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Bone marrow lesion and medial meniscus extrusion width changes following arthroscopic partial meniscectomy for medial meniscal flap tears

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Abstract

Background The current literature evaluating meniscectomy outcomes often mixes various tear patterns, failing to elucidate the impact of specific tear types on procedure results. Flap tears, which are prone to causing mechanical symptoms, require targeted research. This study aims to examine Lysholm scores following a meniscectomy for medial meniscus flap tears, to determine if extensive resections lead to poorer one-year outcomes, and to assess their impact on postoperative bone marrow lesion (BML) risk and medial meniscus extrusion (MME) width.

Methods Patients undergoing arthroscopic meniscectomy for medial meniscal flap tears were classified into three groups: minimum resection, single leaf resection, and subtotal resection. Lysholm scores and medial joint space (MJS) width on Rosenberg view radiographs were measured preoperatively and one year postoperatively. BMLs and MMEs were assessed via MRI preoperatively and at 1, 3, 6, and 12 months postoperatively.

Results Fifty patients (mean age 60 ± 13 years) underwent meniscectomy: minimum resection in 21 (42%), single leaf in 23 (46%), and subtotal in 6 (12%). *The* Lysholm scores improved significantly, from 65.5 ± 17.6 to 93.4 ± 16.5 ($n = 50$) at 12 months in patients overall ($p < 0.001$), while MJS width decreased from 3.9 ± 0.7 mm to 3.5 ± 0.8 mm ($p < 0.001$). There *were* no significant *differences* in Lysholm scores *or* MJS widths among *the* three resection patterns. *The occurrence rate* of BMLs in the medial femoral condyle and tibial plateau increased post-surgery, peaking at 1 month, *but* then improved to near-baseline by 12 months. *The occurrence rate* of BMLs *was* higher in *the* single leaf and subtotal meniscectomy groups post-surgery, but declined across all groups by 12 months. Among the three groups with different resection patterns, MME width at 12 months was 2.*7* ± 1.*8* mm in the subtotal resection group, which was significantly larger than in the other groups.

Conclusions Arthroscopic partial meniscectomy for flap tears yielded favorable 12-month outcomes. Larger resections were associated with greater BML incidence and greater MME width.

Keywords Flap tear, Medial meniscus, Bone marrow lesion, Medial meniscus extrusion, Arthroscopic meniscectomy

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Introduction

Arthroscopic meniscectomy is an established intervention for pain relief in patients with mechanical symptoms due to meniscal tears. The long-term success of this procedure depends on preserving the remaining meniscus function [1, 2]. However, the current literature primarily evaluates the outcomes of meniscecto*mies* by mixing various tear patterns, thereby failing to fully elucidate the impact of specific meniscal tear types on the results of the procedure [2, 3]. Flap tears, which are prone to causing mechanical symptoms, represent a critical area requiring targeted research in the context of arthroscopic meniscectomy outcomes [4].

Bone marrow lesions (BMLs) are a concern in post-meniscectomy outcomes, with their relationship to clinical outcomes, particularly for flap tears, remaining poorly understood [5, 6]. Previous research has been limited by infrequent MRI assessments, overlooking crucial insights into BML progression and its impact on recovery. A more comprehensive monitoring approach could provide an understanding of the relationship between meniscectomy and BMLs.

The complexity of meniscal injuries and their varying morphologies significantly influence post-meniscectomy outcomes. Previous studies have shown that horizontal tears often demonstrate favorable outcomes with conservative treatment, as they typically occur in older patients with degenerative changes and may remain asymptomatic [7]. By contrast, radial tears extending to the outer margin result in poorer outcomes, due to their disruption of circumferential fibers and subsequent loss of hoop stress function [8]. Complex tears generally show variable results depending on their location and extent [9].

Flap tears present a unique clinical challenge, as they frequently cause mechanical symptoms such as locking and catching, necessitating surgical intervention [10]. Another important consideration in meniscal tears is meniscal extrusion, particularly medial meniscal extrusion (MME), which has been associated with worse clinical outcomes and accelerated joint degeneration [11]. Despite these known complications, questions remain regarding the optimal extent of meniscal resection and its impact on recovery, including its relationship with postoperative BMLs and MME progression. This study aims to examine whether more extensive resections for medial meniscus flap tears lead to poorer one-year Lysholm scores, and assess whether they increase the risk of postoperative BMLs or MME width.

Materials and methods

This retrospective longitudinal study was conducted at our hospital. This research has been approved by the authors' affiliated institutions. Informed written consent was obtained from all patients prior to their surgery.

Inclusion and exclusion criteria

The study's inclusion criteria were: subjects who underwent an arthroscopic meniscectomy for a medial meniscal flap tear, age 30 to 85 years, unilateral mechanical knee pain for more than three months, and an ability to assess Lysholm scores preoperatively and 12 months postoperatively. The exclusion criteria were: concomitant lateral meniscal injury, valgus deformity with a femorotibial angle (FTA) less than 174 degrees or varus deformity with FTA more than 185 degrees, Kellgren-Lawrence (KL) grade 3 or higher osteoarthritis, concomitant ligament or osteotomy surgery, concurrent meniscal suture, incomplete MRI examination during the five periods from preoperative to 12 months postoperatively, follow-up period less than 12 months, or being lost to follow-up (Fig. 1).

Surgical technique

A single surgeon (H.S.) performed all surgeries. Patients were placed in the supine position under general anesthesia. *No* tourniquet was used. Surgery was performed through two portals, an anterolateral and an anteromedial portal, using a 4 mm 30-degree arthroscope. After identifying the tear pattern of the medial meniscus, unstable flap lesions were resected to preserve as much of the meniscus as possible. In cases with concomitant horizontal tears, resection was limited to the margin, if the resected area was stable. Postoperatively, no weight-bearing restrictions were *imposed*, but patients were instructed to avoid walking for one month. All patients were instructed to perform quadriceps exercises at home upon discharge.

Arthroscopic findings

The ICRS grade of the medial femoral condyle and medial tibial plateau was classified from grade 0 to grade 4, based on Hoemann et al. [12]. The extent of meniscectomy was classified into three groups, partially modifying the classification *devised by* Kim et al. [13]: minimum meniscectomy (*r*emaining meniscus width ≥ 5 mm, meniscus thickness at the margin is preserved), single leaf meniscectomy (*r*emaining meniscus width ≥ 5 mm, meniscus thickness at the margin is reduced due to resection of the horizontal tear), and subtotal meniscectomy (*r*emaining meniscus width ≤ 3 mm) (Fig. 2). The presence or absence of a horizontal tear was also recorded (Fig. 2).

Primary outcomes

The Lysholm score was used to assess clinical outcomes [14]. The Lysholm score is a patient-reported rating scale with eight items, including pain and swelling, and is scored from 0 to 100 points. Higher scores indicate less severe symptoms and higher functional levels. Each

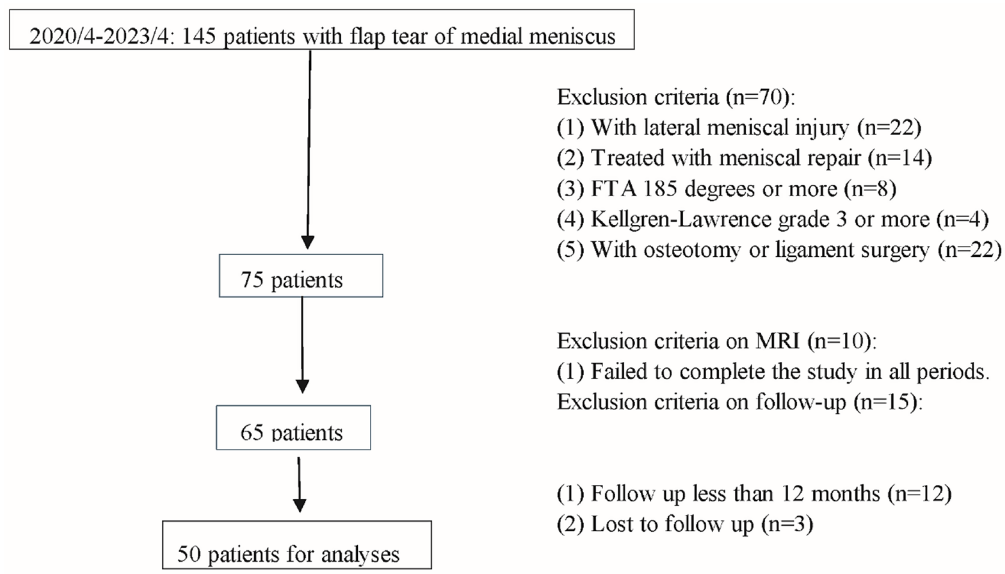

Fig. 1 Enrollment of patients. Fifty subjects who met the criteria were included in the study

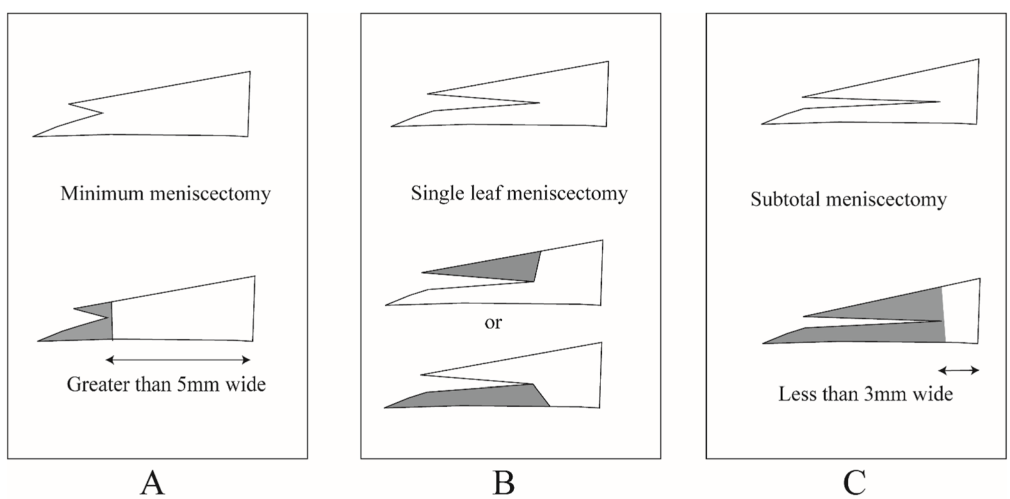

Fig. 2 Classification of the size of meniscus resection, based on Kim et al. (AJSM 2015)

patient's Lysholm score was assessed preoperatively and at 12 months postoperatively.

Secondary outcomes

The presence or absence of BML on the medial femoral condyle and medial tibial condyle, and MME width, were evaluated via MRI. MRI scans were performed preoperatively and at 1, 3, 6, and 12 months postoperatively. MRI scans from all patients were examined by two reviewers (H.S, K.T.) collaboratively. If the reviewers' evaluations differed, a single conclusion was reached through discussion. Subchondral BML was defined as a locus of increased signal on sagittal, coronal cartilage-sensitive proton density-weighted high-resolution fast spin echo sequences. The extent of BML was classified according to Bisson et al. [5] as none (no tibiofemoral BML), submeniscal (focally contained above or below the meniscus, extending to a maximum of 1 cm subchondrally), or extensive (extending beyond the meniscus and/or greater than 1 cm subchondrally) (Fig. 3). MME width was measured according to the method outlined by Su et al. [15] as the amount of displacement (mm) of the medial edge of the tibia, relative to the level of the MCL from the medial meniscus.

Radiographic variables were evaluated using standardized protocols. The medial joint space (MJS) width was measured on Rosenberg views with the knee flexed at 45 degrees under weight-bearing conditions. Following Jeon et al.'s method, MJS was defined as the distance between the center of the medial femoral condyle and the center

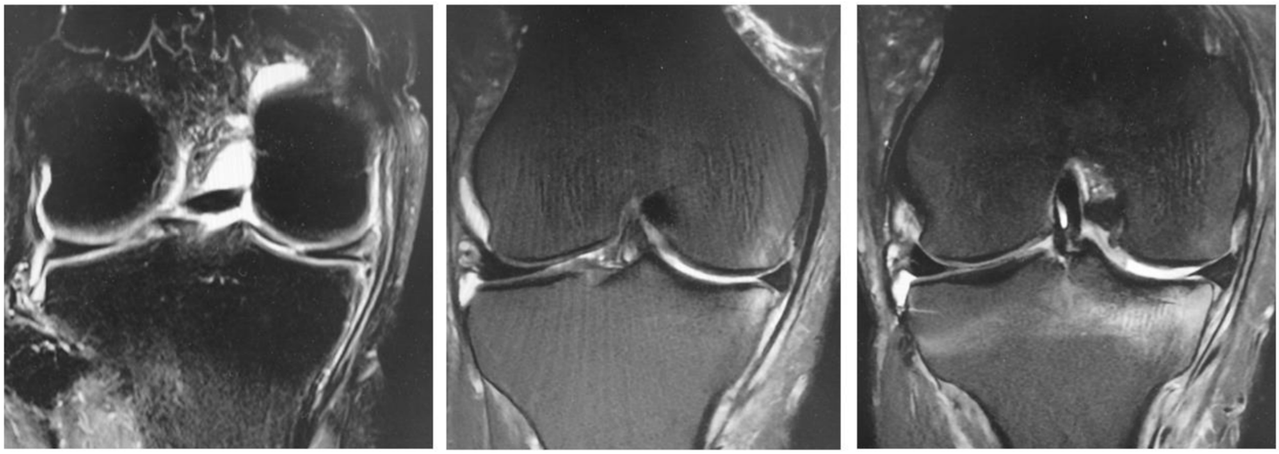

Fig. 3 A representative BML example for each classification. The coronal image on the left demonstrates the absence of bone marrow lesions in the medial femoral condyle and tibial plateau, and is therefore classified as "none." The coronal image in the center reveals a subchondral bone marrow lesion localized beneath the meniscus at the tibial plateau, warranting classification as "submeniscal." Finally, the coronal image on the right illustrates a subchondral bone marrow lesion extending beyond the meniscus at the medial tibial plateau, which is classified as "extensive."

of the medial tibial plateau. The intraclass correlation coefficient for intra-observer reliability was 0.948, based on measurements from 10 randomly selected patients.

KL grades were assessed on weight-bearing anteroposterior radiographs with full knee extension. The grading system was defined as follows: grade 0 (no OA features), grade 1 (equivocal osteophytes), grade 2 (definite osteophytes), grade 3 (joint space narrowing), and grade 4 (bone-to-bone appearance with definite deformity) [16].

The FTA was measured using standing full-length radiographs including the pelvis and entire lower limb, with the patella facing forward. The anatomical femoral axis was defined by connecting the midpoints of the endosteal cortices from the proximal femoral shaft to the center of the distal femoral shaft, 10 cm proximal to the joint line. Similarly, the anatomical tibial axis was determined by connecting the midpoints of the endosteal cortices from 10 cm distal to the tibial plateau to the distal tibial shaft [17]. FTA was measured as the lateral angle between these anatomical axes.

Statistical analysis

Preoperative and postoperative outcomes were compared using *the* Wilcoxon rank-sum test for Lysholm scores and paired t-test for MJS width. For comparisons among *the* different types of meniscectomy, Lysholm scores were analyzed using *the* Kruskal–Wallis test, BMLs were analyzed using Fisher's exact test, *and* MJS width and MME were compared using one-way analysis of variance (ANOVA) followed by a post-hoc Bonferroni's test. A Pearson correlation analysis was conducted on bone marrow lesions with patient demographics (age, sex, BMI), radiographic parameters (MJS, FTA, KL grade), cartilage status (ICRS grade), meniscal characteristics (presence of horizontal tears, types of meniscectomy), and MME. Statistical analyses were performed using SPSS version 25 and SAS version 9.4. The significance level was set at 5%.

Results

Patient selection and demographic characteristics

We performed 145 surgeries for meniscus flap tears over a 3-year period, beginning in April 2020. Fifty patients who had undergone resection for medial meniscus flap tears met the inclusion criteria and were enrolled in the study. The average age was 60 years, and 66% of patients were male (Table 1). Their mean body mass index (BMI*)* was 23.6 kg/m^2. Concomitant horizontal tears were observed in 43 patients (86%). The most common types of meniscectomy were single leaf resection (46%) and minimum resection (42%). All patients were KL grade 2 or less, with 52% being grade 2. Both medial femoral condylar and medial tibial condyle cartilage were ICRS grade 0–2. The mean medial meniscus extrusion width was 1.*8* mm.

Lysholm scores and medial joint space width*s* after meniscectomy

Overall, among all 50 knees, the Lysholm score showed a significant improvement 12 months after meniscectomy (Table 2). Conversely, the MJS width on Rosenberg views showed a significant decrease over the same period. The mean reduction in joint space width was -0.4 ± 0.5 mm (Table 2).

Bone marrow lesions after meniscectomy

The medial femoral condyle showed no BMLs in most cases, with a slight increase in submeniscal and extensive lesions at one month, followed by a return to near-baseline levels (Table 3). The medial tibial plateau showed

Table 1 Patient demographics

	Mean ± SD or number (%)
Number of patients	50
Age at surgery	60 ± 13 y
Gender	
Male	33 (66%)
Female	17 (34%)
BMI	23.6 ± 2.7 kg/m^2
Femoro-tibial angle	177.0 ± 2.4 degrees
With or without horizontal tear	
With	43 (86%)
Without	7 (14%)
Types of meniscectomies	
Minimum	21 (42%)
Single leaf	23 (46%)
Subtotal	6 (12%)
Kellgren-Lawrence grade	
Grade 0	2 (4%)
Grade 1	22 (44%)
Grade 2	26 (52%)
ICRS grade of medial femoral condyle	
Grade 0	20 (40%)
Grade 1	18 (36%)
Grade 2	12 (24%)
ICRS grade of medial tibial condyle	
Grade 0	24 (48%)
Grade 1	22 (44%)
Grade 2	4 (8%)
Medial meniscus extrusion width	1.8 ± 0.9 mm

Table 2 Lysholm score and medial joint space

	Before	12 months	Δ	*p* value
Lysholm score	65.5 ± 17.6	93.4 ± 16.5	27.9 ± 16.5	$p < 0.001^a$
Medial joint space width (mm) in a Rosenberg view	3.9 ± 0.7	3.5 ± 0.8	-0.4 ± 0.5	$p < 0.001^b$

^{a}:Wilcoxon rank-sum test, ^{b}:paired t-test

Table 3 Number and percentage of bone marrow lesions

	Before	1 M	3 M	6 M	12 M
Medial femoral condyle					
None	45 (90%)	37 (74%)	45 (90%)	46 (92%)	46 (92%)
Submeniscal	5 (10%)	7 (14%)	2 (4%)	1 (2%)	2 (4%)
Extensive	0 (0%)	6 (12%)	3 (6%)	3 (6%)	2 (4%)
Medial tibial plateau					
None	37 (74%)	28 (56%)	41 (82%)	46 (90%)	47 (94%)
Submeniscal	12 (24%)	14 (28%)	6 (12%)	3 (6%)	3 (6%)
Extensive	1 (2%)	8 (16%)	3 (6%)	1 (2%)	0 (0%)

more variability. None of BMLs decreased initially at one month (56%), but steadily improved, reaching 94% at 12 months. Submeniscal lesions peaked at one month (28%), before declining. Extensive lesions also peaked at one month (16%), but there were none by 12 months. Bone marrow lesions showed no significant correlations with patient demographics, radiographic parameters, cartilage status, meniscal characteristics, or MME. No osteonecrosis-like lesions were observed during the series of MRI evaluations.

Comparisons of outcomes among different types of meniscectomy

The Lysholm score at 12 months was lower in the subtotal meniscectomy group, compared to the minimum meniscectomy group and the single leaf meniscectomy group; however, these differences were not statistically significant (Table 4). MJS width varied initially, but showed no significant differences at 12 months. BMLs at the medial femoral condyle and medial tibial plateau were higher in the single leaf and subtotal meniscectomy groups, particularly at 1–3 months post-surgery. At one month, BML occurrence at the medial femoral condyle was highest in the subtotal group and at the medial tibial condyle in the single leaf group, with significant differences observed. By 12 months, BML rates had declined across all groups. The MME increased progressively in the subtotal meniscectomy group, showing significant differences at 6 and 12 months, compared to the minimum meniscectomy group.

Discussion

This study found that patients' postoperative Lysholm scores at one year (93.4) were significantly higher than their preoperative scores (65.5). Nabiyev et al. reported a postoperative Lysholm score of 81.7 at three years for various tear types [18]. Jeon et al. reported 3-year outcomes of single-leaf partial resection and single-leaf edge resection for medial meniscus horizontal tears, with Lysholm scores of 92.7 and 87.8, respectively [19]. Kamimura et al. divided 130 patients aged 50 years or older who underwent arthroscopic partial meniscectomy of the medial meniscus into six types: mid-body transverse tear, posterior root injury, posterior body horizontal tear, flap tear, micro-tear, and complex tear [4]. They evaluated the effectiveness of the surgery as "effective" or "not effective" at two years postoperatively and reported that flap tears showed the most effective outcomes. However, they did not provide specific clinical scores. Our results also suggest that arthroscopic resection for flap tears is an effective procedure.

Minimum meniscecto*mies* showed the highest Lysholm score improvement (95.2), while subtotal meniscecto*mies* showed the least (85.0) at 12 months, although the differences were not significant. Kim et al. [20] retrospectively studied 65 patients with medial meniscus horizontal tears who required arthroscopic surgery for pain and found that 45 patients (69%) had associated unstable flap tears. In our study, 86% of flap tears were associated

Table 4 Comparison of patient characteristics, clinical outcomes, and MRI findings after different types of meniscectomy

		Minimum meniscectomy	Single leaf meniscectomy	Subtotal meniscectomy	*p* value by ANOVA	*p* value by post-hoc
Age at surgery (y)		59 ± 12	58 ± 15	68 ± 9	$p = 0.264$	A&B, $p = 1.000$ A&C, $p = 0.458$ B&C, $p = 0.328$
BMI (kg/m^2)		23.4 ± 3.2	24.2 ± 1.9	21.8 ± 2.8	$p = 0.122$	A&B, $p = 0.802$ A&C, $p = 0.617$ B&C, $p = 0.143$
Lysholm score	Before	64.2 ± 18.0	70.2 ± 16.9	52.0 ± 11.9	$p = 0.044$[a]	A&B, $p = 0.161$[b] A&C, $p = 0.102$[b] B&C, $p = 0.022$[b]
	12 M	95.2 ± 5.6	94.0 ± 6.8	85.0 ± 11.8	$p = 0.081$[a]	A&B, $p = 0.811$[b] A&C, $p = 0.025$[b] B&C, $p = 0.052$[b]
MJS width (mm)	Before	4.1 ± 0.5	3.6 ± 0.7	3.9 ± 1.0	$p = 0.040$	A&B, $p = 0.034$ A&C, $p = 1.000$ B&C, $p = 1.000$
	12 M	3.7 ± 0.7	3.2 ± 0.7	3.5 ± 0.9	$p = 0.067$	A&B, $p = 0.063$ A&C, $p = 1.000$ B&C, $p = 1.000$
BML at medial femoral condyle (%)	Before	0 (0%)	4 (17%)	1 (17%)	$p = 0.099$[c]	A&B, $p = 0.109$[c] A&C, $p = 0.222$[c] B&C, $p = 1.000$[c]
	1 M	4 (19%)	6 (26%)	3 (50%)	$p = 0.362$[c]	A&B, $p = 0.724$[c] A&C, $p = 0.290$[c] B&C, $p = 0.339$[c]
	3 M	0 (0%)	3 (13%)	2 (33%)	$p = 0.041$[c]	A&B, $p = 0.234$[c] A&C, $p = 0.043$[c] B&C, $p = 0.269$[c]
	6 M	0 (0%)	2 (9%)	2 (33%)	$p = 0.034$[c]	A&B, $p = 0.489$[c] A&C, $p = 0.043$[c] B&C, $p = 0.180$[c]
	12 M	1 (5%)	2 (9%)	1 (17%)	$p = 0.608$[c]	A&B, $p = 1.000$[c] A&C, $p = 0.402$[c] B&C, $p = 0.515$[c]
BML at medial tibial plateau (%)	Before	3 (14%)	8 (35%)	2 (33%)	$p = 0.236$[c]	A&B, $p = 0.169$[c] A&C, $p = 0.303$[c] B&C, $p = 1.000$[c]
	1 M	4 (19%)	14 (61%)	4 (67%)	$p = 0.009$[c]	A&B, $p = 0.007$[c] A&C, $p = 0.044$[c] B&C, $p = 1.000$[c]
	3 M	2 (10%)	5 (22%)	2 (33%)	$p = 0.289$[c]	A&B, $p = 0.416$[c] A&C, $p = 0.204$[c] B&C, $p = 0.612$[c]
	6 M	1 (5%)	2 (9%)	1 (17%)	$p = 0.608$[c]	A&B, $p = 1.000$[c] A&C, $p = 0.402$[c] B&C, $p = 0.515$[c]
	12 M	0 (0%)	2 (9%)	1 (17%)	$p = 0.244$[c]	A&B, $p = 0.489$[c] A&C, $p = 0.222$[c] B&C, $p = 0.515$[c]

Table 4 (continued)

		Minimum meniscectomy	Single leaf meniscectomy	Subtotal meniscectomy	*p* value by ANOVA	*p* value by post-hoc
MME	Before	1.6 ± 0.6	1.9 ± 1.0	2.0 ± 1.1	$p = 0.338$	A&B, $p = 0.510$ A&C, $p = 1.000$ B&C, $p = 1.000$
	1 M	1.6 ± 0.6	2.0 ± 0.8	2.3 ± 1.5	$p = 0.121$	A&B, $p = 0.383$ A&C, $p = 0.206$ B&C, $p = 1.000$
	3 M	1.6 ± 0.6	1.9 ± 0.8	2.5 ± 1.5	$p = 0.076$	A&B, $p = 0.814$ A&C, $p = 0.076$ B&C, $p = 0.348$
	6 M	1.6 ± 0.5	1.9 ± 0.7	2.5 ± 1.5	$p = 0.044$	A&B, $p = 0.545$ A&C, $p = 0.045$ B&C, $p = 0.312$
	12 M	1.6 ± 0.6	1.9 ± 0.8	2.7 ± 1.8	$p = 0.039$	A&B, $p = 1.000$ A&C, $p = 0.034$ B&C, $p = 0.144$

with horizontal tears. Our results and those of Kim et al. [20] suggest that flap and horizontal tears may be closely related in patients with severe pain. It has been reported that a single-leaf resection is biomechanically less compressive than a double resection for horizontal tears and that it is crucial to minimize double-leaf resections [21, 22]. Jeon et al. [19] also reported that single-leaf partial resection*s* result in less joint space narrowing than edge resection*s*.

The extent of resection was related to BML occurrence in the femur at three and *six* months postoperatively and in the tibia at one month postoperatively. Sowers et al. reported that BML was 4.3 times more likely in women with osteoarthritis and that BML ≥ 1 cm was associated with cartilage loss and increased subchondral bone load [23]. Link et al. reported that BML increased with increasing KL grades [24]. These findings strongly suggest that increased subchondral bone load due to meniscectomy may be related to BML in our study. However, in our current study, BML decreased at 12 months postoperatively, suggesting that BML was a transient phenomenon, unlike in cases of osteoarthritis or significant cartilage defects.

One of the strengths of this study was that we evaluated the same patients with MRI five times, from the preoperative period to 12 months postoperatively. This allowed us to determine that BMLs are more likely to occur in the femur and tibia one month after arthroscopic meniscectomy, but that they decrease over time. This longitudinal assessment provides valuable insights into the dynamic nature of BMLs following meniscectomy.

The transient nature of BMLs observed in our study warrants discussion from a histopathological perspective. Previous studies have demonstrated that BMLs represent a complex combination of bone marrow necrosis, fibrosis [25], and trabecular abnormalities and are often accompanied by increased bone remodeling [26] and inflammatory infiltrates [27]. This interpretation is supported by histological studies showing that early-stage BMLs are characterized by increased fluid content and vascular permeability [28], which can resolve with appropriate mechanical offloading and healing time. Without direct histological examination, we cannot definitively characterize the exact nature of the tissue changes, and future studies incorporating bone biopsies would be valuable to better understand the biological basis of these reversible MRI findings.

The early postoperative appearance of BMLs at one and three months holds significant clinical implications for patient management. These lesions likely represent an acute response to altered biomechanical loading patterns immediately following meniscectomy before the joint adapts to its new mechanical environment [29]. Their presence during this critical early rehabilitation period may influence immediate postoperative pain and functional recovery [30], potentially necessitating modified rehabilitation protocols for patients with extensive meniscal resection. Early detection through monitoring could help identify patients who might benefit from interventions, such as partial weight-bearing protocols or activity modifications [27], allowing clinicians to optimize long-term outcomes during the acute rehabilitation phase.

MME is a significant factor in knee biomechanics and osteoarthritis progression that warrants consideration in meniscectomy studies [16, 31]. Our finding of progressive MME increases in the subtotal meniscectomy group suggests that more extensive tissue removal may compromise the meniscus's ability to resist radial displacement under load. This increased extrusion likely reflects both the reduced meniscal volume and potential disruption of the circumferential fiber network that normally maintains meniscal position. The significant differences observed at 6 and 12 months between subtotal and minimum meniscectomy groups indicate that this mechanical alteration persists and may even worsen over time. This progressive nature of MME following subtotal meniscectomy could contribute to increased mechanical stress on articular cartilage and subchondral bone, potentially accelerating joint degeneration [32]. These findings support the concept that preserving meniscal tissue volume and maintaining circumferential fiber continuity, where possible, may be crucial for long-term joint health.

Different meniscal tear morphologies demonstrate varying clinical outcomes and healing responses after surgical intervention. While horizontal tears, particularly in older patients with degenerative changes, often show favorable outcomes with conservative treatment and limited resection [7], radial tears extending to the peripheral rim typically result in poorer outcomes due to the disruption of circumferential fibers and loss of hoop stress function [33]. Complex tears show variable outcomes depending on their location and extent, though medial tears generally have less favorable progno*ses*, compared to lateral tears [34]. In our study focusing on flap tears, we observed specific patterns of BML occurrence and MME extent that differ from these other tear morphologies. Flap tears are particularly notable for causing mechanical symptoms that necessitate surgical intervention [10], yet the optimal extent of resection remains debatable. Our findings regarding the relationship between resection extent and BML occurrence may not be directly applicable to other tear patterns, highlighting the need for morphology-specific surgical approaches and postoperative management strategies.

A limitation of this study was the relatively high number of excluded patients. Patients with mechanical symptoms and medial meniscus flap tears were uncommon, and it was relatively difficult to complete five regular MRIs, from the preoperative period to 12 months postoperatively. However, we believe that narrowing the focus to patients with medial meniscus flap tears allowed us to mitigate the limitation of the relatively short postoperative observation period of 12 months. The incidence of BMLs on MRI peaked at one and three months and then decreased, suggesting that 12 months of MRI follow-up is sufficient. Pihl et al. compared the outcomes of resection and suture at one year and five years and found that the one-year outcomes were maintained for up to five years [35] This suggests that one year is also acceptable for evaluating clinical outcomes.

Conclusion

Arthroscopic meniscectomy for medial meniscus flap tears with mechanical symptoms yielded favorable 12-month outcomes. Extensive meniscal resection was associated with an increased risk of postoperative BML and *a* higher *incidence* of MME.

Author contributions

H. S. and K. T. wrote the main manuscript text, and H. O. and Y. K. and K. Y prepared all figures and Tables. All authors reviewed the manuscript.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

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