Clinical and Radiologic Outcomes After Meniscus Allograft Transplantation at 1-Year and 4-Year Follow-up

Jeong Ku Ha, M.D., Hyung-Won Jang, M.D., Jae Eun Jung, M.S., Seung Ik Cho, M.S., and Jin Goo Kim, M.D., Ph.D.

Purpose: To assess the clinical and radiologic outcomes of meniscus allograft transplantation (MAT) with serial evaluation at 1 year and at 4 years. Methods: Among 151 patients who received MAT between March 2006 and June 2009, we prospectively recruited the patients who had undergone clinical and radiologic examinations at 1 year after the operation. The Lysholm score, International Knee Documentation Committee score, and Knee Society Score were determined. Plain radiography was used for evaluation of osteoarthritis, and magnetic resonance imaging (MRI) was used to assess the cartilage status and meniscal extrusion. Results: Thirty-nine patients with a mean age of 40 ± 9 years were recruited. The first visit was conducted at a mean of 13.6 months (range, 11 to 17 months) postoperatively, and the last visit was conducted at a mean of 50.4 months (range, 48 to 72 months) postoperatively. Of the patients, 29 were men. The lateral side was involved in 27 patients. The Lysholm knee score increased to a median value of 89 (range, 75 to 100) at the first visit and 88 (range, 76 to 100) at the second visit from a preoperative median value of 79 (range, 37 to 99), which was statistically significant according to the Kruskal-Wallis test. According to the Kellgren-Lawrence grade based on anteroposterior radiographs, 21 patients (54%) showed no arthrosis progression and the overall status of arthrosis on anteroposterior radiographs was significantly changed (P < .001). On MRI, 25 patients (64%) showed no cartilage status change and the overall status was not changed significantly (P = .178). The meniscal extrusion extent was 4.2 ± 0.4 mm at the first visit and 4.2 ± 0.6 mm at the second visit (P = .678), and the relative percentage of extrusion was 0.44 ± 0.16 and 0.51 ± 0.21, respectively (P = .059). The subgroup in which arthrosis had progressed on MRI showed a larger amount of change in the relative percentage of extrusion (P = .023). No correlation was observed between meniscal extrusion and various outcomes. Conclusions: Repeat assessment at 4 years showed that MAT showed improvement in knee function, but it had decreased over time. Considerable meniscal extrusion was observed, but it did not increase during follow-up and did not show any correlation with other outcomes. Extrusion progression showed significant correlation with arthrosis progression. Level of Evidence: Level IV, therapeutic case series.

Meniscus allograft transplantation (MAT) has been popularized as the treatment of choice in young patients who have undergone previous meniscectomy. Many researchers have reported encouraging results after MAT. Encouraging clinical results, a good healing rate on imaging evaluation, and a good chondroprotective effect on second-look arthroscopy have been shown in several reports.1-3 However, there are still many controversial issues. Does the MAT have a chondroprotective effect on long-term follow-up? How much does the allograft extrude during follow-up, and does it relate with clinical outcomes? Furthermore, how do the outcomes change over time? To our knowledge, there has been no serial evaluation of clinical and radiologic outcomes more than 2 years after MAT.

The purpose of this study was to assess the clinical and radiologic outcomes of MAT with serial evaluation at 1 year and at 4 years. The hypotheses were as follows: (1) MAT will improve knee function, but the function will decrease over time. (2) Considerable meniscal extrusion will be observed, but it will not increase during follow-up and will not correlate with clinical outcomes and radiologic findings.

Methods

A total of 151 patients had undergone MAT at our institute from March 2006 to May 2009. The inclusion...
criteria were patients who underwent MAT during the aforementioned period and who underwent clinical and radiologic examinations at approximately 1 year after surgery. The exclusion criteria were infection and graft rejection.

MAT was performed in patients who had moderate to severe pain after total or subtotal meniscectomy with a 12-month interval from meniscectomy to MAT on the medial side and a 6-month interval on the lateral side. Contraindications for this surgical procedure were uncorrected instability, moderate to severe osteoarthritic changes, axial-limb malalignment, and age older than 45 years. This study was approved by the institutional review board of our hospital.

**Surgical Technique**

MAT was performed by one experienced surgeon (J.G.K.) who had performed more than 200 cases of MAT. Grafts were sized on anteroposterior (AP) and lateral radiographs with a scanogram for correction of magnification, as described by Pollard et al.4 Medial MAT was performed by a modified bone-plug technique developed by the senior author (J.G.K.),5,6 in which the graft contains separate bone plugs attached to the horns and the bone plug of the posterior horn is smaller than that of the anterior horn for easy passage. Lateral MAT was performed by the “keyhole” technique described by Wilcox and Goble,7 in which the graft contains a common bone bridge attached to both anterior and posterior horns.

In all cases we used fresh-frozen allografts. Additional procedures, such as cruciate ligament reconstruction (9 cases, 23%), posterolateral corner reconstruction (1 case), cartilage microfracture technique (2 cases, 1%), high tibial osteotomy (1 case), and autologous chondrocyte implantation (2 cases, 1%), were performed concomitantly or as separate staged procedures.

**Evaluation Methods**

The Lysholm knee score, International Knee Documentation Committee (IKDC) subjective knee score, and Knee Society Score (knee score and functional score) were used to assess the clinical results. Extension weight-bearing AP radiography (AP view) and 45° posteroanterior flexion weight-bearing radiography (Rosenberg view) were used to evaluate joint space narrowing of the involved compartment. The Kellgren-Lawrence grade was used to grade the osteoarthritic status of the knee. All measurements were documented by 2 different orthopaedic surgeons (J.K.H., H-W.J.) and a radiologist. Grades for which consensus was reached were used after the discussion. Interobserver agreement was observed in 25 to 34 patients for the magnetic resonance imaging (MRI) arthrosis grade and Kellgren-Lawrence grade on AP and Rosenberg views. The intraclass correlation coefficients for interobserver reliability ranged from 0.75 to 0.87.

MRI examinations were performed in all cases using 1.5-T cylinder-shaped equipment (Intera Achieva; Philips, Eindhoven, Netherlands). Meniscal extrusion was defined as the greatest distance from the most peripheral aspect of the meniscus to the border of the tibia, excluding any osteophytes on coronal images. It was measured to the nearest millimeter on the coronal images (fast spin-echo intermediate weighted image; repetition time/echo time, 2,000 to 3,800 milliseconds/35 to 45 milliseconds; 4-mm section thickness; 1-mm interslice gap) using an MRI-generated scale on each image by 2 different orthopaedic surgeons and a radiologist, and average values were used. The relative percentage of extrusion (RPE), defined as the percentage of the width of extruded menisci compared with the entire meniscal width, was also measured.8,9 This method was developed to standardize the measurement for knees of different sizes (Fig 1). Cartilage status was evaluated according to the modified Outerbridge grading scale.

**Rehabilitation Protocol**

Immediately after surgery, the patients were placed in a long leg splint, which was worn for approximately 5 to 7 days. The allowed ranges of motion at 3 weeks and 6 weeks were 90° and 120°, respectively, in lateral MAT cases and 120° and full, respectively, in medial MAT cases. Because previous biomechanical studies showed that the lateral tibial condyle moved internally more than the medial side during knee motion, more restricted range of motion was applied to the lateral side for early protection of the sutured graft. Patients were allowed partial weight bearing during the first 6 weeks. Light running was allowed at 3 months, with return to sports at 6 months, although strenuous contact sports were prohibited.

**Statistical Methods**

We performed repeated-measures analysis of variance for the IKDC and modified Hospital for Special
Surgery (mHSS) scores. The Friedman test was used for the analysis of the serial results of the Lysholm score, Kellgren-Lawrence grade, and Outerbridge grade. Bonferroni adjustment was applied after a paired t-test and Wilcoxon signed rank test, which were used for comparison of the results for each follow-up time. The Pearson correlation coefficient for the IKDC and mHSS scores and Spearman ρ for the Lysholm score, Kellgren-Lawrence grade, and Outerbridge grade were estimated for evaluation of the correlation between meniscal extrusion and the parameters. In addition, we performed subgroup analysis, dividing the patients into 2 groups according to the absence or presence of arthrosis progression and comparing the extrusion amount between the 2 groups.

Results

Of 151 patients, 39 were evaluated twice. One case was excluded because of an infection. The first evaluation was conducted at a mean of 13.6 months (range, 11 to 17 months) postoperatively, and the second evaluation was conducted at a mean of 50.4 months (range, 48 to 72 months) postoperatively. The mean age was 40 ± 9 years, and 29 patients were men. The medial meniscus was involved in 12 cases and the lateral meniscus in 27. The mean height was 170 ± 9 cm, the mean weight was 74 ± 14 kg, and the mean body mass index was 25.6 ± 3.7 kg/m².

The Lysholm knee score increased to a median value of 89 (range, 75 to 100) at the first visit and 88 (range, 76 to 100) at the second visit from a preoperative median value of 79 (range, 37 to 99). During the first period (from preoperatively to the first visit), the Lysholm score increased significantly (P = .013), whereas during the second period (from the first visit to the second visit), it decreased slightly but there was no significant difference (P = .765). This pattern, showing significant improvement during the first period and a nonsignificant change during the second period, was also observed for all subjective questionnaires (IKDC score, Knee Society Score—knee, and Knee Society Score—function) (Fig 2).

The Kellgren-Lawrence grading system was used to evaluate arthrosis of the involved compartment. During the first period, as evaluated by AP radiographs, no arthrosis progression occurred in 29 patients (74%) whereas progression by 1 grade occurred in 10 patients (26%). On the Rosenberg view, 29 patients showed no progression and 10 patients showed progression by 1 grade. The Wilcoxon signed rank test was performed. There were significant differences during the first period (P = .002 and P = .011 for AP view and Rosenberg view, respectively). During the second period, as evaluated by AP radiographs, no arthrosis progression occurred in 30 patients (74%) whereas progression by 1 grade occurred in 9 patients (26%). On the Rosenberg view, 27 patients showed no progression and 12 patients showed progression by 1 grade. There were significant differences during the second period (P = .002 and P = .011 for AP view and Rosenberg view, respectively). During the total follow-up period (from preoperatively to the second visit), as evaluated by AP radiographs, no arthrosis progression occurred in 21 patients (54%), progression by 1 grade occurred in 17 patients (44%), and progression by 2 grades occurred in one patient (3%). On the Rosenberg view, 21 patients (54%) showed no progression, 15 patients (39%) showed progression by 1 grade, and 3 patients (8%) showed progression by 2 grades. Significant differences between preoperatively and the second visit were found for both the AP view and Rosenberg view (P < .001 and P < .001, respectively) (Figs 3 and 4).

Cartilage status was evaluated by MRI according to the modified Outerbridge system. The ipsilateral femoral

Fig 2. Subjective scores during follow up period. *P < .02; **P < .01. (IKDC, International Knee Documentation Committee; KSS, Knee Society Score.)

Fig 3. Kellgren-Lawrence grade in AP X-ray. P < .001, Friedman test; *P < .001, post hoc with Wilcoxon Signed-rank test.
cartilage was assessed at each visit. During the first period, no cartilage status change occurred in 29 patients (74%), and progression by 1 grade occurred in 7 patients (18%), whereas 3 patients (8%) had recovered by 1 grade. Of these 3 patients, 2 had undergone autologous chondrocyte implantation and 1 had undergone microfracture during the index surgical procedure. During the second period, no cartilage status change occurred in 29 patients (74%), progression by 1 grade occurred in 4 patients (10%), and progression by 2 grades occurred in 6 patients (15%). During the total follow-up period, no cartilage status change occurred in 25 patients (64%), progression by 1 grade occurred in 5 patients (13%), progression by 2 grades occurred in 3 patients (8%), and progression by 3 grades occurred in 3 patients (8%). Three patients (8%) had recovered by 1 grade. Statistical analysis showed no statistically significant differences during the follow-up period ($P = .179$, Friedman test).

The intraclass correlation coefficients for the interobserver reliability of meniscal extrusion and RPE were 0.70 and 0.87, respectively. The mean absolute extrusion extent was $4.2 \pm 0.4$ mm at the first visit and $4.2 \pm 0.6$ mm at the second visit. There was no significant difference ($P = .678$). The mean RPE was $0.44 \pm 0.16$ at the first visit and $0.51 \pm 0.21$ at the second visit ($P = .059$). On subgroup analysis, recruited patients were classified according to the absence or presence of arthrosis progression on MRI during each period. The subgroup with no progression during the second period showed less RPE change, with $0.02 \pm 0.14$, than the subgroup with progression of more than grade 1, with $0.19 \pm 0.18$ ($P = .023$). However, the Kellgren-Lawrence grade change did not show a significant difference in meniscal extrusion (Table 1). Between meniscal extrusion and the various parameters, including subjective scales and radiologic findings, no significant correlations were observed at each visit.

### Discussion

According to our hypotheses, the results can be summarized as follows: (1) Knee function improved significantly after MAT. It decreased over time, but it was not statistically significant. (2) Considerable extrusion was observed, but it did not increase during follow-up and did not correlate with clinical outcomes and radiologic findings.

At the first postoperative visit, the Lysholm score, IKDC score, and Knee Society Score improved significantly compared with preoperatively, but they decreased slightly at the second visit, which was not statistically significant. Numerous studies have reported

<table>
<thead>
<tr>
<th>Table 1. Comparison of Amount of Change in RPE Between Groups Divided According to Arthrosis Progression During Second Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in RPE</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>No progression (n = 29)</td>
</tr>
<tr>
<td>Progression (n = 10)</td>
</tr>
<tr>
<td>$P$ value*</td>
</tr>
<tr>
<td>KL grade on AP view</td>
</tr>
<tr>
<td>No progression (n = 21)</td>
</tr>
<tr>
<td>Progression (n = 18)</td>
</tr>
<tr>
<td>$P$ value*</td>
</tr>
<tr>
<td>KL grade on Rosenberg view</td>
</tr>
<tr>
<td>No progression (n = 21)</td>
</tr>
<tr>
<td>Progression (n = 18)</td>
</tr>
<tr>
<td>$P$ value*</td>
</tr>
</tbody>
</table>

KL, Kellgren-Lawrence.

*Independent $t$ test.

Fig 4. Kellgrena-Lawrence grade in AP X-ray. $P < .001$, Friedman test; *$P < .001$, post hoc with Wilcoxon Signed-rank test; |$P = .011$.

Fig 5. Modified Outerbridge grade of ipsilateral femoral cartilage in MRI during follow-up period. There were no significant differences among the outcomes.
encouraging results regarding clinical outcomes after MAT during follow-up.\textsuperscript{10} Kim et al.\textsuperscript{1} reported improvement of clinical outcomes with 49.4 months’ follow-up. Moreover, Koh et al.\textsuperscript{11} reported significant improvement of clinical outcomes with 32 months’ follow-up. Saltzman et al.\textsuperscript{12} described long-term results with a minimum of 7 years’ follow up, showing a high satisfaction rate and significant improvement in several outcome scoring systems. Regarding serial follow-up results, Stone et al.\textsuperscript{13} reported prospective results at 2 to 12 years’ follow-up that showed a serial subjective outcome score change. At each time point during the follow-up period, all scores showed a significant improvement compared with the preoperative status, and there were no significant changes over time. These findings are similar to our results.

In terms of meniscal extrusion, most of the published series on transplanted menisci consistently showed some degree of allograft extrusion, even though they showed good knee function.\textsuperscript{1,2,14-19} The results of our study are similar to those of previous studies. There have been several explanations regarding the extrusion: preoperative size mismatch, over-tensioning of the meniscal suture during surgery, individual factors, overstuffing, geometrically unmatched allograft, and unrestored normal ligamentous structure.\textsuperscript{2,9,20,21} However, there is no established consensus. Lee et al.\textsuperscript{9} reported that serial follow-up MRI during the first postoperative year after MAT showed no progression of meniscal extrusion. They suggested that the position at the initial stage is the most important measure of meniscal extrusion. However, the conclusion was based on 1-year follow-up results only.\textsuperscript{9} Our results showed serial changes at a mean of 45 months after MAT in similar patients. To our knowledge, no previous studies reported serial results like this study.

Although there have been several reports showing that meniscal extrusion did not have a significant relation with clinical outcomes,\textsuperscript{1,2,9,14} meniscal extrusion may have negative effects on the biomechanics of the knee. It is well known that meniscal extrusion not only has a high index of association with tears but also is believed to be related to the development of osteoarthritis.\textsuperscript{22-24} In our study a significant change in RPE was observed in the subgroup that showed arthrosis progression on MRI. In other subgroups, there were no significant changes in extrusion.\textsuperscript{2} These findings suggest that meniscal extrusion may be related to the development of osteoarthritis. Recently, many authors have discussed the causes and results of meniscal extrusion and have described methods to overcome meniscal extrusion; however, there is no established consensus on the topic.\textsuperscript{2,3,9,17,25-27} Further study of the clinical and radiologic consequences of meniscal extrusion is needed.

**Limitations**

Our study has several limitations. First, fewer than 30% of the total patients were recruited in this study; thus there could be a selection bias. Second, patients with concomitant surgical procedures were not excluded or were not considered separately during analysis. Those procedures could affect the results of MAT, so there could be a bias. Third, the chondroprotective effects of MAT could have been more obvious by performing a comparison with a control group consisting of nonoperatively treated symptomatic patients who had undergone meniscectomy. However, the creation of a control group was not possible for ethical reasons. Meniscus-deficient patients who underwent osteotomy without MAT would comprise a good control group for a future study. The measurement of meniscal extrusion had some limitations. We only measured this in the lateral direction on the coronal view and only in the supine position. Measurement in the AP direction or under weight bearing might have shown different results than those in our study.

Despite these limitations, this study has some strengths. We performed a thorough evaluation including subjective scales, objective functional performance measures, and assessment by plain radiography and MRI.

**Conclusions**

Repeat assessment at 4 years showed that MAT showed improvement in knee function, but it had decreased over time. Considerable meniscal extrusion was observed, but it did not increase during follow-up and did not show any correlation with other outcomes. Extrusion progression showed significant correlation with arthrosis progression.

**References**

6. Kim JG, Lee YS, Lee SW, Kim YJ, Kong DH, Ko MS. Arthroscopically assisted medial meniscal allograft


