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RESEARCH ARTICLE

Medial Meniscus Extrusion on MRI: A Critical Indicator for High-Risk Tears and Associated Intra-Articular Pathologies

Manyetik Rezonans Görüntülemede Medial Menisküs Ekstrüzyonu: Yüksek Riskli Yırtıklar ve Eşlik Eden İntra-Artiküler Patolojiler için Kritik Bir Gösterge

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ABSTRACT

Objective: To evaluate the relationship between medial meniscus (MM) tear morphology and meniscal extrusion, and to determine whether extrusion can be used as an indicator for identifying high-risk tears based on knee MRI findings.

Materials and Methods: This retrospective study included 183 knee examinations from 160 patients. MM pathologies were classified as degeneration, horizontal-oblique tear, radial tear at the root region, and complex tear. Lateral meniscal pathologies, chondromalacia, joint effusion, and anterior cruciate ligament (ACL) status were recorded. Meniscal extrusion was measured on coronal proton-density–weighted images. Intergroup differences were analyzed using the chi-square and Kruskal–Wallis tests. Receiver operating characteristic (ROC) analysis was performed to predict high-risk tears. A multivariate logistic regression model was used to investigate independent predictors of extrusion ≥3 mm.

Results: Radial root tears and complex tears demonstrated significantly greater extrusion compared with other pathologies. Chondromalacia and joint effusion were significantly more frequent in knees with extrusion ≥3 mm. ACL rupture was associated with both increased extrusion and complex MM tears. ROC analysis identified a threshold value of 3.27 mm (clinically approximated as 3 mm) for discriminating high-risk tears (sensitivity 84.4%, specificity 70.2%, AUC 0.82). In the regression analysis, low-risk and high-risk tear groups as well as chondromalacia were identified as independent predictors of pathological extrusion.

Conclusion: MM extrusion, particularly values ≥3 mm, is a strong radiological indicator of radial root and complex tears and reflects accompanying degenerative changes. Quantitative assessment of extrusion may contribute to the early diagnosis of surgically significant meniscal tears.

Keywords: Meniscus tear, meniscal extrusion, MRI, anterior cruciate ligament rupture, chondromalacia

ÖZET

Amaç: Medial menisküs (MM) yırtık morfolojisi ile menisküs ekstrüzyonu arasındaki ilişkiyi ve ekstrüzyonun yüksek riskli yırtıkların belirlenmesinde bir gösterge olarak kullanılıp kullanılamayacağını diz MRG bulguları üzerinden değerlendirmek.

Gereç ve Yöntemler: Bu retrospektif çalışmaya 160 hastaya ait 183 diz değerlendirmesi dahil edilmiştir. MM patolojileri dejenerasyon, horizontal-oblik, kök bölgesinde radyal yırtık ve kompleks yırtık olarak sınıflandırılmıştır. Lateral menisküs patolojileri, kondromalazi, efüzyon ve ön çapraz bağ (ÖÇB) durumu kaydedilmiştir. Menisküs ekstrüzyonu koronal proton-ağırlıklı kesitlerde ölçülmüştür. Gruplar arası farklar Ki-kare ve Kruskal-Wallis testleri ile değerlendirilmiş; yüksek riskli yırtıkları öngörmek için ROC analizi yapılmıştır. Multivaryant lojistik regresyon modeli ≥3 mm ekstrüzyonun bağımsız belirleyicilerini araştırmıştır.

Bulgular: Radyal kök yırtığı ve kompleks yırtıklar diğer patolojilere göre belirgin derecede daha yüksek ekstrüzyon göstermiştir. Kondromalazi ve efüzyon, ≥3 mm ekstrüzyonu olan dizlerde anlamlı olarak daha sık görülmüştür. ÖÇB rüptürü, hem yüksek ekstrüzyon hem de kompleks MM yırtıkları ile ilişkili bulunmuştur. ROC analizinde yüksek riskli yırtıkları ayırt etmek için 3,27 mm (klinik olarak 3 mm) eşik değeri belirlenmiştir (duyarlılık %84,4; özgüllük %70,2; AUC 0,82). Regresyon analizinde düşük-risk ve yüksek-risk yırtık grupları ile kondromalazi, patolojik ekstrüzyonun bağımsız belirleyicileri olarak bulunmuştur.

Sonuç: MM ekstrüzyonu özellikle 3 mm ve üzerindeki değerlerde, radyal kök ve kompleks yırtıkların güçlü bir radyolojik göstergesidir ve eşlik eden dejeneratif değişiklikleri yansıtır. Ekstrüzyonun nicel değerlendirilmesi, cerrahi açıdan önemli yırtıkların erken tanısına katkı sağlayabilir.

Anahtar Kelimeler: Menisküs yırtığı, menisküs ekstrüzyonu, MRG, ön çapraz bağ yırtığı, kondromalazi

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INTRODUCTION

Magnetic Resonance Imaging (MRI) is a reliable method in the diagnosis of knee pathologies. Since 1985, when Reiche et al first used MRI for knee pathologies, MRI has become a non-invasive alternative to knee arthroscopy with its day-by-day increasing sensitivity and specificity (1). Ability to have images in three planes, having no radiation, high contrast in soft tissue, allowing elaborate examination in cartilage tissue besides the bony structures, and superiority in different scans for tissue characterization, MRI plays an important role in musculoskeletal imaging, especially for knee imaging (2). This positioning establishes MRI as the principal or exclusive imaging technique for evaluating suspected internal knee derangements, given that traditional radiography and CT arthrography exhibit limitations in thoroughly assessing the capsule, collateral ligaments, menisci, and tendons (3).

The menisci in the knee are crucial for load transmission, shock absorption, joint stability, nutrient supply, lubrication, and proprioception (4). They also enhance joint congruency and load transmission by increasing the contact area. While meniscal tears are prevalent knee pathologies, other conditions affecting connective tissues and bones can present with symptoms mimicking meniscal injuries (5). MRI provides the physician with proper diagnostic information in meniscus injuries and accompanying knee pathologies. This comprehensive imaging capability allows for a detailed assessment of meniscal integrity, including the identification of various tear types and associated extrusions, which are crucial for determining appropriate management strategies (6).

This study aims to explore the relation of knee pathologies, which may be seen in knee joint effusion, cartilage damage, anterior cruciate ligament rupture, and the relationship of these signs with meniscus degeneration, different tear types, and meniscus shift. Our hypothesis is that major medial extrusion amounts could be a sign of high-risk tears of medial meniscus tears and even can be related with lateral meniscal and other intraarticular pathologies.

MATERIAL AND METHODS

After obtaining the ethical board approval from our institution (2009/324,26-02-2009, Selçuk University Meram School of Medicine), a total of 183 knees from 160 patients who presented to our clinic with a knee MRI request between January 2009 and August 2010 were included in this study. Patients reported by the same musculoskeletal radiologist were searched retrospectively. All knee MRI reports during this period were screened in the PACS archive, and meniscal pathologies were identified using the keywords “radial”, “complex”, “horizontal”, “discoid”, and “degeneration. The patients were stratified based on meniscal pathology, comprising 40 knees with medial meniscal degeneration, 40 with horizontal or horizontal oblique medial meniscal tears, 50 with medial meniscal radial tears of the root, 40 with complex medial meniscal tears, and 13 with discoid lateral menisci. Cases with more than one tear were evaluated in the complex tear group. Patient selection was consecutive within each predefined pathology subgroup: the first eligible examinations that met all imaging and reporting criteria were included until the intended sample size (40–50 knees) was reached. This approach was chosen to avoid subjective case picking while maintaining analytically meaningful subgroup sizes. Lateral meniscus pathologies of the patients were also recorded. The 13 knees with discoid lateral menisci were analyzed as a separate group for LM pathology; however, any co-existing medial meniscal pathologies within this group were also included in the corresponding MM pathology subgroups for analysis. Radiographic Kellgren–Lawrence grading was not available in this retrospective MRI-based dataset. Exclusion criteria were applied to minimize confounding factors and included: prior knee surgery (such as meniscectomy or ligament reconstruction), acute fractures or bone tumors, clearly documented inflammatory arthropathies, and inadequate image quality or missing sequences that prevented accurate extrusion measurement.

The imaging of all of the patients were performed by 1,5 Tesla MRI device (Symphony, Siemens, Germany) with knee coil using a protocol of Proton density plus T2A turbo spin echo (TE: 14 ve101, TR: 3450, Matrix: 183x256, FOV: 160, slice thickness 3,5 mm) sagittal; T2-A turbo spin-echo fat sat (TE: 88, TR:3300, Matrix: 183x256, FOV: 160, slice thickness 4 mm) coronal; Proton density turbo spin-echo (TE: 22, TR: 3300, Matrix: 183x256, FOV: 160, slice thickness 4 mm) coronal; proton density turbo spin-echo fat sat (TE: 14, TR: 3800, Matrix: 180x 256, FOV: 160, slice thickness 4 mm) transverse images. Images were evaluated on the PACS system (Enlil Paks, Eroglu software, Eskisehir). Tear types and degeneration condition of medial and lateral menisci, extrusion amounts of medial and lateral menisci, anterior cruciate ligament, synovial effusion condition, and periarticular cartilage and bone were evaluated. The anterior cruciate ligament is evaluated in three groups as normal, mucinous degeneration, and tear. Synovial effusion is evaluated especially on the T2A and PD images, and chondromalacia is evaluated on the coronal images. Medial and lateral menisci extrusion amounts were measured on the magnified coronal PD images on radiological monitors, from the most distal point of the meniscus to the tibial plate. Measurement was performed perpendicular to the tibial plateau, from the outer margin of the meniscal body to the edge of the tibial cortex at the level of the medial compartment (Figure 1).

Statistical Analysis

Meniscus status and extrusion rates of the groups; ACL conditions, joint effusions, and development of chondromalacia were compared. Chi-square test was performed to reveal the relationship between anterior cruciate ligament, effusion, and chondromalacia conditions with lateral and medial meniscus pathologies and MM deviation amounts. The amount of medial and lateral meniscus extrusion according to tear types was determined by Kruskal-Wallis one-way analysis of variance. If the result was significant, the Bonnferroni-corrected Mann-Whitney U test was applied. A multivariable binary logistic

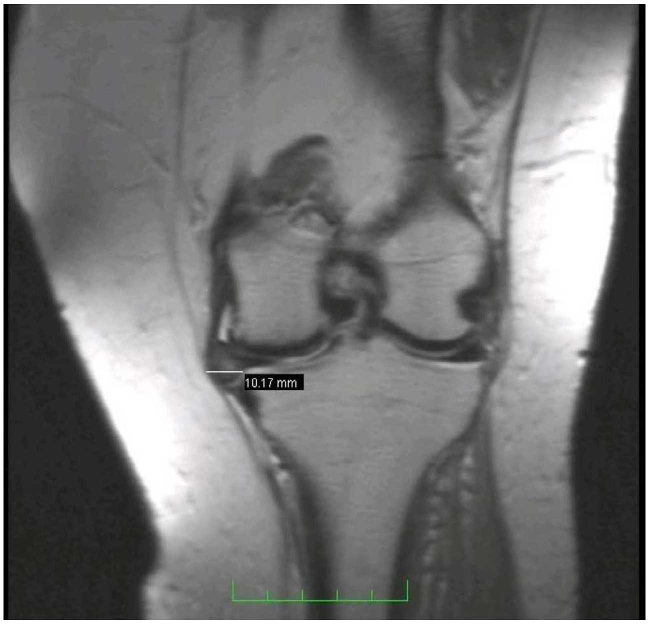

Figure 1. Measurement of the amount of extrusion in the medial meniscus in the coronal proton-weighted knee MRI image. The horizontal distance between the edge of the tibial plateau and the outermost edge of the meniscus was measured.

regression model was constructed to identify independent factors associated with pathological MME. The dependent variable was pathological MME (≥ 3 mm). Independent variables entered the model were age (years, continuous), sex (male vs. female), presence of chondromalacia (yes/no), presence of joint effusion (yes/no), presence of ACL pathology (yes/no), and meniscal risk group (low risk and high risk vs. degenerative). Odds ratios (ORs) with 95% confidence intervals (CIs) and p values were calculated. Statistical significance was set at $p < 0.05$.

RESULTS

The patients were between 18 and 62 years old, and their average age was 43. There were 85 women and 75 men. Ages of the females and males in each of the MM pathologies groups was not significant (p>0.05).

Distribution of Meniscal Pathologies

Medial meniscus (MM) pathologies included 6 normal (3.2%), 44 degeneration (24.0%), 43 horizontal–oblique (HO) tears (23.0%), 50 radial tear of the root (27.8%), and 40 complex tears (22.0%). Lateral meniscus (LM) pathologies comprised 113 normal (62.1%), 23 degeneration (12.6%), 27 HO tears (14.8%), 5 complex tears (2.7%), and 14 discoid menisci (7.7%).

Joint Effusion

Effusion was present in 52 of 183 knees (28.4%).

Effusion was present at all ages. In younger age groups, effusion was often associated with acute traumatic pathology (ACL tear, root tear, high grade meniscal tears). In older groups, effusion was more frequently seen together with chondromalacia and degenerative meniscal tears, reflecting chronic synovial irritation rather than only acute trauma.

• Association by LM pathology: Effusion occurred in 24.8% of normal LM, 43.5% of degeneration, 33.3% of HO, 40.0% of complex, and 21.4% of discoid.

The association was not statistically significant (χ^2=3.41, p=0.49).

• Association by MM pathology: Effusion was 0% in normal MM, 9.1% in degeneration, 21.4% in HO, 43.1% in radial root, and 42.5% in complex. The distribution was significant (χ^2=14.28, p=0.0065).

Effusion was significantly more frequent in radial root and complex tears compared to normal MM.

• Association by MM extrusion severity: Effusion was 17.6% with no extrusion, 17.1% with <3 mm, and 36.1% with ≥3 mm. The association was significant (χ^2=7.68, p=0.022).

Effusion was significantly more common in ≥3 mm extrusion compared to both 0 mm and <3 mm groups.

Chondromalacia

Chondromalacia was observed in 98/183 knees (53.6%). Across the entire cohort, knees with chondromalacia were older on average than those without chondromalacia.

• Association by LM pathology: It was present in 82.6% of degeneration, 74.1% of HO, 100% of complex, 45.1% of normal, and 21.4% of discoid LMs. The distribution was significant (χ^2=18.97, p=0.0008).

LM degeneration and LM complex groups had significantly higher chondromalacia than LM discoid and LM normal groups. LM discoid showed significantly lower chondromalacia than all other LM groups.

• Association by MM pathology: Chondromalacia was 16.7% in normal MM, 36.4% in degeneration, 33.3% in HO, 74.5% in radial root, and 72.5% in complex.

The association was highly significant (χ^2=34.77, p<0.001).

Radial root and complex tears had significantly higher chondromalacia compared to normal and degenerative MM. Differences between radial root and HO, and between complex and HO, were also significant.

• Association by MM extrusion severity: Chondromalacia was 38.2% with 0 mm, 24.4% with <3 mm, and 70.4% with ≥3 mm extrusion.

The association was highly significant (χ^2=29.53, p<0.001). ≥3 mm extrusion had significantly higher chondromalacia than both 0 mm and <3 mm groups (Figure 2).

Anterior Cruciate Ligament (ACL)

ACL was normal in 101 knees (55.2%), degenerated in 61 (33.3%), and ruptured in 21 (11.5%). Patients <30 and 30–39 categories had the highest proportion of ACL tears, consistent with trauma related injuries. In the ≥50 groups, ACL tears were relatively infrequent, whereas degenerative ACL changes constituted a higher proportion of findings.

• Association by LM pathology: With normal ACL, LM was usually normal (68.3%).

With ACL degeneration, LM was more often with HO (18.3%). With ACL rupture, LM degeneration and HO were frequent

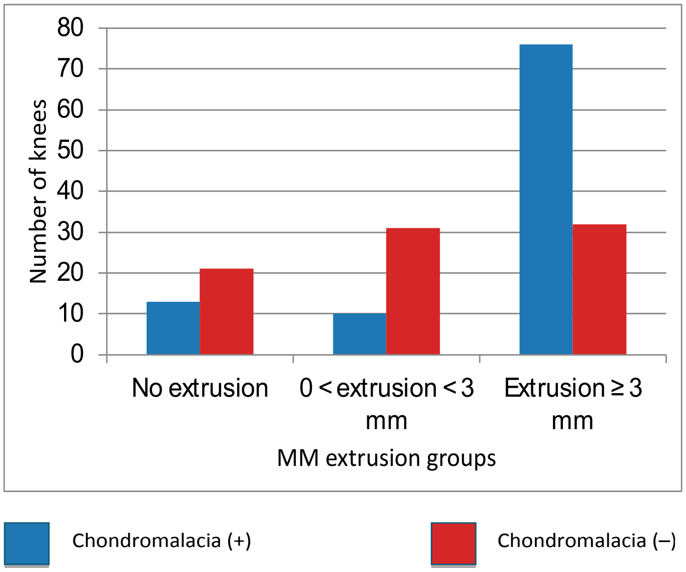

Figure 2. Extrusion amounts of MM according to chondromalacia. Chondromalacia was seen more common in knees with major medial meniscus extrusions. MM: Medial meniscus.

(both 28.6%). The association was significant (χ^2=17.49, p=0.025). LM degeneration and HO groups were significantly more common in ACL rupture compared to normal ACL.

• Association by MM pathology: With normal ACL, MM most often showed degeneration (28.7%) or HO (25.7%).
With ACL degeneration, MM radial root was most common (45.9%).

With ACL rupture, MM complex was most common (47.6%).
The association was highly significant (χ^2=42.03, p<0.001).
Radial tear of the root was significantly associated with ACL degeneration. Complex tears were significantly associated with ACL rupture. Normal MM was significantly associated with normal ACL compared to degeneration/rupture groups.

• Association by MM extrusion severity: ACL rupture was 11.8% with 0 mm, 2.4% with <3 mm, and 14.8% with ≥3 mm extrusion. The association was significant (χ^2=12.15, p=0.016). ACL rupture was significantly more common in ≥3 mm extrusion compared to <3 mm.

Extrusion Measurements

Mean MM extrusion was 3.79 ± 2.82 mm (range 0–11.6). Mean LM extrusion was 0.27 ± 0.91 mm (range 0–6).

• Association by LM pathology: MM extrusion was 3.27 ± 2.53 mm in normal, 5.24 ± 3.16 in degeneration, 5.25 ± 2.78 in HO, 5.66 ± 3.71 in complex, and 2.12 ± 2.04 in discoid LM. Kruskal–Wallis showed significance (χ^2=19.3, p<0.001).
MM extrusion was significantly higher in LM degeneration, HO, and complex compared to LM discoid; complex was also higher than LM normal.

LM extrusion (0.16–2.09 mm) did not differ significantly (p=0.27).

• Association by MM pathology: MM extrusion was 1.08 ± 1.37 mm in normal, 1.40 ± 1.77 in degeneration, 3.34 ± 1.98 in HO, 5.92 ± 2.56 in radial root, and 4.67 ± 2.51 in complex. Kruskal–Wallis showed strong significance (χ^2=92.6, p<0.001). Radial root and complex tears had significantly higher extrusion than all other MM groups. HO was significantly higher than degeneration and normal MM. LM extrusion across MM pathologies (0.18–0.53 mm) showed no significant differences (p=0.47).

• Association by LM pathology distribution across extrusion categories: ≥3 mm extrusion was more frequent in LM degeneration (78%) and HO (81%) compared to normal (52%) and discoid (29%). The association was significant (χ^2=18.93, p=0.041).

• Association by MM pathology distribution across extrusion categories: ≥3 mm extrusion occurred in 92% of radial root and 80% of complex tears, but only 17% of normal, 23% of degeneration, and 43% of HO.

The association was highly significant (χ^2=91.86, p<0.001) (Figure 3).

ROC Analysis-Cut off point for extrusion

ROC analysis was performed to distinguish high-risk MM lesions (defined as radial root and complex tears, n=90) from low-risk lesions (normal, degeneration, and horizontal oblique tears, n=93). A 3.27 mm extrusion was found to be the optimal cut-off point to differentiate these two categories with the following results (Figure 4). AUC: 0.82, Sensitivity: 84.4%, Specificity: 70.2%, PPV: 73.1%, NPV: 77.2%. This indicates that MM extrusion ≥3.27 mm reliably discriminates against high-risk meniscal tears.

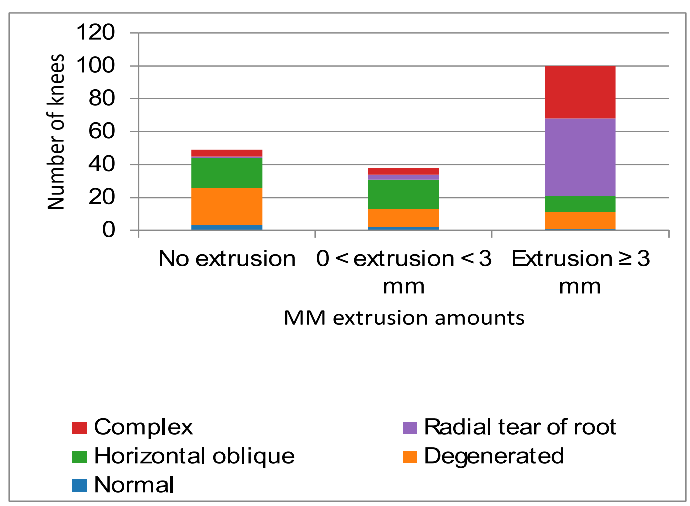

Figure 3. MM pathology types according to extrusion amounts. Knees with medial meniscus extrusion equal to and more than 3 mm had significantly more risk of radial and complex medial meniscus tears on knee MRI. MM: Medial meniscus.

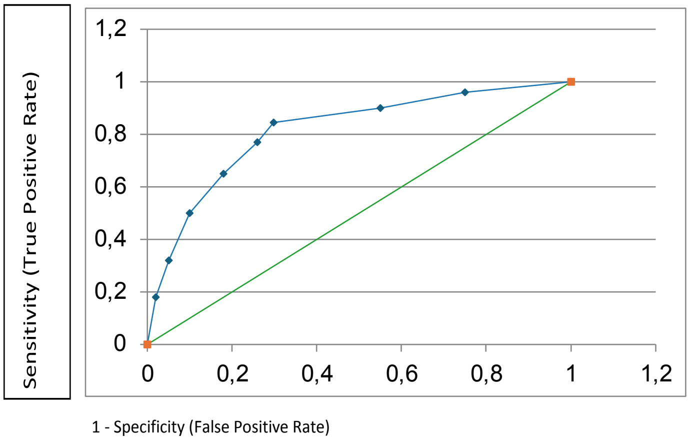

Figure 4. ROC curve to explore the optimum extrusion amount to use as a cut-off point in between tear types. AUC: 0.82, Sensitivity: 84.4%, Specificity: 70.2%, PPV: 73.1%, NPV: 77.2%. Cut-off for medial meniscus extrusion ≥3.27 mm reliably discriminates high-risk meniscal tears.

Multivariance analysis

After evaluating the variables with basic statistics, we performed multivariant logistic regression to find the independent effects of the variables on MM extrusion, searching for each one's variance analysis. In the multivariable logistic regression model, meniscal tear risk group and chondromalacia were independently associated with pathological medial meniscal extrusion (MM Extrusion ≥ 3 mm) (Table 3). Compared with degenerative meniscal changes, both low risk and high risk tear types demonstrated significantly higher odds of pathological MM Extrusion (low risk vs. degenerative: OR 7.34, 95% CI 1.78–30.17, p = 0.006; high risk vs. degenerative: OR 4.90, 95% CI 1.49–16.12, p = 0.009). The presence of chondromalacia was also associated with an increased likelihood of pathological MM Extrusion (OR 3.83, 95% CI 1.42–10.32, p = 0.008).

Male sex was associated with a lower odd of pathological MME compared with female sex (OR 0.29, 95% CI 0.10–0.84, p = 0.022). Age, joint effusion, and ACL pathology were not significantly associated with pathological MM Extrusion after adjustment for other variables in the model (all p > 0.05).

DISCUSSION

Effusion

Fifty-two of the 183 (28%) knees who were all patients with medial meniscus pathologies had synovial effusion. Specifically, the presence of effusion often accompanies advanced meniscal tears and degenerative changes, suggesting a reactive synovitis (7,8). Academic literature indicates that synovial inflammation, frequently observed as effusion, is strongly associated with meniscal pathology and represents a substantial risk factor for the worsening of structural joint deterioration in osteoarthritis (9). This correlation underscores the significance of evaluating joint effusion in conjunction with meniscal extrusion, as it may function as a clinical indicator of ongoing intra-articular pathology and a prognostic marker for patient outcomes (10).

Effusion is found to be significantly more common in patients with 3 mm or more extrusion (p=0.022). This observation suggests that significant meniscal extrusion may serve as an indicator of increased intra-articular inflammation, contributing to synovial fluid accumulation. Most patients with medial meniscus degeneration, without any tears, did not have effusion. This might imply that while degeneration can occur without significant inflammatory exudates, the mechanical disruption and instability caused by meniscal extrusion are more directly linked to the induction of a synovial inflammatory response and subsequent effusion (11,12). Because detailed clinical data such as trauma mechanism, symptom duration, and whether presentations were acute or chronic were not systematically documented in the retrospective records, effusion could not be analyzed separately for acute versus chronic knee pain. This lack of clinical stratification should be considered when interpreting the effusion findings and is acknowledged as a limitation of the study.

Chondromalacia

It is known that osteoarthritis changes are related to the degree of the meniscal extrusion, and MM extrusion is an independent predictor for both cartilage loss and osteoarthritic changes (7,11,13). Meniscal extrusion itself likely represents a

Table 3. Logistic regression between pathological medial meniscus extrusion and other variables.

Variable	OR	95% CI	p-value
Intercept	0.14	0.01–3.94	0.250
Meniscal risk group: low vs. degenerative	7.34	1.78–30.17	0.006
Meniscal risk group: high vs. degenerative	4.90	1.49–16.12	0.009
Age (per 1-year increase)	1.01	0.97–1.05	0.560
Sex: male vs. female	0.29	0.10–0.84	0.022
Chondromalacia: present vs. absent	3.83	1.42–10.32	0.008
Joint effusion: present vs. absent	1.03	0.33–3.18	0.964
ACL pathology: present vs. absent	1.23	0.42–3.63	0.706

Binary logistic regression between pathological MME (≥ 3 mm) as the dependent variable and, given independent variables.
MME, medial meniscal extrusion; OR, odds ratio; CI, confidence interval; ACL, anterior cruciate ligament.

complex interplay of joint tissue degradation and mechanical stressors within the osteoarthritic process, highlighting its role as both a consequence and a contributor to disease progression (13). Similarly, our study demonstrated that 71% of the patients with MM extrusion had chondromalacia, which is consistent with the previous studies (11,14). A study with 548 cadavers revealed that cadavers with a radial tear of the posterior horn had more cartilage damage (15). The authors suggested early repair of posterior horn radial tears to protect the joint from subsequent possible degeneration. In a parallel way, in our study, patients with radial tear of the MM root having chondromalacia (37/50, 74%) and knees with chondromalacia having radial tears of the root compared to the other pathologies (37/98, 38%) are shown to be statistically significant. This finding reinforces the notion that specific meniscal tear patterns, particularly radial tears, significantly predispose the knee to early chondral degeneration (Figure 5). Lateral meniscus degeneration and chondromalacia were seen together significantly in our series. The lateral meniscus carries 70% of the load applied to the lateral compartment (16). As a result, in a patient with LM degeneration, a diminished function of LM may reflect the load to the cartilage more than in a patient with normal LM and can cause degenerative changes of the cartilage (8).

It is also shown that discoid LM is associated with the absence of chondromalacia. Conversely, the normal morphology of a discoid lateral meniscus, despite its atypical shape, may offer a broader contact area, thereby distributing forces more evenly across the articular cartilage and mitigating localized wear. This situation reveals that increased meniscal volume in the discoid meniscus causes a decreased load reflecting to the cartilage. This study is notable for demonstrating that discoid meniscus may be a protective factor from chondromalacia, although it can cause knee complaints itself. The larger surface area of a discoid meniscus may help it dissipate compressive forces across the tibiofemoral joint, reducing localized stress on the articular cartilage (17,18).

Figure 5. Proton Density Coronal image demonstrating the chondromalacia and cartilage irregularity concomitant with radial tear of root of medial meniscus.

ACL pathologies

Studies were showing and denying the relation between MM extrusion and ACL tears (19,20). In this study, patients with extrusion had 40% and patients without a major or minor extrusion had 20% percent mucinous degeneration of ACL, and this relation was significant. This finding suggests that substantial meniscal displacement may contribute to altered knee kinematics, potentially predisposing the anterior cruciate ligament to degenerative changes (11). Similarly, ACL tear had a significant relation with major extrusion (16/21). This indicates that the mechanical instability induced by significant meniscal extrusion may predispose the ACL to injury or accelerate its degeneration, thereby contributing to broader knee joint pathology (13,16). This study revealed consistent results with previous studies regarding ACL and meniscal tears (36%). Furthermore, the presence of an ACL tear often exacerbates meniscal extrusion due to increased joint laxity, creating a vicious cycle of instability and accelerated cartilage degradation (19). This result could be anticipated due to the close relation of ACL and MM and the coexistence of their pathologies (10).

There was not any normal MM in the degenerated or ruptured ACL group. We observed that the presence of a complex tear in the half of the patients with ruptured ACL and a radial tear of the root in the patients with degenerated ACL was significant according to chi square test($p<0,005$). This observation underscores the critical role of ACL stability in maintaining meniscal integrity and preventing the progression of complex meniscal tears.

LM-MM Extrusion difference

It is reported that MM is more prone to extrusion due to the movements of the medial capsule (21). In our study, we found a mean extrusion of 3,8 at MM and 0,27 mm at LM. Consistent with prior research, a statistically significant difference in extrusion between the medial and lateral menisci has been observed (22). Whereas Rennie, with his younger study group, said that there is no significant difference between MM and LM extrusions (12). This can be a clue that extrusion may be developing mostly after degenerative changes instead of acute traumas, which are more commonly seen in the younger patient group (23). This age-related disparity in extrusion prevalence suggests that chronic biomechanical stresses and degenerative processes likely play a more substantial role in medial meniscal extrusion than acute traumatic events. Furthermore, the anatomical differences in capsular attachments and meniscotibial ligaments contribute to the greater mobility of the lateral meniscus compared to the more rigidly fixed medial meniscus, inherently predisposing the medial compartment to higher extrusion rates under chronic loading (11). A key finding of this study, distinct from

Table 1. Lateral and medial meniscus extrusion amounts in mm, according to medial meniscus pathologies.

Mm Condition	Mm*	Lm
Normal	1,078	0,53
Degenerated	1,401	0,19
Horizontal Oblique Tear	3,341	0,39
Radial Tear Of Root	5,920	0,18
Complex Tear	4,672	0,30
Total	3,796	0,27

Medial meniscus extrusion significantly alters in between MM pathologies.

previous research, was the differential effect of meniscal pathologies on extrusion. While both LM and MM pathologies were significantly associated with an increase in MM extrusion, neither pathology type significantly affected LM extrusion. This suggests the lateral meniscus is more resilient to extrusive forces, likely due to its greater mobility, whereas the more fixed medial meniscus is susceptible to extrusion resulting from pathology in either compartment.

Meniscal pathologies-meniscal extrusion

Costa et al. showed a relation between minor extrusion of less than 3 mm and oblique tear (22). There are studies demonstrating the relation of radial tear, complex tear, and root avulsion with major extrusion (20,24,25). Magee et al showed that when MRI is compared with arthroscopy, patients having 3mm or more extrusion on MRI had severe degeneration, complex tear, or radial tear of the MM root arthroscopically. Among these patients 55% had radial tears displayed both on MRI and arthroscopically (26). Distinct from previous studies, this study searched for the effect of LM pathologies apart from MM pathologies on LM and MM extrusion. There was a significant relation between LM tear types and MM extrusion, but it was not true for LM tear types and LM extrusion (Table1). Similarly, while MM pathologies are not found to be affecting LM extrusion whereas there was a significant relation between MM extrusion amount and MM pathologies (Table2). This can be interpreted as LM is less sensitive to MM and LM pathologies in the aspect of extrusion due to its increased mobility shown in dynamic studies (16). Likewise, because of its anatomical configuration and close relation with the capsule, MM is more prone to extrusion as a result of MM and LM pathologies as

Table 2. Lateral and medial meniscus extrusion amounts in mm, according to lateral meniscus pathologies.

Lm Condition	Mm*	Lm
Normal	3,268	0,16
Degenerated	5,238	0,43
Horizontal Oblique Tear	5,253	0,29
Complex Tear	5,660	2,09
Discoid Meniscus	2,123	0,23
Total	3,789	0,27

Medial meniscus extrusion significantly alters in between LM pathologies.

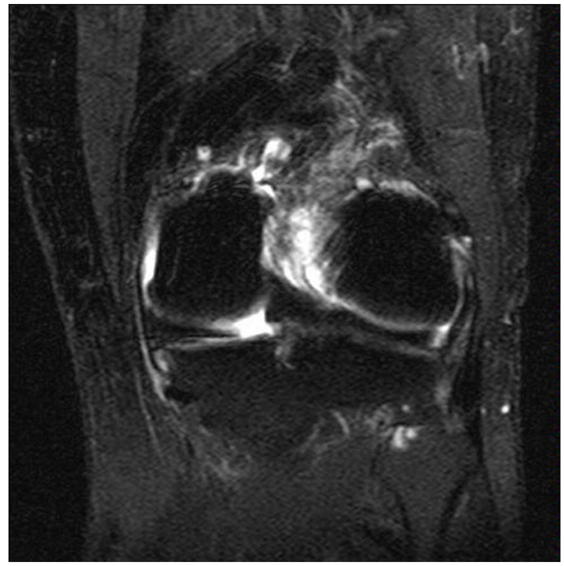

Figure 6. T2 Fat Saturated coronal MRI image of knee. There is a radial tear at the root of the medial meniscus.

tears and degeneration (27). A cut-off value of MM extrusion amount is tried to find to predict the MM pathologies. We found that 3mm or more of extrusion of MM can be used as a reliable tool in differentiating the degeneration and HO tear patients from complex tear and radial tear of the root group, with a sensitivity of 84% and specificity of 70% (Figure 6). Costa et al showed that advanced meniscal degeneration, which is a close entity to a tear, is related to the major extrusion (22). However, most of the patients with any degree of degeneration did not demonstrate extrusion in the current study.

MM posterior root tears are a form of avulsion fracture occurring within the 1st cm of the tibial bony attachment (28). MM root tear is known to increase osteoarthritic changes in the knee (29). This could be due to the disruption of the continuity of circumferential fibers and resulting in loss of hoop tension and meniscal extrusion, which is a cause of rapid osteoarthritic changes (30). MM root tears can be overlooked arthroscopically if a detailed examination is not performed, especially if the tear is close to the tibial insertion site. For this reason, recognizing radial tears of the root by MRI is important in the aspect of enlightening the physician during the arthroscopy (28). Studies show that diagnosing radial tears of the root on MRI is difficult (28,31). These tears are often seen at the knees, with osteoarthritis and coexisting degeneration can mask the tear (24). Also, it is shown that extrusion develops very shortly after the root tear (32). Extrusion of MM can be used as a helpful tool in evaluating the radial tear of the root, and it can provide the chance of early diagnosis and treatment before the development of osteoarthritic changes (24,29). There are biomechanical studies show that repair of radial tears of the root at the MM is successful in sustaining the normal biomechanics of the knee (33). For this reason, early diagnosis and repair of radial tear of the root as a treatable disease are important (34).

In this study, meniscal tear morphology and chondromalacia emerged as the strongest independent predictors of pathological medial meniscal extrusion (MME). Both low-risk and high-risk meniscal tear groups showed markedly increased odds of MME ≥ 3 mm compared with degenerative changes alone. And high-risk tears resulting in even more severe extrusions. This finding supports the concept that structural disruption of the meniscal hoop fibers, even in so-called "low-risk" tear patterns, can lead to loss of meniscal containment and medial displacement of the meniscus. Also, it is demonstrated that radial, root, complex, and bucket-handle tears are associated with greater meniscal extrusion and altered tibiofemoral contact mechanics, which in turn accelerates cartilage degeneration and osteoarthritis progression (17,22,35). The strong association between chondromalacia and pathological MME in our model is also in line with previous reports linking meniscal extrusion to cartilage damage and knee osteoarthritis severity (11,17). Meniscal extrusion reduces the effective load-bearing surface of the meniscus, increases focal cartilage stress, and may reflect an advanced stage of menisco-chondral disease. Our results therefore reinforce the idea that MME is not only a marker of meniscal pathology but also a potential imaging marker of early degenerative joint change.

Interestingly, male sex was associated with lower odds of pathological MME compared with female sex, even after adjustment for meniscal tear type and chondromalacia. Although sex differences in knee osteoarthritis prevalence and pain perception have been described, the relationship between sex and meniscal extrusion is less clear (36). Potential explanations include sex-related differences in knee alignment, ligamentous laxity, or hormonal influences on soft tissue and cartilage biomechanics; however, these hypotheses require further investigation. Despite sole meaningful, joint effusion, and ACL pathology were not independently associated with pathological MM Extrusion in our multivariable model. While ACL rupture and chronic instability have been related to meniscal tears and secondary osteoarthritic changes, our results suggest that, when meniscal tear morphology and chondromalacia are considered, ACL abnormalities per se may not be the primary determinant of extrusion (37). The lack of association with age may reflect the predominance of structural factors (tear pattern and cartilage damage) over chronological age in driving MME in our cohort. Overall, our findings highlight the importance of carefully characterizing meniscal tear morphology and assessing MME and cartilage status in routine knee MRI. Early recognition of tear patterns prone to extrusion, together with the presence of chondromalacia, may have implications for treatment decisions and prognosis.

Clinical variables such as body mass index, activity level, and detailed injury mechanism were not available in the radiology archive and therefore could not be included in the analysis. The single observer measurements planning of the study is a limitation that should be mentioned. Also, the absence of arthroscopic correlation can be considered a limitation of this study. However, we aimed to evaluate meniscal extrusion, not the recognizability of tears on MRI, so tear diagnosis by arthroscopy was not included in the study plan. Future prospective studies incorporating direct arthroscopic correlation would be valuable to further validate the 3 mm extrusion threshold as a definitive diagnostic sign.

CONCLUSION

This study demonstrates a correlation between extrusion and important tears as the root tear of the posterior horn and complex tear, highlighting the importance of its diagnosis via MRI. An extrusion of 3 mm or more can serve as an indicator of radial tear of the root, prompting closer examination of the root to avoid overlooking this treatable condition. Furthermore, significant extrusion is indicative of concurrent degenerative changes, underscoring the clinical value of quantitatively assessing meniscal extrusion through imaging as a critical early sign of substantial intra-articular pathologies, especially those that are surgically manageable.

DECLARATIONS

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REFERENCES

1. Fox MG. MR Imaging of the Meniscus: Review, Current Trends, and Clinical Implications [Review of MR Imaging of the Meniscus: Review, Current Trends, and Clinical Implications]. Magnetic Resonance Imaging Clinics of North America. 2007;15(1):103. doi:10.1016/j.mric.2007.02.004.
2. Shapiro LM, Staroswiecki E, Gold GE. Magnetic Resonance Imaging of the Knee: Optimizing 3 Tesla Imaging [Review of Magnetic Resonance Imaging of the Knee: Optimizing 3 Tesla Imaging]. Seminars in Roentgenology. 2010;45(4):238. doi:10.1053/j.ro.2009.12.007.
3. Vaidya S, Aneesh MK, Mahajan SM, et al. Radiological Assessment of Meniscal Injuries of the Knee on Magnetic Resonance Imaging. International Journal of Current Research and Review. 2020;12(15):98. doi:10.31782/ijcrr.2020.121511.
4. Cao J, Chen B. Function, Injury, and Treatment for Meniscus. Highlights in Science Engineering and Technology. 2022;8:263.

doi:10.54097/hset.v8i.1145.
5. McDermott I, Masouros SD, Amis AA. Biomechanics of the menisci of the knee. Current Orthopaedics. 2008;22(3):193. doi:10.1016/j.cuor.2008.04.005.
6. Luvsannyam E, Jain MS, Leitao AR, et al. Meniscus Tear: Pathology, Incidence, and Management [Review of Meniscus Tear: Pathology, Incidence, and Management]. Cureus. 2022. doi:10.7759/cureus.25121.
7. Bo K, Liu X, Zhang Y, et al. Associations between the meniscal lesion parameters and knee joint structures and symptoms in patients with symptomatic knee osteoarthritis. Arthritis Research & Therapy. 2025;27(1). doi:10.1186/s13075-025-03583-y.
8. Nie S, Li H, Jing-ping G, et al. Association between anatomical risk factors and medial meniscus posterior root tears: a retrospective study. BMC Musculoskeletal Disorders. 2025;26(1). doi:10.1186/s12891-025-08676-y.
9. Olivotto E, Trisolino G, Belluzzi E, et al. Macroscopic Synovial Inflammation Correlates with Symptoms and Cartilage Lesions in Patients Undergoing Arthroscopic Partial Meniscectomy: A Clinical Study. Journal of Clinical Medicine. 2022;11(15):4330. doi:10.3390/jcm11154330.
10. Kim DH, Lee GC, Kim HH, et al. Correlation between meniscal extrusion and symptom duration, alignment, and arthritic changes in medial meniscus posterior root tear: research article. Knee Surgery and Related Research. 2019;32(1). doi:10.1186/s43019-019-0019-x.
11. Crema MD, Roemer FW, Felson DT, et al. Factors Associated with Meniscal Extrusion in Knees with or at Risk for Osteoarthritis: The Multicenter Osteoarthritis Study. Radiology. 2012;264(2):494. doi:10.1148/radiol.12110986.
12. Rennie WJ, Finlay D. Meniscal Extrusion in Young Athletes: Associated Knee Joint Abnormalities. American Journal of Roentgenology. 2006;186(3):791. doi:10.2214/ajr.04.1181.
13. Papalia GF, Zà P, Saccone L, et al. Meniscal extrusion: risk factors and diagnostic tools to predict early osteoarthritis. Orthopedic Reviews. 2023;15. doi:10.52965/001c.74881.
14. Hada S, Ishijima M, Kaneko H, et al. Association of medial meniscal extrusion with medial tibial osteophyte distance detected by T2 mapping MRI in patients with early-stage knee osteoarthritis. Arthritis Research & Therapy. 2017;19(1). doi:10.1186/s13075-017-1411-0.
15. Kan A, Oshida M, Oshida S, et al. Anatomical significance of a posterior horn of medial meniscus: the relationship between its radial tear and cartilage degradation of joint surface. BMC Sports Science Medicine and Rehabilitation. 2010;2(1). doi:10.1186/1758-2555-2-1.
16. Koo JH, Choi SH, Lee SA, et al. Comparison of Medial and Lateral Meniscus Root Tears. PLoS ONE. 2015;10(10). doi:10.1371/journal.pone.0141021.
17. Bloecker K, Wirth W, Guermazi A, et al. Relationship Between Medial Meniscal Extrusion and Cartilage Loss in Specific Femorotibial Subregions: Data From the Osteoarthritis Initiative. Arthritis Care & Research. 2015;67(11):1545. doi:10.1002/acr.22615.
18. Hada S, Kaneko H, Liu L, et al. Medial meniscus extrusion is directly correlated with medial tibial osteophyte in patients received reconstruction surgery for anterior cruciate ligament injury: A longitudinal study. Osteoarthritis and Cartilage Open. 2022;4(4):100320. doi:10.1016/j.ocarto.2022.100320.
19. Ma X, Liu Q, Xu D, et al. Biomechanical impact of progressive meniscal extrusion on the knee joint: a finite element analysis. Journal of Orthopaedic Surgery and Research. 2024;19(1). doi:10.1186/s13018-024-05249-y.
20. Makiev KG, Vasios IS, Georgoulas P, et al. Clinical significance and management of meniscal extrusion in different knee pathologies: a comprehensive review of the literature and treatment algorithm [Review of Clinical significance and management of meniscal extrusion in different knee pathologies: a comprehensive review of the literature and treatment algorithm]. Knee Surgery and Related Research. 2022;34(1). doi:10.1186/s43019-022-00163-1.
21. Li L, Yang X, Yang L, et al. Biomechanical analysis of the effect of medial meniscus degenerative and traumatic lesions on the knee joint. PubMed. 2019;11(2):542. PMID: 30899361; PMCID: PMC6413253. https://pubmed.ncbi.nlm.nih.gov/30899361.
22. Costa C, Morrison WB, Carrino JA. Medial Meniscus Extrusion on Knee MRI: Is Extent Associated with Severity of Degeneration or Type of Tear? American Journal of Roentgenology. 2004;183(1):17. doi:10.2214/ajr.183.1.1830017.
23. Allen DM, Li L, Crema MD, et al. The relationship between meniscal tears and meniscal position. Therapeutic Advances in Musculoskeletal Disease. 2010;2(6):315. doi:10.1177/1759720x10383198.
24. Lee D, Lee B, Kim J, et al. Predictors of degenerative medial meniscus extrusion: radial component and knee osteoarthritis. Knee Surgery Sports Traumatology Arthroscopy. 2010;19(2):222. doi:10.1007/s00167-010-1274-2.
25. Muzaffar N, Kirmani O, Ahsan MS, et al. Meniscal Extrusion in the Knee: Should only 3 mm Extrusion be Considered Significant? An Assessment by MRI and Arthroscopy. Malaysian Orthopaedic Journal. 2015;9(2):17. doi:10.5704/moj.1507.013.
26. Magee T. Usefulness of Unenhanced MRI and MR Arthrography of the Shoulder in Detection of Unstable Labral Tears. American Journal of Roentgenology. 2015;205(5):1056. doi:10.2214/ajr.14.14262.
27. Gajjar SM, Solanki K, Shanmugasundaram S, et al. Meniscal Extrusion: A Narrative Review [Review of Meniscal Extrusion: A Narrative Review]. Orthopaedic Journal of Sports Medicine. 2021;9(11). doi:10.1177/23259671211043797.
28. Choi CJ, Choi YJ, Lee JJ, et al. Magnetic Resonance Imaging Evidence of Meniscal Extrusion in Medial Meniscus Posterior Root Tear. Arthroscopy The Journal of Arthroscopic and Related Surgery. 2010;26(12):1602. doi:10.1016/j.arthro.2010.05.004.
29. Furumatsu T, Kintaka K, Higashihara N, et al. Meniscus extrusion is a predisposing factor for determining arthroscopic treatments in partial medial meniscus posterior root tears. Knee Surgery and Related Research. 2023;35(1). doi:10.1186/s43019-023-00182-6.
30. Daszkiewicz K, Łuczkiewicz P. Biomechanics of the medial meniscus in the osteoarthritic knee joint. PeerJ. 2021;9. doi:10.7717/peerj.12509.
31. Lee SY, Jee WH, Kim JM. Radial Tear of the Medial Meniscal Root: Reliability and Accuracy of MRI for Diagnosis. American Journal of Roentgenology. 2008;191(1):81. doi:10.2214/ajr.07.2945.
32. Krych AJ, LaPrade MD, Hevesi M, et al. Investigating the Chronology of Meniscus Root Tears: Do Medial Meniscus Posterior Root Tears Cause Extrusion or the Other Way Around? Orthopaedic Journal of Sports Medicine. 2020;8(11). doi:10.1177/2325967120961368.
33. Xu ZH, Li Y, Rao J, et al. Biomechanical assessment of disease outcome in surgical interventions for medial meniscal posterior root tears: a finite element analysis. BMC Musculoskeletal Disorders. 2022;23(1). doi:10.1186/s12891-022-06069-z.
34. Moon H, Choi C, Jung M, et al. Medial Meniscus Posterior Root Tear: How Far Have We Come and What Remains? [Review of Medial Meniscus Posterior Root Tear: How Far Have We Come and What Remains?]. Medicina. 2023;59(7):1181. doi:10.3390/

medicina59071181.
35. LaPrade CM, Foad A, Smith SD, et al. Biomechanical consequences of a nonanatomic posterior medial meniscal root repair. Am J Sports Med. 2015;43(4):912-20. doi:10.1177/0363546514564150.
36. Srikanth VK, Fryer JL, Zhai G, et al. A meta-analysis of sex differences in prevalence, incidence and severity of osteoarthritis. Osteoarthritis Cartilage. 2005;13(9):769-81. doi:10.1016/j.joca.2005.04.014.
37. Dunn WR, Spindler KP. Predictors of activity level 2 years after anterior cruciate ligament reconstruction (ACLR): A multicenter Orthopaedic Outcomes Network (MOON) ACLR cohort study. Am J Sports Med. 2010;38(10):2040-50. doi:10.1177/0363546510370283.