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Original article

Effect of inside-out meniscal repair on meniscal dimension in meniscal tear patients

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ABSTRACT

Background: It remains controversial whether meniscal repair causes meniscal extrusion. This study aimed to investigate the effect of inside-out meniscal repair on meniscal dimensions in patients with meniscal tear of the mid-body–posterior horn.

Methods: This retrospective study included 75 patients who underwent meniscal repair followed by MRI within 2 weeks after surgery between 2020 and 2022. Patients with a discoid lateral meniscus, pull-out repair, concomitant osteotomy, all-inside repair only, and revision surgery were excluded. Thirty-three meniscal tear treated using an inside-out arthroscopic repair technique were included in the lateral meniscus (LM, $n = 19$) and medial meniscus (MM, $n = 14$) tear groups. Thirty-six participants with intact meniscus were included as controls. Meniscal extrusion and posterior shift were measured on coronal and sagittal MRI pre-operatively and within 2 weeks postoperatively.

Results: Preoperative coronal extrusion was significantly greater in the LM tear group than in the control group ($P = 0.001$). Coronal extrusion and posterior shift were significantly smaller postoperatively than preoperatively in the LM tear group ($P < 0.001$ and, $P = 0.008$, respectively). Pre- and postoperative coronal extrusion in the MM tear group were not significantly different ($P = 0.291$). Postoperative coronal extrusion in both LM and MM tear groups were not significantly correlated with the number of sutures required for repair (LM: $P = 0.765$, $R = -0.076$, MM: $P = 0.1$, $R = 0.497$).

Conclusions: The torn meniscus of the mid-body - posterior horn before surgery was extruded and shifted posteriorly in both LM and MM tears, and repair using an inside-out arthroscopic technique was effective in reducing meniscal extrusion and posteriors shift in the LM tear immediately after surgery.

1. Introduction

The meniscus plays an important role in shock absorption across the tibiofemoral joint. Meniscectomy results in a decreased contact area and increased contact stress.[1,2] A meniscus tear can cause decreased contact area and increased contact pressure, and meniscal repair restores native meniscal biomechanics.[3,4]

Since the meniscus functions by converting axial pressure forces into hoop stress,[5] meniscal tears, such as radial tears,[6,7] longitudinal tears,[8] and root tears,[9] can cause meniscal extrusion. Meniscal extrusion reduces the contact area, increases contact pressure,[10,11] and is related to cartilage damage and subchondral bone lesions.[12,13] Meniscal extrusion and posterior shift are defined as the distance between the meniscus margin and the tibial margin on coronal and sagittal image of MRI, respectively.[8,14] Pull-out repair for lateral meniscal root tear (LMPRT) improves extrusion or prevents extrusion progression,[15,16] whereas this procedure for medial meniscal root tear (MMPRT) prevents[17] or progresses extrusion.[18] Furthermore, greater the number of sutures, greater the amount of the meniscal extrusion,[8] and lower the failure rate.[19] However, it remains controversial whether the number of sutures affects meniscal extrusion. To the best of our knowledge, limited data are available regarding the effects of meniscal repair of longitudinal tear or radial tear on meniscal extrusion.[8,20,21] Furthermore, few studies have evaluated the condition of the meniscus immediately after meniscal repair even though it is preferable to evaluate the effect of surgery more directly by magnetic resonance imaging (MRI) immediately after surgery because it can minimize the other effects such as rehabilitation.[20]

This study aimed to investigate the effect of meniscal repair on

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meniscal extrusion and posterior shift in patients with meniscal tear. We hypothesized that repair using an inside-out arthroscopic technique would effectively improve meniscal extrusion and posterior shift immediately after surgery.

2. Materials and methods

2.1. Participants

This retrospective study included 99 patients with meniscal tear who underwent meniscal repair between September 2020 and December 2022. Of 99 patients, 75 underwent (MRI pre-operatively and within 2 weeks postoperatively. Meniscal repair was indicated for longitudinal, radial, horizontal, and flap tears regardless of age and chronicity; highly degenerative meniscus was not a surgical indication. Patients with a discoid lateral meniscus and those who underwent pull-out repair, concomitant osteotomy, all-inside repair alone, and revision surgery were excluded. Overall, 33 patients with meniscal tear treated using the inside-out arthroscopic repair technique were included in the LM (n = 19) and MM (n = 14) tear groups (Fig. 1). The time from the time of meniscus injury or the onset of symptoms to surgery was examined. The control group consisted of patients with an intact LM or MM, as determined using arthroscopy, who underwent anterior cruciate ligament (ACL) reconstruction only and patients who underwent LM or MM meniscal surgery only. Thirty-nine patients with normal menisci were included in the control group. Pre- and postoperative comparisons were performed, as well as comparisons between the tear and control groups, and additional comparisons were performed by tear type. Furthermore, a subgroup analysis of the LM tear group was performed for the tear type. Participants with longitudinal tears were classified into the L group, and those with radial and parrot beak tears were classified into the R group. The overall lower limb alignment pre-operatively was defined by the hip-knee-ankle angle (HKA). Informed consent was obtained from all participants included in the study. This study was approved by the hospital ethics committee and internal review board of our institution (approval number: 3071).

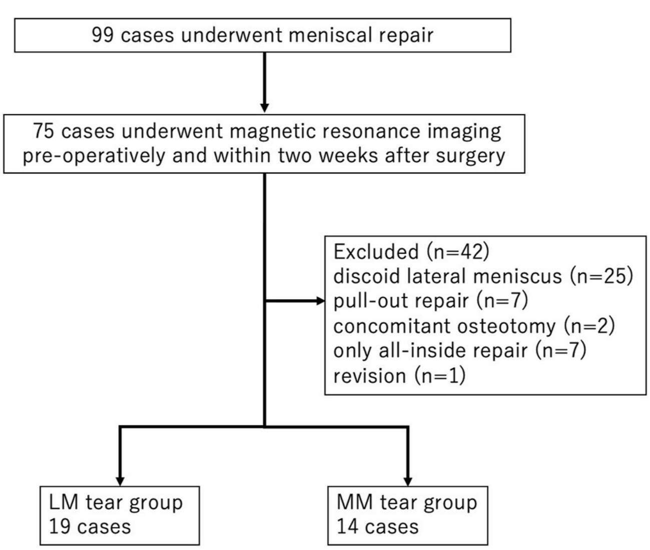

Fig. 1. Flowchart of participant enrolment
A total of 99 cases underwent meniscal repair and 75 cases underwent MRI pre-operatively and within 2 weeks after surgery. In total, 42 cases were excluded because of discoid lateral meniscus, pull-out repair, concomitant osteotomy, only all-inside repair and revision meniscal surgery. Nineteen patients in the lateral meniscus (LM) tear group and 14 in the medial meniscus (MM) tear group were included.

2.2. Surgical procedure

The surgical procedure was performed as previously reported.[22–24] All surgeries were performed by one senior surgeon who had more than 20 years of experience in orthopaedic surgery or under his supervision. Diagnostic arthroscopy was performed via an anterolateral portal with a 30° oblique arthroscope, and a probe was introduced via an anteromedial portal to determine the morphology and location of the meniscal tears. In case of an unstable longitudinal tear or a hypermobile meniscus which was diagnosed as excessive mobility of posterior segment with suction or with a probe, the meniscal repair was performed using the inside-out technique with a stacked suture (2-0 WAYOLAX, Matsuda, Tokyo, Japan). Multiple vertical stacked sutures were placed the upper and lower sides of the tear at 3-mm interval. Horizontal tears along the capsular site were repaired using the inside-out technique. In cases of radial tears, meniscal repair was performed using an inside-out technique with tie-grip sutures which consisted of two vertical mattress sutures and two horizontal sutures that passed over the vertical mattress sutures and is part of a type of inside-out repair technique. The number of sutures was determined based on the initial tear size. While the inside-out technique enables a more precise adherence to the tear, careful retraction should be performed to protect the neurovascular structures. The knee was immobilized in a brace for 1 week postoperatively and subsequently limited to a knee range of motion of 0°–90° for 3 weeks, followed by protected weightbearing for 6 weeks.

2.3. MRI protocol and measured parameters of meniscal dimensions

MRI was performed pre-operatively and within 2 weeks postoperatively. Mid-coronal and sagittal plane images were obtained using the following imaging parameters: repetition time/echo time [TR/TE], 2117/10 ms; field of view [FOV], 16 cm; matrix, 256 × 256 to 192; slice thickness, 3.3 mm; and fat saturation (TR/TE, 3460/80 ms; FOV, 16 cm; matrix, 256 × 56 to 192; slice thickness, 3.3 mm).

The following outcome variables were measured on MRI. The meniscal midbody width index (MMWI) and meniscal extrusion were measured on coronal images (Fig. 2A) [25,26]. Meniscal extrusion was defined as the distance between the margin of the tibial plateau and the meniscal outer margin (Fig. 2A).[25,26] MMWI was defined as the percentage of the width of the meniscus compared to the entire width of the tibia (Fig. 2 A). Meniscal dimensions and sagittal ratios were measured on sagittal images (Fig. 2B).[25,26] Meniscal dimensions were defined as follows: (a) distance between the anterior margin of the tibial plateau and the meniscal anterior margin; (b) distance between the meniscal anterior margin and the meniscal anterior–inner margin; (c) distance between the meniscal anterior-inner margin and the meniscal posterior–inner margin; (d) distance between the meniscal posterior–inner margin and the meniscal posterior margin; and (e) distance between the meniscal posterior margin and the posterior margin of the tibial plateau, as previously described.[25,26] ‘a’ or ‘e’ represented meniscal anterior or posterior shift; a smaller ‘a’ or ‘e’ indicated a larger anterior or posterior shift, respectively. The sagittal ratio was defined as the percentage of the total length of ‘b,’ ‘c,’ and ‘d’ compared to the entire width of the tibia (Fig. 2B).[25,26] A low density area was interpreted as a meniscus. Intraclass correlation coefficients were assessed by two orthopaedic surgeons to measure the inter- and intra-observer reliabilities for each measured parameter. Measurements were performed twice 6 weeks apart. The observers were blinded to meniscal tear type, surgical procedure, and previous results.

2.4. Statistical analysis

The Mann–Whitney U test or Student’s t-test was used to evaluate between-group differences in continuous variables, after confirming normality using the histogram, and the assumption of equal variance

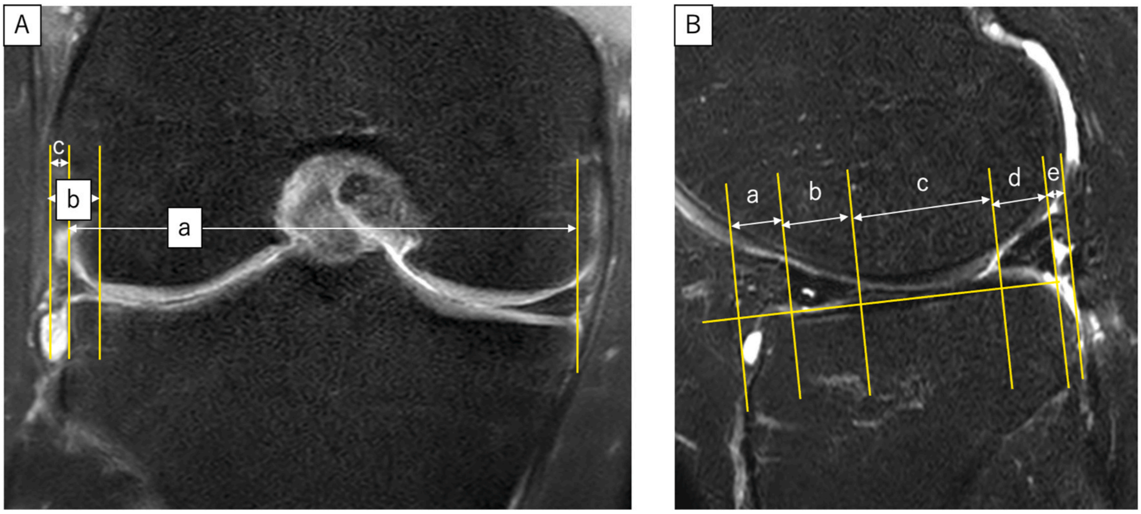

Fig. 2. Measured parameters of meniscal dimensions
(A) Mid-coronal MRI measurement was shown. To obtain the MMWI percentage, meniscal width (b) was divided by tibial width (a). The meniscal extrusion (c) was defined as the distance between the margin of the tibial plateau and the meniscal outer margin.
(B) The lateral meniscal length in the sagittal plane is shown. The length measurements are defined as follows: (a) distance between the anterior margin of the tibial plateau and the meniscal anterior margin; (b) distance between the meniscal anterior margin and the meniscal anterior–inner margin; (c) distance between the meniscal anterior-inner margin and the meniscal posterior–inner margin; (d) distance between the meniscal posterior–inner margin and the meniscal posterior margin; and (e) distance between the meniscal posterior margin and the posterior margin of the tibial plateau, according to the method established by Kim et al. [25,26]. A smaller value of 'a' or 'e' indicated a larger anterior or posterior shift, respectively.
MMWI; meniscal midbody width index.

was examined using the F test. A paired *t*-test was performed to compare continuous variables between pre- and postoperative data in the same patients. The chi-squared test was used to compare the sex distribution between the groups. The relationships between coronal meniscal extrusion and the number of sutures, and coronal meniscal extrusion and the HKA were assessed using Pearson's correlation coefficient. Statistical significance was set at a $p < 0.05$. EZR software (Saitama Medical Center, Jichi Medical University, Saitama, Japan) was used throughout the study. Power analysis was performed with the power, value, difference, and standard deviation set at 0.8, 0.05, 1.32, and 1.28, respectively, for coronal extrusion between the LM tear group preoperatively and postoperatively. The analysis revealed that the minimum number of cases required was 10.

3. Results

Age at surgery, sex, height, weight, and BMI were not significantly different between the LM tear and LM control groups, or between the MM tear and MM control groups (Table 1). The average time from injury or onset of symptoms to surgery in the LM tear and MM tear groups was 19.1 and 14.4 months respectively. The intraoperative data are summarized in Table 2. Eight cases of LM tear and 11 cases of MM tear underwent concurrent ACL reconstruction. The types of meniscal tear were as follows: LM: longitudinal, (n = 10), horizontal (n = 3), radial (n = 3), parrot beak (n = 2), hypermobile meniscus (n = 1), and MM: all longitudinal tears. The average suture number was 13.4 for LM tear and 13.5 for MM tear. There were no significant differences in demographics and intraoperative data between the L and R subgroups (Table 3). The inter- and intra-class correlation coefficients for inter- and intra-observer agreements, respectively, are shown in Table 4 for each measured parameter.

Table 2
Intraoperative data.

Variable	LM tear (n = 19)	MM tear (n = 14)
Concurrent ACL reconstruction, n	8	11
Tear type		
Longitudinal tear, n	10	14
Horizontal tear, n	3	0
Radial tear, n	3	0
Parrot beak tear, n	2	0
Hypermobile meniscus, n	1	0
Location		
Mid-body, n	6	0
Posterior-body, n	3	1
Mid-body - posterior horn, n	10	13
Suture number, n (range)	13.4 (8–20)	13.5 (5–25)

ACL; anterior cruciate ligament.

3.1. Influence of LM tear

The MMWI score in the preoperative LM tear group was significantly lower than that in the LM control group ($P < 0.001$; Table 5). Coronal extrusion in the preoperative LM tear group was significantly greater

Table 1
Comparison of baseline demographics between the Tear group and the Control group.

Variable	LM tear (n = 20)	LM control (n = 21)	P	MM tear (n = 14)	MM control (n = 18)	P
Age, years (range)	24.7 (14–53)	25.6 (13–61)	0.744	20.2 (14–45)	26.1 (14–53)	0.443
Sex, n, male/female	11/9	9/12	0.373	7/7	8/10	0.383
Height, cm (range)	170.2 (158–184)	166 (153–177)	0.074	165.5 (151–178)	167.2 (155–180)	0.525
Weight, kg (range)	68.7 (49–90)	63 (49–79)	0.066	66 (54–86)	63 (42–80)	0.424
Body mass index, kg/cm^2 (range)	23.7 (17.8–30.9)	222.8 (16.8–27)	0.343	23.8 (19.8–29.2)	22.7 (17.5–30.9)	0.175
Time from injury to surgery, months (range)	19.1 (1–120)	NA	NA	14.4 (1–120)	NA	NA

Table 3
Comparison of baseline demographics and intraoperative data between L group and R group.

Variable	L group (n = 10)	R group (n = 5)	P
Age, years (range)	22 (14–46)	17.6 (15–23)	0.42
Sex, n, male/female	8/2	2/3	0.333
Height, cm (range)	171.9 (163–180)	171.6 (159–184)	0.928
Weight, kg (range)	67.5 (52–80)	72.6 (64–78)	0.368
Body mass index, kg/cm^2 (range)	22.7 (19.8–25.7)	24.8 (21.1–30.9)	0.244
Time from injury to surgery, months (range)	13.3 (1–84)	13.8 (2–36)	0.969
Concurrent ACL reconstruction, n	6	1	0.282
Suture number, n (range)	13.5 (9–20)	16.3 (11–20)	0.29

Table 4
The intraclass correlation coefficient for the interobserver and intraobserver reliability of each parameter.

Variable	Interobserver ICC	Intraobserver ICC
MMWI	0.793	0.837
Coronal extrusion	0.779	0.851
a	0.898	0.975
e	0.771	0.784
Sagittal ratio	0.893	0.833

ICC; Intraobserver correlation coefficient, MMWI; meniscal midbody width index.

than that in the LM control group (P = 0.002; Table 5, Fig. 3A and C). ‘a’ in the preoperative LM tear group was significantly smaller than that in the LM control group (P = 0.022; Table 5). ‘c’ in the preoperative LM tear group was significantly greater than that in the LM control group (P < 0.001; Table 5). The sagittal ratio in the preoperative LM tear group was significantly greater than that in the LM control group (P < 0.001; Table 5).

3.2. Effects of LM repair

The MMWI in the postoperative LM tear group was significantly greater than that in the preoperative LM tear group and was not significantly different from that in the LM control group (P = 0.023 and P = 0.68, respectively; Table 5). Coronal extrusion in the postoperative LM tear group was significantly smaller than that in the preoperative LM tear group and was not significantly different from that in the LM control group (P < 0.001 and P = 0.738, respectively; Table 5, Fig. 3A–C). ‘e’ in the postoperative LM tear group was significantly greater than that in the preoperative LM tear group and was not significantly different from that in the LM control group (P = 0.008, P = 0.075; Table 5, Fig. 3D–F). The sagittal ratio in the postoperative LM tear group was significantly smaller than that in the preoperative LM tear group and not significantly different from that in the LM control group (P = 0.019 and P = 0.151, respectively; Table 5). Coronal extrusion after surgery in the LM tear group was not significantly correlated with the number of sutures required for repair (P = 0.765, R = −0.076).

3.3. Influence of MM tear

Coronal extrusion in the preoperative MM tear group was significantly greater than that in the MM control group (P = 0.028; Table 6, Fig. 4A and C). ‘e’ in the preoperative MM tear group was significantly smaller than that in the MM control group (P = 0.022; Table 6, Fig. 4D–F). The sagittal ratio in the preoperative MM tear group was significantly greater than that in the MM control group (P = 0.035; Table 6).

3.4. Effects of MM repair

Although coronal extrusion in the postoperative MM tear group was significantly greater than that in the MM control group (P = 0.027; Table 6, Fig. 4B and C), there was no significant difference between the preoperative and postoperative MM tear groups (P = 0.291; Table 6, Fig. 4A and B). Although ‘a’ in the postoperative MM tear group was significantly smaller than that in the MM control group (P = 0.004; Table 6), there was no significant difference between the preoperative and postoperative MM tear groups (P = 0.061; Table 6). ‘c’ in the postoperative MM tear group was significantly greater than that in the MM control group (P = 0.003; Table 6). ‘e’ in the postoperative MM tear group was significantly greater than that in the preoperative MM tear group but not significantly different from that in the MM control group (P = 0.007, P = 0.846; Table 6, Fig. 4D–F). The sagittal ratio in the postoperative MM tear group was significantly greater than in the MM control group (P = 0.019; Table 6). In the MM tear group, coronal extrusion after surgery was not significantly correlated with the number of sutures required for repair (P = 0.1, R = 0.497).

3.5. Comparison of preoperative and postoperative outcomes within and between the L and R subgroups

Meniscal extrusion in the postoperative L and R subgroups was significantly smaller than that in the preoperative L and R subgroups (P = 0.009, P = 0.005; Table 7). MMWI in the postoperative L group was significantly greater than that in the preoperative L subgroup (P = 0.04; Table 7). Meniscal extrusion in the preoperative and postoperative L subgroups was significantly smaller than that in the R tear subgroup (P = 0.035, 0.042; Table 7).

Table 5
Comparison of MRI evaluations of LM tear pre- and postoperatively and LM control and each group.[25,26]

Variable	LM tear group pre-operative (n = 19)	LM tear group postoperative (n = 19)	P	LM control group (n = 21)	P*	P**
Coronal images						
MMWI	0.12	0.15	0.023	0.15	<0.001	0.68
Extrusion, mm	2.1	0.81	<0.001	0.072	0.002	0.738
Sagittal images						
a, mm	8.1	8.9	0.25	10.4	0.022	0.027
b, mm	11.5	11.3	0.738	10.4	0.05	0.031
c, mm	14.9	12.5	0.062	11.1	<0.001	0.295
d, mm	9.4	10.1	0.089	9	0.581	0.456
e, mm	1.4	3.9	0.008	2.6	0.127	0.075
Sagittal ratio	0.79	0.73	0.019	0.7	<0.001	0.151

MMWI; meniscal midbody width index.
P* for comparison between LM control group and LM tear group preoperative.
P** for comparison between LM control group and LM tear group postoperative.

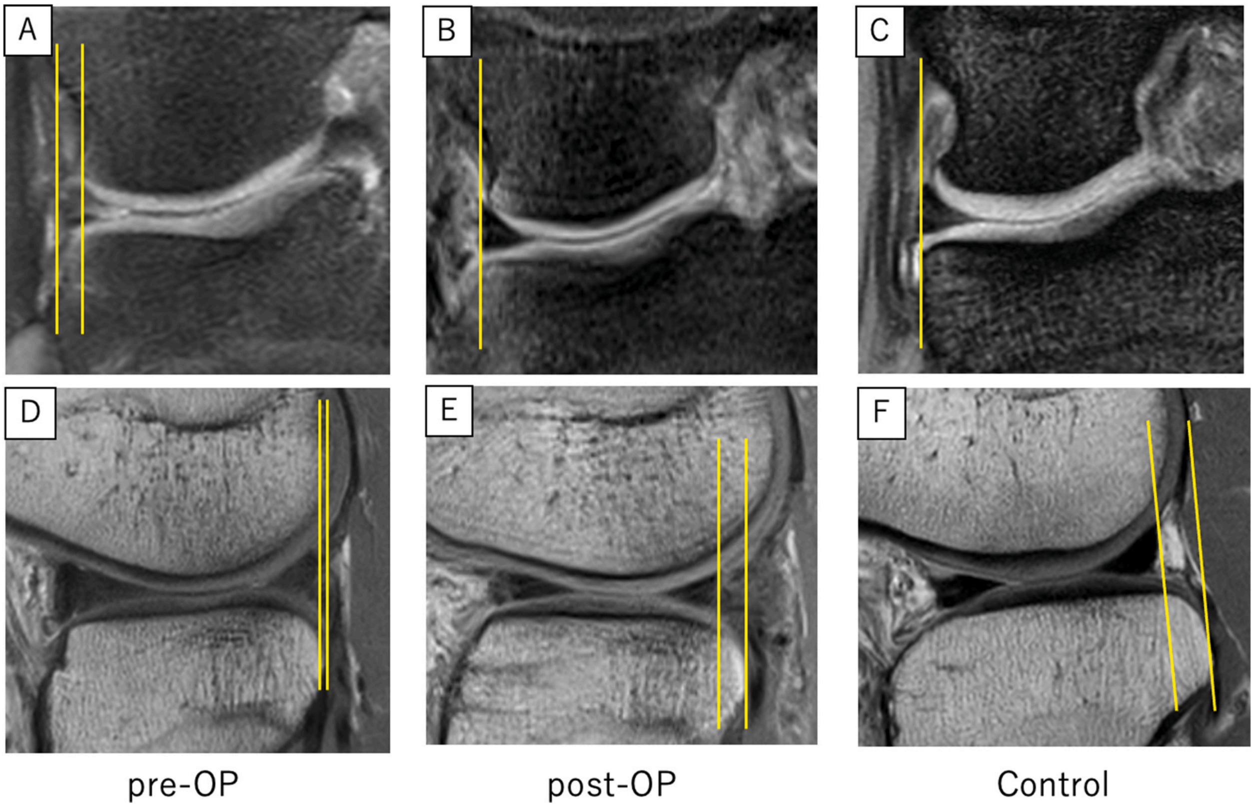

Fig. 3. Effects of lateral meniscus repair
Coronal MRI of the knee demonstrating lateral meniscal extrusion (A) and no lateral meniscus extrusion (B, C). Sagittal MRI of the knee demonstrating posterior shift of lateral meniscus (D) and no posterior shift of lateral meniscus (E, F).

Table 6
Comparison of MRI evaluations of MM tear pre- and postoperatively and MM control and each group.[25,26]

Variable	MM tear group pre-operative (n = 14)	MM tear group postoperative (n = 14)	P	MM control group (n = 18)	P*	P**
Coronal images						
MMWI	0.12	0.13	0.724	0.12	0.805	0.377
Extrusion, mm	1.3	1.6	0.291	0.57	0.028	0.027
Sagittal images						
a, mm	0.4	−0.94	0.061	1.0	0.379	0.004
b, mm	10.5	9.6	0.051	10.4	0.765	0.215
c, mm	18.1	20.0	0.202	16.2	0.169	0.003
d, mm	15.0	14.4	0.523	14.7	0.76	0.764
e, mm	0.74	2.3	0.007	2.2	0.022	0.846
Sagittal ratio	0.98	0.97	0.764	0.93	0.035	0.019

MMWI; meniscal midbody width index.
P* for comparison between MM control group and MM tear group preoperative.
P** for comparison between MM control group and MM tear group postoperative.

3.6. Correlation between meniscal extrusion and HKA

The average HKA in the LM tear group and in the MM tear group was 180.2° (174°–185°) and 179.9° (174°–185°) respectively. There was no significant difference between the LM tear group and the MM tear groups ($P = 0.741$). LM extrusion preoperatively and postoperatively was not significantly correlated with the HKA ($P = 0.994$, $R = -0.002$, $P = 0.099$, $R = -0.401$). Similarly, MM extrusion preoperatively and postoperatively was also not significantly correlated with the HKA ($P = 0.061$, $R = -0.512$, $P = 0.055$, $R = -0.523$).

4. Discussion

The most important findings of this study are that torn meniscus indicated for inside-out repair was extruded and shifted posteriorly and repair using an inside-out arthroscopic technique was effective in reducing coronal LM extrusion and both LM and MM posterior shifts. These results are consistent with our hypotheses. In this study, MRI was performed immediately after surgery to investigate the effect of surgery itself, and showed that repair did not cause meniscal extrusion progression immediately after surgery, which is an important finding for surgeons. Furthermore, the distance of meniscal extrusion did not increase as the number of sutures increased; therefore, it is recommended to concentrate on properly repairing the tear without limiting the number of sutures.

LM extrusion has been reported to associate with radial LM tears,[6,21] whereas no difference has been reported between longitudinal or radial LM tears and an intact LM.[20] While these reports described concomitant ACL injuries, the present study included both concomitant ACL injuries and meniscal injuries. In this study, radial LM tears had greater meniscal

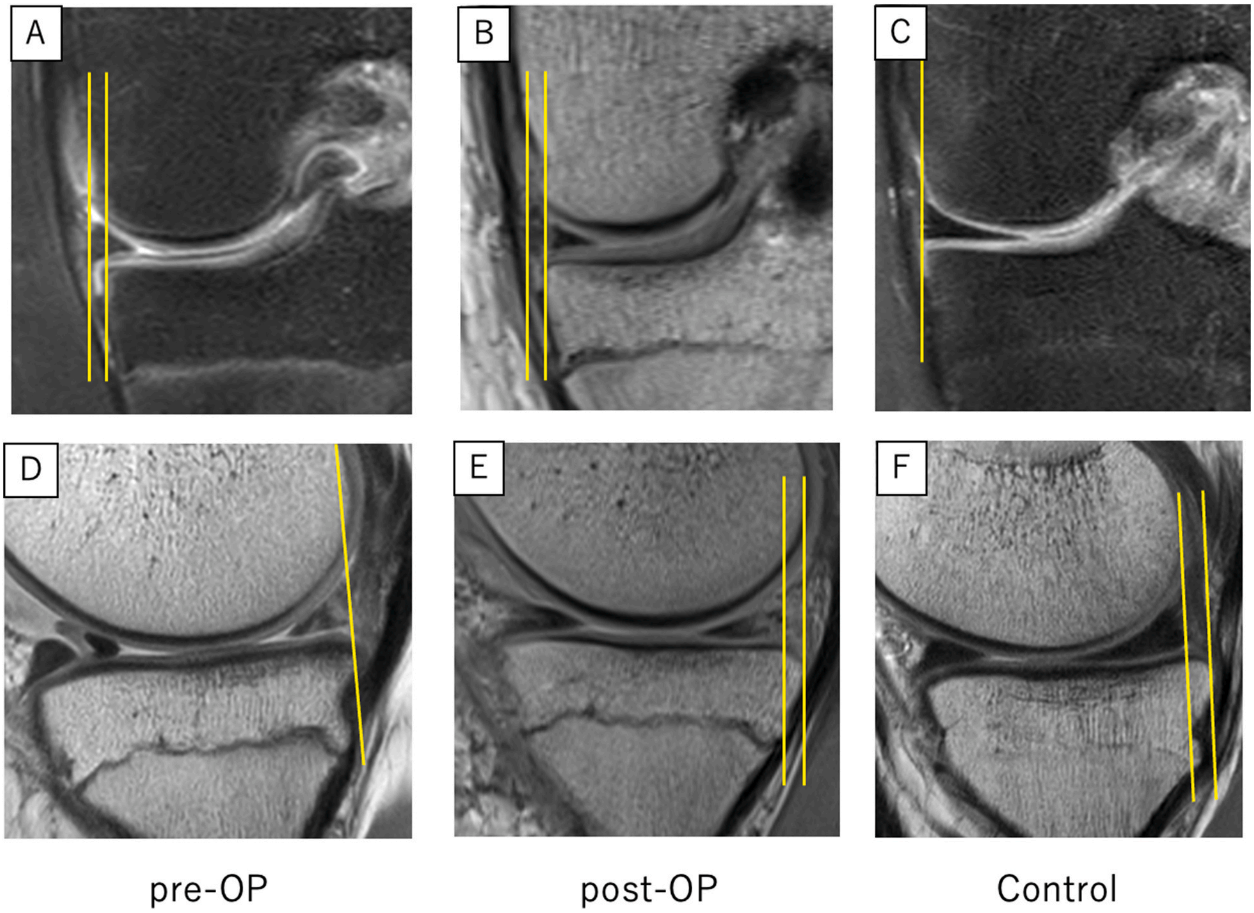

Fig. 4. Effects of medial meniscus repair
Coronal MRI of the knee demonstrating medial meniscal extrusion (A, B) and no medial meniscus extrusion (C). Sagittal MRI of the knee demonstrating a posterior shift of medial meniscus (D) and no posterior shift of medial meniscus (E, F).

Table 7
Comparison of preoperative and postoperative outcomes within and between the L and R groups.[25,26]

Variable	L group preoperative (n = 10)	L group postoperative (n = 10)	P	R group preoperative (n = 5)	R group postoperative (n = 5)	P	P*	P**
Coronal images								
MMWI	0.111	0.146	0.04	0.145	0.178	0.262	0.169	0.303
Extrusion, mm	1.97	0.44	0.009	3.46	1.7	0.005	0.035	0.042
Sagittal images								
a, mm	7.87	9.61	0.188	8.14	8.72	0.61	0.884	0.361
b, mm	12.6	11.3	0.255	10.9	12.1	0.322	0.188	0.403
c, mm	14.6	12.6	0.297	16.6	10.7	0.09	0.319	0.547
d, mm	9.79	10.5	0.362	10.4	11.4	0.185	0.724	0.522
e, mm	1.74	3.73	0.052	−0.98	4.6	0.07	0.161	0.579
Sagittal ratio	0.79	0.72	0.078	0.844	0.72	0.113	0.337	0.999

MMWI; meniscal midbody width index.
P* for comparison between L group preoperative and R group preoperative.
P** for comparison between L group postoperative and R group postoperative.

extrusion than longitudinal LM tears. Furthermore, the amount of meniscal extrusion in the LM tear group in this study was larger than those in previous reports.[20,27,28] MM extrusion also has been reported to be associated with longitudinal MM tears.[8] MM tear and meniscotibial ligament injury are related and could be predisposed to meniscal extrusion.[29]

A recent study showed that both LM coronal extrusion and posterior shift did not improve immediately after meniscal repair.[20] The pre-operative period may have influenced the differences in the results between this study and previous reports. Preoperative coronal LM extrusion was greater in this study than in a previous report, possibly because of the longer time from injury to surgery. Another study showed that LM oblique radial tears increased meniscal extrusion and meniscus repair reduced meniscal extrusion.[30] In this study, meniscal extrusion in both longitudinal and radial LM tears was reduced by meniscal repair. Furthermore, the MMWI in longitudinal LM tears increased following meniscal repair, indicating reduction of the displaced meniscus.

In this study, the LM sagittal ratio was increased by meniscal tear and decreased following meniscal repair. A previous study has shown that LM radial tear spreads in the sagittal direction.[31] In constant, the MM sagittal ratio was increased by a meniscal tear but was not significantly changed by a meniscal repair. In LM tears, a meniscal repair is effective in pulling the extruded meniscus toward the center in both the coronal and sagittal dimensions and may restore hoop function, while its effect on the MM is more limited than that on the LM. Differences in the amount of meniscal extrusion between LM and MM have been previously reported.[32] The difference in the results between the LM and MM in this study may be related to the greater mobility of the LM[33,34] and because the joint capsule attachment around the LM is more fragile and can be easily damaged.[35] There was no significant difference in alignment between the LM tear group and the MM tear group, and there was no correlation between pre- and postoperative meniscal extrusion and alignment, suggesting that the difference in extrusion improvement between LM and MM after meniscal repair was not due to alignment. Another possible reason why the MM extrusion did not improve is that the amount of extrusion preoperatively was not very large; hence, the effect of meniscal repair was difficult to appear.

The present study showed improvement in MM posterior shift, however did not show improvement in MM coronal extrusion, as reported previously.[8] While reportedly meniscal repair alone for MM tear did not change the MM posterior shift,[36] meniscal repair concurrent ACL reconstruction for MM tear with ACL injury improved the posterior shift.[14] A previous study also reported that ACL reconstruction improves the MM posterior shift,[37] and the effect of ACL reconstruction may be significant in MM as a large number of concomitant ACL reconstruction cases were included in this study.

Although previous studies have reported a correlation between the number of sutures and extrusion,[8] we found no such correlation in this study. The different results may have been caused by the facts that the timing of the evaluation was different in this study (immediately after surgery), and in previous studies (3 months after surgery), the number of sutures in this study was considerably higher than in previous reports, and that the study was limited to inside-out repair. Greater the number of sutures, the lower the failure rate[19]; therefore, it is recommended to focus on properly repairing the tear without limiting the number of sutures.

The result that meniscal repair could improve the meniscal extrusion, regardless of whether the type of injury was a longitudinal tear or a radial tear, would be useful information for surgeons. The R group showed a greater amount of pre- and postoperative meniscal extrusion than did the L group, and this result was consistent with that of previous reports.[20] The finding that the amount of meniscal extrusion was greater in the R group than in the L group could be due to the collapse of circumferential collagen fibers.[2]

This study did not evaluate clinical outcomes or imaging with a long-term follow-up; however, previous studies have shown that meniscal extrusion causes progression of osteoarthritis[38,39] and early-stage osteoarthritis is associated with meniscal extrusion.[40] Therefore, improving meniscal extrusion may prevent osteoarthritis progression.

5. Limitations

This study has several limitations. First, the potential for selection bias is due to the retrospective design of the study. Second, the study included a relatively small number of patients. Third, there may be some variations in the MRI findings depending on how the slices were cut. Fourth, the study includes different factors such as meniscal repair with and without ACL reconstruction and different types of meniscal tears, which were examined collectively. Fifth, the MRI evaluation was non-weight-bearing and did not assess the condition of the meniscus under loading. Sixth, the evaluation was performed at the non-weight-bearing stage, and changes after loading were unclear. Finally, as the study is based on short-term results, the long-term condition of the meniscus and clinical outcomes have not been examined. Therefore, future research is needed to investigate medium-to long-term results.

Conclusion

The torn meniscus of the mid-body - posterior horn before surgery was extruded and shifted posteriorly in both LM and MM tears, and repair using an inside-out arthroscopic technique was effective in reducing meniscal extrusion and posteriors shift in the LM tear immediately after surgery.

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Ethics approval

This study approved by the hospital ethics committee and the internal review board of our institution (3071).

Informed consent

Informed consent was obtained from all participants include in the study.

Patients signed informed consent regarding publishing their data and photographs.

Declaration of competing interest

The authors have no relevant financial or non-financial interests to disclose.

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