

# Suture-Only Fixation Technique Leads to a Higher Degree of Extrusion Than Bony Fixation in Meniscal Allograft Transplantation

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**Background:** Most of the published series of transplanted menisci have consistently shown some degree of allograft extrusion. The speculation is that this meniscal extrusion may be caused by the soft tissue technique used to fix the allograft.

**Hypothesis:** The percentage of extruded meniscal graft would be higher if the allograft were only fixed with sutures rather than with associated bony fixation.

**Study Design:** Cohort study; Level of evidence, 2.

**Methods:** We performed a prospective series of 88 meniscal allograft transplantations. Thirty-three of the grafts were fixed with the suture-only technique (group A). The remaining 55 cases were performed with the bone plug method (group B). All patients were studied with magnetic resonance imaging (MRI) at a minimum 3 years' follow-up to determine the degree of meniscal extrusion. The time between surgery and MRI evaluation was 40 months (range, 36–48 months) in both groups. Meniscal extrusion was measured on coronal MRI. The percentage of the meniscal body width that was extruded was calculated. The average percentage of extrusion for each group was compared. The Lysholm score was analyzed in relation to the fixation method and degree of meniscal extrusion. Tears of the allograft that required surgical intervention were also reported.

**Results:** The average percentage of meniscal tissue extruded in group A was 36.3% ± 13.7% without differences between the medial (35.9% ± 18.1%) and lateral (38.3% ± 14.4%) compartments ( $P = .84$ ). Group B had a mean 28.13% ± 12.2% of the meniscal body extruded without differences between the medial (25.8% ± 16.2%) and lateral (30.14% ± 13.5%) compartments. A higher percentage of extruded meniscal tissue was found in group A than in group B ( $P < .001$ ). No association between the degree of meniscal extrusion and the functional score was observed ( $P = .4$ ). Graft tears were observed in 21.4% of the cases in group A and in 7.3% of the cases in group B ( $P = .09$ ).

**Conclusion:** A meniscal allograft fixed with the suture-only technique showed a significantly higher degree of extruded meniscal body than that fixed with the bony fixation method, with no influence on the functional outcome. There was also a considerably higher rate of graft tears observed in those menisci fixed only with sutures, although this difference was not statistically significant with the numbers available.

**Keywords:** meniscal transplantation; meniscal extrusion; meniscal allograft; meniscal fixation

The transplantation of a meniscus as a free graft was developed in Germany in the mid 1980s<sup>21</sup> in an attempt to replace damaged tissue and to prevent progressive deterioration of the joint that occurs after meniscectomy.<sup>11,17</sup>

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The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

One of the goals of a meniscal transplant is to restore the mechanical properties of the meniscectomized knee. Most cadaveric studies have shown that secure anatomic fixation of bone plugs is required to restore the normal contact mechanics for medial and lateral allografts, whereas the joint load distributions are similar to meniscectomized knees when only suture fixation is performed.<sup>3,7,24</sup>

When the meniscus is partially or totally displaced beyond the tibial margin, it is defined as meniscal extrusion. It has been suggested that if the meniscus is extruded beyond the tibial plateau edge, leaving the articular surface of the tibia uncovered, it will not fulfill all its functions.<sup>35</sup> Consequently, the meniscus would not adequately absorb the load applied to the tibial cartilage. This might imitate the effect of a meniscectomy, which alters the physical behavior of the knee joint.<sup>12</sup> In meniscal

TABLE 1  
Composition of Both Groups Before Surgery<sup>a</sup>

Variable	Group A	Group B	Significance (P)
Age, y	38.8 ± 6.3	35.7 ± 7.9	.06
Gender, male/female, %	27/73	40/60	.12
Lysholm	65.4 ± 11.6	62.3 ± 9	.03
Tegner	3.1 ± 2.1	3.4 ± 1.4	.21
Visual analog scale	6.4 ± 2	6.7 ± 2	.07
Radiographic joint space narrowing, mm	3.2 ± 1.2	3.1 ± 1.5	.44
Ahlbäck grade 0/III, %	9.1/54.5/36.4	12.7/49.1/38.2	.18

<sup>a</sup>Values expressed as mean ± standard deviation unless otherwise indicated.

allograft transplantation, extrusion of the graft might minimize some of its beneficial effects.

There is no agreement with respect to the amount of meniscal subluxation that can be considered physiological. Several studies used 3 mm as a threshold value for meniscal extrusion.<sup>8,9</sup> However, instead of a fixed measure and to standardize the results, Miller et al<sup>22</sup> defined meniscal extrusion as when more than 25% of the meniscal body width is beyond the tibial margin. However, the percentage that can be considered as normal in cases of meniscal allograft transplantation is still controversial.

Little about the incidence and predisposing factors relative to meniscal extrusion has been described. Osteoarthritic knees are known to present a high incidence of meniscal extrusion.<sup>4</sup> However, it has been recently demonstrated that meniscal extrusion is much more common in nonosteoarthritic knees than had been previously thought.<sup>26</sup>

Most of the published series of transplanted menisci showed good knee function but consistently showed some degree of allograft extrusion.<sup>14,18,33</sup> It has been speculated that this meniscal extrusion could be caused by the soft tissue technique used to fix the allograft.<sup>3</sup> This is still a speculation, and it might be, in part, because of the lack of clinical studies comparing meniscal extrusion in meniscal grafts fixed only with sutures versus meniscal grafts that include bony fixation.

The aim of this study was to determine, on a midterm basis, whether the fixation method of the transplanted menisci had any influence on the degree of meniscal extrusion. The hypothesis was that the percentage of extruded meniscal graft would be higher if the allograft was only fixed with sutures.

## MATERIALS AND METHODS

Between 2001 and 2008, a prospective study was performed on 88 consecutive patients who underwent meniscal allograft transplantation (MAT). The senior surgeon (J.C.M.) performed all the surgical procedures. Informed consent was obtained from each patient following the guidelines laid down by our local Ethics Committee. The inclusion criterion was joint line pain due to a previous meniscectomy. Although no relationship has been established between malalignment and meniscal extrusion, malalignment was

considered an exclusion criterion. Normal alignment was considered up to 5° varus alignment and 7° valgus alignment. Patients who had an Ahlbäck grade<sup>2</sup> greater than grade II with posteroanterior 45° flexion weightbearing radiographs were also excluded. Finally, only patients with a body mass index below 30 were included.

The series was composed of 56 men (64%) and 32 women (36%) with a mean age of 37.26 years (range, 15-51 years). Forty transplantations (45%) were performed to replace the medial meniscus and 48 (55%) to replace the lateral meniscus. Fifty-four (61%) were performed on right knees and 34 (39%) on left knees. The first 33 of the grafts (37.5%) were fixed with a suture-only technique (group A) and the following 55 cases (62.5%) with associated bony fixation (group B). Both groups were comparable in terms of age, gender, and radiographic as well as functional preoperative state (Table 1).

## Surgical Technique

Fresh-frozen (−80°C), nonirradiated, non-antigen matched meniscal allografts were used in this series. Local authorized tissue banks supplied the allografts. Allograft sizing was done according to the method described by Pollard et al.<sup>25</sup>

The surgical technique was completely arthroscopic. 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. In those allografts corresponding to group A, No. 2 high-strength sutures (FiberWire, Arthrex, Naples, Florida) with a Krackow mattress were placed at both horns. In those patients corresponding to group B, a 6-mm-diameter and 10-mm-long bone plug was left on each horn, and a No. 2 FiberWire suture (Arthrex) was passed through a 1.5-mm tunnel drilled transversally in each bone plug. One additional vertical mattress suture was placed at the junction between the posterior horn and the body of the meniscus in every allograft of both groups. The posterior-horn suture was used to pull the meniscal allograft in place. The additional vertical suture aids in situating the graft because it is first retrieved from the posterolateral or posteromedial corner with an outside-in technique and pulled when the graft is being introduced into the joint. The allograft was then well fixed to the rim by use of either an inside-out technique with vertical mattress sutures (SharpShooter,

ConMed Linvatec, Largo, Florida) or an all-inside technique (FasT-Fix, Smith & Nephew, Andover, Massachusetts). Finally, the sutures placed in the anterior and posterior horns or through the bone plugs of each horn were tied together over the tibial cortical surface.

### Magnetic Resonance Imaging (MRI) Evaluation

To determine the degree of meniscal extrusion, all 88 patients underwent an MRI examination on the operated knee joint in the supine position with full knee extension before surgery and between 36 and 48 months of follow-up. All studies were performed with a 1.5-T superconducting magnet (Prestige 2T, Elscint, Haifa, Israel) using a knee-specific circular coil. A positioning device for the ankle was used to ensure uniformity. The standard knee protocol for each patient consists of the following sequence: axial fast spin echo T2-weighted with fat saturation (repetition time [TR], 2300 msec; echo time [TE], 30 msec; flip angle [FA], 90°; slice thickness [ST], 3 mm; field of view [FOV], 20 cm), coronal fast spin echo intermediate-weighted (TR, 2500 msec; TE, 30 msec; FA, 90°; ST, 4 mm; FOV, 18 cm), sagittal spin echo intermediate-weighted (TR, 700 msec; TE, 14 msec; FA, 90°; ST, 4 mm; FOV, 18 cm), and sagittal fast spin echo T2-weighted with fat saturation (TR, 2500 msec; TE, 85 msec; FA, 90°; ST, 4 mm; FOV, 18 cm).

The MRI scans of the cases were individually evaluated twice by 2 of the authors and then averaged. It was performed using the PACS workstation (Centricity Enterprise Web V3.0, General Electric Healthcare, Milwaukee, Wisconsin). The evaluators were blinded to the type of MAT fixation technique by only allowing them to observe the selected coronal image. Thus, these authors could not scroll through the MRI scans, as it would have allowed them to see when any bone plug was present. The intraclass correlation coefficient was calculated. Values ranged between 0 (poor) to 1 (excellent) agreement.

Based on the work performed by Puig et al,<sup>26</sup> meniscal extrusion was measured in those coronal images where extrusion was maximum with the use of an MRI-generated scale on each image. Those coronal images usually coincided at the level of the corresponding collateral ligaments.<sup>29</sup>

The measurement was performed by first drawing 2 lines. The first one was a vertical line that intersected the peripheral margin of the medial/lateral tibial plateau at the point of transition from horizontal to vertical. Next, a perpendicular line was drawn from the outer margin of the meniscus to the former line. The perpendicular line's length in millimeters was defined as the amount of meniscal extrusion.<sup>9</sup> Based on the study performed by Costa et al,<sup>9</sup> when subluxation of the meniscus was <3 mm, it was considered *minor* extrusion. Conversely, when the measured extrusion was >3 mm, it was defined as *major* extrusion. Afterward, the percentage of extruded meniscus size was calculated to standardize the results (Figure 1). This was performed by dividing each measurement of meniscal extrusion by the total measured width of the meniscus in the same MRI scan.



**Figure 1.** Magnetic resonance image showing the used method for meniscal extrusion calculation. Distance ab, meniscal extrusion in mm;  $ab/ac \times 100$ , percentage of meniscal extrusion.

The number of major and minor extrusions as well as the percentage of extruded meniscal tissue observed were compared between group A and group B. Then, the differences between the degrees of graft extrusion of the transplanted medial menisci versus the transplanted lateral menisci into each group were also calculated.

Tears of the allograft that required surgical intervention were also reported on. Functional evaluation at final follow-up with the 100-point Lysholm score was also reported and compared between groups. Although the series is consecutive, the evaluations of functional scores corresponding to a similar follow-up period were done at the same time. This was possible as all the patients completed a Lysholm score questionnaire at each of their yearly follow-up visits. In addition, the relationship between the functional status and the percentage of meniscal extrusion was also calculated.

### Statistical Analysis

Categorical variables are presented as percentages and frequencies. Continuous variables are presented as mean  $\pm$  standard deviation. Interobserver agreement was analyzed using the intraclass correlation coefficient. In those relevant cases, a 95% confidence interval was calculated. The Pearson correlation coefficient was also calculated. The relationships between categorical variables were described with contingency tables. The inference was studied with the  $\chi^2$  test or Fisher exact test depending on what corresponded. Meniscal extrusion rates and functional scores were compared between the 2 groups using the Student *t* test. Multiple linear regression analysis was used to determine whether meniscal extrusion and functional

TABLE 2  
Differences in Major and Minor Meniscal Extrusion Grades Between Groups

Extrusion Grade	Group A (n = 33)	Group B (n = 55)	Significance (P)
Minor	9 knees (27.3%)	38 knees (69.1%)	<.001
Major	24 knees (72.7%)	17 knees (30.9%)	<.001

evaluation were associated. The meniscal extrusion of medial and lateral compartments was defined as independent or explanatory variables. Results of multiple linear regression analyses were summarized using coefficients of determination and *P* values.

Statistical analysis was performed using SPSS 19 (SPSS Inc, Chicago, Illinois). Statistical significance was set at .05.

## RESULTS

No patients were lost during follow-up. Based on the aforementioned extrusion criteria, 47 knees (53.4%) had minor graft extrusion ( $2.31 \pm 0.52$  mm), and 41 (46.6%) had major graft extrusion ( $3.85 \pm 0.64$  mm). However, while group A showed grafts with major extrusion in 72.7% of the cases, only 30.9% of the patients in group B had major graft extrusion ( $P < .001$ ) (Table 2).

The percentage of extruded meniscal tissue in group A was  $36.3\% \pm 13.7\%$ . No difference ( $P = .84$ ) between the medial ( $35.9\% \pm 18.1\%$ ) and lateral ( $38.3\% \pm 14.4\%$ ) compartments was observed. Group B had a mean percentage of meniscal body with extrusion of  $28.13\% \pm 12.2\%$ . Differences between the medial ( $25.8\% \pm 16.2\%$ ) and lateral ( $30.14\% \pm 13.5\%$ ) compartments were not observed either. When comparing the degree of meniscal extrusion with the type of fixation employed, a higher percentage of extruded menisci was found in group A in both compartments ( $P < .001$ ) (Table 3).

With regard to the functional results assessed with the Lysholm score, an overall improvement was obtained. The final follow-up score in group A was  $88.6 \pm 7$  and in group B was  $91.2 \pm 7$  ( $P = .38$ ). Additionally, when the Lysholm score was compared with the degree of meniscal extrusion, no relationship was observed (Pearson correlation coefficient,  $-1.117$ ;  $P = .4$ ).

There were 7 graft tears in group A (21% of the cases). Four of them had later loss of allograft fixation requiring refixation. The allograft had to be completely removed in the remaining 3 cases, and they were obviously excluded for the meniscal extrusion analysis. Conversely, in group B, only 4 graft tears (7.3% of the cases) were observed after a minimum follow-up of 40 months ( $P = .09$ ). Two ruptures of grafts required refixation, whereas the allografts had to be completely removed in the remaining 2 cases. The intraclass correlation coefficient (.89) as well as the Pearson correlation coefficient (.91) for the interobserver agreement both qualified as excellent.<sup>15</sup>

TABLE 3  
Differences in Percentage of Meniscal Tissue Extrusion Between Groups<sup>a</sup>

Extrusion	Group A	Group B	Significance (P)
Global	$36.3 \pm 13.7$	$28.13 \pm 12.2$	<.001
Medial compartment	$35.9 \pm 18.1$	$25.8 \pm 16.2$	<.001
Lateral compartment	$38.3 \pm 14.4$	$30.14 \pm 13.5$	<.001

<sup>a</sup>Values expressed as mean  $\pm$  standard deviation.

## DISCUSSION

Transplanted menisci fixed with a suture-only technique showed a higher percentage of extruded tissue than those performed with the bony fixation technique. Although the differences were small, this confirmed our hypothesis. In addition, a considerably higher percentage of graft tears were observed in group A. It is unclear whether the latter is because of this higher tendency to extrude the menisci only fixed with sutures. However, the higher graft extrusion and graft tear rate observed in group A might have a relationship to the inferior biomechanical performance reported in the literature when the meniscal allograft does not include bony fixation.<sup>3,7,24</sup>

Although there is no agreement with respect to the amount of meniscal subluxation that can be considered physiological, most studies used a fixed measure of 3 mm as a threshold value for meniscal extrusion.<sup>8,9</sup> When a native meniscus is subluxated more than 25%, it can also be considered abnormal.<sup>22</sup> Nevertheless, assessing the percentage of allograft extrusion instead of a fixed measure might be more reliable, as it avoids the influence of the variability in knee sizes. While the percentage of meniscal extrusion in MAT that can be considered as normal also remains controversial, the present study focused on the differences in meniscal extrusion observed in the 2 fixation techniques performed instead of considering whether the extrusion observed should be considered physiological or not.

Most of the published series of transplanted menisci showed good knee function but consistently showed some degree of allograft extrusion.<sup>8,9,14,18,24,26,33</sup> Whether MAT provides some chondroprotective effect is up for debate,<sup>10,30</sup> but a recent experimental study with an animal model has shown less cartilage degeneration after MAT compared with meniscectomy.<sup>16</sup> Some studies have suggested that allograft extrusion may lead to increased degeneration of the cartilage and graft failure.<sup>28</sup> Some relationship between meniscal allograft extrusion with a meniscal tear and early osteoarthritis has also been found.<sup>1,13</sup> A higher degree of medial meniscal extrusion in the symptomatic osteoarthritic knee in comparison with the asymptomatic knee has been also reported.<sup>1,4,13</sup> It has been speculated that allograft meniscal extrusion may be caused by the soft tissue technique used to fix the graft.<sup>3</sup> This is in agreement with the results observed in the current study. However, no differences in clinical outcomes have been shown when analyzing

the published series performed with different graft fixation methods,<sup>10</sup> which is also in concordance with the functional results observed in the present investigation. This may be attributable to several factors. First, the present study has shown only small differences in meniscal extrusion between the suture-only and bony fixation techniques. Second, other MAT series were in contrast with our findings and have shown the same proportion of graft extrusion with different fixation techniques performed.<sup>14,18,33</sup> Third, no differences in the progression of cartilage degeneration between the group with graft extrusion and the one without graft extrusion have been reported.<sup>34</sup> In addition, no radiological differences between the amount of extrusion and degree of joint space narrowing have been recently documented.<sup>18</sup> Finally, and most importantly, meniscal allograft extrusion tends to be stable over the long term, and clear clinical relevance has not been proven to exist.<sup>19</sup> This was also supported in the present study when the degree of meniscal extrusion had no influence on the functional outcome of the patients.

Meniscal subluxation can often be seen in nonarthritic asymptomatic knees.<sup>4,6,27</sup> Although the reported ratio of extrusion of native menisci is variable,<sup>13,23</sup> it is clear that meniscal extrusion is more common in transplanted menisci than in normal knees.<sup>9</sup> Ha et al,<sup>14</sup> in their series of meniscal transplantation performed with a bony fixation technique, reported a mean percentage of extruded meniscal tissue of 42.1% and a major extrusion rate in 75% of their patients. This is similar to the results observed in the suture-only fixation group of the present study. On the other hand, the bony fixation group showed a considerably lower degree of graft subluxation as well as a lower percentage of patients with major extruded grafts in the current investigation. A recent study performed by Lee et al<sup>19</sup> has shown a global extrusion percentage of 33% and a mean relative graft extrusion percentage of 29.2% at 6 weeks, 29.4% at 3 months, 32.4% at 6 months, and 31.9% at 1-year follow-up in meniscal grafts performed with bony fixation. This rate is similar to the results found in the current investigation, but with a much longer follow-up. However, it seems that the percentage of tissue extrusion does not progressively rise and tends to be stable over time.<sup>19</sup> The mean 36.3% of extruded meniscal tissue observed in the group with only soft tissue fixation was statistically higher than the 28.13% seen in the group with bony fixation. Although the slight difference might suggest no clinical relevance, the major extrusion observed in group A was twice that of group B. These findings suggest that isolated soft tissue fixation more easily allows the grafts to extrude.

The studies conducted by van Arkel et al<sup>31,32</sup> showed, in their series performed with an open technique and fixed only with sutures, that the graft subluxated or even completely displaced over the peripheral border of the tibial plateau in 87.5% of their cases. This was in close agreement with the 70.6% extrusion rate observed in the Verdonk et al study<sup>34</sup> performed with a similar surgical technique, but after more than 10 years of follow-up.

Although those previous reports did not reveal correlations between meniscal extrusion and other parameters, meniscal extrusion may have adverse effects on long-term

clinical results. It has been speculated that this meniscal extrusion might be caused by degeneration and tears of the meniscus, reducing the resistance to hoop strain,<sup>9</sup> or caused by the soft tissue technique used to fix the allograft,<sup>3</sup> leading to loosening of the graft's meniscocapsular attachment.<sup>6</sup> Thus, improvement in the surgical techniques and biomechanical studies of these phenomena are necessary to reduce or prevent these effects. Lee et al<sup>18</sup> suggested various techniques to reduce meniscal extrusion, including the use of the bone plug method to achieve firm fixation. In fact, the current study is the first investigation of MAT that reports a difference in meniscal extrusion between 2 different fixation techniques. Although not statistically significant probably because of its low occurrence, it also shows a considerably higher graft tear rate in those menisci fixed only with sutures. This might suggest a cause and effect relationship between the suture-only fixation, graft tears, and extrusion. This is still a matter of speculation.

One limitation of this work is that, although prospective, the study was not randomized as the first 33 patients were assigned to group A and the following cases to group B. We started the meniscal transplantation procedures, performing the suture-only technique in more than 50 cases. Because of an initial perception of there being a high degree of mechanical failures and the experimental scientific data supporting bony fixation,<sup>3</sup> the decision was made to switch to a bony fixation technique. It is important to remark that to minimize the learning curve, the patients included in group A were the last 33 patients operated with the suture-only technique. In addition, both groups were comparable in terms of age, gender, and radiographic and functional preoperative state. Another weakness was the lack of a control group of untreated knees. However, the main limitation of the study was that extrusion was assessed in static images taken in the supine decubitus position. Boxheimer et al<sup>5</sup> showed, in an MRI study, that the meniscus moves from posterior to anterior as the knee goes into flexion and that maximum extrusion was found in the weightbearing position. Although this is a common limitation observed in the studies of this area,<sup>20,26,29</sup> it cannot be considered a reason to completely justify this weakness of the study design. The fact that the same condition was uniformly distributed among all the patients in both groups minimizes this limitation. Regardless of the aforementioned limitations, our study provides the first analysis of the relationship between the fixation method used in MAT and the percentage of extruded meniscal allograft.

## CONCLUSION

Meniscal allografts fixed with a suture-only technique had a slightly higher degree of extruded meniscal body than those fixed with the bony fixation method, with no influence on the functional outcome. There was also a considerably higher rate of graft tears observed in those menisci fixed only with sutures, although this difference was not statistically significant with the numbers available.

## ACKNOWLEDGMENT

We are grateful to Ignaci Gich for assisting in the statistical analysis. We also thank Eric Goode for his help in correcting the article.

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