A Prospective Outcomes Study of Meniscal Allograft Transplantation

Robert F. LaPrade,*† MD, PhD, Nicholas J. Wills,‡ MD, Stanislav I. Spiridonov,‡ and Scott Perkinson,‡ MD

From the †Steadman Philippon Research Institute, Vail, Colorado, and ‡Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, Minnesota

Background: Symptomatic early-onset chondromalacia often develops after a meniscectomy in the affected knee compartment. The role of meniscal transplantation in reducing pain and improving function in patients with prior ipsilateral meniscectomy is still being defined.

Hypothesis: Patients with symptomatic early-onset chondromalacia of the knee after ipsilateral meniscectomy will have improved clinical outcomes after meniscal transplantation.

Study Design: Case series; Level of evidence, 4.

Methods: All patients who underwent meniscal allograft transplantation between July 2003 and December 2006 were prospectively followed. The indications for surgery were unicompartmental knee pain and postactivity effusions after total or near-total meniscectomy in patients with closed physes. High-field magnetic resonance imaging (1.5-T or 3-T magnets) was used to assess the articular cartilage of the affected compartment. The meniscal transplantations were performed with an arthroscopically assisted technique. Modified Cincinnati knee and International Knee Documentation Committee (IKDC) subjective and IKDC objective outcome scores were obtained on all patients preoperatively and postoperatively to evaluate patients' outcomes.

Results: Forty patients with an average age of 25 years and a body mass index of 25.4 were included. After an average final follow-up of 2.5 years, IKDC subjective scores increased significantly from 54.5 to 72.0 ($P < .001$). Modified Cincinnati knee scores increased from 55.2 to 75.3 ($P < .001$). The preoperative IKDC objective scores measuring effusion improved significantly from 6 As (normal), 29 Bs (nearly normal), and 5 Cs (abnormal), when compared with the postoperative scores of 33 As (normal) and 1 B (nearly normal) ($P < .01$). Five patients sustained tears of their meniscal transplants and underwent partial meniscectomies of the transplant graft.

Conclusion: The results confirm that meniscal transplantation significantly reduces pain, decreases activity-related effusions, and improves function in patients with prior meniscectomy; however, the long-term chondroprotective effects remain unknown.

Keywords: meniscal transplantation; articular cartilage; medial meniscus; lateral meniscus

The menisci have been reported to perform vital roles in the knee joint, including load bearing, load transmission, shock absorption, joint stability, joint lubrication, and joint congruity.[9,22] In its shock-absorbing role, the medial meniscus has been demonstrated to bear approximately 50% of the medial compartment load and the lateral meniscus 70% of the lateral compartment load with the knee in full extension.[22] It has been recognized that partial and complete meniscectomies increase the resultant forces seen on the ipsilateral compartment articular cartilage.[2,7] However, while it is usually recommended to repair a meniscus whenever possible, this often may not be possible because of the type of tear, location of tear, patient age, and other factors. It is well established that premature, progressive chondromalacia of the ipsilateral compartment occurs after total meniscectomy.[2,7] Therefore, increased emphasis has been placed on the preservation of meniscal tissue whenever possible. Unfortunately, in many cases the meniscus is not repairable, requiring a meniscectomy that leads to symptomatic early-onset chondromalacia of the affected compartment when a significant portion of the meniscus has been resected. In these patients, meniscal transplantation is an option for symptomatic patients that can potentially result in pain relief, decreased effusions, and improved function.[3,15,19,21,29,32] The improved function seen after meniscal transplantation is presumably due to an increase in intra-articular contact area and a decrease in contact pressures across the knee joint compared with a knee after

*Address correspondence to Robert F. LaPrade, MD, PhD, Director, Biomechanics Department, Steadman Philippon Research Institute, The Steadman Clinic, 181 W. Meadow Drive, Suite 900, Vail, CO 81657 (e-mail: drlaprade@sprivail.org).

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meniscectomy.[1,17] Cadaveric studies have reported that total medial meniscectomy increases these pressures by 136%, while total lateral meniscectomy increases maximum tibial plateau contact pressures by 235% to 335%.[1,17]

To date, there is no clear consensus regarding the indications and timing for surgery, long-term function, or efficacy of meniscal transplantation.[12,20] The primary candidate appears to be a young patient who has undergone a meniscectomy and subsequently develops ipsilateral compartment knee pain and effusions with activity. Some authors state that the presence of early-onset chondromalacia is mandatory for meniscal transplantation, while others believe that the ideal candidate has minimal or no arthritic changes.[3,12,25]

The purpose of this prospective study was to report the clinical outcomes of meniscal transplantations in a consecutive series of patients who had undergone a previous total or subtotal meniscectomy and who had pain and activity-related effusions. We hypothesized that meniscal transplants would significantly reduce pain and improve patient function, demonstrated by a significant improvement in patient outcome scores.

MATERIALS AND METHODS

We prospectively followed the outcomes of meniscal transplants in forty consecutive patients between July 2003 and December 2006. The senior author (R.F.L.) performed all of the operations. All patients were carefully screened preoperatively with high-field MRI scans, plain radiographs with sizing markers, and alignment radiographs to determine their suitability for a meniscus transplant. The grafts were aseptically processed with no terminal sterilization or irradiation. The meniscus grafts were stored at –20° C for up to 6 months; for longer storage, they were stored at –80° C. The grafts had an expiration date of 5 years. The age criterion for donors was 12 to 40 years of age for both male and female donors.

The indications for surgery were unicompartmental knee pain and postactivity effusions after total or near-total meniscectomy in patients with closed physes. Patients either demonstrated ligamentous stability or underwent a concurrent cruciate ligament reconstruction surgery to address their instability. Weightbearing AP and lateral radiographs with sizing markers and long-leg alignment radiographs were obtained and evaluated for arthritic changes and potential malalignment. Patients were defined to be in varus alignment if the weightbearing mechanical axis passed medial to the tip of the medial tibial eminence. Patients were defined to be in valgus alignment if their weightbearing axis passed lateral to the lateral tibial eminence. Postoperative alignment correction was performed to correct the weightbearing axis to pass through the downslope of the lateral tibial eminence for all patients in varus alignment, while patients in valgus alignment had their weightbearing axis corrected to have it pass through the tip of the medial tibial eminence. In all patients, the postoperative weightbearing mechanical axis was corrected out of varus or valgus alignment. High-field MRI (1.5-T or 3-T magnets) was used to assess the articular cartilage of the affected compartment. Patients who had more than small localized areas of grade 4 chondromalacia (except in those who were candidates for a concurrent articular cartilage resurfacing procedure) or who had grade 4 chondromalacia "kissing lesions" of the affected tibiofemoral surfaces were not thought to be candidates for meniscal transplantation. Patients with a deficient medial meniscus and genu varus alignment underwent a proximal tibial biplanar opening-wedge osteotomy followed by the medial meniscal transplant after the osteotomy healed. Patients with a deficient lateral meniscus and genu valgus alignment underwent a concurrent opening-wedge distal femoral osteotomy with the lateral meniscus transplant.

When a patient had a failed previous anterior cruciate ligament (ACL) reconstruction with a 3+ Lachman and pivot shift and had no other cause such as lack of secondary restraints to cause this increase in anterior translation and rotatory instability, the lack of the posterior horn of the medial meniscus was assumed to be the cause of the lack of secondary restraints. In this patient subgroup (n = 3), a concurrent medial meniscus transplant was performed concurrently with a revision ACL reconstruction.

Operative Technique

The meniscal transplantations were performed with an arthroscopically assisted technique. Diagnostic arthroscopy was used to evaluate the articular cartilage surfaces and the remaining remnant of the affected native meniscus to verify that the patient was a candidate for meniscal transplantation. Articular cartilage degeneration was classified according to the Outerbridge classification.[16] After the patient was arthroscopically confirmed to be a candidate for a meniscal transplant, the graft was slowly thawed in room temperature saline. A vascular recipient bed was created by debridement of the residual meniscal tissue to an approximately 1-mm bleeding rim. Medial meniscal repair incisions were made over the medial joint line and directly anterior to the superficial medial collateral ligament. The sartorius fascia was incised and the interval between the posterior joint capsule and the medial gastrocnemius was developed (Figure 1). Lateral meniscal repair incisions were made directly over the lateral joint line along the distal border of the superficial layer of the iliotibial band. The interval between the fibular collateral ligament and the lateral gastrocnemius tendon, just proximal to the fibular head, was then developed to gain access to the posterior joint capsule. In both approaches, an arthroscopic probe was placed into the joint and palpated against the surgeon's finger on the posterior joint capsule to verify that the meniscal repair approach was anterior to all posterior knee structures.

All meniscal transplant grafts had 4 nonabsorbable sutures placed vertically through the superior and inferior meniscal surfaces, 1 mm from the meniscocapsular junction, in both the anterior and posterior horns that were later used to suture the meniscus transplant graft to the corresponding anterior and posterior joint capsule. Before placement of the meniscal transplant graft, 4 passing sutures were passed through the posterior capsule using an Adson point hemostat (Roboz Surgical, Gaithersburg, A

B

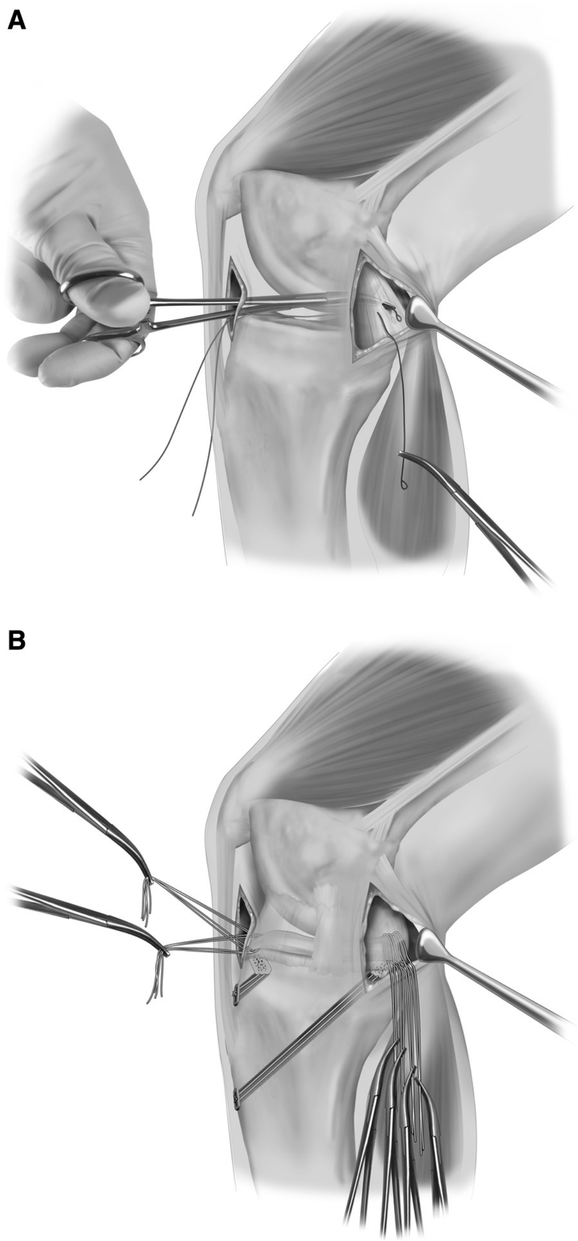

Figure 1. A, illustration of the surgical approach for a right knee medial meniscal allograft transplantation. The medial meniscal repair incision has been performed through the sartorius fascia and the medial gastrocnemius has been retracted posteriorly. The passing sutures are placed though the posterior capsule to subsequently pull the sutures placed in the posterior horn of the meniscus transplant graft into place. Also note the previously reamed posterior horn bone plug tunnel (arrows). B, illustration demonstrating a right knee medial meniscus transplant graft with bone tunnels and anterior and posterior horn sutures in place.

Maryland), corresponding to the location of the previously placed sutures in the posterior horn of the meniscal transplant (Steinar Johansen, Oslo, Norway, personal communication) (Figure 1). The sutures in the posterior horn of the meniscus transplant graft were then pulled out posteriorly via loops tied in the passing sutures.

Nine-millimeter coring reamers were used to prepare bone plugs for the medial meniscus transplant grafts in all patients. Nine-millimeter bone tunnels were prepared at the anatomic attachment sites of the anterior and posterior root attachments of the medial meniscus by drilling a guide pin antegrade for the posterior root attachment and retrograde for the anterior horn attachment and reaming a 9-mm acorn reamer over the guide pin. The posterior meniscus root attachment guide pin was reamed at approximately a 45° angle and exited posteriorly just anterior to the posterior cruciate ligament and along the downslope of the far posterolateral aspect of the medial tibial plateau. For lateral meniscus transplants, the lateral bone trough was prepared at the far medial edge of the lateral tibial plateau (Figure 2). The posterior root attachment of the lateral meniscus and the anterior horn attachments were identified first. A small curet was then used to outline a straight line exactly between these 2 attachment sites, which was located just lateral to the lateral border of the tibial attachment of the ACL. A trapezoidal bone trough (9-mm–wide base and 7-mm–wide top) was then prepared with the remaining rim of bone at the far posterior aspect of the bone trough being only a cortical shell of bone, usually about 1 to 2 mm wide. In this manner, the posterior horn of the lateral meniscus transplant graft was placed as far posteriorly as possible in the bone trough to prevent impingement on the graft from the lateral femoral condyle.

For medial meniscal transplants, the posterior horn root attachment bone plug was next positioned into the previously reamed tibial tunnel (Figure 3). Once proper positioning of the medial meniscus was verified, the sutures through the posterior horn root bone plug were tied over a button on the anteromedial aspect of the tibia to secure the bone plug into the tibial tunnel. At this point, a closed-socket bone tunnel was prepared for the anterior bone plug. This tunnel was prepared by placing a guide pin into the remnant of the native anterior horn medial meniscus root attachment, approximately 3 to 4 mm posterior to the anterior tibial cortex. The guide pin was angled away from any potential revision ACL reconstruction tunnels. A 9-mm reamer was used to prepare a 9-mm–diameter by 15-mm–deep tunnel over the guide pin.

The lateral meniscus transplant grafts were positioned into the joint by both pushing the trapezoidal bone plug into the previously prepared bone trough and by placing traction on the posterior horn meniscal sutures. Once the bone plugs were reduced, the 4 anterior horn sutures previously placed into the meniscal transplant were secured to the anterior capsule via a horizontal mattress stitch using a free needle. Next, the posterior horn sutures in the transplant, which had been placed through the posterior capsule, were tied to create a horizontal mattress stitch to the adjacent passing suture over the posterior capsule by either freehand ties or via a knot pusher. The remaining nonsecured portion of the meniscus transplant graft was anchored to the joint capsule using from 6 to 10 nonabsorbable vertical mattress sutures on both its superior and inferior surfaces with an arthroscopic-assisted “inside-out” technique.

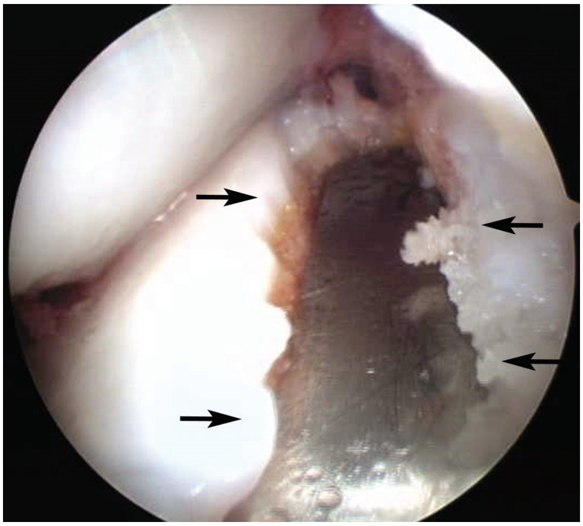

Figure 2. Intraoperative image of a lateral meniscus bone trough with a metal trough dilator in place (arrows, right knee).

Postoperative Management

Postoperatively, patients were placed into a knee immobilizer and remained nonweightbearing for 6 weeks. All patients were placed on 6 weeks of daily 325-mg enteric-coated aspirin for deep venous thrombosis prophylaxis. Quadriceps-setting exercises and straight-leg raises exercises in the brace were initiated on the first postoperative day. Patients were maintained in full extension for 1 week and began progressive range of motion from 0° to 90° over the next 2 weeks, after which full motion was allowed as tolerated with physical therapy. At 6 weeks postoperatively, patients were allowed to bear weight as tolerated and to wean off crutches when they could ambulate without a limp. They were started on a stationary bike at low resistance and allowed to perform leg presses at 1-quarter body weight to a maximum of 70° of knee flexion. Deep squats and sitting cross legged were discouraged for 4 months postoperatively. Progressive low-impact rehabilitation of the musculature was then encouraged to include walking, swimming, biking, and the use of elliptical machines. A gradual return to full low-impact activity was allowed over 6 to 9 months. Return to any high-impact activity was permanently discouraged in any patient who had more than grade 1 chondromalacia of the affected compartment or in patients who had effusions develop with high-impact activities.

Clinical Evaluation

Baseline outcome scores were obtained before surgery. Subjective functional data were collected through the International Knee Documentation Committee (IKDC) subjective evaluation form and the modified Cincinnati knee rating survey. Objective outcome scores were obtained through the IKDC scoring system. The same outcome scores were obtained at routine clinical follow-up in all patients.

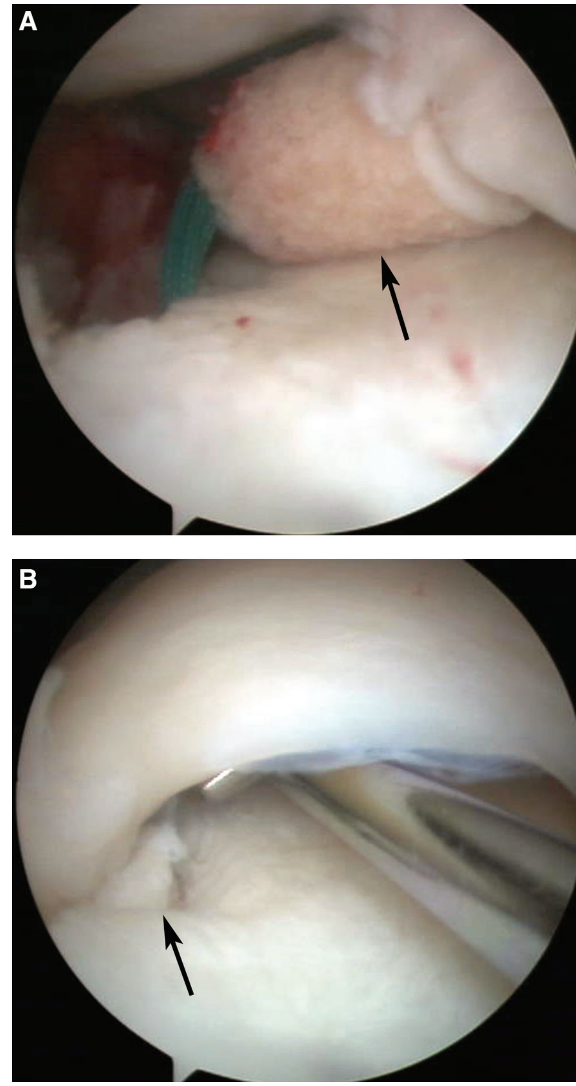

Figure 3. A, medial meniscus transplant posterior bone plug (arrow) before reduction. B, medial meniscus transplant posterior bone plug reduced (arrow) (right knee).

Statistical Analysis

Statistical comparison between the preoperative and follow-up outcome scores was performed using a Student t test. The level of significance was set at $P < .05$.

RESULTS

Forty patients were prospectively enrolled during this study. There were 26 males and 14 females with an average age of 25 years (range, 16-42 years) at the time of surgery. The average body mass index (BMI) at the time of surgery was 25.4 (range, 19.7-39.9). Individual patient demographics and graft/donor information are illustrated in Table 1.

Nineteen of the transplanted menisci were medial and 21 were lateral. Medial meniscal allografts were

TABLE 1
Patient Demographics and Graft/Donor Information[a]

Study ID No.	Sex	Patient Age, y	BMI	Years Since Original Injury	Outerbridge Grade	Surgery Performed
1	M	29	39.9	5	I-II	Lateral transplant, distal femoral osteotomy
2	M	19	23.1	10	II-III	Lateral transplant
3	M	19	24.3	2	III-IV	Lateral transplant, microfracture MFC
4	M	30	25.7	2	I	Medial transplant, hardware removal
5	M	29	30.9	3	I-II	Medial transplant, ACLR
6	M	35	36.7	3	I	Medial transplant, ACLR, hardware removal
7	M	18	21.7	2	II-III	Medial transplant
8	M	42	25.6	7	III	Medial transplant, microfracture MFC
9	M	21	26.4	2	III	Lateral transplant, microfracture LFC
10	M	34	27.8	14	III	Lateral transplant
11	F	34	21.1	1	IV	Medial transplant, ACLR, OA allograft
12	F	33	21.6	6	I	Medial transplant
13	F	18	20.4	2	I	Medial transplant
14	F	37	20.1	26	I-II	Medial transplant, ACLR
15	F	21	24.4	3	I	Medial transplant
16	F	25	21.7	2	I-II	Lateral transplant, ACLR
17	F	16	22.2	4	II-III	Lateral transplant
18	M	17	23.5	1	II-III	Lateral transplant
19	F	20	36	7	IV	Medial transplant, OA allograft
20	M	18	21.7	4	III	Lateral transplant
21	M	20	24.4	2	I-II	Lateral transplant
22	M	17	20.3	2	II-III	Lateral transplant
23	M	23	24.4	6	I	Lateral transplant, re-revision ACLR, distal femoral osteotomy
24	M	18	27.3	1	II	Medial transplant, revision ACLR
25	M	28	21.7	9	I-II	Medial transplant revision, revision ACLR
26	M	18	23.2	3	I	Lateral transplant, microfracture LFC, distal femoral osteotomy
27	F	35	23.2	2	I-II	Medial transplant
28	M	17	20.8	5	I	Lateral transplant
29	F	25	19.7	3	I	Medial transplant, re-revision ACLR
30	F	23	25	4	I	Lateral transplant
31	M	18	25.8	3	III-IV	Lateral transplant
32	F	36	25.4	1	II	Lateral transplant, microfracture LFC
33	M	29	35.2	2	I-II	Revision medial transplant
34	M	30	28.8	5	II-III	Lateral transplant
35	M	16	37.5	7	I-II	Medial transplant, ACLR
36	F	33	22.6	3	II	Lateral transplant
37	M	21	25.1	5	II-III	Lateral transplant
38	M	20	21.5	4	II-III	Lateral transplant
39	M	21	26.5	3	I	Medial transplant, hardware removal
40	M	38	25.8	3	I	Medial transplant, OA allograft
Average	25	25.4	4.5			

[a]Patient age and BMI are from the day of surgery. Years since original injury were determined through history. Outerbridge grade was determined intraoperatively. Surgery performed includes all concurrent procedures at the time of meniscal transplantation. Transplant refers to a meniscal transplantation.

BMI, body mass index; MFC, medial femoral condyle; ACLR, anterior cruciate ligament reconstruction; LFC, lateral femoral condyle; OA = refrigerated osteoarticular.

transplanted in 11 males and 8 females with an average age of 27 years (range, 17-42 years) at the time of surgery. The average BMI at the time of surgery was 25.4 (range, 20-36.7), while the average time between the original injury and transplantation was 6 years (range, 1-26 years). Lateral meniscal allografts were transplanted into 16 males and 5 females with an average age of 24 years (range, 16-40 years) at the time of surgery. The average BMI at the time of surgery was 26.5 (range, 19.7-39.9), and the average time between the original injury and transplantation was 5 years (range, 1-14 years).

The outcomes of patients in 3 distinct BMI groups were analyzed and showed no significant difference. The patients were put into 1 of 3 groups: BMI $\leq$25, BMI >25 but $\leq$30, and >30. The outcomes of patients in 3 age groups were compared. The 3 groups were $\leq$30, 31 through 35, and $\geq$36 years. The patients who were $\geq$36 years of age had a preoperative Cincinnati score lower than the rest of the groups, with a *P* value of .03. However, the postoperative Cincinnati score outcomes were not statistically different. The IKDC scores showed no significant differences.

TABLE 2
Previous Surgeries[a]

No. of Patients (N = 40)	Previous Procedure(s)
0	None
20	Partial or total lateral meniscectomy
17	Partial or total medial meniscectomy
14	ACL reconstruction
4	Meniscal repair
4	Arthroscopic debridement
1	Microfracture of lateral femoral condyle
1	Iliotibial band excision
3	Meniscal transplantation
4	Proximal tibial osteotomy
1	ACL thermal shrinkage

[a]Number of patients undergoing meniscal transplantation with listed previous surgery on the ipsilateral knee. Procedures listed included arthroscopically performed and open procedures. ACL, anterior cruciate ligament.

All patients had undergone at least 1 prior ipsilateral knee surgery (Table 2). Twenty-one patients had concurrent procedures performed on the ipsilateral knee at the time of meniscal transplantation (Table 3). All concurrent surgeries healed with no evidence of failure of articular cartilage–resurfacing procedures or lack of correction of concurrent osteotomies. In all patients who underwent osteotomies (n = 7), the postoperative weightbearing mechanical axis was corrected out of varus or valgus alignment. There was no significant difference between the outcomes of patients with isolated and combined procedures. Likewise, there was no significant difference between patients who did (n = 3) or did not undergo a concurrent osteotomy.

The mean Outerbridge grade of the affected compartment was 2.1 (range, 1-4). In patients who received medial meniscal transplants, the mean Outerbridge grade at the time of surgery was 1.7 (range, 1-4). In patients who received lateral meniscal transplants, the mean Outerbridge grade was 2.4 (range, 1-4). All patients with an Outerbridge grade 4 articular cartilage lesion had a concurrent articular cartilage resurfacing procedure of the affected area (microfracture [n = 5] or refrigerated osteoarticular allograft [n = 3].[13])

The outcomes of patients with 3 distinct Outerbridge groups were analyzed and showed no significant difference. The patients were put into 1 of 3 groups; the first group included patients with grades of 1 to 1.5; the second, was 2 to 2.5; and the third, 3 to 4. There were no significant differences in the outcomes between any of the patients within these groups.

Baseline overall Cincinnati knee rating scores on the entire population averaged 55.2 for all patients and 53.7 for the 34 patients who were available for follow-up. At an average of 2.5 years (range, 1.8-4.0 years), 34 patients were available for follow-up. Their overall Cincinnati knee rating scores improved to an average of 75.3 ($P < .001$). The IKDC-subjective form demonstrated a baseline score of 54.5 for all patients and 54.3 for the 34 patients who were available for follow-up. Thirty-four patients had complete IKDC subjective forms available at follow-up. These

TABLE 3
Concurrent Procedures[a]

No. of Patients (N = 40)	Procedure(s) Performed Concurrently With Meniscal Transplantation
19	None
6	ACL reconstruction
4	Revision ACL reconstruction
4	Hardware removal
5	Microfracture of femoral condyle
3	Osteoarticular allograft
3	Distal femoral osteotomy

[a]ACL, anterior cruciate ligament.

patients demonstrated a significant improvement in IKDC subjective scores to 72.0 ($P < .001$). We were not able to reach 6 patients for further follow-up, and none were known to have undergone further surgery.

The 21 patients who underwent lateral meniscal transplants had baseline Cincinnati scores of 57.8. Fifteen of these patients had follow-up scores averaging 77.9 ($P < .001$). Nineteen patients who underwent medial meniscal transplants had baseline Cincinnati scores of 52.3, which improved 11 points to 73.2 ($P < .001$). On the IKDC subjective questionnaire, patients who underwent lateral meniscal transplants (n = 21) improved from baseline scores of 57.6 to an average of 76.6 ($P < .001$). For patients undergoing medial meniscal transplants, baseline IKDC subjective scores (n = 19) averaged 51.2 and improved to 68.2 ($P < .001$).

Preoperatively, the IKDC objective scores were 6 As (normal), 29 Bs (nearly normal), 5 Cs (abnormal), and 0 Ds (severely abnormal) for effusion (Figure 4); 0 As (normal), 9 Bs (nearly normal), 20 Cs (abnormal), and 11 Ds (severely abnormal) for the single-legged hop test (Figure 5); and 29 As (normal), 0 Bs (nearly normal), 4 Cs (abnormal), and 7 Ds (severely abnormal) for the maximum manual Lachman test (Figure 6). Postoperatively, the IKDC objective scores were all significantly improved: 33 As (normal) and 1 B (nearly normal) for effusion ($P < .001$); 10 As (normal), 18 Bs (nearly normal), and 6 Cs (abnormal) for the single-legged hop ($P < .001$); and 32 As (normal) and 2 Bs (nearly normal) for the maximum manual Lachman test ($P < .01$).

Complications and Subsequent Procedures

One patient developed an infection 5 months postoperatively attributed to secondary seeding from an infected ipsilateral foot psoriatic lesion and required a subsequent arthroscopic irrigation and debridement with retention of the meniscus transplant graft. The patient had no further sequelae and did well postoperatively. Five patients sustained tears of their meniscal transplants and underwent partial meniscectomies of the transplant graft. The average time from transplantation to reinjury was 24 months. The patients who underwent meniscectomies had an average Cincinnati score of 49.6 and IKDC score of 50.2 at the time of final follow-up. On average, less than 20% of the meniscus graft was removed in the area of the tear. Two of the patients had multiple procedures at the time of

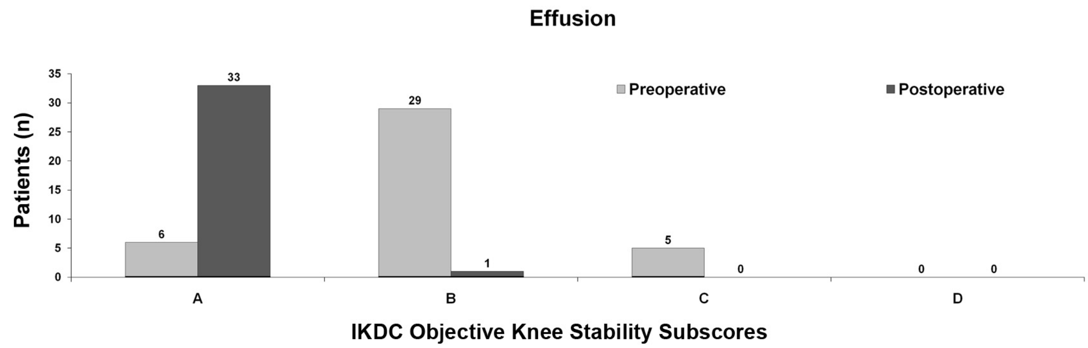

Figure 4. International Knee Documentation Committee (IKDC) objective outcome scores: preoperative and postoperative outcome scores measuring effusion.

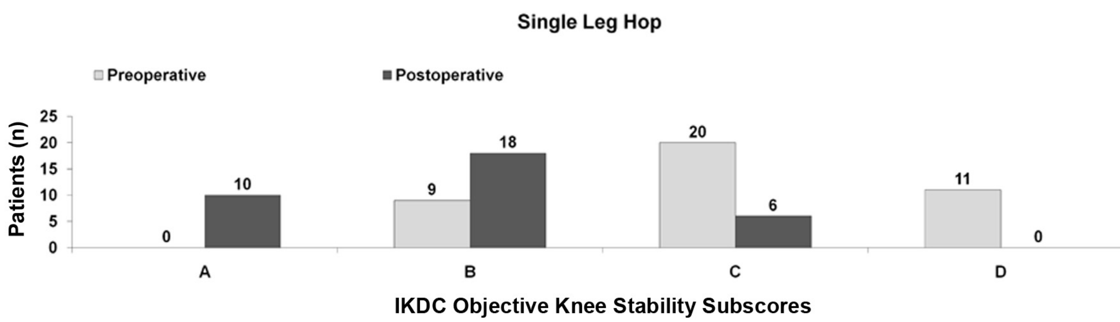

Figure 5. International Knee Documentation Committee (IKDC) objective outcome scores: preoperative and postoperative outcome scores measuring the single-legged hop test.

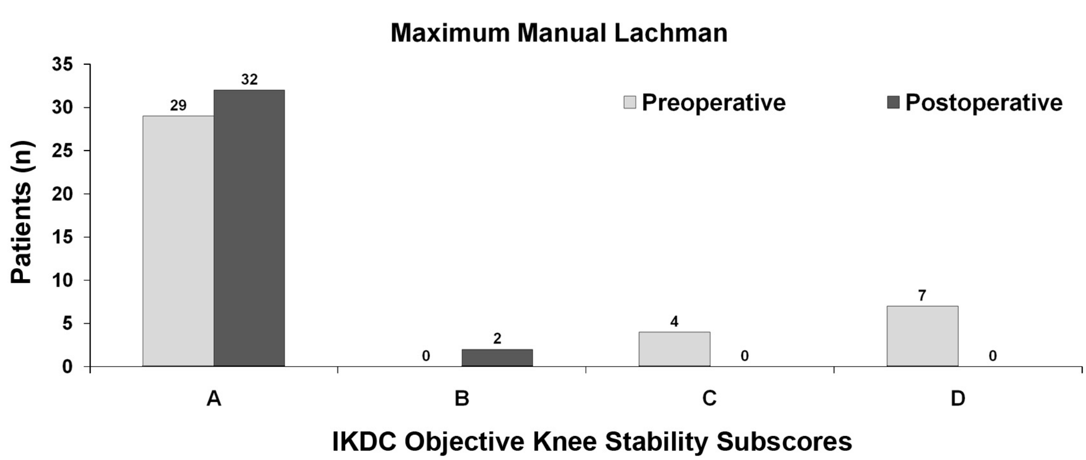

Figure 6. International Knee Documentation Committee (IKDC) objective outcome scores: preoperative and postoperative outcome scores measuring the maximum manual Lachman test.

original surgery, while 3 patients had isolated meniscal transplantation. At the time of final follow-up, there were no other complications identified. Three of the torn transplants were medial and 2 were lateral. Two of the patients had multiple procedures at the time of original surgery, while 3 patients had isolated meniscal transplantation. At the time of final follow-up, no other complications were identified. Two of these tears were caused by a motor vehicle accident and 1 was a contact sports injury. One patient gradually developed ipsilateral joint line pain with no history of trauma and was subsequently found to have a small meniscal transplant graft tear on MRI. The final patient tore his transplant graft when he caught his knee and fell while putting on a pair of pants. One patient developed a low-grade synovitis throughout his knee 2 years postoperatively that required an arthroscopic synovectomy; the patient subsequently recovered.

DISCUSSION

This prospective study found that meniscal transplantations significantly reduced pain, decreased activity-related effusions, and improved function in patients with previous meniscectomy. After a minimum 2-year follow-up, 91% of patients showed improved pain relief and function in the affected knee as measured by the Cincinnati subjective outcome survey, with 14.7% of patients sustaining a tear of their meniscus transplant graft. The primary indications for surgery in our patient population were pain localized to a single compartment and effusions with activity in patients who had previously undergone a meniscectomy. The IKDC objective scores measuring effusion also significantly improved from preoperative levels compared with the postoperative scores. These findings confirm previously published reports that meniscal transplantation can be a successful operation for relieving pain, decreasing effusions, and improving function in a properly selected patient population.

It is well established that subtotal meniscectomy can lead to progressive articular cartilage degeneration of the knee.[2,7] Meniscal transplantation has been proposed as an option for delaying postmeniscectomy arthritis. Several clinical studies have reported that meniscal transplantation significantly reduces pain and improves function; however, whether the allografts actually prevent or delay postmeniscectomy articular cartilage degeneration remains controversial.[5,17] Basic science and biomechanical studies have previously shown that meniscal transplants heal at the periphery to the joint capsule, are repopulated with viable host cells, and generally provoke a subclinical immune response.[6,10,11,20,32] Furthermore, several investigators have emphasized that secure, anatomic fixation with bone plugs attached to the anterior and posterior horns was required to restore optimum joint contact mechanics.[1,4,17]

Milachowski et al[14] were the first to report clinical results with meniscal allograft transplantation in 1989. They performed 22 meniscal transplantations using 6 deep-frozen allografts and 16 lyophilized allografts and demonstrated that meniscal transplantation was a viable treatment option. In 2002, Wirth et al[32] reported 14-year follow-up results on 23 patients from Milachowski's original series. They found the average Lysholm score increased to 84 ± 12 from a baseline of 59 ± 11 at 3 years postoperatively, but then decreased to 75 ± 23 14 years postoperatively. It was also noted that the 6 patients with deep-frozen allografts had improved outcomes compared with the patients with lyophilized allografts. In 2007, von Lewinski et al[31] published a 20-year follow-up looking at 5 of these original patients who received deep-frozen allografts. The patients' mean Lysholm score remained above the preoperative value. Radiographic examination revealed that 20 years after transplantation, the radiographic joint space of the affected knee was minimally thinner than the noninvolved knee. Although this represents the only true long-term follow-up of meniscal transplant patients in the literature, these patients were among the first meniscal transplantations and much advancement has been made in surgical technique, allograft harvesting, and allograft sizing over the past 2 decades.

Since the first report by Milachowski et al, several clinical studies have evaluated the results of meniscal transplants in patients with previous meniscectomy. Meniscal transplants have been reported to be successful in the majority of patients[3,24,26] and also to result in improved patient outcomes when performed concurrently with a revision ACL reconstruction.[8,23] Because of the important stabilizing role of the posterior horn of the medial meniscus, it has been recommended that a concurrent medial meniscus transplant be performed in revision ACL reconstructions if the posterior horn of the medial meniscus is absent.[8,23]

We found that patients who underwent a medial meniscal transplant or lateral meniscal transplant experienced a significant improvement in their symptoms as measured with the Cincinnati and IKDC subjective surveys. We saw no significant difference in the outcomes of the medial versus lateral meniscal transplants. Several studies have attempted to compare patient outcomes between medial and lateral meniscal transplants with varying results. Verdonk et al[29] reported that 28% of the medial allografts and 16% of the lateral allografts failed after a mean follow-up of 7.2 years. The survival plots for the isolated medial and lateral allografts did not differ significantly from one another. Other studies also found no difference in outcomes between medial and lateral meniscal transplants.[21] van Arkel and de Boer[27] found a significant difference in clinical results between lateral and medial meniscal transplants. The cumulative survival rates of the lateral, medial, and combined transplants in the same knee at final follow-up were 76%, 50%, and 67%, respectively. Failure of medial meniscal transplants occurred at a mean of 25 months and failure of lateral meniscal transplants occurred at a mean of 53 months after implantation.

One of the limitations of this study was that we did not use MRI or second-look arthroscopy to further characterize the transplant grafts. There may have been meniscal allografts that were torn but were asymptomatic. Although these cases could have been identified by MRI or arthroscopy, the correlation between these findings and clinical outcome is itself debatable.[18,28,30] We also recognize the inherent flaws with a study lacking a control group. However, the high risk of progression of postmeniscectomy arthritis in patients who have undergone functional or complete subtotal meniscectomies should suffice as a historical control. The only study to date with an age-matched control group that had undergone meniscectomies without transplantation was published in 2002 by Wirth et al[32] and concluded that, after a 14-year follow-up, patients with deep-frozen meniscal transplants had improved function and less arthritis than patients who had undergone meniscectomy. In addition, the inclusion of patients who underwent a concomitant procedure on the affected knee adds confounding variables, and it is unknown which procedure was responsible for the clinical improvement or if it affected the pace of recovery. In patients receiving a combined meniscal transplantation and ACL reconstruction, for example, it is unclear which procedure contributed what degree of the pain relief and function improvement that the patients experienced. Although the outcomes of patients with isolated and combined procedures were analyzed and the analysis showed no significant difference, further studies with larger numbers of patients may be necessary to determine if there are significant differences between patients undergoing isolated meniscal transplantation versus combined concurrent procedures.

In conclusion, the results of this study demonstrate that meniscal transplantation reduces pain, decreases activity-related effusions, and improves function in patients experiencing the signs and symptoms of postmeniscectomy arthritis, when ligamentous instability or axial malalignment was also corrected, at an average follow-up of 2.5 years. The potential long-term chondroprotective effects of this treatment are unknown at this time. However, it makes intuitive sense that if pain and swelling are decreased, then the rate of progression of arthritis is slowed because pain and swelling are the main signs of arthritis progression in these patients.

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REFERENCES

1. Alhalki MM, Hull ML, Howell SM. Contact mechanics of the medial tibial plateau after implantation of a medial meniscal allograft: a human cadaveric study. *Am J Sports Med*. 2000;28(3):370-376.
2. Allen PR, Denham RA, Swan AV. Late degenerative changes after meniscectomy: factors affecting the knee after operation. *J Bone Joint Surg Br*. 1984;66(5):666-671.
3. Cameron JC, Saha S. Meniscal allograft transplantation for unicompartmental arthritis of the knee. *Clin Orthop Relat Res* 1997;337:164-171.
4. Chen MI, Branch TP, Hutton WC. Is it important to secure the horns during lateral meniscal transplantation? A cadaveric study. *Arthroscopy*. 1996;12(2):174-181.
5. Cummins JF, Mansour JN, Howe Z, Allan DG. Meniscal transplantation and degenerative articular change: an experimental study in the rabbit. *Arthroscopy*. 1997;13(4):485-491.
6. Debeer P, Decorte R, Delvaux S, Bellemans J. DNA analysis of a transplanted cryopreserved meniscal allograft. *Arthroscopy*. 2000;16(1):71-75.
7. Fairbank TJ. Knee joint changes after meniscectomy. *J Bone Joint Surg Br*. 1948;30(4):664-670.
8. Graf KW Jr, Sekiya JK, Wojtys EM. Long-term results after combined medial meniscal allograft transplantation and anterior cruciate ligament reconstruction: minimum 10-year follow-up study. *Arthroscopy* 2004;20(2):129-140.
9. Henning CE, Lynch MA. Current concepts of meniscal function and pathology. *Clin Sports Med*. 1985;4(2):259-265.
10. Jackson DW, McDevitt CA, Simon TM, Arnoczky SP, Atwell EA, Silvino NJ. Meniscal transplantation using fresh and cryopreserved allografts: an experimental study in goats. *Am J Sports Med*. 1992;20(6):644-656.
11. Jackson DW, Whelan J, Simon TM. Cell survival after transplantation of fresh meniscal allografts: DNA probe analysis in a goat model. *Am J Sports Med*. 1993;21(4):540-550.
12. Klimkiewicz JJ, Shaffer B. Meniscal surgery 2002 update: indications and techniques for resection, repair, regeneration, and replacement. *Arthroscopy*. 2002;18(9 Suppl 2):14-25.
13. LaPrade RF, Botker J, Herzog M, Agel J. Refrigerated osteoarticular allografts to treat articular cartilage defects of the femoral condyles: a prospective outcomes study. *J Bone Joint Surg Am*. 2009;91(4):805-811.
14. Milachowski KA, Weismeier K, Wirth CJ. Homologous meniscus transplantation: experimental and clinical results. *Int Orthop*. 1989;13(1):1-11.
15. Noyes FR, Barber-Westin SD, Rankin M. Meniscal transplantation in symptomatic patients less than fifty years old. *J Bone Joint Surg Am*. 2005;87 Suppl 1(Pt 2):149-165.
16. Outerbridge RE. The etiology of chondromalacia patellae. 1961. *Clin Orthop Relat Res*. 2001;389:5-8.
17. Paletta GA Jr, Manning T, Snell E, Parker R, Bergfeld J. The effect of allograft meniscal replacement on intraarticular contact area and pressures in the human knee: a biomechanical study. *Am J Sports Med*. 1997;25(5):692-698.
18. Potter HG, Rodeo SA, Wickiewicz TL, Warren RF. MR imaging of meniscal allografts: correlation with clinical and arthroscopic outcomes. *Radiology*. 1996;198(2):509-514.
19. Rath E, Richmond JC, Yassir W, Albright JD, Gundogan F. Meniscal allograft transplantation: two- to eight-year results. *Am J Sports Med*. 2001;29(4):410-414.
20. Rodeo SA, Seneviratne A, Suzuki K, Felker K, Wickiewicz TL, Warren RF. Histological analysis of human meniscal allografts: a preliminary report. *J Bone Joint Surg Am*. 2000;82(8):1071-1082.
21. Ryu RK, Dunbar VWH, Morse GG. Meniscal allograft replacement: a 1-year to 6-year experience. *Arthroscopy*. 2002;18(9):989-994.
22. Seedhom BB, Dowson D, Wright V. Proceedings: functions of the menisci. A preliminary study. *Ann Rheum Dis*. 1974;33(1):111.
23. Sekiya JK, Giffin JR, Irrgang JJ, Fu FH, Harner CD. Clinical outcomes after combined meniscal allograft transplantation and anterior cruciate ligament reconstruction. *Am J Sports Med*. 2003;31(6):896-906.
24. Sekiya JK, West RV, Groff YJ, Irrgang JJ, Fu FH, Harner CD. Clinical outcomes following isolated lateral meniscal allograft transplantation. *Arthroscopy*. 2006;22(7):771-780.
25. Shelton WR, Treacy SH, Dukes AD, Bomboy AL. Use of allografts in knee reconstruction: I, basic science aspects and current status. *J Am Acad Orthop Surg*. 1998;6(3):165-168.
26. Stollsteimer GT, Shelton WR, Dukes A, Bomboy AL. Meniscal allograft transplantation: a 1- to 5-year follow-up of 22 patients. *Arthroscopy*. 2000;16(4):343-347.
27. van Arkel ER, de Boer HH. Survival analysis of human meniscal transplantations. *J Bone Joint Surg Br*. 2002;84(2):227-231.
28. van Arkel ER, Goei R, de Ploeg I, de Boer HH. Meniscal allografts: evaluation with magnetic resonance imaging and correlation with arthroscopy. *Arthroscopy*. 2000;16(5):517-521.
29. Verdonk PC, Verstraete KL, Almqvist KF, et al. Meniscal allograft transplantation: long-term clinical results with radiological and magnetic resonance imaging correlations. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(8):694-706.
30. Verstraete KL, Verdonk R, Lootens T, Verstraete P, De Rooy J, Kunnen M. Current status and imaging of allograft meniscal transplantation. *Eur J Radiol*. 1997;26(1):16-22.
31. von Lewinski G, Milachowski KA, Weismeier K, Kohn D, Wirth CJ. Twenty-year results of combined meniscal allograft transplantation, anterior cruciate ligament reconstruction and advancement of the medial collateral ligament. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(9):1072-1082.
32. Wirth CJ, Peters G, Milachowski KA, Weismeier KG, Kohn D. Long-term results of meniscal allograft transplantation. *Am J Sports Med*. 2002;30(2):174-181.