Prospective Evaluation of Allograft Meniscus Transplantation

A Minimum 2-Year Follow-up

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Background: Clinical and biomechanical studies have demonstrated the increase in contact pressure and progressive deterioration of the tibiofemoral compartments that occur after partial or complete meniscectomy. Meniscus transplantation has been indicated for the symptomatic postmeniscectomy patient to alleviate symptoms and potentially prevent the progression of articular degeneration.

Purpose: To report the early-term results after allograft meniscus transplantations from a single institution performed by a single surgeon.

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

Methods: Forty-four meniscus transplants in 39 patients were evaluated at minimum 2-year follow-up using the Lysholm, Tegner, International Knee Documentation Committee, Knee Injury and Osteoarthritis Outcome Score, Noyes symptom rating and sports activity, and SF-12 scoring systems; visual analog pain scales; patient satisfaction; and physical examination. Four transplants failed early, leaving 40 transplants in 36 patients for review. Patients were grouped into medial and lateral transplant groups as well as those with isolated and combined procedures. Twenty-one menisci were transplanted in isolation (52.5%), and 19 were combined with other procedures (47.5%) to address concomitant articular cartilage injury.

Results: Patients demonstrated statistically significant improvements in standardized outcomes surveys and visual analog pain and satisfaction scales. In 7 patients, treatment had failed at final follow-up. Overall, 77.5% of patients reported they were completely or mostly satisfied with the procedure, and 90% of patients were classified as normal or nearly normal using the International Knee Documentation Committee knee examination score at final follow-up. There were no significant differences in the medial and lateral subgroups, although the lateral subgroup did demonstrate a trend toward greater improvement. No significant differences were noted in the isolated and combined subgroups.

Conclusion: Meniscus transplantation alone or in combination with other reconstructive procedures results in reliable improvements in knee pain and function at minimum 2-year follow-up. Longer term studies are necessary to determine if transplantation can prevent the articular degeneration associated with meniscectomy.

Keywords: meniscus; meniscus transplant; meniscectomy

The understanding of the importance of the meniscus and its function has greatly increased over the past few decades. Initially, the importance of the meniscus was poorly understood, which led to meniscal excision as the primary treatment for meniscal injuries. Increased knowledge of the natural history and biomechanical consequences of the postmeniscectomized knee has resulted in more importance being placed on meniscal preservation. However, not all meniscal injuries are amenable to repair, resulting in a group of patients with absent or nonfunctional menisci. After meniscectomy, articular cartilage loading is significantly increased, and predictable degeneration may occur.[10,12,18,30]

In an effort to restore normal knee anatomy and biomechanics, allograft meniscus transplantation is a treatment option for patients with debilitating pain and low-grade arthrosis secondary to meniscectomy. A previous experimental animal study has demonstrated that meniscus

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transplantation in a postmeniscectomized sheep knee resulted in protection of the articular cartilage comparable with that of the native meniscus.[39] Other studies have confirmed the improved contact mechanics, increased surface area, and decreased contact pressure after meniscus transplantation.[2,31] The purpose of this study was to report the early-term results after allograft meniscus transplantation from a single institution performed by a single surgeon.

MATERIALS AND METHODS

Patient Evaluation

All patients underwent an informed consent process approved by the institutional review board and the human subjects committee of our hospital. Patients were followed prospectively after allograft meniscus transplantation for persistent knee symptoms after meniscectomy. Inclusion criteria included persistent symptoms after meniscectomy, relatively well-preserved articular cartilage with less than grade III changes[30] on radiographs and at arthroscopy, normal knee alignment, and a stable joint. Joints that could be rendered stable or realigned by a concomitant procedure at the time of transplantation were also included. Symptoms typically included ipsilateral joint-line pain, activity-related swelling, and occasional giving way and crepitus.

Before transplantation, a comprehensive physical examination was performed to identify relevant comorbidities including malalignment and ligament deficiencies. Plain radiographs including weightbearing AP, lateral, patellofemoral, and 45° flexion weightbearing posteroanterior views were obtained. When clinical examination suggested lower extremity malalignment, weightbearing mechanical axis views were obtained. The weightbearing axis demonstrated varus malalignment in 1 patient with medial meniscus deficiency. This patient underwent medial meniscus transplant combined with opening wedge high tibial osteotomy to correct the weightbearing axis to the lateral edge of the lateral tibial spine.

Magnetic resonance scans were often obtained by the senior author or referring physician to evaluate for the extent of meniscectomy, high-grade chondral change, and subchondral edema in the involved compartment. When available, operative reports and arthroscopic photographs were reviewed to determine the magnitude of meniscal deficiency as well as the status of the articular cartilage. Patients who had severe arthritic change, defined as more than isolated grade III changes; femoral condyle or tibial flattening; or subchondral sclerosis were excluded. Patients with concomitant injuries or abnormalities such as ligament insufficiency, chondral defects, or malalignment were not excluded from the study but, in most cases, underwent simultaneous or staged procedures to address all pathologic changes. The senior author has previously published his algorithm for surgical management of focal articular cartilage defects.[1,8] This algorithm was used to decide which concomitant procedures were performed.

Surgical Planning, Technique, and Rehabilitation

Sizing radiographs were obtained and measured according to the method described by Pollard et al.[33] Although the senior author has no preference for preservation method, the majority of menisci were cryopreserved, with less than 20% being nonirradiated fresh-frozen grafts. All menisci in the medial compartment were transplanted using the double bone plug technique as described by Shelton and Dukes.[38] All menisci in the lateral compartment were transplanted using the keyhole technique as described by Goble et al.[16] The host menisci were debrided arthroscopically to a 1- to 2-mm peripheral rim to achieve punctuate bleeding. On the medial side, a modified low notchplasty was performed between the fibers of the posterior cruciate ligament and the medial femoral condyle to facilitate posterior plug passage. On the lateral side, the tibial trough was expanded by 1 mm to ease graft passage. All menisci were introduced through an anterior mini-arthrotomy. Traditional inside-out meniscal repair techniques were used with 8 to 10 vertically placed No. 2-0 nonabsorbable mattress sutures. On the medial side, bone plugs were secured with suture tied over a button (Acufex, Mansfield, Mass). On the lateral side, the allograft bone block was secured within the keyhole using an allograft cortical bone interference screw. Concomitant procedures such as osteotomies, ligament reconstructions, and cartilage restoration techniques were performed when indicated.

Postoperatively, patients were allowed immediate weightbearing as tolerated with crutches and a hinged knee brace unless concomitant procedures dictated otherwise. Immediate active and passive ranges of motion were instituted without limitation. Flexion weightbearing beyond 90° was restricted for 6 weeks to minimize posterior shear and rotational stress on the newly implanted meniscus. After 6 weeks, the brace was discontinued, and patients were allowed range of motion as tolerated. Jogging was allowed at 12 weeks with a progression to running and sport-specific–type drills.

Outcome Assessment

From September 1997 to February 2003, 76 allograft meniscus transplants were performed in 71 patients. For purposes of this evaluation, only patients with a minimum follow-up of 24 months were included, leaving 45 transplants in 40 patients for inclusion in the study. A single orthopaedic surgeon performed all surgeries and conducted the baseline and follow-up physical examinations. Treatment failures and adverse events were carefully monitored. Patients were evaluated preoperatively and 6 months and 1 year after the procedure, and yearly thereafter using the Lysholm,[21] Tegner,[41] International Knee Documentation Committee (IKDC),[3] Knee Injury and Osteoarthritis Outcome Score (KOOS),[35] Noyes symptom rating and sports activity,[26,29] and SF-12[44] scoring systems. The KOOS is divided into 5 components: pain, symptoms, activities of daily living (ADL), sports, and quality of life (QOL). The SF-12 consists of the physical component summary (PCS) and mental component summary (MCS).

In addition, patients were asked to respond to a series of subjective questions using visual analog scale (VAS) scores graded 0 to 10: (1) level of pain (0, no pain; 10, worst pain imaginable), (2) overall condition of the knee (0, cannot perform daily activities; 10, normal), and (3) satisfaction with the surgical outcome (0, completely unsatisfied; 10, completely satisfied). Next, patients were asked to report their satisfaction with the surgical procedure (completely satisfied, mostly satisfied, satisfied, mostly unsatisfied, completely unsatisfied). Finally, patients were asked if they would have the surgery again under similar circumstances (yes, no).

Physical examination included assessment of range of motion, amount of effusion, and ligament stability. The results were included in the physical examination component of the IKDC preoperatively and at each follow-up. Nonparametric statistical analysis was performed using SPSS for Windows version 11.5 (SPSS Inc, Chicago, Ill). Analysis of subgroups included a comparison of medial versus lateral transplantation and isolated versus combined procedures. The Wilcoxon signed rank test was used to compare baseline and most recent follow-up scores, and the Mann-Whitney test was used to compare scores between subgroups. Statistical significance was set at $P < .05$.

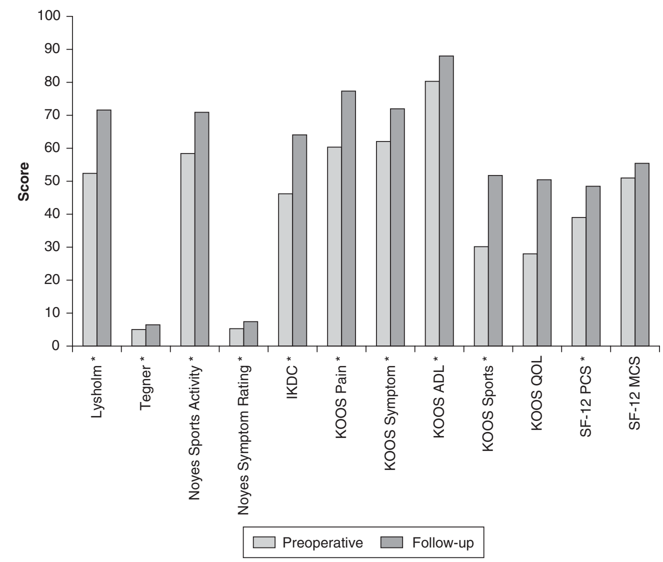

Figure 1. Knee scoring scale results for all allograft meniscus transplantations. *Denotes significant difference between preoperative and follow-up scores ($P < .05$). IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; ADL, activities of daily living; QOL, quality of life; PCS, physical component summary; MCS, mental component summary.

RESULTS

Forty-five allograft meniscus transplants were performed in 40 consecutive patients with a mean follow-up period of 33.5 months (range, 24-57 months). One patient was lost to follow-up. In 3 patients, the transplants failed within 12 months after the procedure, and these patients received knee arthroplasty; 1 of these patients had undergone both a primary and revision meniscus transplantation procedure. These patients were included in the calculation of failure rate after meniscus transplant but were not included in the summary of scoring scales because they went on to have alternative procedures. Thus, a total of 40 meniscus transplants in 36 patients (22 men and 14 women) were evaluated in this study; the patients had a mean age of 31 years (range, 16-48 years; SD, 9.5). Patients had a mean of 2.7 prior surgical procedures (range, 1-6 procedures). One patient had 3 separate menisci transplanted in 3 different compartments (left medial, right lateral, and right medial). Another patient received medial and lateral meniscus transplants in the same knee. A third patient had lateral meniscus transplants in both knees. Twenty-five menisci were transplanted in the medial compartment (62.5%) and 15 in the lateral compartment (37.5%).

Twenty-one menisci were transplanted in isolation (52.5%), and 19 were combined with other procedures (47.5%), including 3 osteochondral allografts, 3 osteochondral autografts, 2 microfractures, 2 osteochondritis dissecans fixations, 1 autologous chondrocyte implantation, and 1 chondral debridement. In addition, there were 6 concurrent ligament reconstructions and 1 osteotomy to address knee instability and malalignment, respectively.

There were statistically significant improvements in the Lysholm, Tegner, Noyes sports activity, and IKDC scoring scales from preoperative values to final follow-up ($P < .05$) (Figure 1). The mean Lysholm score showed significant improvement from 52.4 at baseline (SD, 20.26) to 71.6 (SD, 19.7) at the latest follow-up. The mean preoperative Tegner score was 5.0 (SD, 2.8) and increased to 6.5 (SD, 2.7) at follow-up. The preoperative Noyes sports activity and symptom rating scores were 58.4 (SD, 27.8) and 5.3 (SD, 1.9), respectively. The scores at final follow-up were 70.9 (SD, 27.0) and 7.4 (SD, 1.7), respectively. Mean IKDC scores significantly improved from a preoperative value of 46.2 (SD, 13.0) to 64.1 (SD, 20.0) at final follow-up. Similarly, there were statistically significant improvements in the KOOS pain, symptom, ADL, and sports scores from baseline to follow-up ($P < .05$). No significant difference in KOOS QOL score was noted preoperatively to follow-up ($P = .16$). The SF-12 PCS scores significantly increased from baseline to follow-up ($P < .05$); there was no significant difference in SF-12 MCS score (Figure 1).

The VAS scores declined significantly from preoperative evaluation to final follow-up with regard to both pain and overall knee condition ($P < .05$). Mean satisfaction at follow-up was 7.8. Seventy-five percent (27/36) of patients reported they were completely or mostly satisfied with the procedure. Eighty-six percent (31/36) reported that they would

TABLE 1
Medial and Lateral Allograft Meniscus Transplantation Subgroups: Knee Scoring Scales and Visual Analog Scale Scores[a]

	Medial (n = 25)				Lateral (n = 15)			
Knee Scoring Scale	Preoperative	Follow-up	% Change	*P*	Preoperative	Follow-up	% Change	*P*
Lysholm	52.11	69.20[b]	32.8	.001	52.77	75.60[b]	43.3	.013
Tegner	4.45	5.88	32.1	.091	5.86	7.40	26.3	.261
Noyes								
Sports activity	56.67	63.96	12.9	.180	60.77	82.00	34.9	.108
Symptom	5.39	7.24[b]	34.3	.006	5.15	7.73[b]	50.1	.011
IKDC	45.71	60.62[b]	36.3	.002	46.86	69.55[b]	48.4	.005
KOOS								
Pain	57.57	73.60[b]	27.8	.001	64.59	83.33[b]	29.0	.007
Symptom	61.89	67.81	9.6	.092	62.31	78.91[b]	26.6	.009
ADL	77.17	84.80	9.9	.088	84.92	92.87[b]	9.36	.012
Sports	29.50	47.08[b]	59.6	.001	31.15	59.20[b]	90.0	.007
QOL	23.75	46.80	97.1	.144	33.67	56.50	67.8	.180
SF-12								
PCS	38.84	46.15	18.8	.052	39.31	52.23[b]	32.9	.004
MCS	52.16	55.64	6.7	.307	49.23	55.11	11.9	.154
Visual analog scale								
Pain	5.55	3.36[b]	–39.5	.006	6.14	2.93[b]	–52.3	.005
Overall knee condition	4.50	6.44[b]	43.1	.032	5.00	7.73[b]	40.5	.003
Satisfaction		7.36				8.53		

[a]IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; ADL, activities of daily living; QOL, quality of life; PCS, physical component summary; MCS, mental component summary. There were no significant differences in preoperative scores between subgroups ($P > .05$) and no significant difference in follow-up scores between subgroups ($P > .05$).
[b]Denotes significant difference between preoperative and postoperative scores within a subgroup ($P < .05$).

have the surgery again given a similar situation in their contralateral knees.

Medial Versus Lateral Meniscus Allograft Transplantations

The medial and lateral subgroups showed increased scores from preoperative values to follow-up on all knee scoring scales (Table 1). Statistically significant improvements were detected for the majority of scores within both subgroups; however, there was no significant difference in the Tegner, Noyes sports activity, KOOS QOL, and SF-12 MCS scores within both subgroups ($P > .05$). In addition, the SF-12 PCS, KOOS symptom, and KOOS ADL showed no significant improvement for the medial subgroup. Although there were no significant differences in mean preoperative or mean follow-up scores between the medial and lateral subgroups ($P > .05$), the lateral subgroup showed a trend toward greater improvements than did the medial subgroup on nearly all knee scoring scales (Table 1).

Pain VAS scores decreased significantly ($P < .05$) for both subgroups, although there was a greater decline in the lateral subgroup. Mean patient satisfaction was 7.36 and 8.53 in the medial and lateral subgroups, respectively. Patients were completely or mostly satisfied with 68% of the procedures (17/25) in the medial subgroup and 93% (14/15) in the lateral subgroup. Given a similar situation in their contralateral knees, 84% (21/25) responded they would have the surgery again in the medial subgroup and 93% (14/15) in the lateral subgroup.

Isolated Versus Combined Meniscus Allograft Transplantations

There were no significant differences in mean preoperative or mean follow-up scores between the isolated and combined subgroups ($P > .05$). The majority of knee scoring scales demonstrated a significant increase in scores within both subgroups; however, there was no significant difference from preoperative to follow-up ($P > .05$) in the KOOS QOL and SF-12 MCS scores for both subgroups. In addition, the Tegner, Noyes sports activity, and KOOS ADL scores showed no significant improvement at follow-up in the isolated subgroup ($P > .05$) (Table 2).

Both groups reported a significant and similar degree of decrease in pain VAS scores ($P < .05$). Similarly, overall knee condition scores showed significant improvements ($P < .05$) for both subgroups. Mean patient satisfaction was similar in both subgroups. Patients were completely or mostly satisfied with 81% of the procedures (17/21) in the isolated subgroup and 74% (14/19) in the combined subgroup. Given a similar situation in their contralateral knees, 86% (18/21) in the isolated subgroup responded they would have the surgery again and 84% (16/19) in the combined subgroup.

Physical Examination

All patients were examined by the senior operating surgeon (B.J.C.) before the procedure and at each follow-up visit (Table 3). Mean range of motion preoperatively was from

TABLE 2
Isolated and Combined Allograft Meniscus Transplantation Subgroups: Knee Scoring Scales and Visual Analog Scale Scores[a]

	Isolated (n = 21)				Combined (n = 19)			
Knee Scoring Scale	Preoperative	Follow-up	% Change	*P*	Preoperative	Follow-up	% Change	*P*
Lysholm	47.94	68.05[b]	41.9	.002	57.40	75.53[b]	31.6	.006
Tegner	5.39	6.14	13.9	.326	4.63	6.83[b]	47.5	.032
Noyes								
Sports activity	61.00	67.86	11.2	.240	55.94	74.44[b]	33.1	.046
Symptom	5.00	7.57[b]	51.4	.003	5.56	7.26[b]	30.6	.027
IKDC	43.90	61.77[b]	40.7	.002	48.75	66.46[b]	36.3	.004
KOOS								
Pain	59.06	72.41[b]	22.6	.002	61.69	82.53[b]	33.8	.002
Symptom	57.76	69.05[b]	19.5	.023	66.93	75.20[b]	12.4	.075
ADL	78.25	84.84	8.42	.244	82.67	91.12[b]	10.2	.003
Sports	29.71	50.75[b]	70.8	.09	30.63	52.79[b]	72.3	.006
QOL	34.75	45.86	32.0	.109	19.00	54.84	188.6	.285
SF-12								
PCS	38.06	46.86[b]	23.1	.007	40.29	50.20[b]	24.6	.050
MCS	46.56	53.37	14.6	.125	56.64	57.62	1.73	.373
Visual analog scale								
Pain	6.50	3.67[b]	–43.5	.004	5.00	2.67[b]	–46.6	.003
Overall knee condition	4.17	7.05[b]	69.0	.004	5.31	6.79[b]	27.9	.050
Satisfaction		7.81				7.79		

[a]IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; ADL, activities of daily living; QOL, quality of life; PCS, physical component summary; MCS, mental component summary. There were no significant differences in preoperative scores between subgroups ($P > .05$) and no significant difference in follow-up scores between subgroups ($P > .05$).
[b]Denotes significant difference between preoperative and postoperative scores within a subgroup ($P < .05$).

0.4° to 125°; postoperatively, range of motion was from 0.4° to 128°. This difference was not statistically significant. Preoperatively, the IKDC knee examination grade was normal in 10% (4/40) of patients, nearly normal in 68% (27/40) of patients, abnormal in 10% (4/40) of patients, and severely abnormal in 12.5% (5/40) of patients; at follow-up, these results improved to 57.5% (23/40) normal, 32.5% (13/40) nearly normal, 7.5% (3/40) abnormal, and 2.5% (1/40) severely abnormal (Figure 2). The lateral subgroup demonstrated significantly greater preoperative and follow-up flexion compared with the medial subgroup ($P < .05$).

With regard to IKDC knee examination grade, 0% (0/25) of the medial subgroup was normal at baseline, but 52% (13/25) had a normal grade at final follow-up; 27% (4/15) of the lateral subgroup were graded normal preoperatively compared with 67% (10/15) at final follow-up. Preoperatively, 10% (2/21) of the isolated subgroup were graded normal compared with 57% (12/21) at final follow-up; 11% (2/19) of the combined subgroup were graded normal compared with 58% (11/19) at final follow-up. Of the 4 patients with an abnormal rating at most recent follow-up, 3 had moderate effusions (medial and isolated) and 1 patient with a concurrent osteochondral allograft developed a flexion contracture (medial and combined). Thus, including the 3 frank failures, these results indicated an overall failure rate of 7 of 43 patients (16%) in the current series. There were no complications and no reoperations during the study period.

Failures

Three patients in the current series had failed transplants and required conversion to a unicompartmental or total knee arthroplasty. The first patient was a 36-year-old man who underwent left medial meniscus transplantation. His initial injury occurred at work, and his case was handled under workers' compensation. His alignment was neutral at the time of his initial surgery, and his articular surfaces were well preserved, with only grade I softening of the femoral condyle. He was still experiencing pain at 9 months postoperatively and underwent a revision transplantation. His knee remained persistently painful, and he subsequently underwent unicompartmental knee replacement at 9 months after revision transplantation. The cause of failure was unknown.

The second patient was a 35-year-old woman who underwent a right medial meniscus transplantation. The patient had a history of medial meniscectomy and subsequent high tibial osteotomy but had persistent pain in the medial compartment. At the time of transplantation, she was noted to have diffuse grade III and limited grade IV changes of the medial tibial plateau and a focal grade IV lesion of the medial femoral condyle that was treated with a microfracture. She experienced persistent pain after transplantation, and subsequent arthroscopy demonstrated an intact meniscus but persistent degenerative changes of the articular surfaces. She underwent total

TABLE 3
Physical Examination[a]

	Preoperative						Follow-up					
			IKDC Knee Examination Grade						IKDC Knee Examination Grade			
	Extension, deg	Flexion, deg	A	B	C	D	Extension, deg	Flexion, deg	A	B	C	D
All (N = 40)	0.4 ± 1.2	125.3 ± 15.1	4	27	4	5	0.4 ± 1.4	127.9 ± 7.2	23	13	3	1
Medial (n = 25)	0.5 ± 1.4	120.8 ± 16.2[b]	0	19	3	3	0.7 ± 1.7	125.59 ± 7.5[b]	13	8	3	1
Lateral (n = 15)	0.2 ± 0.6	131.9 ± 10.8[b]	4	8	1	2	0.3 ± 0.8	132.0 ± 4.8[b]	10	5	0	0
Isolated (n = 21)	0.6 ± 1.5	130.4 ± 9.0[b]	2	15	4	0	0.4 ± 1.3	129.1 ± 6.9	12	6	3	0
Combined (n = 19)	0.0 ± 0.0	117.9 ± 19.1[b]	2	12	0	5	0.5 ± 1.5	126.4 ± 7.8	11	7	0	1

[a]Flexion and extension data are mean ± SD. IKDC, International Knee Documentation Committee; A, normal; B, nearly normal; C, abnormal; D, severely abnormal. There was no significant difference between preoperative and follow-up scores ($P > .05$) for any group.
[b]Denotes significant difference between subgroup scores ($P < .05$).

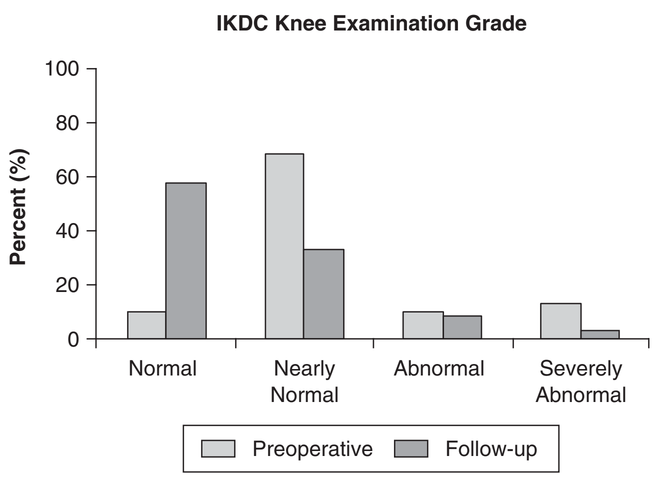

Figure 2. International Knee Documentation Committee knee examination grade.

knee arthroplasty approximately 21 months after transplantation. The cause of failure was thought to be excessive articular degeneration.

The third patient was a 40-year-old woman who had a history of a lateral meniscal tear and subsequent lateral meniscectomy 3 years before transplantation. She had persistent pain in the lateral compartment and underwent lateral meniscus transplantation. Her articular surfaces demonstrated focal areas of grade II changes in the femoral condyle and relatively normal tibial plateau. She suffered a retear of her meniscus approximately 16 months after transplantation and underwent arthroscopic resection of the transplanted meniscus; at the time of surgery, she was noted to have progression of her articular disease. She subsequently underwent total knee arthroplasty 2 years after transplantation.

DISCUSSION

Although the meniscus has several important functions, its primary clinical role is that of load sharing in the tibiofemoral compartments. The medial and lateral menisci transmit 50% and 70% of the load to their respective compartments. Load transmission is also directly related to knee flexion, with 50% of the joint load transmitted in knee extension, whereas nearly 90% of the joint load is transmitted with 90° of knee flexion.[43] Furthermore, the function of the meniscus can be significantly affected even with partial removal; one in vivo study has demonstrated that excision of only 16% to 34% of the meniscus yields a 350% increase in joint contact forces.[22]

A second important role of the medial meniscus is as a secondary restraint to anterior tibial translation in the ACL-deficient knee.[19,20] In a recent cadaveric study, Papageorgiou et al[32] demonstrated that there was a significantly increased load on the ACL graft after a medial meniscectomy. In addition, a biomechanical cadaveric study showed that knees with an absent ACL and a deficient medial meniscus had increased varus-valgus laxity when compared with ACL-deficient knees with intact medial menisci.[22] These data have given support to the indication for medial meniscus transplantation in the setting of revision ACL reconstruction with an absent medial meniscus.

Clinically, several long-term studies have demonstrated a high rate of knee symptoms and degenerative joint disease after medial or lateral meniscectomy.[18,40] The extent of degenerative change is directly proportional to the amount of excised meniscus.[9,24] Recent studies suggest that even partial meniscectomy may have deleterious effects.[4,17,36] In their comparative analysis of partial versus total meniscectomy, McGinty et al[23] reported early changes on radiographs in 62% of their patients who underwent total meniscectomy as compared with 36% of their patients treated with partial meniscectomy. Jaureguito et al[17] reported a 92% success rate at short-term follow-up of patients treated with partial lateral meniscectomy. However, at a mean of 8 years, only 67% had a successful result. In a similar study with longer follow-up, Schimmer et al[36] reported a 92% success rate at 4 years, which declined to 78% at 12 years. It is likely, however, that the degree of concomitant degenerative change is the most important factor determining the outcome after meniscectomy.[15,25,36] In addition, most studies have demonstrated more rapid deterioration after lateral meniscectomy when compared with medial meniscectomy.[18,45]

The goal of meniscus transplantation is to restore normal joint kinematics and load transmission. In vitro studies have shown that meniscus transplants improve contact area and pressures when compared with the postmeniscectomy knee.[2,31] Several clinical studies substantiate the basic science literature. Milachowski et al[24] were the first to perform and report isolated meniscus allograft transplantation. They reported an 86% success rate with their initial experience of 22 allografts with a mean follow-up of 14 months. Garrett et al[13,14] reported the first series of meniscus allograft patients in the American literature. They reported an 81% success rate in 43 patients at 2- to 7-year follow-up. Both of the aforementioned series included a combination of fresh and cryopreserved grafts. In a prospective study of 23 patients treated with cryopreserved meniscus allografts, van Arkel and de Boer[42] reported that 20 (87%) had a satisfactory outcome at 2 to 5 years. Carter[6] reported an 88% success rate in 46 cryopreserved grafts at a minimum of 2-year follow-up. Second-look arthroscopy was performed in 38 patients and revealed 4 graft failures, 4 with graft shrinkage, and 2 with progression of arthritis. Of the 38 patients, 32 demonstrated pain relief and improvement in activities.[6] Cole et al[7] reported on 22 patients who had fresh-frozen meniscus implants at a minimum of 2-year follow-up. Postoperatively, 88% of the patients reported marked pain relief. Twenty-one of the patients (95%) self-reported that their overall knee function was nearly normal or better. The 86% success rate reported in the present series is consistent with other similar reports in the literature.[5,6,11,22,37,40]

In contrast to the previously mentioned favorable reports, Noyes et al[27,28] reported on 96 fresh-frozen, irradiated grafts, which is the largest series to date. In this series, the technique of graft preparation and insertion differed with the current study in that none of the menisci had both horns attached by bone. Most were attached to bone at the posterior horn only. Furthermore, the grafts used in the study were sterilized with gamma irradiation. Overall, 58% of the grafts failed clinically. Of particular importance is that there was a statistically significant association between graft failure and the degree of arthrosis of the knee. There was a 50% failure rate in knees with Outerbridge grade IV changes.[30] Rodeo[34] reported a similar finding with respect to the importance of maintaining osseous attachment to the meniscal horns. In his series, there was an 88% success rate with bone fixation and only a 47% success rate in those without bone fixation.

Patient selection with regard to coexisting degenerative disease is one of the most important factors in achieving a successful outcome after transplantation. Several authors have demonstrated significantly higher failure rates in knees with advanced arthritis.[13,27,28] Similarly, proper limb alignment is an additional factor that is vital for success.[5,10] In the study by van Arkel and de Boer,[42] 3 graft failures were attributed to limb malalignment. Cameron and Saha[5] performed osteotomies in more than half of their patients to unload the involved compartment, thereby achieving good to excellent results in 85% of their patients with combined osteotomy–meniscus transplant. In our patient selection, overall limb alignment is always assessed preoperatively by physical examination and standing mechanical axis radiographs if an abnormality is present. An osteotomy is then performed at the time of transplantation to correct any significant limb malalignment. Correction of the weightbearing axis is performed to the lateral edge of the lateral tibial spine in varus knees using opening wedge high tibial osteotomy and to neutral alignment using opening wedge distal femoral osteotomy in valgus knees. However, in the current series, only 1 patient underwent simultaneous osteotomy.

The purpose of this series was to report the initial results of a series of patients who had undergone allograft meniscus transplantation by a single surgeon with a minimum 2-year follow-up. Our results demonstrate significant improvement on nearly all scoring scales, indicating both symptomatic and functional improvement. Although no statistically significant difference was detected, patients with lateral meniscus transplants tended to have greater improvements on the majority of knee scoring scales, VAS, physical examination measurements, and patient satisfaction. A larger sample size may be necessary to detect a statistically significant difference. With regard to IKDC scores, this study had only a 53% power to detect a significant difference between medial and lateral subgroups. With regard to VAS, this study had only a 13% power to detect a difference between medial and lateral subgroups. The tendency toward better results on the lateral side might be explained by the fact that the lateral meniscus transmits a higher percentage of joint force compared with the medial side, resulting in higher chondral and subchondral forces in the setting of an absent lateral meniscus. This theory is supported by the finding that knees with absent lateral menisci undergo more rapid degeneration than do knees with absent medial menisci. In this case, replacing the lateral meniscus may be more important to "normalize" the knee than is transplantation on the medial side. The exception to this may be in the setting of a combined meniscal transplant and ACL reconstruction in which the medial meniscus is integral in restoring normal AP stability.

With regard to the isolated and combined subgroups, similar results were seen with respect to all scoring scales and patient satisfaction indices. These data suggest that alternative procedures to address concomitant pathologic changes can be combined with meniscus transplantation to achieve optimal results. In these cases, it remains in question whether the improvements were a result of the transplant, the additional procedure, or both. This question has been raised in the setting of combined osteotomy and meniscus transplantation. Further multicenter studies with large numbers of patients would likely be necessary to delineate any differences in outcomes and the ultimate indications for individual versus combined procedures. Interestingly, there was no statistically significant difference in Tegner and Noyes activity scores within the isolated transplant group. Although the reasons for this are unclear, one possible explanation is that patients in the isolated group had diffuse, low-grade chondral abnormalities that were not amenable to cartilage repair techniques and resulted in some persistent low-level symptoms.

Although the early clinical results of meniscus transplantation remain encouraging, it is still not known whether meniscus transplants delay or prevent degenerative changes of the knee. Clearly, the results of numerous clinical and biomechanical studies have shown the adverse effects of meniscectomy and its disruption of the normal force transmission across the knee. In an effort to restore normal knee anatomy and biomechanics, meniscus allograft transplantation is a treatment option for patients with debilitating pain and low-grade arthrosis secondary to meniscectomy. This study, as well as previous clinical studies, has demonstrated the effectiveness of this procedure in providing pain relief, decreasing swelling, and improving knee function. Allograft meniscus transplantation is technically challenging, and the indications are relatively uncommon because most patients initially do well after meniscectomy. However, symptomatic patients with appropriate indications should expect to do well with respect to pain relief and an ability to increase activity levels after transplantation. The results of early and midterm follow-up studies support this observation. Longer term studies will offer the greatest insight into the value of performing this procedure as well as the role of meniscus allografts in preventing the progression of secondary osteoarthritis.

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