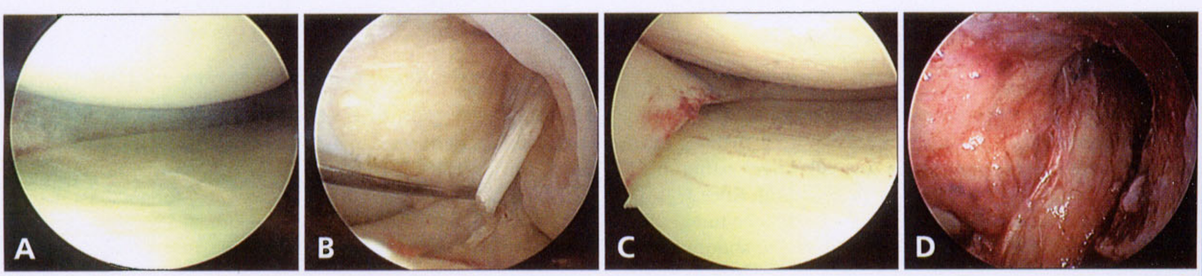


Figure 13.

Clinical example of a patient with (A) prior medial meniscectomy, (B) chronic ACL insufficiency, and varus alignment treated with (C) medial meniscus allograft, (D) autograft bone-patellar-tendon bone ACL reconstruction and high tibial osteotomy. (E) Six-month postoperative anteroposterior radiograph demonstrating proper ACL graft placement and excellent healing of high tibial osteotomy.

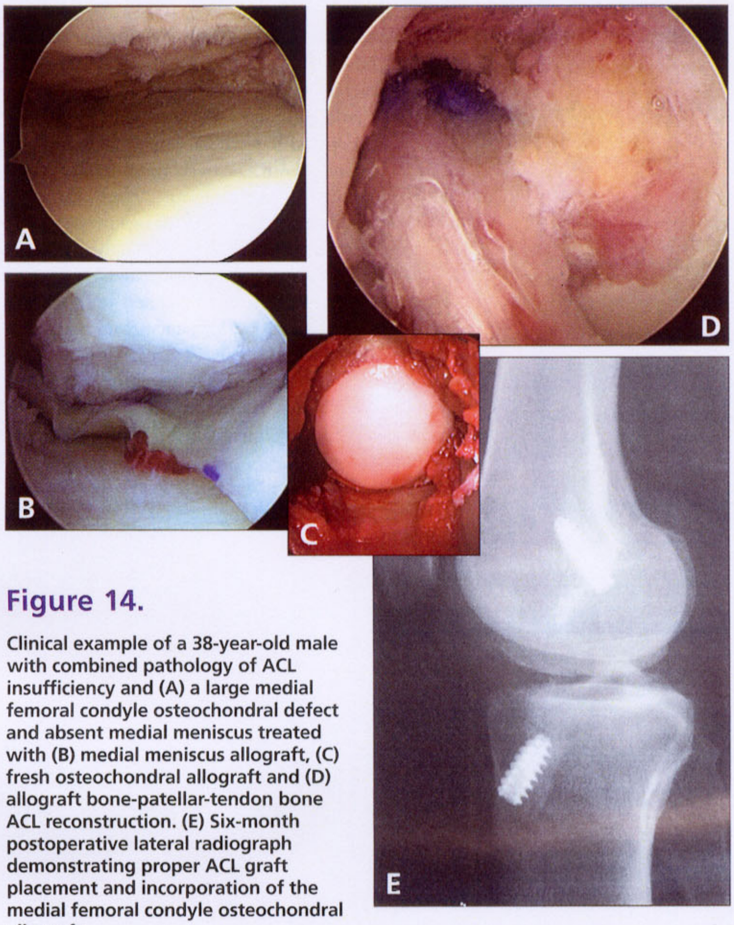


Figure 14.

Clinical example of a 38-year-old male with combined pathology of ACL insufficiency and (A) a large medial femoral condyle osteochondral defect and absent medial meniscus treated with (B) medial meniscus allograft, (C) fresh osteochondral allograft and (D) allograft bone-patellar-tendon bone ACL reconstruction. (E) Six-month postoperative lateral radiograph demonstrating proper ACL graft placement and incorporation of the medial femoral condyle osteochondral allograft.

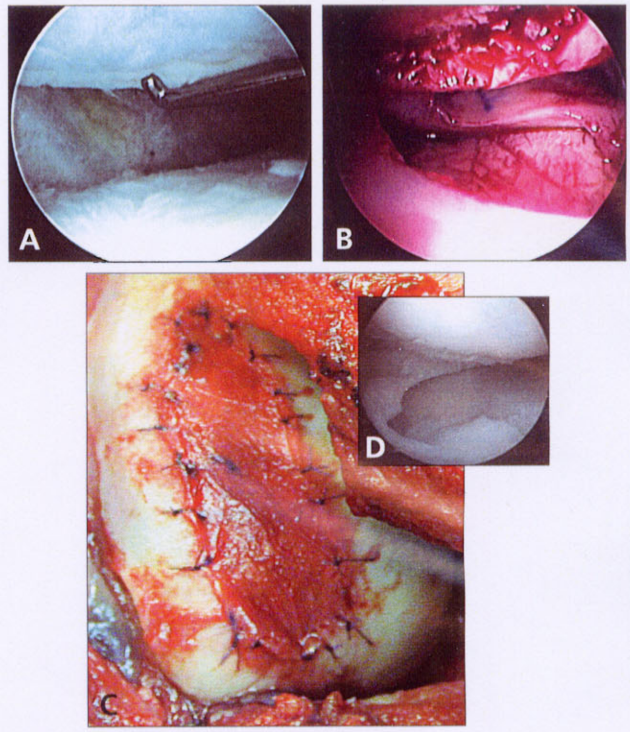


Figure 15.

Clinical example of a 36-year-old male with combined pathology of (A) 7.5 cm^2 chondral defect of lateral femoral condyle and prior lateral meniscectomy treated with a single-stage (B) a lateral meniscus allograft and (C) autologous chondrocyte implantation with (D) excellent restoration of the chondral surface and peripheral healing of the meniscus allograft with slight shrinkage seen 18 months following surgery at second-look arthroscopy.

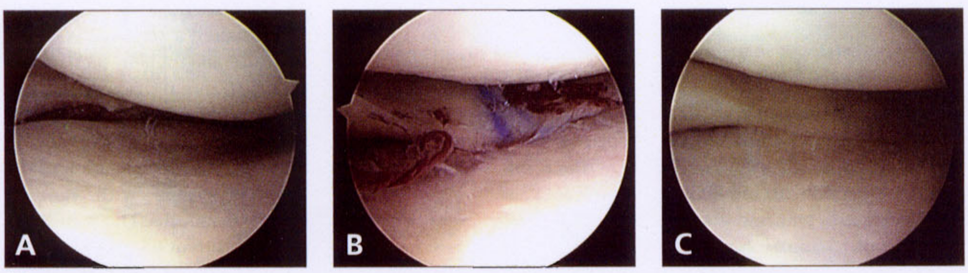


Figure 16.

Clinical example of an 18-year-old woman following (A) subtotal medial meniscectomy treated with B) a medial meniscus allograft leading to (C) complete peripheral healing demonstrated 3 months following implantation at second-look arthroscopy.

patients, with peripheral healing demonstrated in nearly all second-look arthroscopies. Histology demonstrated revascularization with viable meniscal chondrocytes.Three failures, occurring at less than 24 months, were associated with uncorrected malalignment. In 2002, van Arkel and deBoer presented the results of 63 meniscal transplantations in 57 patients with a mean follow-up of 60 months (range, 4 to 126 months). They determined a significant negative correlation between ruptured ACL and successful meniscal transplantation (*P*=0.003) and a significant difference between the results of medial and lateral meniscal transplants (*P*=0.004)[45]

In 1997, Cameron and Saha[46] reported on 67 irradiated menisci implanted without bone insertions, many of which had advanced unicompartmental arthritis. Despite this, at average follow-up of 31 months (range, 1-5.5 years), 86.6% had good to excellent results using a 100-point functional knee score. The most frequent complication was a traumatic posterior horn tear in 6 knees at a mean of 21 months after surgery.

In 1999, Cole and Harner[47] reported the results at a minimum of 2 years after implantation of 22 fresh-frozen menisci. Before surgery, all patients complained of at least moderate knee pain. After surgery, 88% reported marked relief of this pain with an overall knee rating of 87 using the University of Pittsburgh Knee Scale (range, 75-100). Self-reported overall knee function was nearly normal or better in 21 and abnormal in 1.

Also in 1999, Carter[48] reported the results of 46 cryopreserved grafts at minimum follow-up of 2 years (range, 24-73 months). Second-look arthroscopy in 38 patients demonstrated 4 failures, 4 with visible shrinkage and 2 of those also with progression of arthritis. The majority of patients reported substantial improvement in pain and activities, and only 1 patient indicated an unwillingness to undergo the procedure again under similar circumstances.

In 2000, Stollsteimer et al[49] reported on 22 patients with 23 cryopreserved allografts at follow-up of 1 to 5 years. All patients experienced pain relief. Compared to the normal meniscus, the allograft demonstrated an average shrinkage of 37% (range, 0%-69%) by MRI. This finding, however, was not associated with an adverse outcome.

The authors' experience. Since August 1997, the senior author of this review (Cole) performed 53 meniscus allograft transplantations (30 isolated and 23 combined procedures), and 20 have been followed for a minimum of 2 years. Excluding 4 failures that occurred in patients with grade IV arthrosis, the remaining 16 knees were rated as nearly normal (12) or normal (4) according to the International Knee Documentation Committee (IKDC) 100-point rating system.

Regulatory and Reimbursement Issues

More than 5,000 meniscus transplants have been performed in the United States over the past decade. The US Food and Drug Administration has a proposed rule (21 CFR Part 1271)[50] for good tissue practices that defines procedures for recovery, processing, and handling of human tissue. Allografts are regulated as tissue requiring minimal manipulation for homologous use (not as medical devices). Thus, meniscus allograft transplantation is not considered experimental.

In July of 2001, the American Medical Association

Table 4. Published Results of Meniscal Transplantation

Author	Follow-up	n	Results	Findings
Milachowski et al[20]	14 mo	22 patients	87% satisfied	Freeze-dried irradiated group with more shrinkage than fresh
Zukor et al[41]	12 mo	33 allografts	79% success	Complete peripheral healing at second-look arthroscopy
Garrett[42]	2-7 y	43 allografts	74% success	Most failures in patients with grade IV arthrosis
van Arkel and deBoer[44]	2-5 y	23 patients	87% satisfied	Failures due to uncorrected malalignment
Cameron and Saha[46]	31 mo	67 allografts	87% G/E	Soft tissue fixation without bone blocks; 6 posterior horn tears
Cole and Harner[47]	24 mo	22 allografts	88% success	
Carter[48]	24 mo	46 allografts	91% success	
Stollsteimer et al[49]	40 mo	22 patients	100% improved	Allograft shrinkage to 63%, the size of normal meniscus
Milachowski et al [20]	14 y	23 patients	59 pre-op Lysholm score, 84 at 3-y Lysholm score, 75 at 14-y Lysholm score	Slight deterioration in clinical results from 3-y to 14-y follow-up
van Arkel and deBoer[45]	60 mo	57 patients	76% lateral, 50% medial, 67% combined clinical success	88% lateral, 63% medial successful survival of the allograft

(AMA), publishers of the Current Procedural Terminology (CPT) coding guidelines, will have a specific tracking CPT code (0014T) for allograft meniscus transplantation that must be used in place of an unlisted CPT code (29909). At the 2001 annual meeting of the American Academy of Orthopaedic Surgeons in San Francisco, the first formal continuing education initiative on meniscus allografts for orthopedic surgeons was presented. Because of favorable clinical results, the nonexperimental classification of human tissue, and the recent recognition by the AMA, most third-party payers now recognize allograft meniscus transplantation as a viable noninvestigational treatment alternative for a painful knee condition that may otherwise require arthroplasty.

Conclusions

Meniscus allograft transplantation is a sensible treatment alternative for the early arthritic knee. The procedure alleviates pain and provides a measurable improvement in functional level for the appropriately selected postmeniscectomy patient. The allograft heals readily to the host, develops a normal appearance, and repopulates with host cells. Biomechanically, the allograft functions in a manner similar to that of native autograft tissue in its load-sharing properties. Theoretically, restoration of normal meniscal anatomy should decelerate or prevent further degenerative changes. Long-term results with radiographic follow-up will be required to demonstrate this phenomenon. Implant failure, which occurs in less than 5% to 10% of all patients, typically occurs in the first 24 months and is predominantly due to the presence of grade III or greater arthritic change.

As we achieve a better understanding of the risk factors for the progression of arthrosis after meniscectomy and after adequate interpretation of longer-term clinical results, a select subset of relatively asymptomatic patients may emerge as appropriate candidates for early allograft meniscus transplantation to prevent the onset of significant degenerative change. Currently, however, this indication remains investigational.

The basic science and clinical results support the intermediate-term efficacy of allograft meniscus transplantation in patients who are symptomatic due to prior meniscectomy as long as relevant comorbidities are corrected and significant coexisting arthritis is absent. ❖

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