Meniscal Allograft Transplantation Without Bone Blocks: A 5- to 8-Year Follow-Up of 33 Patients

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Purpose: The purpose of this study was to evaluate the functional and radiographic results on a midterm basis, as well as complications, in an initial series of meniscal allograft transplantations performed with suture fixation without any bone block. **Methods:** A series of 33 meniscal allograft transplantations were performed at our institution from January 2001 to October 2003. Inclusion criteria were patients with compartmental joint line pain due to a previous meniscectomy. There were 24 men and 9 women with a mean age of 38.8 years (range, 21 to 54 years). The functional outcomes were evaluated by use of Lysholm and Tegner scores at a mean and minimum follow-up of 6.5 years and 5 years, respectively. A visual analog scale for pain was also used. Radiographic assessment included joint space narrowing on the Rosenberg view and magnetic resonance imaging evaluation. **Results:** The Lysholm and Tegner scores significantly improved from 65.4 to 88.6 ($P < .001$) and from 3.1 to 5.5 ($P < .001$), respectively, after surgery. The visual analog scale score significantly dropped from 6.4 to 1.5 ($P < .001$). The radiographic evaluation did not show any joint space narrowing ($P = .38$). Meniscal extrusion was a constant finding, averaging 36.3% of total meniscal size. According to the Van Arkel criteria, the survival rate was 87.8% at 6.5 years. The rate of complications was 33%. **Conclusions:** This study suggests that this procedure provides significant pain relief and functional improvement in selected symptomatic individuals on a midterm basis. However, there was a high rate of complications (33%) and revision surgery. **Level of Evidence:** Level IV, therapeutic case series.

The menisci consist of fibrocartilage and play an important role in shock absorption, load transmission, and stabilization of the knee joint. King[1] experimentally showed the degenerative changes that occurred in a dog after meniscectomy. Some years later, Fairbank[2] described the same arthritic changes that appear in a meniscectomized knee in human beings. Other researchers have since confirmed those findings.[3-5] These changes are due to the loss of biomechanical functions of the meniscus itself.[6,7] Despite this, total meniscectomy was the treatment of choice for a meniscal rupture for a long period of time. It provided excellent clinical results in the short term, although the long-term results were not so good because of cartilage damage.

In an attempt to restore the normal anatomy and biomechanics of the knee after a meniscectomy, meniscal allografts have been used to replace menisci in selected individuals with symptomatic knees. The transplantation of a meniscus as a free graft was developed in Germany in the mid 1980s.[8] However, 2 surgical teams in North America experimented with

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massive fresh osteochondral allografts, including the corresponding meniscus, to reconstruct post-traumatic defects of the tibial plateau a decade earlier.[9,10]

Meniscal allograft transplantation (MAT) has yielded favorable results and provided significant pain relief and functional improvement on a short- and medium-term basis. There are few series with long-term results reported in the literature,[11-13] and it is difficult to compare those because of the combination of procedures used.[14] The factors limiting comparisons also include graft preservation methods, fixation techniques, and outcome evaluation criteria.

One of the goals of a meniscal transplant is to restore the mechanical properties of the meniscectomized knee. Cadaveric studies have shown that secure anatomic fixation of bone plugs is required to restore normal contact mechanics for medial and lateral allografts, whereas the joint load distributions are similar to meniscectomized knees when only suture fixation is performed.[15-17] McDermott et al.,[18] in a recent study, reported on the effects of lateral meniscal allograft transplantation with bone plugs and with sutures on tibiofemoral contact pressures in vitro. They found that both fixation methods reduce the peak articular contact pressures in meniscectomized knees, even if only fixed by suturing. The aforementioned findings suggest that a chondroprotective effect is operative by use of methods. Therefore a small advantage was found when securing the allografts with bone fixation in addition to the use of the sutures. The rationale for not using bone blocks in our series was based on the lack of definitive clinical data relative to the superiority of the bone block technique, as well as our previous experience with the use of Collagen Meniscus Implant (ReGen Biologics, Franklin Lakes, NJ). Meniscal allografts without bone blocks or even without bone fixation have been extensively used in Europe. In fact, Van Arkel and De Boer[19] and Verdonk[20] reported favorable outcomes with only soft-tissue fixation, and their experiences are among the longest in the world.

Controversy exists as to whether MAT prevents or at least slows cartilage degeneration in a previously meniscectomized compartment.[21,22]

The aim of this work was to assess the functional and radiographic results on a midterm basis, as well as the complications encountered, in the first MAT series performed at our institution by means of suture fixation without any bone block. The hypothesis was that MAT significantly decreases compartmental pain and improves the function of the previously meniscectomized knee on a midterm basis.

METHODS

From January 2001 through October 2003, 33 MATs were performed at our institution by the senior surgeon in patients with persistent compartmental joint line pain due to a previous meniscectomy in an otherwise well-aligned knee. Normal alignment was considered up to 5° varus alignment and 7° valgus alignment.

An anterior cruciate ligament (ACL)–deficient knee was not considered a contraindication if the ligament was reconstructed at the same time as the transplant. Patients who had severe degenerative joint disease defined by advanced Fairbank changes, which means a completely collapsed compartment on the Rosenberg view, were excluded. The series was composed of 24 men and 9 women with a mean age of 38.8 years (range, 21 to 54 years). Nineteen MATs were performed to replace the lateral meniscus and 14 to replace the medial meniscus. The mean time from meniscectomy to transplant was 11.2 years (range, 2 to 25 years).

Additional procedures were performed in 13 patients (39%): ACL reconstruction in 8, microfracture in 8, and chondral shaving in 9 (Table 1). The clinical follow-up was 6.5 years (78 months) (range, 63 to 96 months).

Type of Graft

Fresh-frozen (−80°C) non-irradiated, non–antigen-matched meniscal allografts were used in this series. The allografts were supplied by local authorized tissue banks. Allograft sizing was done according to the morphometric dimensions (weight and size), as well as the radiographic measures of the donor's and recipient's knee, as described by Pollard et al.[23]

Surgical Technique

The surgical technique was completely arthroscopic. After a complete diagnostic arthroscopy, debridement of meniscal remnants was done to achieve

TABLE 1. *Number of Patients With Additional Procedures*

	Additional Procedures
ACL reconstruction	8
Microfractures	8
Chondral shaving	9

NOTE. Some patients underwent more than 1 procedure at the same time as transplantation.

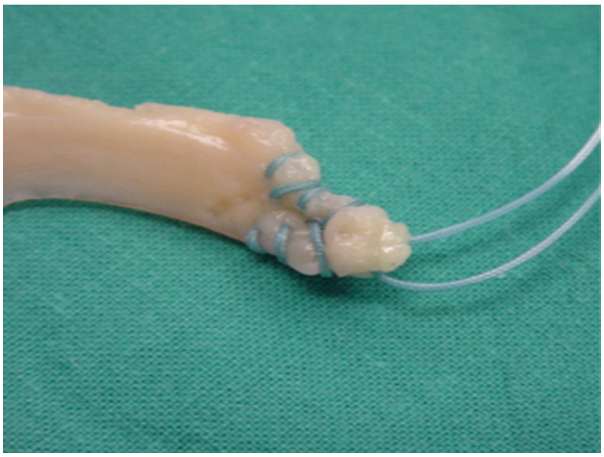

FIGURE 1. High-strength suture with a Krackow mattress placed at anterior horn of medial allograft meniscus.

a good bleeding bed. Then, two 6-mm bone tunnels were drilled at the anatomic sites of meniscal insertion: one at the anterior horn and the other at the posterior horn. After the allograft was thawed in a saline solution bath at 36°C, high-strength sutures (FiberWire; Arthrex, Naples, FL) with a Krackow mattress were then placed at both horns (Fig 1). One additional vertical mattress suture was placed from 1.5 cm of the posterior horn. The posterior-horn suture was used to pull the meniscal allograft in place. The additional vertical suture aids in situating the graft and avoids an additional approach because it is to be retrieved with an outside-in technique. Once the allograft was well fixed to the rim, by use of an inside-out technique with vertical mattress sutures (SharpShooter; ConMed Linvatec, Largo, FL) (Fig 2), the sutures placed in the anterior and posterior horns were tied together over the tibia cortical surface.

Major concomitant procedures included treatment of cartilage injuries and ACL reconstruction or revision. In the case of localized Outerbridge grade IV cartilage injuries, we made microfractures on the bone that had undergone eburnation to promote a healing response. Debridement and shaving were used in cartilage lesions graded as III or less to obtain smooth articular surfaces. When necessary, a standard arthroscopic ACL reconstruction was performed as a final step. This allowed for maximum joint line distraction, especially in stiff joints, at the time of the transplant. The tibial bone tunnel for the ACL graft had previously been established to avoid wall breakage between the different bone tunnels.

Postoperative Protocol

Immediate quadriceps and hamstring muscle exercises, as well as passive range of motion from 0° to 60°, were initiated. Range of motion progressed gradually to 90° of flexion by the end of the first month. Partial weight bearing with a knee immobilizer was allowed at 3 weeks and progressed to full weight bearing at about 6 weeks. Patients returned to a normal workload by the fourth month after surgery. Running was allowed by the sixth month, depending on patient compliance.

Functional and Radiologic Evaluation

Functional follow-up included the 100-point Lysholm score as well as the Tegner score. The Lysholm score was interpreted as follows: excellent, greater than 94 points; good, 84 to 94 points; fair, 65 to 83 points; and poor, less than 65 points.[24,25] A 10-point visual analog scale (VAS) for pain was also used.

Patient satisfaction was evaluated with a subjective score and graded as follows: very satisfied (4 points), satisfied (3 points), neutral (2 points), dissatisfied (1 point), and very dissatisfied (0 points).

Radiographic assessment included a weight-bearing long standing radiograph, as well as the posteroanterior Rosenberg view at 45° of flexion. Because one of the potential effects of MAT might be preservation of the cartilage, we focused on joint space narrowing in the involved compartment measured preoperatively

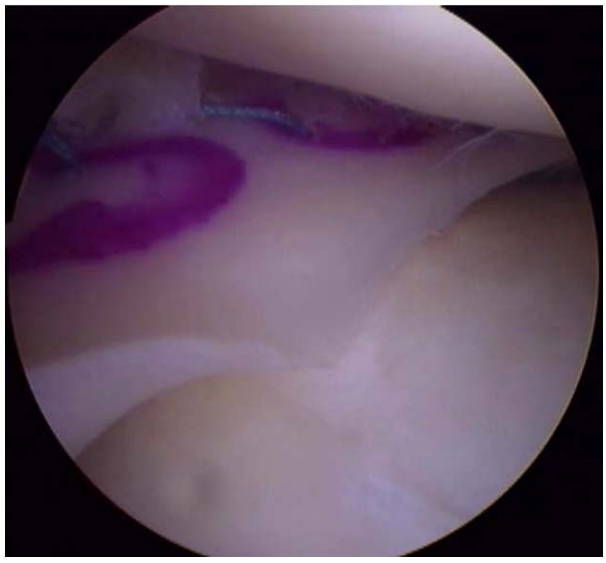

FIGURE 2. Arthroscopic view of meniscal allograft after fixation to rim by use of vertical sutures.

and at final follow-up. The shortest distance between the femoral condyle and tibial plateau of the involved compartment on a posteroanterior Rosenberg view at 45° of flexion was taken as a measure of joint space narrowing.

Magnetic resonance imaging (MRI) evaluation was also done to assess the allograft evolution and possible extrusion in coronal views. All studies were performed at 5 years of follow-up with a superconductive 1.9-T system (Prestige 2T; Elscint, Haifa, Israel) with a quadrature extremity coil. A positioning device for the ankle was used to ensure uniformity between patients. The standard knee protocol for each subject consists of a sagittal fat-saturated proton density–weighted sequence, a coronal T1-weighted sequence, a coronal STIR-weighted sequence (Short T1 Inversion Recovery), and an axial fat-saturated proton density–weighted sequence. A slice thickness of 3 mm with no intersection gap was used. Extrusion was defined as the greatest distance from the most peripheral aspect of the meniscus to the border of the tibia divided by the total width of the meniscus on the same magnetic resonance coronal image. A proportional sizing method, presented not in absolute values but as a percentage of the menisci that passes the tibial plateau limit, was used in this series. This was done to standardize the degree of extrusion to the different sized knees.[26]

Preoperative and postoperative radiologic measures were analyzed by means of the ePACS viewer (version 5.0.0.0; Real Time Image, San Bruno, CA) for clinical imaging.

Medial allografts were also compared with lateral allografts at final follow-up.

The entire functional evaluation was performed by 1 observer, who was not the surgeon.

Statistical Analysis

Categorical variables are presented as percentages and frequencies. Continuous variables are presented as mean ± standard deviation. After testing the normal distribution of the differences between the preoperative and postoperative scores with the Kolmogorov-Smirnov method, we analyzed differences with the paired Student *t* test. Statistical analysis was performed by use of SPSS software (version 13.0; SPSS, Chicago, IL). Statistical significance was set at 0.05.

RESULTS

At a mean of 78 months, all but 1 of the patients were available for follow-up. This patient did well for about 2 years and then died of an unrelated disease.

Functional Results

The Lysholm score improved from 65.4 ± 11.6 to 88.6 ± 7 after the treatment ($P < .001$). The final Lysholm score was excellent in 9 patients (28.1%), good in 13 (40.6%), and fair in 10 (31.2%). Thus, in 68.7% of the patients in this series, the results were good or excellent.

The mean follow-up Tegner score of 5.5 ± 2.1 was significantly improved compared with the mean pretreatment score of 3.1 ± 2.1 ($P < .001$).

The mean VAS score improved by 4.8 points. It dropped from a mean of 6.4 ± 2 to 1.5 ± 1.2 at follow-up ($P < .001$).

When the results were analyzed by compartment (medial *v* lateral), there were no differences found in the final Lysholm, Tegner, and VAS scores (Table 2). The final Lysholm score was 86.6 in the subgroup undergoing ACL reconstruction and 90 in the group undergoing microfracture, whereas it was 88.6 for the whole series. Therefore no significant differences were found among the subgroups ($P > .05$).

The satisfaction of the patients with regard to the procedure was 3.6 points out of a maximum of 4.

Radiographic Findings

The result of the radiographic evaluation with the Rosenberg view did not show any narrowing when the

TABLE 2. *Functional Outcomes Comparing Medial Versus Lateral Meniscal Transplantation*

	Total	Medial Meniscal Transplantation	Lateral Meniscal Transplantation	*P* Value
Lysholm	88.63 ± 7.2	88.37 ± 7.5	89 ± 9.2	.64
Tegner	5.54 ± 2.15	5 ± 1.53	6 ± 2	>.99
VAS	1.52 ± 1.21	1.37 ± 1.5	1.83 ± 1.3	.47
Satisfaction	3.6	3.5	3.75	

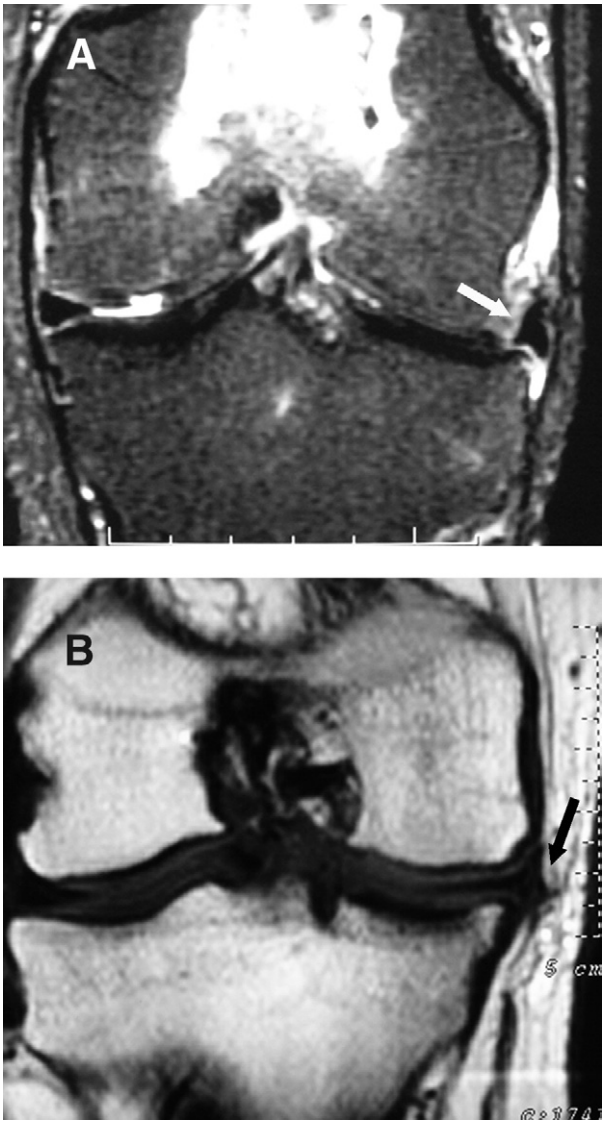

Figure 3. MRI coronal views of 2 knees after (A) lateral and (B) medial meniscal transplantation. A, Complete extrusion of the lateral allograft can be observed (white arrow). B, Partial extrusion of the transplanted meniscus behind the medial collateral ligament can be observed (black arrow).

joint space was analyzed (from 3.19 ± 1.23 mm preoperatively to 3.21 ± 1.96 mm at follow-up, $P = .38$).

The main findings on MRI were as follows. The entire transplanted meniscus was present in all cases except for the explanted. The volume of the transplanted meniscus was smaller than expected (although we could not record this because there was no meniscus for comparison). There was an altered signal, probably indicating ongoing remodeling, some degeneration, or both, as well as some degree of allograft extrusion, in all cases. Meniscal extrusion was a common finding in the whole series, with some degree in all grafts and a mean of 36.3% ± 13.7% of total meniscal size (Fig 3). When analyzed by compartment, medial allografts showed 35.9% ± 18.1% peripheral extrusion whereas lateral allografts showed 38.3% ± 14.4% ($P = .84$).

Complications

Complications included 2 cases of arthrofibrosis and 2 infections requiring arthroscopic arthrolysis and lavage plus specific antibiotic therapy over a period of 6 weeks, respectively. In all 4 cases the transplanted menisci looked viable and were kept in place.

In 7 patients (21.4%), a second surgery was necessary because of a graft tear. Four of them had later loss of allograft fixation requiring refixation. The allograft had to be completely removed in the remaining 3 cases (failure rate, 9%).

Therefore a total of 14 knees underwent second-look arthroscopy for different reasons at different time intervals. Only 11 of them (33% of the series) were because of allograft complications. In 11 of 14 revision surgeries, the allografts appeared to have completely or partially healed and been fixed to both the joint capsule and the insertion horns (Fig 4). Two cases showed severe shrinkage. One of them was of no clinical consequence.

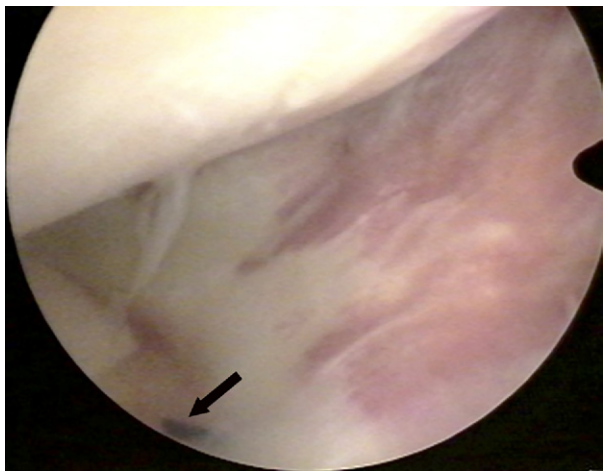

Figure 4. Second-look arthroscopy in a patient with septic arthritis after MAT. There is a broken suture remaining at the anterior horn (arrow). The allograft was observed to have healed to the periphery by vascularized tissue.

DISCUSSION

The main finding of this study was that performing MAT in a patient with persistent compartmental joint line pain due to a previous meniscectomy improves knee function and provides a decrease in pain at least 5 years postoperatively.

In this series the graft fixation was done solely by use of sutures. We chose this method because of our previous experience using Collagen Meniscus Implants. Fixation without bone plugs is technically less demanding and allows easier matching to compartment size. It has been suggested that the use of multiple sutures in shorter tunnels enhances fixation by increasing implant stiffness and improving contact mechanics.[15] Moreover, suture fixation provides a lower risk of eliciting an immunologic or antigenic response.[25]

Several experimental studies have shown good healing of the transplanted allografts when the anterior and posterior horns are sutured without bone plug fixation.[27,28] Hunt et al.[29] showed no differences between either of the techniques in terms of the mean pullout strength of the medial meniscal allograft with posterior horn fixation in a cadaveric model. It has even been reported that nonanatomic bony fixation may lead to enhanced articular cartilage degeneration.[30] There are also clinical studies in which satisfactory results have been obtained with suture fixation.[11,31,32]

The allografts used in this series were fresh frozen (−80°C), the most commonly used preservation method in our environment. These are less likely to provoke an immune response. Nevertheless and in contrast to currently accepted knowledge, Gelber et al.[33] have recently shown that the freezing process alters the menisci's collagen net in terms of both the size and degree of disarray of the collagen fibril. These structural changes might deteriorate the allograft's functions and even lead to its shrinkage.

Allograft shrinkage is difficult to assess not only on MRI but also on second-look arthroscopy. Carter,[34] in 22 second-look surgeries, reported only 3 cases of size reduction. Milachowski et al.[8] noted shrinkage of 33% to 66% in 14 of 23 menisci examined by arthroscopy after 8 months of follow-up. However, the latter series had used lyophilized allografts, and this preservation method is now accepted to constantly produce a decrease in allograft size. Although only 2 of 33 cases (6%) had clearly shrunken in our series, we believe that a significant number of transplants had a size inferior to that expected.

Most of the authors have found pain relief and functional improvement to be the main benefits of MAT, at least during the first years of follow-up.[12,25,32,35-37] Our functional results also show an improvement after surgery in both Lysholm and Tegner scores as well as pain relief reflected by means of the VAS score at a minimum of 5 years' follow-up. Interestingly, these results are in agreement with those reported in the literature regardless of the type of implant or the fixation technique used.[11,19,32]

In a recent clinical trial review,[38] the majority of published series providing outcome data had over 60% of their patients exhibiting a successful outcome. These were also our findings. However, favorable results were observed in 88% of cases in a selective analysis of the more recent studies. Potential causes for this improvement may include refinements in the selection of patients and graft processing and preparation, as well as in the surgical technique.[39]

It has also been reported that lateral allografts yielded better functional scores than medial allografts.[25] This could be explained by the fact that the lateral meniscus transmits more of a load through the knee and so the lateral transplant should be more important in restoring knee biomechanics. This was in contrast to the functional results observed in our study, where lateral and medial meniscal transplantation scored similarly.

We found no deterioration in the joint line space in the affected compartment at the end of the follow-up. In fact, outcomes showed a slight widening of the space (0.02 mm), although this was statistically nonsignificant. Garrett[40] noted no progressive degeneration after 60 months of follow-up in a study with 15 cryopreserved allografts. Similar results were reported by Rath et al.,[41] Van Arkel and De Boer,[19] and Yoldas et al.[42] On the other hand, Stollsteimer et al.[43] reported joint space narrowing of 0.88 mm in their series. However, the long-term effect of these allografts on the progression of osteoarthritis remains to be determined.

The most common complication reported in meniscal transplantation is retearing of the allografts. In a review of 15 series evaluating the clinical outcome of MAT, Matava[38] found a tear rate of 8.2%. Our series showed a tear rate of 21.4% (7 allografts) with repair in 4 cases and removal in the other 3. Therefore our allografts exhibited a failure rate of 9%. With regard to the complication rate, there seems to be a high range of variation in the literature, depending on what is considered a complication. In the aforementioned review of 15 MAT series published by Matava, the

rate of reoperation ranges from not reported[40] to 26%.[43] However, if one examines some other complications, such as loss of motion, the rate ranges from 0% in several series to 11%.[44] In the case of infections, some series reached a rate of 4.5%[8] whereas it was not reported in others. Overall, the rate of complications in our series can be considered high (33%). We consider allograft tears as complications, in addition to whatever factors obliged the surgeon to reoperate.

By use of the criteria of Van Arkel and De Boer,[25] which consider not only meniscal retention but also good knee function, our allografts' survival rate was 87.8% at a mean of 6.5 years postoperatively in consideration of the fact that 3 failures plus 1 worsening of function led to 28 good outcomes.

Meniscal extrusion is a known phenomenon in the natural history of degenerative knee joint disease. Theoretically, a meniscus well fixed at both the anterior and posterior horns is able to translate axial compression into circumferential efforts and thus does not extrude. However, recent evidence suggests that extrusion can also be seen in normal knees.[26] With regard to the transplanted knees, to our knowledge, only 2 reports have focused on extrusion. Verdonk et al.[35] compared the extrusion of 10 lateral allografts with 10 normal knees by means of MRI as well as ultrasonography. They found all the transplanted menisci without bone block fixation but with firm fixation of the horns to the original sites extruding in the lateral direction significantly more than the normal meniscus. This extrusion does not increase with axial load. More recently, Lee et al.[45] also showed that the extruded allograft tends to be stable over the long term and clinically seems to be irrelevant. In our series all allograft menisci showed some degree of extrusion. With regard to the global allograft size, our allografts were extruded some 36.3%. This high percentage of extrusion can be related to the type of fixation used. Even though no clinical correlation has been found, this and some other issues caused us to consider other fixation systems.

The main limitation of this work of course is that, though prospective, the study was not randomized and had no control group. However, we have to mention that when using a meniscal allograft, it is very difficult to find the right control group (osteotomies, unicompartmental knee replacements, total knee replacements). If a total knee replacement is to be used as a comparison, its results in young persons are very limited and the need for further surgeries is a certainty as time passes.

These results suggest that this procedure appears to be a useful option in selected symptomatic individuals. After surgery, these patients might expect some pain relief and an increase in their activity level that remains unchanged over a mean of 6.5 years, which confirmed our hypothesis. However, a reoperation rate of more than 30% seems to be excessive for such a benign procedure, even though the learning curve has to be taken into account.

CONCLUSIONS

This study suggests that MAT performed in the manner we describe provides significant pain relief and functional improvement in selected symptomatic individuals on a midterm basis. However, there was a high rate of complications (33%) and revision surgery.

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