Sports Medicine

Meniscal allograft transplantation

Nicole A. Friel[ab] and Brian J. Cole[abc]

ABSTRACT

Meniscal allograft transplantation has emerged as a successful treatment option for select patients with meniscal deficiencies. Meniscal transplants have been performed with concomitant realignment and instability procedures with success, and recent studies have shown that concomitant cartilage restoration offers good outcomes for patients with focal, full-thickness cartilage lesions. Meniscal sizing and processing continues to provide more accurate and safe methods of preparing the meniscus for transplantation. While most physicians continue to use radiographs to size menisci, several other options have been proposed for optimize sizing. Surgical technique continues to vary among surgeons, with the use of suture, bone plug, and bone bridge fixation. Outcome studies have shown pain relief and increased activity in intermediate-term studies, but long-term follow-up studies are still needed.

Keywords
allograft, meniscectomy, meniscus, transplantation

INTRODUCTION

The surgical treatment of meniscal lesions has changed significantly over time. While meniscal tears were traditionally treated with excision, a greater understanding of the biologic and biomechanical environment of the meniscus-deficient knee has led away from meniscal removal to meniscal preservation.[1,2] Partial meniscectomy and meniscal repair have become the standard of care. Meniscal allograft transplantation represents an option for a select subset of patients who become symptomatic from their meniscal deficiency that offers restoration of anatomical and biomechanical function.

Since 1984, when Milachowski *et al.*[3] completed the first meniscal transplant, numerous studies have been reported related to meniscal transplantation. Although meniscal transplantation is becoming a more popular procedure, there still remains considerable debate regarding indications, tissue sizing and processing, surgical techniques, and long-term outcomes.

Departments of [a]Orthopaedic Surgery
[b]Anatomy & Cell Biology, Rush University Medical Center
[c]Section Head, Rush Cartilage Restoration Center, Chicago, Illinois
Correspondence to Brian J. Cole, MD, MBA, Rush University Medical Center, 1725 W Harrison Ave, Suite 1063, Chicago, IL 60612
Tel: +312 432 2381; fax: +312 563 0579;
e-mail: bcole@rushortho.com

INDICATIONS AND CONTRAINDICATIONS

The success of meniscal transplantation depends on careful selection of the ideal candidate. Typically, patients are relatively young (less than 50 years) and often have had a total or subtotal menisectomy with persistent pain localized to the meniscus-deficient compartment. The knee joint must be stable or stabilized and have normal alignment with intact articular surfaces (grade I or II). Abnormalities in alignment as well as grade III or IV focal cartilage lesions require concomitant treatment.

Concurrent or staged corrective osteotomy is indicated in patients with axial malalignment. Patients with anterior cruciate ligament (ACL) deficiency who have had prior medial menisectomy may benefit from concomitant ACL reconstruction and meniscal transplantation. This more aggressive approach of combination ACL reconstruction and meniscal transplantation has good long-term results.

In the past, full-thickness chondral defects were considered a contraindication; however, cartilage degeneration is not a significant risk factor for meniscal allograft failure.[4] Many of these patients are young and will progress to articular cartilage degeneration without adequate follow-up. While concomitant meniscal transplant and cartilage restoration have only been performed for a few years, outcomes are good.

On a small population of eight patients, concomitant autologous chondrocyte implantation (ACI) plus meniscal transplantation maintained improvement at 3.2 years postoperatively.[5] In another study, Farr *et al.*[6••] evaluated the success of combined ACI and meniscal transplantation surgery on a series of 36 patients at least 2 years from surgery. Standardized outcome scores, visual analog pain and satisfaction scores showed statistically significant improvement, and only four patients required a revision procedure within 2 postoperative years. The authors noted that pain scores were not as low as desired and outcomes were not as good as isolated ACI or isolated meniscal transplantation, but the concomitant procedure did offer improvements in knee symptoms and function.

Rue *et al.*[7••] also looked at combined meniscal transplantation and cartilage restoration. In 31 patients with meniscus allograft transplantion, 16 had concomitant ACI and 15 had concomitant osteochondral allograft. Eighty percent of ACI and 71% of allograft groups were completely or mostly satisfied with their results. Although the study reported only an average of 3.1 years postoperatively, the mid-term results of the combined procedures were comparable to those of the isolated procedures (Table 1).

TABLE 1. Outcomes of meniscal transplantation with concomitant cartilage restoration

Author	N	Cartilage Restoration	Other Concomitant Procedures	Location	Outcomes
Bhosale *et al.*[5]	8	8 ACI	None	5 lateral	• Lysholm: 49 to 66 ($P<0.01$) • 6/8 (75%) had pain relief and improved function at 1 year post-op • 5/8 (62.5%) had functional improvement at mean 3.2 years post-op
Farr *et al.*[6]	29	29 ACI	6 HTO 8 ACLR I TT medialization	21 lateral 8 medial	• Brown Cincinatti patient: 3.9 to 6.3 ($P<0.0l$) • Brown Cincinnati clinical: 4.0 to 6.3 ($P<0.0l$) • Lysholm: 57 to 77.7 ($P<0.01$) • Rest pain: 2.52 to 1.25 ($P<0.01$) • Maximum pain: 7.62 to 5.11 ($P<0.01$) • Satisfaction (range 1-5): 1.1 to 3.13 ($P<0.01$)
Rue *et al.*[7]	31	16 ACI 15 OA	1 HTO 2 hardware removal	11 lateral 20 medical	• Lysholm: 47.8 to 74.0 ($P<0.01$) • IKDC: 38.7 to 66.9 ($P<0.01$) • 26/29 (90%) would have surgery again

ALLOGRAFT SIZING

The success of meniscal transplantation is dependent on careful size-matching of the meniscal allograft to the native meniscus. Meniscal allografts are compartment and size-specific. Allograft sizing is of significant importance, as oversized meniscal allografts lead to greater forces across the articular cartilage.[8] On the other hand, undersized allografts result in greater forces seen by the meniscal tissue.[8]

Currently, radiographic measurements as described by Pollard *et al.*[9] are used to appropriately size the meniscus. As a consistent relationship exists between meniscal size and bony landmarks, most tissue banks currently size the meniscus with tibial plateau width and length measurements (Figures 1 and 2). Despite these standard methods of meniscal sizing, there still remains a 7.4–8.4% standard deviation in the length and width measurements.

Several recent studies have aimed to determine better sizing of meniscal donor tissue. Prodromos *et al.*[10••] determined that the contralateral meniscus, as measured by MRI, is symmetric (to less than 3 mm in size) to the affected, meniscus-deficient knee. Provided that all patients receive a bilateral knee MRI, sizing based on the contralateral meniscus may offer a new, more accurate method for choosing the correct meniscus donor size. Furthermore, the authors suggested that MRI is a more accurate method, as compared with radiographs, for obtaining meniscal sizing measurements. Stone *et al.*[11••] aimed to accurately choose meniscal size based on the characteristics of the patient. They concluded that gender, height and weight should be considered as fast and cost-effective variables by which to predict meniscal dimensions. In a similar study, Van Thiel *et al.*[12] also suggested that gender, height, and weight can be

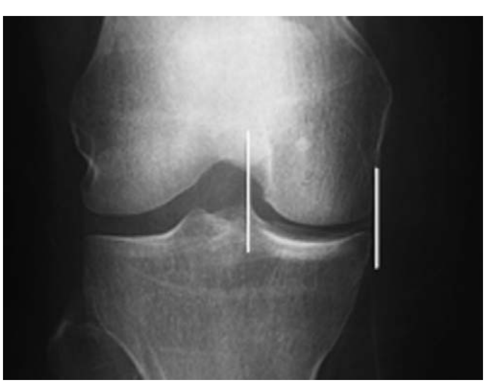

FIGURE 1. Preoperative anteroposterior radiograph used for meniscal sizing. Meniscal width is measured from the peak of the tibial eminence to the medial tibial metaphyseal margin.

FIGURE 2. Preoperative lateral radiograph used for meniscal sizing. Meniscal length is determined by the tibial plateau distance measured at the joint line between a line parallel to the anterior tibia above the tuberosity and one tangential to the posterior plateau margin perpendicular to the joint line.

used to predict meniscal allograft sizing. The authors used data obtained from the Joint Restoration Foundation and applied regression formulas to estimate meniscal dimensions. The resulting matches had lower standard deviations and average error rates compared with the current radiographic sizing methods.

As meniscal grafts are being used more often, characteristics other than sizing are being considered. Bursac *et al.*[13] studied the biochemical and biomechanical (tensile) properties of menisci from donors age 15 to 44 years and found no difference in the properties of the grafts, suggesting that all donor grafts under the age of 45 will provide good quality.

Wilmes *et al.*[14] used cadaver tissue to evaluate the anatomic locations of the insertion sites for the anterior and posterior horns for both the medial and lateral[15] menisci and correlated the relative measurements with standard anteroposterior and lateral radiographs. They determined that the insertions of the anterior and posterior horns of the medial meniscus have constant positions of 57.3% and 56.5% of tibial width and 12.0% and 81.6% of tibial depth, respectively. The anterior and posterior horns of the lateral meniscus have constant positions at 45.1% and 49.8% of tibial width and 41.9% and 72.1% of tibial depth. The results were precise and reproducible, offering a more accurate measurement for insertion site placement during surgery.

MENISCAL GRAFT PROCESSING AND PRESERVATION

Meniscal allografts are ideally harvested within 24 hours after death and frozen to -80°C. While other graft preservation methods are used, fresh frozen remains the most commonly used allograft preservation method.[16] However, shrinkage of the graft has been reported, which alters the accuracy of meniscal sizing and compromises the outcome. Gelber *et al.*[17] evaluated frozen and normal menisci using transmission electron microscopy (TEM) and found that frozen menisci had collagen fibril diameters significantly smaller and with higher disarray than normal menisci. These results suggested that the collagen network is disrupted after freezing and offers a microstructural explanation for graft shrinkage. In a subsequent study evaluating the same microstructural parameters,[18] the authors found that cryopreservation does not alter the meniscal ultrastructure.

Stringent donor selection is based on comprehensive medical and social history. The risk of disease transmission is further reduced by screening for human immunodeficiency virus, human T-lymphocytic 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 débridement, ultrasonic pulsatile washing and use of ethanol to denature proteins, further lowers the risk of disease transmission.[19] Current meniscal graft processing involves an aseptic, antibiotic soak with limited tissue penetration. As standard sterilization methods with ethylene oxide and gamma irradiation increase the incidence of synovitis and decrease mechanical stability, respectively, alternative cleansing is needed to further decrease the risk of disease transmission. McNickle *et al.*[20] investigated the performance of grafts processed using the BioCleanse technique (RTI Biologics, Alachua, FL). The authors used a sheep model to assess the cell viability and biomechanical properties of implanted menisci treated with aseptic techniques or BioCleanse. The authors concluded that the BioCleanse sterilization process does not compromise tissue and can provide additional allograft safety.

As meniscal allografts are used more often, preservation methods need to be improved to allow more time for transport, coordination, and processing of tissues. Lewis *et al.*[21•] looked at the effects of multiple freeze-thaw cycles on donor menisci and demonstrated both biochemical and biomechanical alterations of menisci frozen and thawed four times, indicating that this processing may compromise its ability to resist compression, which is a primary role of the transplanted meniscus.

ARTHROSCOPIC TECHNIQUE

Several techniques have evolved for meniscal transplantation, and debate continues regarding the optimal procedure. Meniscal allografts can be secured by suture fixation as well as bony fixation. Further, bony fixation includes separate bone plugs on the anterior and posterior horns as well as bone bridges (keyhole, trough, dove-tail, and bridge-in-slot variations). The bone bridge is almost always used for the lateral meniscus because of the close proximity between the anterior and posterior horns. The medial meniscus can be anchored with either plugs or a bridge.

While many authors believe in the superiority of bone fixation,[22•,23••] some authors advocate meniscal transplant secured with sutures only. Hunt *et al.*[24] reported the results of a cadaver study, comparing the pull-out strength of the posterior horn of medial meniscal allografts with attached bone plug plus suture or fixation with suture alone. The authors found no differences in the mean pullout strength between the two groups, suggesting that it may not be necessary to maintain the bone plug for medial meniscal transplant fixation. On the other hand, in a contact pressures study by McDermott *et al.*,[25] the authors determined that the peak contact pressures were reduced with two different meniscal allograft fixation methods (bone plug or sutures only) compared with a knee that has had a meniscectomy. Furthermore, the peak contact pressure was slightly lower in specimens transplanted with bone plugs than those with suture only, suggesting that a firm attachment of the anterior and posterior horns is important.

In a similar study of contact pressures, Verma *et al.*[26••] compared the contact pressures of intact knees that have had meniscectomy and medial meniscal transplantation with those that have had a bone plug or bone trough technique. The authors concluded that the double bone plug and bone trough technique had similar contact mechanics. We prefer the bridge-in-slot technique for both lateral and medial menisci for a number of reasons, including its simplicity and secure bony fixation, ability to easily perform concomitant procedures, and the ability to maintain the native anterior and posterior meniscal horn attachments.

While there is still debate regarding the current techniques of meniscal fixation, new approaches are being developed. One proposal has been meniscal fixation with fibrin glue. However, in a rabbit model,[27] the fibrin glue resulted in loosening of the graft and decreased density of cells in the graft tissue, suggesting impairment of the cell's spread into the collagen of the allograft.

MRI EVALUATION

For patients who are symptomatic after transplant, MRI evaluation is debatable, because prior surgery may confound MRI interpretation. The literature offers an array of interpretations for MRI after transplant, from the position that MRI does not predict clinical symptoms[28] to more optimistic opinions, stating that MRI is the best tool to assess the meniscus after transplant.[29,30]

Lee *et al.*[31•] used MRI to evaluate meniscal extrusion at 6 weeks and 3, 6, and 12 months follow-up. With extrusion defined as 3 mm subluxation, the authors found that in patients in whom graft extrusion occurred, it took place within the first 6 weeks and remained at the same extrusion distance for the remainder of the follow-up period. In contrast, menisci that did not extrude early were unlikely to extrude within the first postoperative year.

OUTCOMES

Meniscal allograft transplantation yields good to excellent results in nearly 85% of all patients based on intermediate-term outcomes,[4,6,7,32–35] in which most patients demonstrated decrease in pain as well as an increase in activity.

In addition to the long list of studies looking at the outcomes of meniscal transplantation, more studies have been recently published, including those with longer follow-up periods. Hommen *et al.*[36••] looked at the outcomes of cryopreserved meniscal transplantation at an average 12 years postoperatively. Although the grafts provided decreased pain and increased functionality in 90% of patients, meniscal failures, as determined by postoperative surveys (Lysholm <65), lack of pain relief or change in survey results, and results of second-look arthroscopy and MRI, represented 58% of medial and 50% of lateral allografts. In an attempt to look at the long-term outcomes of meniscal transplantation, Von Lewinski *et al.*[37•] reported five patients at 20 years postoperatively. The results of the International Knee Documentation Committee (IKDC) score revealed 2 as nearly normal, 1 as abnormal and 2 as severely abnormal. Despite the unpromising results, it should be taken into consideration that these patients had untreated cartilage damage (noted at surgery) and concomitant anterior cruciate ligament reconstruction. Before conclusions are drawn regarding the efficacy of meniscal transplantation, more long-term outcome evaluations are necessary to evaluate a larger patient population with meniscal transplantation using the current techniques.

Thijs *et al.*[38] compared proprioception preoperatively and postoperatively in patients with transplanted viable meniscal allografts. At the 6-month follow-up period, patients had improved joint position sense at a reference point of 70° of knee flexion as compared to their preoperative state. Although evaluation occurred at short-term when The Western Ontario and McMasters Universities (WOMAC) scores showed no improvement for the preoperative status, the study showed a significant positive effect of the joint position sense in a previously meniscal-deficient knee.

CONCLUSION

Although many questions remain regarding meniscal allograft sizing and processing, surgical technique, and long-term outcomes, meniscal allograft transplantation has nonetheless provided pain relief and increased function for appropriate patients with meniscal deficiencies. In addition, to further investigating these issues, new meniscal replacement alternatives will be part of the future, such as bioactive scaffolds, synthetic implants, and tissue-engineered menisci, which will offer patients optimal treatment options.

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