Prospective Long-Term Evaluation of Meniscal Allograft Transplantation Procedure: A Minimum of 7-Year Follow-Up

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Abstract

This study reports the long-term effectiveness of meniscal allograft transplantation performed by a single senior operating surgeon. In this study 22 meniscus transplantations in 22 patients were evaluated at a minimum of 7-year follow-up (mean 8.5 $\pm$ 1.3 years) using standardized scoring scales. Subgroup analysis was performed to stratify outcomes based on medial (59.1%) versus lateral (40.9%) meniscus transplantation, and transplantations performed in isolation (36.4%) versus those performed concomitantly (63.6%). Patients reported significant improvement in all scoring scales ($p < 0.05$). Average satisfaction was 8.8 out of 10. All the patients were completely or mostly satisfied with the results of their surgery. Overall subjective knee condition improved from 3.5 to 6.9 ($p < 0.05$). Patients undergoing medial compartment repair and combined transplantations reported greater improvement from baseline to follow-up than did their counterparts. An overall success rate of 88% was found for all patients at the final follow-up. Based on this data, meniscal allograft transplantation is a viable treatment option for meniscal-deficient patients in reducing pain, increasing range of motion, and improving patient function and satisfaction at a minimum of 7 years postsurgery.

Keywords
- meniscus
- meniscus transplant
- meniscectomy
- allograft
- long-term efficacy

Injuries to the meniscus affect the biomechanical transmission of shear forces across the tibiofemoral joint and cause destabilization of the knee, as is evident with radiographic changes in the joint space (►**Fig. 1**).[1] Contact stresses have been shown to increase in proportion to the percentage of meniscus removed.[2] A resection of 20% of the native meniscal tissue is reported to increase articular cartilage contact forces by as much as 350%[3] and such findings have indicated that degenerative changes are a direct result of absent or poorly functioning meniscal tissue.[4–6]

Numerous clinical studies have demonstrated an increased risk of osteoarthritis and joint deterioration of the affected joint in meniscus-deficient patients.[2,7–10] While the goal is to repair meniscal tissue when possible, this is not always feasible. In fact, Lee et al[11] concluded in their cadaveric study that partial meniscectomy is the only course of action in

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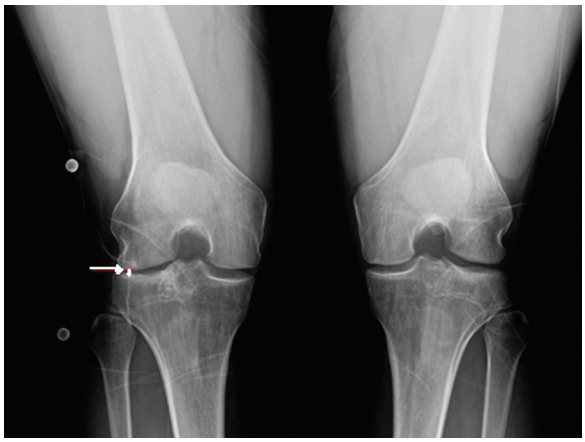

Figure 1 White arrow: example of a patient with lateral joint space narrowing of the right knee (vertical white line shows the joint space narrowed vertical height) compared with normal joint space on the medial side.

80 to 90% of meniscal injuries, and in this percentage of patients the meniscus cannot be salvaged. To improve contact stresses and reduce or delay the development of osteoarthritis, a meniscal transplantation procedure can be performed.[12,13] This procedure is intended for postmeniscectomized patients under the age of 50 years with Outerbridge Grade I or II articular changes and debilitating pain localized to the tibiofemoral articulation who still have not developed advanced osteoarthritis or major grade degenerative changes in the knee.[5,14] The success of this procedure has historically been correlated with tibiofemoral stability (indicating a stabilized anterior cruciate ligament [ACL]), alignment, sizing, processing, placement, and surgical fixation of the graft.[1,15] Relative contraindications to meniscal transplantation include osteophytes that would lead to changes in stability, femoral condyle flattening, instability/malalignment of the joint, a history of infection of the affected joint, or Outerbridge Grade III or IV articular changes.[16,17] Donor allograft tissue in meniscal transplantation has been shown to integrate readily and repopulate with host's trabeculae;[14] additionally, the likelihood that the meniscal tissue is immunologically privileged has been confirmed through the absence of graft rejection.[18]

Short- and intermediate-term outcome studies of allograft transplantation have demonstrated efficacy in improving knee function, pain level, performance on activities of daily living, and impeding the development of tibiofemoral arthrosis.[19–21] Clinical studies reporting the long-term outcomes of allograft meniscus transplantation are limited within the United States. The purpose of this study is to report on the long-term efficacy of meniscal allograft transplantation by a single operating surgeon (senior author[Q1]).

Q1

Methods

Patient Preoperative Assessment

Following IRB approval, all patients were retrospectively selected from a database of prospectively collected data. Each of the patients underwent meniscal allograft transplantation due to continued discomfort in the postmeniscectomized knee. The postsurgical data at a minimum of 7 years were collected to compare pre- and postoperative outcomes. Concomitant procedures such as painful hardware removal, cruciate ligament reconstruction, or other techniques (63.6% of the patients) employed at the time of allograft transplantation were documented. Patients who failed the transplantation and required a unicompartmental knee arthroplasty or revision meniscus surgery—as was the case with three of the patients in our cohort (12.0% of the total patient population from our study)—were not included in the summary of scoring scales.

A thorough physical examination was performed on all patients preoperatively. Only six patients were available at the time of final follow-up for a postoperative examination. The parameters tested included range of motion (ROM), pain, effusion, stability and radiographic evaluation of the joint space and assessment for tibial integration of the bony plugs or the bridge at the site of the allograft placement.

Surgical Planning, Technique, and Rehabilitation

Patient donor meniscus measurements were obtained according to the sizing radiograph method described by Pollard et al[22] and all grafts were preserved using the fresh-frozen technique. Of the 13, 12 medial meniscus transplantations were performed using the double bone plug technique, as described by Shelton and Dukes[23] and one was performed using the bridge in slot technique as illustrated by Cole et al.[24] Of the nine, five lateral meniscus allografts were performed using the keyhole technique as described by Goble et al[25] and the other four were transplanted using the bridge in slot technique.[24]

The first step of all transplants was debridement of the native meniscal remnant to a 1- to 2-mm peripheral rim. The 12 medial meniscus allograft transplantations following the double bone plug technique then received a modified low notchplasty on the medial side between the fibers of the posterior cruciate ligament and the medial femoral condyle allowing for introduction of the posterior plug into the tibiofemoral joint. Menisci were then passed into the joint through a miniarthrotomy and the meniscus was secured on the medial capsule with 8 to 10 vertically placed No. 2–0 nonabsorbable mattress sutures.[19,23]

The five lateral meniscus allograft transplantations following the keyhole technique were also introduced through an anterior miniarthrotomy, and were passed through an expanded tibial trough. An interference screw was placed to hold the donor tissue bone block in place.[19,25] Finally, the remaining five allograft menisci (four lateral and one medial) were transplanted via the bridge in slot technique. For this technique, the graft is prepared using an oscillating saw to create a 7-mm wide bone bridge with intact anterior and posterior meniscal horns. The prepared graft is passed through an arthrotomy into a tibial slot which is prepared with the use of a burr, cannulated drill, and 8-mm box cutting guide. The bone bridge is then fixed into place via a cortical interference screw (►**Fig. 2**).[24] Any concurrent procedures that were needed to stabilize the knee joint and improve the

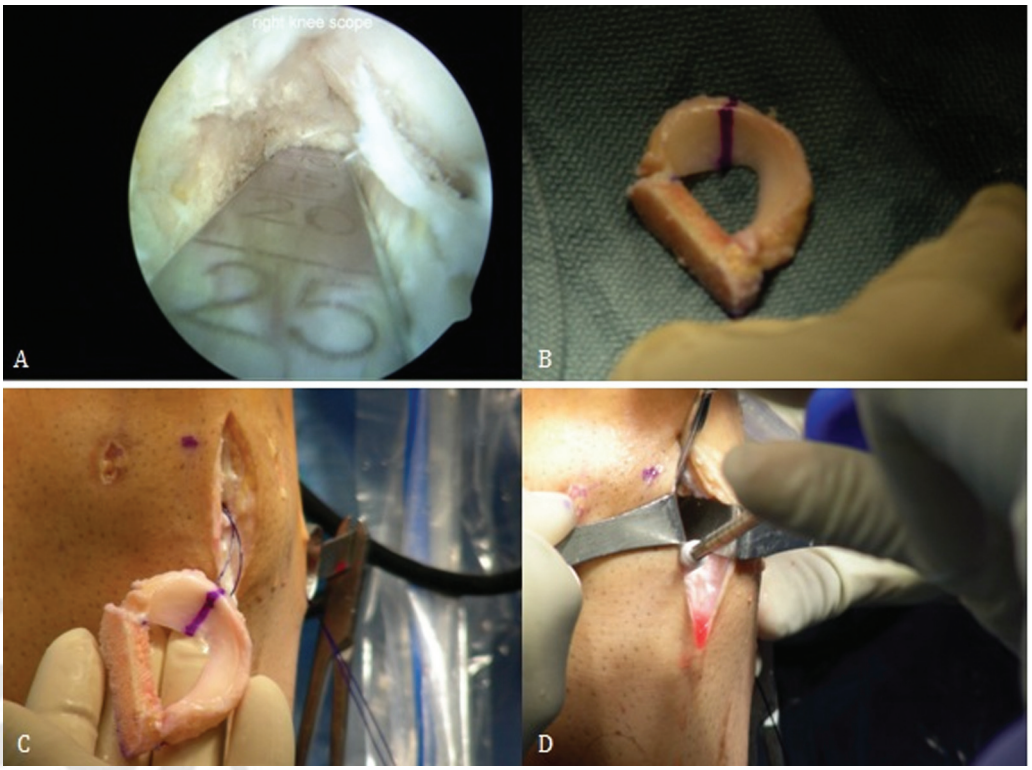

Figure 2 (A) Arthroscopic view of the rectangular rasp used to enlarge and complete the slot on the tibial plateau so that the appropriately sized bone block and meniscal allograft will affix loosely into this trough. (B) Donor graft with the bone bridge. (C) Implantation of the donor graft into the tibial slot. (D) Use of interference screw to stabilize bone bridge.

procedural prognosis were also performed at this time. These included autologous chondrocyte implantation (ACI), hardware removal, ACL reconstruction, and other procedures that would help restore normal anatomy and biomechanical function to the knee joint.

Rehabilitation following the allograft meniscus transplantation involved a three-phase protocol.[19,24] In the initial 6 weeks following the procedure, the patient was allowed partial weight-bearing (with crutches for the first 4 weeks) unless contraindicated by the rehabilitation programs of a concomitant procedure. Mobilization was performed immediately, including heel slides, quad sets, and straight leg raises. Flexion beyond 90 degrees during these initial 6 weeks was minimized to prevent unnecessary forces on the healing graft. During the second phase (6 to 12 weeks postoperative) of rehabilitation, the knee brace was removed and patients were allowed full ROM and weight-bearing. The final 6 weeks further increased the intensity of the allowed exercises, including the addition of jogging, single leg hops, plyometrics, and sports-specific drills.[19]

Patient Outcome Evaluation

Of the meniscal transplantations performed by the senior author between November 1997 and July 2002, 29 patients were contacted who had adequately completed the preoperative surveys and were considered eligible to participate. Of the contacted population, three patients failed transplantation. Of the remaining 26 patients (follow-up 84.6%) 22 with a minimum of 7-year postoperative data (mean 8.5 years) were studied. Patients who underwent any sort of revision procedure or unicompartmental knee arthroplasty following the allograft transplantation were considered "failures." Each of the failures was subjected to an individual case study for plausible explanation for his or her failure.

Outcome evaluations were performed subjectively using validated knee survey analyses of SF-12 physical component summary (PCS) and mental component summary (MCS),[26] Lysholm,[27] International Knee Documentation Committee (IKDC),[28] and the Knee Injury and Osteoarthritis Outcome Score (KOOS),[29] which is divided into five parts: Pain, Symptom, Activities of Daily Living (ADL), Sports, Quality of Life (QOL). In addition, patients were asked to rate their overall satisfaction with the transplantation procedure at the time of follow-up on a 0 to 10 scale (0, completely unsatisfied; 10, completely satisfied), describe their satisfaction with the surgical outcome (1, unsatisfied; 2, somewhat satisfied; 3, mostly satisfied; 4, completely satisfied), rate their overall knee condition at initial and follow-up times (0, cannot perform daily activities; 10, normal), and whether or not they would have the surgery again given similar conditions and circumstances (yes or no). An objective physical examination and radiographs were obtained when possible.

Of the 22, 10 follow-up survey results were obtained using an online survey (OBERD MedAdat©, MedAdat Inc., Columbia, MO). Microsoft Excel© and SPSS for Windows version 1.5 (SPSS Inc., Chicago, IL) were used to perform nonparametric statistical analysis of data groups. Standard t-tests of significance were performed to compare preoperative and

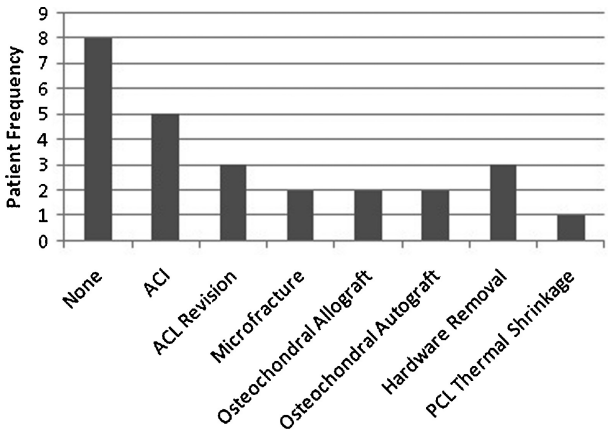

Figure 3 Frequency of concomitant procedures: patients with multiple concurrent procedures were included independently; thus, the total frequency count is greater than 22.

postoperative survey results of the patients placed into different categorical groupings. Subgroups of the following were compared using two-tail Mann-Whitney tests of significance. Statistical significance was set for all analyses at $p < 0.05$.

Results

The mean follow-up period for this cohort (15 men, 7 women; 11 right knees, 11 left knees) was 8.5 years (range, 6.8 to 11.2 years; SD, 1.3). Of these three patients failed their primary transplantation procedure and were excluded from the analysis: two of them had a revision meniscus transplantation (at 24 and 54 months postoperation), and the third had a unicompartmental knee arthroplasty (68 months postoperatively). These three patients were included in the calculation of failure rate, but were excluded in the summary of scoring scales because their follow-up data at this point in time would be reflective of their revision surgeries, and not the original allograft meniscus transplantation procedure. The mean age of the remaining 22 patients at the time of the meniscal graft transplantation was 32.5 years (range, 15 to 53.7 years; SD, 12.3) and the mean age at follow-up was 41.2 years (range, 22 to 61 years; SD, 12.0).

Of the 22, 13 (59.1%) menisci were transplanted into the medial compartment of the affected knee and 9 (40.9%) menisci were transplanted into the lateral compartment. Of the 22, 8 meniscal grafts (36.4%) were transplanted in isolation during the index procedure because the knee was devoid of concomitant pathology that needed to be addressed, while the remaining 14 (63.6%) menisci were combined with concomitant procedures (►**Fig. 3**). Of the 22, 8 (36.4%) patients had a preoperative body mass index (BMI) of less than 25 kg/m^2 while the other 14 (63.6%) had a BMI of greater than 25 kg/m^2.

Follow-Up Survey Results

All patients who completed the follow-up surveys reported statistically significant improvements from preoperative to follow-up values in all scoring scales (►**Table 1**, ►**Fig. 4**).

Additional follow-up survey results showed a mean satisfaction score of 8.8 (out of 10). Of the 22, 8 patients (36.4%) were completely satisfied with the outcome and 14 patients (63.6%) reported being mostly satisfied. Of the 22, 20 patients (90.9%) stated that based on their experience, they would have this surgery again on the contralateral knee if they were to develop similar problems (4.5% said "no" and 4.5% did not answer the question). Overall knee condition increased significantly from a mean value of 3.5 to 6.9 (out of 10) at follow-up ($p < 0.05$).

Postoperative outcomes were also determined from this cohort at 2 and 4 years postoperatively to analyze the postoperative trend. The 2-year follow-up (mean follow-up of 1.96 years) and the 4-year follow-up (mean follow-up time

Table 1 Patient Cohort Mean Preoperative and Follow-Up Scoring Scale Values

Knee Scoring Scale	Preoperative	Follow-Up	*p* Value
SF-12			
PCS	39.35 (9.3)	49.48 (9.8)	<0.001
MCS	41.09 (10.5)	49.44 (8.8)	0.004
Lysholm	53.18 (19.2)	74.14 (16.1)	<0.001
IKDC	41.29 (13.6)	60.97 (16.8)	<0.001
KOOS			
Pain	58.33 (15.6)	79.42 (19.8)	<0.001
Symptom	60.37 (17.3)	75.65 (14.4)	<0.001
ADL	74.16 (17.1)	87.17 (15.8)	<0.001
Sports	32.14 (14.4)	60 (28.1)	<0.001
QOL	31.25 (17.9)	54.83 (24.2)	0.001

*The values in parentheses correspond to the standard deviation.[Q2]

ADL, activities of daily living; IKDC; International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCS; mental component summary; PCS; physical component summary; QOL, quality of life

Q2

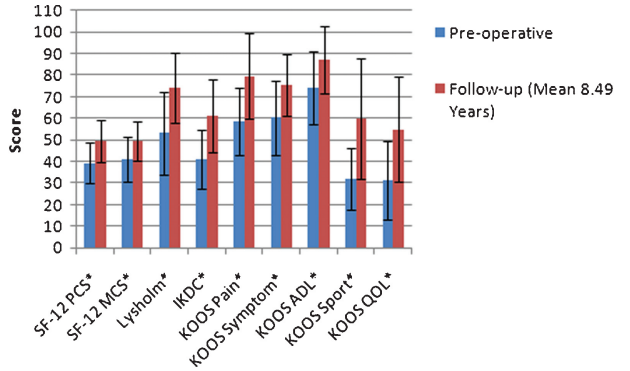

Figure 4 Knee scoring survey scale results: *Denotes statistical significance between preoperative and follow-up scores ($p < 0.05$).

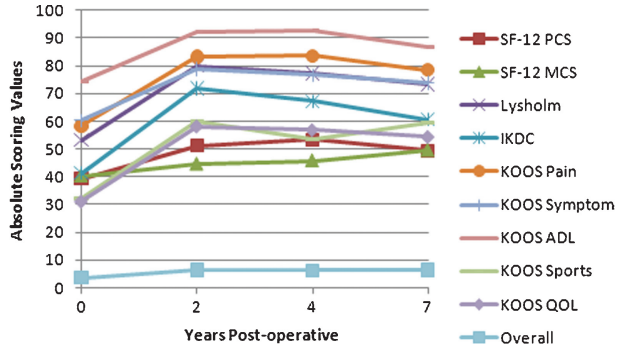

Figure 5 Outcome trends.

of 4.36 years) demonstrated continued improvement in the majority of outcome scores. In all categories, outcomes improved from preoperative means to the 2-year follow-up means. Following the postoperative data between 2 and 7 years, some outcome scores improved, while others reported a small decrease over time. Overall, the scores were generally maintained at the original level of improvement, indicating a sustained level of improvement from short-term to long-term follow-up (►**Fig. 5**).

An additional analysis was performed to assess for the presence of a correlation between improvement in each of the individual scoring scales (SF-12 PCS, SF-12 MCS, Lysholm, IKDC, KOOS [all five scales], Overall Knee Condition) and the reported patient satisfaction with the surgery. The highest correlation ($r = 0.33$) with patient satisfaction was with the patient's reported change in overall knee condition (from pre- to postoperative state).

Subgroup Analysis: Medial versus Lateral Meniscal Allograft Transplantation

The data were grouped based on side of the meniscal allograft transplantation (medial or lateral) and analyzed (►**Table 2**). Patient satisfaction for the medial meniscus transplantation

Table 2 Medial and Lateral Meniscal Transplantation Subgroup Outcome Analysis

	Medial ($n = 13$)				Lateral ($n = 9$)			
Knee Scoring Scale	Preoperative	Follow-Up (8.72 Years)	%Change	*p* Value	Preoperative	Follow-Up (8.15 Years)	%Change	*p* Value
SF-12								
PCS	35.88	47.74[a]	33.04	0.0002	43.98	52	18.22	0.119
MCS	40.08	47.64	18.84	0.077	42.55	52.05[a]	22.31	0.023
Lysholm	49.38	72.08[a]	45.95	0.0009	58.67	77.11[a]	31.44	0.0056
IKDC	38.09	55.03[a]	44.47	0.0034	45.92	69.54[a,b]	51.45	0.0003
KOOS								
Pain	52.55	74.36[a]	41.51	0.004	66.05	86.73[a]	31.31	0.0028
Symptom	59.23	73.35[a]	23.85	0.006	61.90	78.97[a]	27.56	0.018
ADL	69.18	82.58[a]	19.48	0.026	80.88	93.79[a]	15.96	0.0001
Sports	29.58	53.46[a]	80.72	0.007	35.56	69.44[a]	95.31	0.0003
QOL	28.13	50[a]	77.78	0.035	35.71	61.80[a]	73.06	0.012
Visual analog scale								
Overall knee condition	2.83	6.85[a]	141.63	0.0001	4.44[b]	6.89[a]	55	0.0076
Satisfaction		9				8.56		
% have surgery again		84.6%				100%		

[a]Denotes significant difference between pre- and postoperative scores within a subgroup scoring scale ($p < 0.05$).
[b]Denotes statistical significance between respective pre- or postoperative values between subgroups ($p < 0.05$).
ADL, activities of daily living; MCS; mental component summary; IKDC; International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; PCS; physical component summary; QOL, quality of life.

subgroup at follow-up was 9 out of 10 with 6 of the 13 (46.2%) medial meniscal transplantation patients reported being completely satisfied with the procedure, and 7 of the 13 (53.8%) medial meniscus patients mostly satisfied. In this subgroup, 84.6% of patients would have the surgery done again. The lateral meniscus subgroup reported an overall patient satisfaction of 8.6 out of 10; two of the nine (22.2%) lateral meniscal transplantation patients were completely satisfied with the procedure, while the remaining seven (77.8%) were mostly satisfied. All patients in this subgroup would have the surgery done again if given the choice.

At the 7-year postoperative time point, the Overall Knee Condition, IKDC, Lysholm, and all five KOOS subgroup scores improved significantly ($p < 0.05$) in both the medial and lateral groups compared with the preoperative scores. Further, there was a significant improvement in the SF-12 PCS scores in the medial group and the SF-12 MCS scores in the lateral group at the 7-year postoperative time point. Compared with the medial group, the lateral group had significantly higher ($p < 0.05$) preoperative Overall Knee Condition and postoperative IKDC survey scores. There was not a significant difference between the medial and lateral groups at either time point for any of the other scores analyzed in this study.

The significant increases in the specific aforementioned scores indicate that both medial and lateral meniscus allograft transplantation procedures improved overall patient symptoms, level of knee pain, ability to perform most ADL, sports activity, and quality of life. That the medial group did not improve significantly in the SF-12 MCS score suggests that the medial meniscal transplantation did not elevate the patients' social functioning or emotional/mental health from their perspective. The absence of significant improvement in the SF-12 PCS score with the lateral group illustrates that in the patient's opinion there remains a deficit in his or her physical functioning which has caused limitations in daily functioning.

Subgroup Analysis: Isolated versus Combined Procedure Meniscal Allograft Transplantation

The data were grouped based on whether the meniscal allograft transplantation was performed in isolation (because patients did not have other knee pathology to repair) or combined with a necessary concomitant procedure. This analysis was performed to determine whether addressing concurrent knee pathology at the time of meniscal allograft transplantation would decrease the success or long-term improvements from the procedure. Overall patient satisfaction for the isolated meniscus transplantation subgroup was 8.3 out of 10 with one (12.5%) of the eight isolated meniscal transplantation patients reported being completely satisfied with the procedure. Of the 8, 7 patients (87.5%) reported being mostly satisfied with the procedure. In this subgroup 88% of patients indicated that they would have the surgery done again. The overall patient satisfaction for the combined meniscus transplantation procedure subgroup was slightly higher at 9.1 out of 10 with 6 of the 14 (42.9%) combined meniscal transplantation patients reported being completely satisfied with the procedure, while 8 of the 14 (57.1%) were mostly satisfied. In this subgroup 93% of patients reported that they would have the surgery done again (►**Table 3**) (see ►**Fig. 3** for concurrent procedures).

Meniscal transplantation performed in conjunction with concomitant procedures demonstrated a trend of greater improvement than for transplants performed in isolation. The isolated transplantation group reported significant improvements in the SF-12 MCS, IKDC, KOOS Symptom, and KOOS Sports scores. Overall Knee Condition improved from 3.29 to 6.00 out of 10 ($p < 0.05$). The combined transplantation group reported significant improvements in the SF-12 PCS, Lysholm, IKDC, KOOS Pain, KOOS Symptom, KOOS ADL, KOOS Sports, and KOOS QOL scores. Overall Knee Condition improved from 3.6 to 7.4 out of 10 ($p < 0.05$). Significance was observed when comparing the isolated and combined subgroups with respect to follow-up Lysholm (combined [79.5] > isolated [64.8]), KOOS Pain (combined [85.7] > isolated [68.4]), and KOOS QOL (combined [64.3] > isolated [38.3]) ($p < 0.05$) (►**Table 3**).

Although both isolated and combined transplantation subgroups improved to some degree from pre- to postoperative in all categories, the combined transplantation group showed greater relative improvement in the SF-12 Physical, Lysholm, IKDC, KOOS Pain, KOOS Symptom, KOOS ADL, KOOS QOL, and Overall Knee Condition scores (all $p < 0.05$), while the isolated meniscus transplantation reported greater relative improvement in the remaining categories of SF-12 Mental and KOOS Sports (both $p < 0.05$) (►**Table 3**). Overall, the percentage change within each subgroup indicated that the combined transplantation subgroup demonstrated a trend toward greater improvements as compared with the isolated transplantation subgroup, although statistically significant differences were detected only between the relative preoperative to follow-up improvements of the two subgroups in the SF-12 Physical and KOOS QOL categories ($p < 0.05$).

The significant increases in the specific aforementioned scores indicate that patients who undergo meniscal allograft transplantation in isolation felt they improved significantly with regards to symptoms, sports activity, social functioning, emotional/mental health, and the overall condition of the knee. The lack of significance in improvement with the remaining scoring categories illustrates that the procedure in isolation did not improve patients' overall quality of life, ability to perform normal activities on a day-to-day basis, or level of knee pain. The combined procedure meniscal allograft transplantation scores demonstrate that it significantly improved a patient's opinion of his or her symptoms, physical functioning, sports activity, level of knee pain, overall knee condition, and quality of life, but that the combined procedure did not improve the patient's social functioning or emotional/mental health from his or her point of view.

Subgroup Analysis: Patients with BMI under 25 kg/m^2 versus BMI over 25 kg/m^2

Patients were grouped into subgroups based on their preoperative BMI of less than 25 kg/m^2 ($n = 8$, 36.4% of cohort) and greater than 25 kg/m^2 ($n = 14$, 63.6% of cohort). The mean

Table 3 Isolated and Combined Procedure Meniscal Allograft Transplantation Subgroups

	Isolated ($n = 8$)					Combined ($n = 14$)		
Knee Scoring Scale	Preoperative	Follow-Up (8.92 Years)	%Change	p Value	Preoperative	Follow-Up (8.24 Years)	%Change	p Value
SF-12								
PCS	42.44	44.24	4.24	0.249	37.81	52.48[a]	38.78	0.0002
MCS	39.33	51.46[a]	30.83	0.019	42.10	48.29	14.69	0.096
Lysholm	49.50	64.75	30.81	55.29	79.50[ab]	43.80	0.0001	
IKDC	37.65	52.94[a]	40.60	0.024	43.37	65.55[a]	51.14	0.0001
KOOS								
Pain	51.19	68.40	33.62	0.078	61.90	85.71[ab]	38.46	0.0001
Symptom	64.29	75.45[a]	17.36	0.036	58.42	75.76[a]	29.69	0.0024
ADL	67.23	78.31	16.48	0.204	77.63	92.23[a]	18.81	0.0001
Sports	28.57	56.88[a]	99.06	0.004	33.93	61.79[a]	82.11	0.0018
QOL	36.46	38.28	5.00	0.533	28.41	64.29[ab]	126.29	0.0003
Visual analog scale								
Overall knee condition	3.29	6[a]	82.61	0.029	3.64	7.13[a]	101.96	0.0001
Satisfaction		8.29				9.08		
% have surgery again		87.5%				92.9%		

[a]Denotes significant difference between pre- and postoperative scores within a subgroup scoring scale ($p < 0.05$).
[b]Denotes statistical significance between respective pre- or postoperative values between subgroups ($p < 0.05$).
ADL, activities of daily living; IKDC; International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCS; mental component summary; PCS; physical component summary; QOL, quality of life.

BMI of those in the under-25 subgroup was 22.8 (range, 21.5 to 24.7; SD, 1.6), and the mean BMI of those in the over-25 subgroup was 28.8 (range, 25.7–31.9; SD, 2.9). Overall patient satisfaction for the BMI under-25 subgroup was 9.0 out of 10 with 3 (37.5%) of the 8 BMI under-25 patients reported being completely satisfied with the procedure. Of the 8, 5 patients (62.5%) reported being mostly satisfied with the procedure. All the patients in this subgroup indicated that they would have the surgery done again. The overall patient satisfaction for the BMI over-25 subgroup was slightly lower at 8.7 out of 10 with 4 of the 14 (28.6%) BMI over-25 patients reported being completely satisfied with the procedure, while 10 of the 14 (71.4%) were mostly satisfied. In this subgroup 86% of patients reported they would have the surgery done again.

Both subgroups demonstrate similar improvements between pre- and postoperative scores, although a greater number of improvements in scaling scores were found for the BMI over-25 subgroup. The BMI under-25 patient subgroup reported significant improvements in the Lysholm, IKDC, KOOS Symptom, and KOOS Sports scores. Overall Knee Condition improved from 3.38 to 7.25 out of 10 ($p < 0.05$). The BMI over-25 patient subgroup reported significant improvements in the SF-12 PCS, SF-12 MCS, Lysholm, IKDC, and all 5 KOOS scores. Overall Knee Condition improved from 3.62 to 6.64 out of 10 ($p = 0.550$). Although both BMI under-25 and BMI over-25 subgroups improved to some degree from pre- to postoperative values, the BMI under-25 patient subgroup showed greater relative improvement in the categories of Lysholm ($p < 0.05$), KOOS Symptom ($p < 0.05$), KOOS QOL, and Overall Knee Condition ($p < 0.05$). The BMI over-25 patient subgroup showed greater relative improvement in the remaining categories of SF-12 Physical, SF-12 Mental, IKDC, KOOS Pain, KOOS ADL, and KOOS Sports (all $p < 0.05$). Overall, percentage changes within each subgroup's scoring scales were very similar, and thus indicate no discernible trend toward greater improvements with either subgroup.

The significant increases in the specific aforementioned scores indicate that patients with preoperative BMI under-25 felt they improved significantly with regards to symptoms, sports activity, and the overall condition of the knee. The lack of significance in improvement with the remaining scoring categories illustrate that the procedure in isolation did not improve patients' overall quality of life, ability to perform normal activities on a day-to-day basis, level of knee pain, social functioning, or emotional/mental health. Postoperative scores for patients with preoperative BMI over-25 demonstrate that the procedure significantly improved these patients' opinion of their symptoms, physical functioning, sports activity, level of knee pain, social functioning,

emotional/mental health, and quality of life, but did not significantly elevate the patients' opinions of their overall knee condition. The extent to which the patient feels that their symptoms and overall quality of life have improved is greater with those patients who had preoperative BMI under-25.

Physical Examination and Radiographic Studies: Case Study of Six Patients

In total, six patients from our cohort presented for a follow-up physical examination with radiographic evaluation. The first patient was a man who underwent isolated lateral meniscal allograft transplantation at 23 years of age. Preoperatively, the patient presented with normal ROM and stability at the tibiofemoral joint. He had early flattening of the lateral femoral condyle, very early subchondral sclerosis, trace to 1 + effusion, and minimal joint space narrowing. At follow-up 8.8 years postoperative, the patient was normal with regards to gait, alignment, habitus, ROM, stability, and had only mild effusion and lateral clicking. Plain weight-bearing anteroposterior radiographic images showed mild joint space narrowing.

The second patient was a woman who underwent lateral meniscal allograft transplantation with concomitant ACL revision at 24 years of age. Her preoperative physical examination showed a nonantalgic gait, 3-cm heel height difference, 105 degrees of flexion of the affected leg compared with 130 degrees on the contralateral side, lateral joint line, and posterolateral discomfort, and slight crepitus of the patellofemoral joint. Additionally, she had grade 1A instability of the ACL. At follow-up, 8.3 years postoperatively, the patient was normal with regards to gait, alignment, habitus, ROM, and stability. The patient had a moderate effusion that did not require aspiration. Her follow-up radiographic images showed minor lateral joint space narrowing, an anterior compartment bony ossicle, and intact ACL tunnels.

The third patient presented preoperatively at 15 years of age with slightly antalgic gait on the affected side. She demonstrated normal ROM (0 to 130 degrees). Her lateral joint line presented with crepitus and exquisite tenderness with mild tenderness over the lateral femoral condyle. Physiological valgus was symmetric bilaterally between 2 and 4 degrees, both supine and standing. Preoperative radiographs showed evidence of a widened joint space, consistent with the patient's prior discoid meniscus. She underwent lateral meniscal allograft transplantation with concomitant ACI on the lateral femoral condyle. At follow-up, 7.46 years postoperatively, the patient was normal in all facets including alignment, habitus, and stability. She presented with no pain or effusion. Her follow-up X-rays showed a well-healed tibial slot from the transplant surgery with maintenance of her joint space.

The fourth patient underwent medial meniscal allograft transplantation with concomitant osteochondral autograft surgery at the age of 41 years, presented preoperatively with full ROM, good patellar mobility, slight valgus alignment, and trace effusion with tenderness to palpation on the affected medial joint line. She presented for her follow-up 10 years postoperatively with pain on terminal extension, but excellent motion from 0 to 110 degrees. She was mildly tender to palpation over the medial aspect of her knee and had a mild effusion. Her follow-up radiographic images showed a mild to moderate amount of arthritic changes in the medial compartment with joint space narrowing but a well-healed tibial slot from the procedure.

The fifth patient was a man who underwent medial meniscal allograft transplantation with concomitant hardware removal from a previous ACL reconstruction surgery at the age of 44 years due to weight-bearing discomfort on the medial side of the affected knee. The patient was in 2 degrees valgus, with excellent joint space despite pain attributed to a failed microfracture. He was unable to perform most activities of daily living due to instability, weakness, and mild effusion. At follow-up, 8.45 years postoperatively, the patient presented with moderate crepitus and tenderness of the affected knee, but all other aspects of the physical examination and radiographic imaging were normal.

The sixth patient underwent medial meniscal allograft transplantation with concomitant osteochondral allograft surgery at the age of 41 years. He presented with instability of the ACL, medial joint line pain and tenderness at the affected joint, and radiographic joint space narrowing in flexion of the injured knee. His follow-up visit at 9.58 years postoperatively showed numerous positive findings of improvement, including effusion and tenderness of the affected knee. Radiographic images at follow-up showed reduced joint space both medially and laterally, but the tibia showed complete integration of the donor meniscus bone plugs.

Failures: Case Study of Three Patients

In this study, three patients had failed their primary transplant and required subsequent intervention. The mean survival time of the allografts for these three failures (12.0% of total patient population) was 48.7 months. The first failure was a 42-year-old man who underwent lateral meniscus transplantation of the left leg. At the time of his initial surgery, early secondary arthrosis of the affected knee joint was noted, as was a focal chondral defect of the lateral femoral condyle. After concomitant meniscus and osteochondral allograft transplantations, he did very well for 24 months with no pain and full activity until feeling a “pop” while golfing one morning. At this time, he noted small effusion of the joint, weight-bearing pain, and pain beyond 30 degrees of flexion of the left knee. While magnetic resonance imaging (MRI) showed the integrity of the joint remained intact, the patient had suffered a bucket-handle tear of his graft. Operative findings included a displaced bucket-handle tear with a radial split back to the popliteus tendon. The osteochondral allograft was completely intact, and there was no progressive degeneration of the osteochondral plug. Such a failure was attributed to sports-induced trauma.

The second patient was a 16-year-old girl who underwent right lateral meniscus transplantation. The patient had undergone three earlier knee surgeries before the transplant. She had undergone an osteochondral autograft transplant for a focal chondral defect of the lateral femoral condyle. While

the osteochondral autograft was successful, she still complained of significant joint-line pain and swelling following activity, so complete lateral meniscectomy was performed. Postmeniscectomy, the patient underwent a meniscal transplantation and at the time of the initial transplantation, she had grade II chondromalacia of the lateral tibial plateau. At 6 months posttransplantation, the patient experienced lateral femoral condyle pain after playing sports, and was concerned she may have torn her meniscus: subsequent arthroscopy revealed no tear of the allograft. However, 54 months later, it was found that the patient's transplanted meniscus had undergone progressive degeneration. Revision meniscal transplantation was performed with concurrent distal femoral osteotomy to correct valgus alignment of the affected leg.

The third patient underwent medial meniscal transplantation at the age of 55 years. The patient had undergone a meniscectomy 32 years prior to his initial transplantation surgery and did well until he developed persistent medial-sided joint-line pain. He experienced recurrent effusions and difficulty with daily activities. At the time of the initial transplantation surgery, he was devoid of the medial meniscus and had a focal grade IV tibial plateau defect anteriorly. At 4-year follow-up, the patient was not able to twist or pivot while in a squatting position. At 68 months from the initial transplant, the patient underwent right medial unicompartmental knee arthroplasty.

Discussion

Over the last few decades, short- and intermediate-term outcomes and efficacy of meniscal transplantation have been reported. Milachowski et al[20] reported good follow-up results for 20 patients at mean 14-month follow-up from the first meniscus transplantations executed in 1984; their results pointed toward fresh-frozen allografts as the superior choice of graft as compared with freeze-dried allografts. Using the Lysholm knee scoring scale, Cameron and Saha[30] reported an 87% success rate at a mean follow-up of 31 months. Similarly Carter[31] reported favorable outcomes at a mean 35-month follow-up in 45 of 46 patients. Other clinical studies have also reported short-term success of isolated meniscal allograft transplantation.[19,32,33] In addition, adequate literature has been published exploring the success of a meniscal transplant with concomitant procedures, with most reporting successful outcomes over a short-term follow-up.[34–36]

One of the most relevant long-term studies reported 3- and 14-year follow-ups of 23 patients who received concomitant meniscal allograft transplantations with ACL reconstructions. It showed significant improvement in patients according to Lysholm scoring scales at both 3- and 14-year follow-up times, with the 14-year follow-up scores less than those at 3-year follow-up ($p > 0.05$).[37] Another long-term study shows that 70% of patients reported significant pain relief and improved knee function at a mean of 7.2-year follow-up which remained significantly improved at the 10-year follow-up time; the remaining 30% of the patients demonstrated improvement that was no longer significant from preoperative to postoperative levels at the 10-year follow-up.[38] Similarly, a third study demonstrated an improvement in level of function at long-term follow-up (mean 13.8 years), however, the postoperative function scoring had declined over time and was no longer statistically significant as it was in the short-term follow-up (mean 3.1 years); in addition, this patient cohort had an overall failure rate of 29% at a mean 10.3 years postoperative.[39]

In this study, all allograft meniscus transplantations were performed by a single operating surgeon (senior author) to minimize any variability that can be attributed to the performance of the procedure itself. At an average follow-up time of 8.5-years (SD, 1.3) all patients reported improved outcomes in all survey criteria (SF-12 PCS/MCS, Lysholm, IKDC, KOOS [Pain, Symptom, ADL, Sports, QOL]), supporting the long-term success of meniscus transplantation as did the three long-term studies referenced above. Furthermore, analysis of the patient cohort at 2 and 4 years postoperative generally showed well-sustained levels of improvement from short- to long-term follow-up with only minor increases or decreases in some of the scoring categories as follow-up time increased, similar to the 3- and 14-year follow-up study referenced above. Also, the failure rate of 12% at a mean 4.1 years postoperative for the meniscal allograft procedure in this study was less than the 29% failure rate at a mean 10.3 years postoperative in the study referenced above.[Q3]

With meniscal injury, the underlying pathoanatomy usually dictates the need for concomitant procedures such as ligament reconstruction, osteotomy to address alignment, or cartilage restoration procedures. Comparison of the subgroups of isolated transplantations versus combined procedures with allograft transplantation demonstrated that patients in both subgroups improved, and those patients who underwent combined procedures tended to have superior improvements on nearly all scoring scales. As those patients in the isolated transplantation subgroup did not have any concomitant pathology in the knee that needed to be addressed (that is, there was no treatment being withheld from patients in this subgroup at the time of the procedure), this comparison illustrates only that repairing concurrent pathology of the knee at time of meniscal allograft transplantation does not decrease the success of the procedure when it is performed in isolation. Data suggest that the meniscus deficiency should not be viewed in isolation, as concomitant procedures to repair concurrent anatomical pathologies of the affected knee joint can be performed with an allograft meniscus transplantation to enhance joint stability and biomechanics, and thus create an optimal environment for the graft. An aggressive approach should be taken preoperatively to screen for concomitant pathology to correct these at the time of transplant.

Comparison of the subgroups of patients with preoperative BMI under-25 to patients with preoperative BMI over-25 did not demonstrate a significant difference in improvement. Most of the previous outcome studies on the meniscus allograft transplantation have not analyzed outcomes based on BMI. Our results did not show a difference between the two subgroups, indicating that patient BMI is not a factor in

predicting which patients have more favorable long-term outcomes from the procedure.

The case studies of the six patients who were assessed physically at follow-up provided a more objective measurement of the meniscus transplantation procedure than the subjective survey scorings. General characterizations of these patients at follow-up were positive as signified by minimal pain and effusion and near-normal ROM. Additionally, radiographic images showed consistent successful bony integration of the bone plugs/bridge from the allograft meniscus at the tibia. There was joint space narrowing in some of the patients, which may have just been a consequence of an aging knee. From an overall physical and radiological standpoint, the six patients assessed in our case study showed physical improvements as compared with their baseline state.

Our study does have some limitations. Small patient populations, low follow-up rates, and lack of a control group limit the power of the evidence presented. Due to the nature of the intervention, generating controlled variables with which to compare our data are difficult. In addition the fact that many patients had concomitant procedures makes comparisons more difficult. Evaluating each patient with the use of cartilage-specific MRI sequences would have ultimately allowed us to assess the integrity of the chondral surfaces and the meniscus; however, due to monetary limitations, MRI was not a viable option.

The long-term efficacy of meniscal allograft transplantation is promising. Short- and intermediate-term clinical outcome reports in the past few decades are consistent with our long-term follow-up and confirm that meniscal allograft transplantation is an excellent surgical intervention for reducing pain, increasing activities of daily living, halting/delaying degenerative joint disease, restoring normal knee biomechanical function, and anatomy in properly selected patients. Future research of longer patient follow-up will help better assess the value of the allograft meniscus transplantation procedure in preventing the progression of secondary osteoarthritis and maintaining an improved level of pain and function.

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