Lateral Capsular Stabilization in Lateral Meniscal Allograft Transplantation

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Final revision submitted January 28, 2021; accepted March 10, 2021.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Eulji Medical Center Institutional Review Board (protocol No. EMCS 2020-03-003).

The Orthopaedic Journal of Sports Medicine, 9(11), 23259671211028652
DOI: 10.1177/23259671211028652
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Background: Stabilization of the lateral capsule to the tibial plateau may decrease midbody extrusion after lateral meniscal allograft transplantation (MAT). However, there is a paucity of literature reporting on postoperative magnetic resonance imaging (MRI) findings after lateral capsular stabilization (LCS) at the time of lateral MAT.

Purpose/Hypothesis: The purpose was to describe MRI findings after LCS and compare postoperative extrusion between isolated lateral MAT and lateral MAT with LCS. It was hypothesized that allograft extrusion would be reduced after MAT with LCS but that the stabilized capsule would increase the risk of tears to the capsule or allograft.

Study Design: Cohort study; Level of evidence, 3.

Methods: Included were patients who underwent lateral MAT with 6-month follow-up MRI. Concomitant LCS was performed for patients with redundant lateral capsule displaced from the lateral tibial plateau as evident on coronal MRI or arthroscopic examination (MAT + LCS group); otherwise, patients underwent MAT only (isolated MAT group). The Lysholm score, Tegner score, and lateral joint space on radiographs were compared between the 2 groups at 2 years postoperatively, and the stabilized lateral capsule and allograft were evaluated using 6-month follow-up MRI. Extrusion, rotation, and position of the allograft bridge were compared between the 2 groups. Regression analysis was performed to identify factors predictive of degree of extrusion.

Results: There were 10 patients in the MAT + LCS group and 13 patients in the isolated MAT group. No significant differences were found between groups in preoperative patient characteristics or postoperative Lysholm score, Tegner score, lateral joint space, or MRI parameters. Postoperative extrusion was not related to obliquity angle, position of the bony bridge, or presence of LCS. In the MAT + LCS group, 1 patient showed a tear of the lateral capsule and a radial tear of the allograft, and 3 patients had a meniscocapsular separation at the midbody of the allograft. In the isolated MAT group, 1 patient had a peripheral tear at the midbody, but there was no tear of the allograft in the other patients.

Conclusion: LCS did not decrease extrusion of lateral meniscal transplantation, but it can lead to increased risk for graft or capsule tear.

Keywords: lateral meniscal allograft transplantation; extrusion; lateral capsule stabilization

Allograft extrusion is commonly observed after meniscal transplantation.7,15 Extrusion of the meniscus is biomechanically harmful and can be associated with cartilage volume loss, decrease in cartilage thickness, and increase in denuded bone in the lateral compartment of the knee.11 A recent long-term follow-up after meniscal allograft transplantation (MAT) demonstrated a greater decrease in joint space in the extrusion group than in the nonextrusion group.8

Several strategies have been proposed to decrease the degree of meniscal allograft extrusion.9 Anatomic placement of the lateral meniscal allograft is important in decreasing extrusion.1,7 Redundant lateral capsule is suggested as a cause of postoperative extrusion. If the midbody of the allograft is sutured to redundant lateral capsule located away from the lateral tibial plateau, postoperative extrusion is anticipated. Several authors have proposed stabilizing the lateral capsule to the tibial plateau in an...
attempt to decrease midbody extrusion.\textsuperscript{2,5,9} To fix the lateral capsule at the rim of the lateral tibial plateau, Jung et al\textsuperscript{2} and Koga et al\textsuperscript{5} used suture anchors, and Masferrer-Pino et al\textsuperscript{9} used transosseous sutures. Masferrer-Pino et al\textsuperscript{9} reported that the capsulodesis technique resulted in less meniscal extrusion compared with the bone-bridge fixation technique. However, these methods may limit the normal mobility of the meniscus during knee motion, resulting in a potential tear of the allograft or the stabilized capsule.

There is a paucity of literature on postoperative magnetic resonance imaging (MRI) findings after lateral capsular stabilization (LCS) at the time of lateral MAT. Therefore, the purpose of this retrospective study was to describe the MRI findings after LCS and compare postoperative extrusion between isolated lateral MAT and lateral MAT with LCS. We hypothesized that allograft extrusion would be reduced after MAT with LCS but that the stabilized capsule would increase the risk of tears to the capsule or allograft.

**METHODS**

**Patients**

We retrospectively enrolled patients who underwent lateral MAT and completed an MRI of the knee at 6 months postoperatively between February 2005 and November 2012. MAT with or without LCS was performed in a single center by a single surgeon (N-H.C.) who has >20 years of experience in performing arthroscopic surgeries. Excluded were patients who did not have follow-up MRI scans or were lost to follow-up after lateral MAT. Indications of the lateral meniscal transplantation were as follows: (1) pain on the lateral compartment >6 months after subtotal or total meniscectomy, (2) chondromalacia on the lateral compartment classified as Outerbridge grade <3, (3) malalignment <5\textdegree, and (4) no cruciate ligamentous deficiency. LCS was performed for patients with redundant lateral capsule displaced from the lateral tibial plateau on the coronal view of MRI scans or via arthroscopic examination (MAT+LCS group) (Figure 1). Isolated MAT was performed for patients who did not have a redundant lateral capsule (isolated MAT group). The study protocol was reviewed and approved by an institutional review board, and all patients signed an informed consent form.

**Surgical Procedures**

The lateral meniscal allograft was prepared with a bony bridge. The recipient meniscus was debrided using a motorized shaver to expose the meniscocapsular junction of the posterior horn and midbody. A mini-arthrotomy was performed, and the anterior horn of the recipient meniscus was excised. A bony trough was made just lateral to the anterior cruciate ligament insertion on the tibia along the line between the anterior and posterior horns of the lateral meniscus. The bony bridge of the allograft was inserted into the bony trough. The allograft was positioned precisely on the lateral tibial plateau, and arthroscopy was used to confirm the correct position of the meniscal allograft. Open meniscal repair using No. 2.0 absorbable sutures (Ethicon) was done for the anterior horn of the allograft, and the arthrotomy was closed. The rest of the meniscal repair for the midbody and posterior horn was done via the arthroscopic inside-out technique using multiple No. 1 absorbable sutures (Ethicon).

In patients who underwent LCS, an area was determined where the lateral capsule was most displaced from the rim of the lateral tibial plateau while viewing from the anteromedial portal. The determined area was abraded gently using a motorized bur to remove cartilage from the rim of the lateral tibial plateau. A small stab wound was made at the center of the abraded area, and a small pilot hole was created in the abraded area on the lateral edge of the lateral tibial plateau. A 2.8-mm anchor (Smith & Nephew...
Endoscopy) was inserted (Figure 2A). Another 2 stab wounds were made 1 cm anterior and posterior to the previous stab wound, respectively. The Arthro-Pierce (Smith & Nephew Endoscopy) was introduced through the anterior and posterior stab wounds to retrieve each strand (Figure 2, B and C). The 2 limbs of suture of the anchor were tied outside the joint capsule (Figure 2D). Stabilization of the lateral joint capsule onto the rim of the lateral tibial plateau was confirmed via arthroscopic evaluation. After the LCS, lateral MAT was performed (Figure 2E).

Postoperatively, the identical postoperative rehabilitation protocol was utilized for the MAT+LCS and isolated MAT groups. No postoperative brace was used. In the MAT+LCS group, the cross-leg position was not allowed for 3 months. Partial weightbearing was allowed immediately after surgery. Closed kinetic chain exercises and quadriceps setting exercises were started as early as possible. Full weightbearing was permitted 6 weeks after surgery. Jogging was started after 8 weeks. Return-to-sports activity was allowed after 10 months.

Postoperative Evaluation

Functional outcomes included the Lysholm score, Tegner activity score, and lateral joint space at 2 years postoperatively. The lateral joint space was measured by an orthopaedic fellow (J-S.H.) on a Picture Archiving and Communications System (GE Healthcare). In addition, patients underwent MRI (Magnetom Verio; Siemens Healthcare, Erlangen) at the 6-month follow-up, and maximum extrusion, rotation, and position of the allograft bridge were measured on MRI scans.

On coronal MRI scans, a view showing the maximum extrusion of the midbody was chosen, and extrusion was measured as the distance between the outer edge of the articular cartilage of the tibial plateau and the outer edge of the allograft (Figure 3). Rotation of the allograft bridge was measured using the obliquity angle (Figure 4A). On axial MRI scans, a view showing the bony bridge clearly was chosen, and a line perpendicular to the tangential line along both posterior edges of the medial and lateral tibial plateau was drawn. Another longitudinal line along the center of the bony bridge was drawn, and the obliquity angle was measured between these 2 lines (Figure 4A). To calculate the position of the bony bridge of the allograft on the tibial plateau, the center between the medial and lateral edges of the bony bridge was first identified. The position of the bony bridge was calculated as the distance between the outer edge of the lateral tibial plateau and the center of the bony bridge divided by the length of the entire
tibial plateau (Figure 4B). In the MAT + LCS group, the tear of the lateral capsule or allograft where the lateral capsule was stabilized to the tibial plateau was determined on coronal MRI scans. An orthopaedic fellow (J-S.H.) who was not involved in the MAT measured all parameters.

Statistical Analysis

For each study group, we compared the change in extrusion from pre- to postoperatively. In addition, extrusion, rotation, and position of the allograft bridge were compared between the MAT + LCS and isolated MAT groups. Regression analysis was performed to identify which measured parameters among the presence of LCS, rotation, and position of the allograft bridge were predictive of the degree of extrusion. Analysis was performed using SPSS for Windows release 12.0 (IBM Corp), and significance was assumed at $P < .05$.

RESULTS

Twenty-six patients underwent lateral meniscal transplantation. Thirteen patients underwent LCS concomitantly with the MAT, and another 13 patients underwent isolated lateral MAT. Among the 13 patients who underwent LCS, 3 did not have follow-up MRI. Therefore, there were 10 patients in the MAT + LCS group and 13 in the isolated MAT group. The average age of the patients at the time of surgery was 29.9 years (range, 17-48 years). Fifteen patients were male, and 8 were female. There were no differences in preoperative patient characteristics between the 2 groups (Table 1).

The Lysholm score, Tegner score, and lateral joint space did not differ between the 2 groups (Table 2). The isolated MAT group showed that postoperative extrusion increased significantly compared with preoperative extrusion ($P = .026$). In the MAT + LCS group, postoperative extrusion decreased but was not statistically significant ($P = .186$) (Table 3). Postoperative extrusion, obliquity angle, and position of the bridge demonstrated no differences between the 2 groups (Table 4). Regression analysis demonstrated that postoperative extrusion was not related to the obliquity angle, position of the bridge, or presence of the LCS. In the MAT + LCS group, 1 patient showed a tear of the lateral capsule and a radial tear of the allograft (Figure 5A). Three patients had a meniscocapsular separation at the midbody of the allograft (Figure 5B). The other 6 patients had no tear of the lateral capsule or the allograft. In the isolated MAT group, 1 patient had a peripheral tear at the midbody, but there was no tear of the allograft in the other patients.
was correlated with the position of the bony bridge of the graft and the cutoff percentage above which extrusion did not occur was 42.1%. An externally rotated allograft can result in allograft extrusion. Lee et al\textsuperscript{7} measured the axial trough angle between a tangential line along the posterior tibial condyle and a longitudinal line along the center of the bony trough of the allograft. They reported that 23 (47%) knees had extruded grafts. An increase in axial trough angle was found to be correlated with an increase in extrusion, and the cutoff value was 5.6°. Original meniscal subluxation may also result in postoperative subluxation after MAT.\textsuperscript{6} In the MAT procedure, both anterior and posterior horns of the graft are fixed using bone plugs or a trough. However, the rest of the allograft is sutured to the capsule of the knee joint. In patients whose lateral capsule is redundant and located away from the lateral tibial plateau, the midbody of the allograft is sutured to redundant, lateral capsule, resulting in extrusion after surgery.

To tighten redundant or loose capsule, or reduce the extruded midbody of the lateral meniscus, 2 types of therapeutic options have been reported. Jung et al\textsuperscript{2} described a novel technique to place displaced lateral joint capsule onto the rim of the lateral tibial plateau using a suture anchor. After stabilization of the lateral capsule, transplantation of the lateral meniscus was then performed. They reported that the midbody of the allograft was not extruded on follow-up MRI scans. Koga et al\textsuperscript{5} described a similar technique to reduce extruded midbody of the lateral meniscus. The indication for their technique was extrusion of the midbody of the lateral meniscus confirmed preoperatively via

### TABLE 1
Preoperative Patient Data of the 2 Groups\textsuperscript{a}

|          | MAT+LCS (n = 10) | Isolated MAT (n = 13) | P  |
|----------|-----------------|----------------------|----|
| Ages, y  | 28.2 ± 8.9      | 31.0 ± 10.9          | .504 |
| Sex, male/female | 6/4          | 9/4                  | .490 |
| BMI      | 22.1 ± 1.7      | 23.9 ± 3.7           | .343 |
| Kellgren-Lawrence grade 1/grade 2 | 6/4          | 8/5                  | .940 |
| Outerbridge grade 1/grade 2 | 5/5          | 9/4                  | .417 |
| Preoperative extrusion, mm | 2.3 ± 1.1 | 1.3 ± 1.5 | .113 |

\textsuperscript{a}Data are reported as mean ± SD or n. BMI, body mass index; LCS, lateral capsule stabilization; MAT, meniscal allograft transplantation.

### TABLE 2
Follow-up Clinical Scores and Radiologic Outcomes\textsuperscript{a}

|          | MAT+LCS (n = 10) | Isolated MAT (n = 13) | P  |
|----------|-----------------|----------------------|----|
| Lysholm score | 84.3 ± 17.1 | 84.9 ± 12.6          | .912 |
| Tegner score  | 4.8 ± 0.7      | 4.1 ± 1.4            | .129 |
| Lateral joint space, mm | 4.6 ± 0.9 | 4.2 ± 1.4 | .314 |

\textsuperscript{a}Data are reported as mean ± SD. LCS, lateral capsule stabilization; MAT, meniscal allograft transplantation.

### TABLE 3
Preoperative Versus Postoperative Extrusion of the Study Groups\textsuperscript{a}

|          | MAT+LCS (n = 10) | Isolated MAT (n = 13) | P  |
|----------|-----------------|----------------------|----|
| Preoperative extrusion, mm | 2.3 ± 1.1 | 1.3 ± 1.5 |          |
| Postoperative extrusion, mm | 1.2 ± 2.1 | 2.6 ± 1.3 | .186 .026 |

\textsuperscript{a}Data are reported as mean ± SD. Bolded P value indicates a statistically significant difference from pre- to postoperatively (P < .05). LCS, lateral capsule stabilization; MAT, meniscal allograft transplantation.

### TABLE 4
Postoperative MRI Parameters Between Study Groups\textsuperscript{a}

|          | MAT+LCS (n = 10) | Isolated MAT (n = 13) | P  |
|----------|-----------------|----------------------|----|
| Postoperative extrusion, mm | 1.2 ± 2.1 | 2.6 ± 1.3 | .083 |
| Obliquity angle, deg | 85.9 ± 10.0 | 92.5 ± 10.1 | .137 |
| Position of the bridge, % | 44.2 ± 3.5 | 44.4 ± 2.6 | .904 |

\textsuperscript{a}Data are reported as mean ± SD. LCS, lateral capsule stabilization; MAT, meniscal allograft transplantation; MRI, magnetic resonance imaging.

### DISCUSSION

The most important finding of this study was that 6-month follow-up MRI scans showed a capsular tear and menisco-capsular separations in 4 (40%) patients from the MAT+LCS group. However, LCS did not decrease postoperative extrusion of the allograft significantly, and there were no differences in the Lysholm, Tegner, and lateral joint space measurements between the 2 groups. Our hypotheses were partially confirmed.

MAT has been performed to prevent the development of arthritic changes due to meniscal deficiency. However, MAT did not delay or prevent arthritic progression of the tibiofemoral joint.\textsuperscript{13} Van Der Straeten et al\textsuperscript{13} reported clinical outcomes at a mean of 6.8 years after 329 MATs; 19.2% were converted to arthroplasty at a mean of 10.3 years. Cumulative allograft survivorship was 15.1% at 24.0 years. Although several origins for low allograft survivorship were discussed, nonanatomic placement of the allograft may be the most important cause. Nonanatomically inserted meniscal transplant results in degenerative cartilage changes and inferior biomechanical properties.\textsuperscript{12,16} A clinical study demonstrated that nonanatomic horn position increases the risk of early graft failure after lateral MAT.\textsuperscript{3}

Therefore, anatomic placement of the meniscal allograft is imperative to achieve satisfactory clinical outcomes. Laterally placed meniscal allografts can affect the degree of extrusion. Choi et al\textsuperscript{1} reported that the amount of extrusion...
an MRI coronal view. The capsule at the margin between
the midbody of the lateral meniscus and the capsule was
sutured to the lateral edge of the lateral tibial plateau using
suture anchors. Follow-up MRI scans showed that the
extrusion in 9 patients who had it preoperatively was sig-
ificantly reduced from 5.0 mm (range, 3-9 mm) to 1.1 mm
(range, 0-3 mm). One patient showed postoperative extru-
sion because of torn sutures.4 Masferrer-Pino et al9 com-
pared the postoperative extrusion and the functional
outcomes after lateral MAT between a bony fixation tech-
nique and a soft tissue fixation technique with capsulod-
esis. Although they allocated the patients randomly to
either bony fixation or soft tissue fixation groups, they
found redundant or loose lateral capsule in the soft tissue
fixation with capsulodesis group. In the capsulodesis group,
they made two 2.4-mm tunnels placed 10 mm apart and
then drilled from the anteromedial tibial cortex in an obli-
que direction toward the edge of the lateral plateau where
the capsule is redundant or loose. Two transtibial sutures
that captured the lateral capsule and meniscal remnants
were tied to each other on the medial tibial cortex. They
compared the incidence of the numbers of patients between
the minor (<3 mm) and major (>3 mm) extrusion groups. A
lower percentage of extruded menisci was found in the
MAT with capsulodesis group. Patient-reported outcomes
were similar between the 2 groups.

LCS in this study did not decrease postoperative extru-
sion of the allograft significantly, contrary to results of the
study by Koga et al.4 Differences in inclusion criteria might
cause a difference. In this study, patients who underwent lateral
MAT were included. In the study of Koga et al,4 patients
with discoid or nondiscoid meniscus were included. Compari-
sion of postoperative extrusion between this study and
that of Masferrer-Pino et al9 is also difficult because post-
operative extrusion can be affected by the position of the
bony trough or keyhole of the graft, as well as addition of
the LCS.

The aforementioned procedures have a risk of limiting
the normal mobility of the meniscus during knee motion.

Vedi et al14 examined meniscal translation in healthy
volunteers while weightbearing from full extension to
90° of flexion in vivo using open MRI and found that the
anterior horn of the lateral meniscus translates posterior-
ly 9.5 mm, while the posterior horn translates
5.6 mm. Recently, McCulloch et al10 measured normal post-
operative translation of the lateral meniscus from cadaveric
knees using roentgen stereophotogrammetric analysis.
They divided the lateral meniscus into 6 regions: anterior
root, anteromedial, anterolateral, posterolateral, postero-
medial, and posterior root. Among them, the anteromedial
and anterolateral regions showed translations of 11.20 ±
4.81 and 11.13 ± 3.86 mm, respectively. However, postop-
erative MRI findings of the lateral capsule after either
stabilizing or capsulodesis were not reported in the
literature.

In this study, the MAT+LCS group demonstrated a cap-
sular tear in 1 patient and meniscocapsular separations in
3 patients. The meniscocapsular separations were located
in the area where the lateral capsule was fixed. It is pos-
sible that the large penetrator contributed to the capsular
tear or meniscocapsular separation. However, 6 patients
in the MAT+LCS group had no capsular tear or menisco-
capsular separation. Although the exact reason is not
known why 4 patients had complications and 6 did not,
differences in activities of daily living might have affected
the results. Limited excursion of the lateral meniscal allo-
graft by LCS during squatting may increase the risk of tear
of the capsule or the allograft. Beginning postoperative
rehabilitation too soon may result in complications. How-
ever, the postoperative rehabilitation protocol was identical
for both groups, and other researchers have reported sim-
ilar postoperative rehabilitation.4,9 The clinical impli-
cations of capsular tear or localized meniscocapsular
separations in MAT are not clear. Although functional out-
comes were not compared between the patients with and
those without complications, functional outcomes between
the MAT+LCS and isolated MAT groups showed no
differences.

Figure 5. (A) Postoperative coronal proton density–weighted magnetic resonance imaging (MRI) scan of the right knee demon-
strated a tear in the stabilized lateral capsule (arrow) and a full-thickness radial tear of the allograft. (B) Postoperative coronal T2-
weighted MRI scan of the left knee showed extrusion of the midbody and a meniscocapsular separation (arrows) of the allograft.
There were several limitations in this study. First, there were small numbers of patients in both groups. Indications of MAT are very narrow in our country. Moreover, the patients very rarely require LCS. Post hoc power analysis showed 0.6, which indicates the study was underpowered and a limitation of the study. Second, functional outcomes were evaluated at 2 years, and follow-up MRI was obtained at 6 months postoperatively. Follow-up MRI findings might not be correlated with functional outcomes. Third, follow-up MRI scans in this study were checked at 6 months postoperatively. We did not evaluate the meniscus at time zero. Furthermore, MRI scans at a longer follow-up period may show an increased incidence of tears of the capsule or allograft.

CONCLUSION

In this study, LCS did not decrease extrusion of lateral meniscal transplantation, but it can lead to an increased risk for graft or capsule tear.

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