



Original article

Tear gap and severity of osteoarthritis are associated with meniscal extrusion in degenerative medial meniscus posterior root tears



Jae-Young Kim, Seong-Il Bin*, Jong-Min Kim, Bum-Sik Lee, Sung-Mok Oh, Min-Ho Park

Department of Orthopedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, 88, Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Republic of Korea

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ABSTRACT

Introduction: Meniscal extrusion is a typical finding of medial meniscus posterior root tear, and it causes loss of the chondroprotective function of the meniscus as well as progression of osteoarthritis; it is therefore associated with poor clinical outcomes. The purpose of this study was to investigate factors associated with meniscal extrusion in degenerative medial meniscus posterior root tear. It was hypothesized that larger displacement from the posterior root insertion was associated with larger meniscal extrusion.

Materials and methods: One hundred and nine knees with degenerative medial meniscus posterior root tears were retrospectively reviewed. Multiple regression analysis was used to determine whether factors such as age, weight, body mass index, chondral wear at surgery, Kellgren-Lawrence (KL) grade, alignment, tibial slope, and tear gap on performing magnetic resonance imaging (MRI) were associated with meniscal extrusion. Subjects were divided based on the amount of displacement (displaced group: tear gap \geq 1 mm, non-displaced group: tear gap < 1 mm) to compare meniscal extrusion, chondral wear, and severity of arthritis.

Results: The mean age of the patients was 58.14 ± 9.64 years, the mean absolute extrusion was 4.02 ± 1.22 mm, the mean relative percentage of extrusion was $44.53 \pm 13.09\%$, and the mean tear gap was 2.39 ± 2.42 mm. Multiple regression analysis showed that absolute extrusion was only associated with tear gap on MRI ($B = 0.242, p = 0.001$) and that the relative percentage of extrusion was associated with tear gap ($B = 1.894, p = 0.001$) and the K-L grade ($B = 4.492, p = 0.024$). Absolute extrusion was significantly higher in the displaced group than in the non-displaced group (4.29 ± 1.04 mm vs. 3.01 ± 1.35 mm, $p = 0.001$). Relative percentage of extrusion was also significantly higher in the displaced group than in the non-displaced group ($47.70 \pm 11.44\%$ vs. $36.17 \pm 13.65\%$, $p = 0.001$). The proportion of chondral wear (Outerbridge grade III and IV) on the medial femoral condyle and K-L grade III and IV were significantly greater in the displaced group than in the non-displaced group (76% vs. 53.3% , $p = 0.023$ and 13.9% vs. 0% , $p = 0.001$, respectively).

Discussion: Greater tear gap is significantly associated with increasing meniscal extrusion in medial meniscus posterior root tear. Additionally, severity of arthritis is significantly associated with increasing relative percentage of extrusion. Chondral wear and severity of arthritis tended to be significantly worse in the displaced group than in the non-displaced group.

Level of evidence: III, comparative retrospective study.

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1. Introduction

Posterior root attachment of the meniscus is essential for maintaining hoop tension, which provides the load distributing function of the knee [1,2]. Medial meniscus posterior root tear (MMPRT) is defined as a radial meniscal tear within 10 mm of the root insertion

site; it is visible as a linear defect (cleft sign) at the root insertion site on the coronal plane in magnetic resonance imaging (MRI), with tear gap formation caused by peripheral displacement [3]. A large proportion of root tears seen in clinical practice are degenerative MMPRTs in middle-aged or older patients [4–6]. MMPRTs have recently received attention because of their association with cartilage wear, joint space narrowing, and eventually progressive osteoarthritis [4,7–15]. MMPRTs account for 10 to 27.8% of all medial meniscus tears [16,17]. Risk factors, treatment strategy (meniscectomy vs. repair), and postoperative results of MMPRT

* Corresponding author.

E-mail address: sibin@amc.seoul.kr (S.-I. Bin).

are being actively researched in attempts to delay osteoarthritis progression via restoration of hoop strain [4,7,11,18–21]. Meniscal extrusion defined as medial displacement of the medial meniscus with respect to the medial tibial plateau margin may be a pathognomonic indicator of MMPRT [22–24]. Meniscal extrusion was significantly associated with decreased total contact area of the medial compartment and increased peak contact pressure, which are comparable to the total meniscectomy state; medial extrusion may be associated with functional failure in shock absorption and accelerates joint degeneration and osteoarthritis progression [1]. Additionally, many studies have been conducted on extrusion, with radial component of tears, severe osteoarthritis, obesity, and varus deformity reported as representative associative factors of extrusion [12,14,15,25]. However, it is still unknown whether meniscal extrusion was the cause or a simultaneous process of osteoarthritis. Therefore, we investigated factors that may be associated with meniscal extrusion, such as age, weight, body mass index (BMI), tibial slope, chondral wear at arthroscopy, severity of osteoarthritis, and tear gap on MRI in patients with MMPRT. Meniscal extrusion was expected to increase with greater peripheral displacement from the posterior root insertion, but few studies on this have been reported [26–28]. It was hypothesized that larger displacement from the posterior root insertion was associated with larger meniscal extrusion in MMPRT.

2. Materials and methods

2.1. Patients

This study was ethically approved by the institutional review board on our institution (IRB number: S2017-1166-0001 on June 26th, 2017) Patients who underwent arthroscopic surgery by one surgeon between August 2006 and February 2017 were retrospectively reviewed. Inclusion criteria were (a) patients with arthroscopic confirmation of MMPRT (type 2 according to La Prade's classification), (b) hip-knee-ankle (HKA) angle of ≤ 5 degrees, (c) availability of high-resolution MRI (1.5 T or 3 T) with the interval between MRI and surgery being within 6 months, and (d) no major trauma history. Exclusion criteria were (a) patients without preoperative MRI or those with poor resolution, (b) meniscal tear other than root tear, (c) definite major trauma history, and (d) varus alignment (HKA angle > 5 degrees). A total of 109 knees from 107 patients were included.

2.2. Extrusion, cartilage status, and tear gap

Extrusion was evaluated on the mid-coronal plane in preoperative MRI by measuring the absolute extrusion and relative percentage of extrusion (RPE). Absolute extrusion was defined as the distance between two lines drawn perpendicular to the articular surface, one on the outer margin of the medial tibial plateau and the other on the outer edge of the meniscus. RPE was defined as the percentage of meniscus extruded from the width of the entire meniscus (Fig. 1) [12]. Medial meniscal extrusion > 3 mm was categorized as major extrusion, and extrusion with lesser values was categorized as minor according to Coasta's study [29].

The cartilage status of the medial femoral condyle (MFC) and medial tibial plateau (MTP) was assessed during arthroscopic surgery by the senior author using the modified Outerbridge (OB) classification for analysis. It was documented on the electronic medical record system immediately after surgery. To measure the tear gap on MRI, the coronal plane image with the most prominently visible medial meniscus posterior root insertion was selected. The medial joint line was drawn while considering the obliquity of the medial tibial plateau. A line perpendicular to the

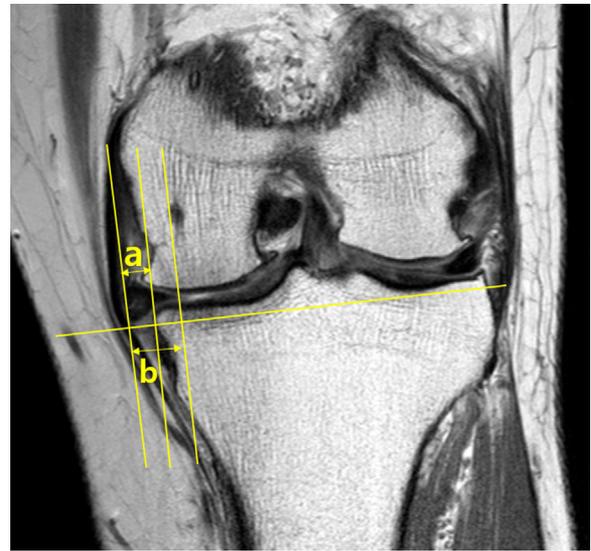


Fig. 1. Extrusion measurement. Relative percentage of extrusion (RPE) is defined as the width of the extruded meniscus divided by the width of the entire meniscus (%): $RPE = a/b \times 100$, where a is the absolute extrusion (mm) and b is the width of the entire meniscus (mm).

medial joint line was drawn on the intercondylar fossa (or, in applicable cases, the location of the remaining insertional ligament). A second line perpendicular to the medial joint line was drawn on the medial edge of the displaced meniscus. The distance between these two lines was defined as tear gap (Fig. 2).

2.3. Preoperative radiographic assessment

Preoperative radiographs of standing anteroposterior, 45° flexion posteroanterior, and lateral and long-standing anteroposterior views were obtained just before surgery, and measurement tools in Picture Archiving and Communication System (PACS; GE Health Care, Chicago, IL, USA) were used to measure various radiologic parameters. Mechanical alignment was evaluated by the HKA angle between the line from the center of the femoral head to the intercondylar notch and the line from the tibial spine to the center of the talus. Tibial slope was determined from the lateral X-ray by measuring the angle between the line perpendicular to the mid-diaphysis and the posterior inclination of the tibial plateau [30]. Severity of osteoarthritis was assessed using the Kellgren-Lawrence (KL) grade.

2.4. Statistical analysis

Statistical analysis was performed using SPSS (version 18.0 for Windows; SPSS Inc). Multiple linear regression analysis was used to determine factors associated with meniscal extrusion. Patients were divided based on whether the tear gap was ≥ 1 mm (displaced group) or < 1 mm (non-displaced group) on MRI. Student's t -test was performed to compare absolute extrusion, RPE, chondral wear, and arthritic changes in the displaced and non-displaced groups. A pilot study was performed using selected patients in the displaced and non-displaced group ($n = 10$ per group). To identify the sample size required to detect differences in meniscal extrusion between the two groups, the alpha value was set at 0.05 and power at 0.9. Mean absolute extrusion was 4.3 mm for the displaced group and 2.9 mm for the non-displaced group. Standard deviation (SD) for meniscal extrusion was 1.02 mm. A sample size of 22 cases was required to detect survival differences between the groups. The Chi² test was performed to determine the effect of tear gap on major extrusion. Measurement reliability was assessed using the

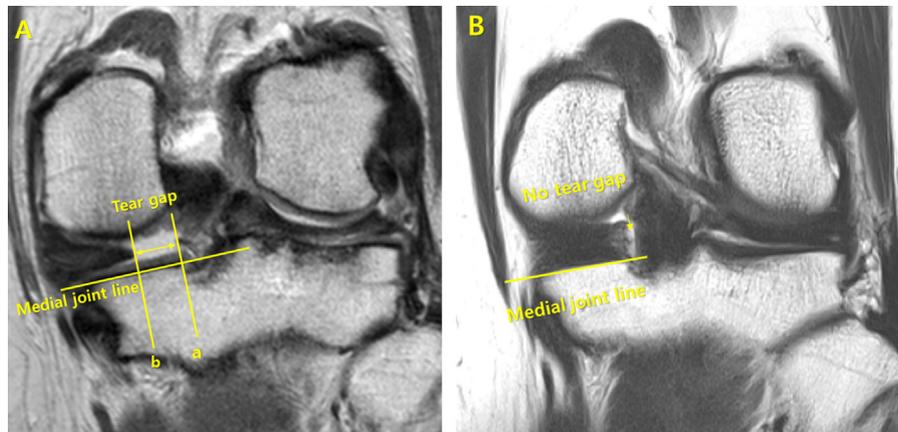


Fig. 2. Tear gap measurements were made using coronal images in MRI with the most prominently visible medial meniscus posterior root insertion (image A). Tear gap was defined as the distance between the vertical line from the intercondyloid fossa or remnant insertional ligament (a) to the medially displaced meniscus edge (b). Image B shows medial meniscus posterior root tear, but the transected meniscus was not displaced from the root.

Table 1
Patient demographics and preoperative radiographic evaluations.

Parameter	Value
Age (years)	58.14 ± 9.64
Male/female ratio	26/83
Symptom duration (months)	3.72 (0.1 to 11)
Weight (kg)	65.99 ± 10.84
BMI (kg/m ²)	26.02 ± 3
Hip-knee-ankle angle (degrees)	Varus 2.05 ± 2.39
Posterior slope (degrees)	9.12 ± 2.94
Absolute extrusion (mm)	4.02 ± 1.22
Relative percentage of extrusion (%)	44.53 ± 13.09
Tear gap on MRI (mm)	2.90 ± 2.11

BMI: body mass index; MRI: magnetic resonance imaging.

intraclass correlation coefficient (ICC). The mean ICC for intra- and interobserver reliability of meniscal extrusion was 0.91 and 0.86, respectively ($p = 0.001$). The mean ICC for intra- and interobserver reliability of the tear gap was 0.88 and 0.82, respectively ($p = 0.001$).

3. Results

One hundred and nine patients were included. Patient demographics and radiographic assessments are summarized in Table 1. The mean patient age was 58.14 ± 9.64 years, the male-to-female ratio was 26:83, the mean absolute extrusion was 4.02 ± 1.22 mm, the mean RPE was 44.53 ± 13.09%, and the mean tear gap was 2.90 ± 2.11 mm.

Seventy-nine patients were included in the displaced group and 30 in the non-displaced group (Table 2). The proportion of chondral wear (grade III and IV) on the MFC and K-L grade III and IV was significantly greater in the displaced group than in the non-displaced group. The proportion of chondral wear (grade III and IV) was not statistically significant (Table 2).

3.1. Factors affecting extrusion

Multiple regression analysis was used to determine which factors may be associated with absolute extrusion and RPE. Tear gap ($B = 0.242$, $P = 0.001$) was the only factor associated with absolute extrusion ($R^2 = 0.23$) and tear gap ($B = 1.894$, $p = 0.001$) and K-L grade ($B = 4.492$, $p = 0.024$) were associated with RPE ($R^2 = 0.17$). Tear gap was associated with both absolute extrusion and RPE and was more strongly associated with RPE than K-L grade. Age, weight, BMI, OB grade (MFC and MTP), and posterior slope were not significantly associated with meniscal extrusion (Table 3).

Table 2
Number of knees with chondral wear and arthritic changes at surgery in the displaced and non-displaced group.

	Outerbridge grade of MFC		p-value	
	Grade I&II	Grade III&IV		
Displaced group (n = 79)	19 (24%)	60 (76%)	0.023	
Non-displaced group (n = 30)	14 (46.7%)	16 (53.3%)		
Outerbridge grade of MTP				
		Grade I&II	Grade III&IV	
Displaced group	5 (6.3%)	74 (93.7%)	0.125	
Non-displaced group	8 (26.7%)	22 (73.3%)		
Kellgren–Lawrence grade				
		Grade I&II	Grade III&IV	
Displaced group	68 (86.1%)	11 (13.9%)	0.001	
Non-displaced group	30 (100%)	0 (0%)		

MFC: medial femoral condyle; MTP: medial tibial plateau.

3.2. Age and meniscal extrusion in the displaced and non-displaced group

Age of patients tended to be higher in the displaced group than in the non-displaced group, but it was not statistically significant. Absolute extrusion and RPE were significantly higher in the displaced group than in the non-displaced group (Table 4). The odds ratio of major extrusion in the displaced group was 7.866 (95% CI: 2.725–22.703, $p = 0.001$). The sensitivity and specificity of major extrusion in the displaced group were 91.1% and 43.3%, respectively (Table 5).

4. Discussion

The most important finding of this study was that in patients with MMPRT, tear gap was significantly associated with meniscal extrusion; a greater tear gap is associated with a greater meniscal extrusion, in accordance with our hypothesis. Along with tear gap, severity of arthritis also showed a significant association with RPE.

Adam and Gale et al. explained the association of joint space narrowing and extrusion, which was similar to the correlation between arthritis and RPE in the present study [22,31]. A cadaveric study by Hein et al. demonstrated that in root tears, meniscal extrusion at the mid position is significantly greater than that in the native meniscus, with the application of physiologic loading (1800 N); gap

Table 3
Multiple regression analysis to identify factors affecting extrusion.

Dependent variables	Independent variables	Unstandardized coefficients		Standardized coefficients β	<i>p</i> -value
		B	SE (B)		
Absolute Extrusion	Age	0.029	0.013	0.218	0.69
	Weight	0.024	0.017	0.217	0.153
	BMI	0.037	0.059	0.092	0.529
	OB grade of MFC	0.083	0.150	0.068	0.582
	OB grade of MTP	0.027	0.188	0.016	0.884
	KL grade	0.96	0.200	0.44	0.43
	Tear gap	0.242	0.042	0.483	0.001
	Mechanical axis	0.002	0.045	0.005	0.958
	Posterior slope	0.032	0.036	0.078	0.369
	Relative Percentage of extrusion	Age	0.314	0.146	0.231
Weight		0.289	0.190	0.240	0.131
BMI		0.449	0.660	0.103	0.497
OB grade of MFC		0.617	1.635	0.047	0.707
OB grade of MTP		1.226	2.054	0.067	0.552
KL grade		4.492	1.959	0.203	0.024
Tear gap		1.894	0.478	0.351	0.001
Mechanical axis		0.572	0.502	0.104	0.257
Posterior slope		0.369	0.397	0.083	0.356

Adjusted R^2 values for absolute extrusion and relative percentage of extrusion were 0.23 and 0.17, respectively. Bold indicates factors significantly associated with absolute or relative percentage of extrusion. *MFC: medial femoral condyle; MTP: medial tibial plateau; OB grade: Outerbridge grade; KL grade: Kellgren–Lawrence grade.

Table 4
Age, tear gap, and extrusion in the displaced and non-displaced group.

	Displaced group (n = 79)	Non-displaced group (n = 30)	<i>p</i> -value
Age (years)	59.24 ± 4.25	57.59 ± 7.11	0.075
Tear gap on MRI (mm)	3.30 ± 2.26	0.43 ± 0.21	0.001
Absolute extrusion (mm)	4.29 ± 1.04	3.01 ± 1.35	0.001
Relative percentage of extrusion (%)	47.70 ± 11.44	36.17 ± 13.65	0.001

magnetic resonance imaging.

Table 5
Comparison of the proportion of major extrusion in the displaced and non-displaced group.

	Displaced group	Non-displaced group	Total
Major extrusion (> 3 mm)	72 (66%)	17 (15.6%)	20 (81.6%)
Minor extrusion (≤ 3 mm)	7 (6.4%)	13 (12%)	89 (18.4%)
Total	79 (72.5%)	30 (27.5%)	109 (100%)

OR: 7.866 (95% CI: 2.725–22.703), $p=0.001$. Sensitivity of major extrusion in the displacement group: 91.1% and specificity: 43.3%.

distance is significantly greater in the root tear group than in the repaired group at both 0N and 1800N. These results suggest the long-standing physiologic load applied after the initial development of MMPRT results in a greater displacement of the tear gap and meniscal extrusion uncovering the tibial articular surface, eventually resulting in chondral wear progression. This may explain the more severe chondral wear and more severe osteoarthritis in the displaced group than in the non-displaced group in the present study [4]. MFC chondral lesions and MMPRT are associated with meniscal extrusion [32]. In the present study, chondral wear of the MFC was not significantly associated with meniscal extrusion in multiple linear regression analysis, but the proportion of chondral wear of the MFC (grade III and IV) was significantly higher in the displaced group.

Varus malalignment was a risk factor for meniscal extrusion, but patients with over HKA angle varus 5 degrees were not enrolled; this is the reason alignment was not a significant associative factor [25]. According to Munugoda et al., meniscal extrusion is greater in the higher BMI group (35–40 kg/m²) than in the normal BMI group (18.5–25 kg/m²) in MMPRT combined with osteoarthritis [14]. In

the demographic data of the present study, the mean BMI was 26.02 ± 3 kg/m², which is near the normal BMI, and the difference in BMI between the two groups was not significant. For this reason, BMI was not a factor significantly associated with meniscal extrusion in the present study.

The relationship between meniscal extrusion and osteoarthritis in MMPRT is complex. It is still unknown whether the meniscal extrusion was the cause or a simultaneous process in osteoarthritis. This study demonstrated the association between meniscal extrusion and osteoarthritis, but did not fully explain the causation of extrusion and osteoarthritis. Nevertheless, from the viewpoint of clinical relevance, this study revealed that tear gap was pathognomonic sign of MMPRT and quantitatively associated with meniscal extrusion. Moreover, several parameters reflecting the joint condition tended to be significantly worse in the displaced group than in the non-displaced group, indicating that tear gap can reflect MMPRT stage. Further studies performing serial short-term MRI are needed to investigate how the tear gap changes from the non-displaced MMPRT.

There are a number of limitations to this study. First, it is a retrospective study with a small sample size. The results of the retrospective study are critically dependent on the availability and reliability of the medical records. All arthroscopic parameters including characteristics of tears and severity of chondral wear were recorded by a single experienced senior surgeon using preformatted electronic medical forms, thus minimizing recall bias. Moreover, the sample size had acceptable power for the primary endpoint. Second, selection bias was inevitable because subjects were from a symptomatic patient cohort and underwent arthroscopic surgery. Therefore, it may be inappropriate to compare these results with patients with asymptomatic MMPRT. Third, extrusion in the sagittal plane was not considered. Further studies on meniscal extrusion in the sagittal plane may be a worthy topic in future research [33].

5. Conclusion

Greater tear gap is associated with increasing meniscal extrusion in MMPRT. Additionally, severity of arthritis is associated with increasing RPE. Chondral wear and severity of arthritis tend to be significantly worse in the displaced group than in the non-displaced group.

Disclosure of interest

The authors declare that they have no competing interest.

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Contribution

All authors read and approved the final submitted version of the manuscript.

Research design: Jae-Young Kim, Seong-Il Bin, Jong-Min Kim, Bum-Sik Lee.

Data acquisition and entry: Jae-Young Kim, Sung-Mok Oh, Min-Ho Park.

Manuscript preparation: Jae-Young Kim.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.revmed.2019.09.001>.

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