"Correlating Meniscal Extrusion with Cartilage, Bone, and Ligament Lesions in Medial Meniscus Posterior Root Tears"

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ABSTRACT

Background: Injuries to the menisci are a significant source of musculoskeletal complications. To the best of our knowledge, few studies have investigated cartilage and bone lesions associated with medial meniscus posterior root (MMPR) tears. However, ligament damage may occur as a result of meniscus damage. Notably, the relationship between tears and ligament damage has only been investigated in one study thus far. Considering the importance of this issue and the limitations of the conducted studies, this study aimed to determine the relation between the severity of the gap caused by MMPR tears and extrusion of the medial meniscus along with bone, cartilage, and ligament abnormalities.

Methods: In this analytical cross-sectional study, patients with medial meniscus tears referred to the radiology department who underwent knee magnetic resonance imaging (MRI) were examined. Data related to age, sex, length of meniscus tear, degree of protrusion, bone marrow edema, and abnormalities of the bone, cartilage, and ligaments were collected. Additionally, the amount of gap caused by the posterior root tear of the medial meniscus was recorded. Finally, data was analyzed by IBM SPSS version 25 statistical software.

Results: In this study, 160 patients were examined, of whom 108 (67%) were female. All patients had medial tibial plateau (MTP) and medial femoral condyle (MFC) cartilage damage. One-quarter of patients had subchondral cysts, and 53% of patients had bone marrow edema. The mean extrusion length in these patients was 4.64 mm. The results indicated that 49% of the patients had an anterior cruciate ligament (ACL) injury, 28% had a posterior cruciate ligament (PCL) injury, and 91% had a tibial collateral ligament (TCL) injury. Patients with minor tears were more likely to have low-grade MFC damage (58%), while patients with major tears were more likely to have high-grade MFC damage. Additionally, low-grade MTP injuries were more common in patients with minor tears (65%), while high-grade injuries mostly occurred in patients with major tears (58%).

Conclusion: The results indicate that the type of meniscus tear may affect the distribution and frequency of cartilage and ligament injuries. Therefore, these findings can help clinicians better diagnose and treat patients with meniscus injuries and other joint problems more effectively.

Keywords: Ligament, Meniscus, Posterior Root Tear.

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Introduction

Knee menisci, two fibrocartilaginous discs, play a crucial role in joint coordination, load transfer management, and shock absorption due to their unique biochemical composition and structure. However, treating and repairing these structures is challenging, and prolonged injuries may lead to knee joint degeneration. Understanding the intricate structures of menisci is essential for exploring treatment options to restore their function after injury or degeneration.[1]

Meniscal injuries contribute significantly to musculoskeletal complications, with arthroscopic treatment accounting for 10-20% of all orthopedic surgeries.[1] MRI is the preferred diagnostic method for meniscal root tears, given the absence of specific findings in patients' history and physical examination. T2-weighted sequences on MRI are particularly effective in evaluating meniscal root damages.[2]

Meniscal surgery, including arthroscopic partial meniscectomy, is a widespread orthopedic procedure.[3] It has been proven to be effective for patients with symptomatic meniscal tears who are unresponsive to conservative treatment.[4]

Intrasubstance signal abnormalities in the meniscus are linked to an increased risk of degenerative meniscus tears in the same segment. MMPR tears are significant events in knee osteoarthritis and are associated with cartilage loss and meniscal extrusion. While limited studies have explored cartilage and bone lesions associated with MMPR tears, meniscal damage may lead to ligament damage.[5-7] The relation between MMPR tear gap severity and ligament damage has been studied in only one investigation to date.[8] Given the importance of this issue and the limitations of existing studies, this research aimed to establish the relation between MMPR tear-induced gap severity and medial meniscus extrusion, as well as bone, cartilage, and ligament abnormalities in the medial knee compartment, using MRI. The focus is on determining these relations rather than relying solely on radiological criteria when selecting patients for surgery.

Methods

Patients and settings

In this analytical cross-sectional study, patients with MMPR tears referred to Poursina Hospital's radiology department in Iran, who underwent knee MRI (Signa, General Electric Medical Systems), were investigated. The inclusion criteria were age over 18 and under 65 years, and confirmation of meniscal tear diagnosis by MRI, while the exclusion criteria included meniscal tears other than posterior horn root tears, prior knee surgery, and a history of severe trauma or fracture.

Data Gathering

Data, including MRI results and patients' characteristics such as age, sex, meniscus tear length, extent of protrusion, and bone marrow edema, were collected in a standardized form.

The evaluation focused on images from patients who underwent knee MRI in 2023 for various reasons and exhibited meniscal tears. During MRI, patients assumed a supine position, and the standard protocol involved a 3 mm slice thickness with a 1 mm gap. Tear gap measurements were conducted on the coronal images, emphasizing the tibial insertion site of the MMPR. Recorded values are in millimeters, and patients were categorized based on gap length: ≤4 mm was considered as a minor tear, and >4 mm was considered a major meniscus tear.

Absolute meniscus extrusion in the coronal plane was measured as the distance between the outer edge of the MTP and the outer edge of the medial meniscus. The relation between ligament damage and tear gap was assessed by evaluating the ACL, PCL, and TCL. The study concentrated on internal compartment pathologies, excluding lateral fibular ligament and lateral compartment chondromalacia lesions. Additionally, bone and cartilage abnormalities were explored, and clinical symptoms and examinations were completed due to potential weaknesses in ACL diagnosis.

Ethical Considerations

This study was approved by the ethics committee of Guilan University of Medical Sciences (ethical code: IR.GUMS.REC.1402.423). All research was performed in accordance with relevant guidelines and regulations.

Statistical Analysis

Descriptive and analytical methods were used to analyze the data obtained from the research. In the descriptive analysis, the mean, standard

deviation, median and interquartile range, frequency, and percentage were calculated. To check the analytical assumptions, the normality of the quantitative research variables was assessed using the Shapiro-Wilk test. The Mann-Whitney U test was used to compare quantitative variables. The level of significance in the current research was set at 5% for all hypotheses, and IBM SPSS version 25 software was used to analyze the data.

Results

In this study, 160 patients were included, of whom 108 (67.5%) were women. The mean (standard deviation) age of the investigated subjects was 50.30 (10.29) years. Most patients (100 patients, 62.5%) had major meniscus tears, while the remaining patients (60 patients, 37.5%) had minor meniscus tears. All subjects had MFC cartilage damage, with first-, second-, third-, and fourth-grade cartilage damage observed in 19 patients (11.9%), 40 patients (25%), 33 patients (20.6%), and 68 patients (42.5%), respectively. In other words, most patients (101 patients, 63.1%) had high-grade damage.

All subjects had MTP cartilage damage, with first-, second-, third-, and fourth-grade cartilage damage noted in 23 patients (14.4%), 58 patients (36.3%), 23 patients (14.4%), and 56 patients (35.0%), respectively. Among these patients, 81 (50.7%) had minimal damage to the MTP cartilage.

In this study, 40 patients (25%) had subchondral cysts, and 85 patients (53.1%) had bone marrow edema. The mean (standard deviation) extrusion was 4.46 (1.26) mm.

Table 1 shows that 49.4% of patients had ACL ligament injuries, with the highest prevalence being incomplete tears (30 patients, 18.8%). Additionally, 28.7% of the patients had PCL ligament injuries, with degeneration being the most common type of injury (38 patients, 23.8%). Moreover, 91.3% of the patients had TCL ligament injuries, with incomplete tears being the most common (78 patients, 48.8%).

Variables	Number	Percent
ACL ligament injury		
Degeneration	34	21/3
Incomplete tear	30	18/8
Complete tear	15	9/4
No	81	50/6
PCL ligament injury		
Degeneration	38	23/8
Incomplete tear	7	4/4
Complete tear	1	0/6
No	114	71/3
TCL ligament injury		
Degeneration	66	41/3
Incomplete tear	78	48/4
Complete tear	2	1/3
No	14	8/8

Table 1: The frequency of different types of ligament injuries associated with MMPR tears.

Due to the non-normal distribution of the extrusion length variable, the Mann-Whitney U test indicated that the extrusion length in the group with a minor tear (mean [standard deviation]: 3.96 [1.04] and median [interquartile range]: 4 [3-5]) was significantly lower than that

in the group with a major tear (mean [standard deviation]: 4.77 [1.29] and median [interquartile range]: 5 [4.75-5.75]) (P < 0.001).

The evaluation of MFC injury in meniscal tears revealed a significant difference between the two groups (Table 2). In the minor tear group, the majority of patients had low-grade MFC damage, whereas in the major tear group, the majority of patients had high-grade damage (P < 0.001).

There was also a significant difference in the frequency of MTP damage based on meniscus tears (Table 2). In the minor tear group, the majority of patients had low-grade MTP damage, while in the major tear group, the majority of patients had high-grade MTP damage (P = 0.006).

Comparing the frequency of subchondral cysts based on the meniscal tears revealed that there was no difference between the two groups (Table 2). In both the minor and major tear groups, the majority of patients did not have subchondral cysts (P = 0.186).

Although the frequencies of bone marrow edema, and ACL, PCL, and TCL injuries were higher in the major tear group, the differences between the two groups were not significant (P = 0.072 for bone marrow edema and P > 0.05 for ligament injuries)-(Table 2).

Variables	Meniscus tear		Statistical analysis
	Minor tear Num (%)	Major tear Num (%)	
MFC injury			
Low-grade injury	(%58/3) 35	(%24) 24	>0/001
High-grade injury	(%41/7) 25	(%76) 76	
Total	(%100) 60	(%100) 100	
MTP injury			
Low-grade injury	(%65) 39	(%42) 42	0/006
High-grade injury	(%35) 21	(%58) 58	
Total	(%100) 60	(%100) 100	
Subchondral cyst			
Yes	(18/3%)11	(%29) 29	0/186
No	49 (81/7%)	(%71) 71	
Total	(%100) 60	(%100) 100	
Bone marrow edema			
Yes	(%43/3) 26	(%59) 59	0/072
No	(56/7 %)34	(%41) 41	
Total	(%100) 60	(%100) 100	
ACL ligament injury			
Degeneration	(%16/7) 10	(%24) 24	0/715
Incomplete tear	(%18/3) 11	(%19) 19	
Complete tear	(%10) 6	(%9) 9	
No	(%55) 33	(%48)48	
Total	(%100) 60	(%100) 100	

PCL ligament injury			
Degeneration	(%21/7)13	(%25) 25	0/427
Incomplete tear	%) 11/7(	(%6) 6	
Complete tear	(%0) 0	(%1) 1	
No	(%76/7) 46	(%68)68	
Total	(%100) 60	(%100) 100	
TCL ligament injury			
Degeneration	(%51/7) 31	(%35) 35	0/063
Incomplete tear	(%35) 21	(%57) 57	
Complete tear	1(1/7%)	(%1) 1	
No	(%11/7) 7	(%7)7	
Total	(%100) 60	(%100) 100	

Table 2: Comparison of the frequency of different structural injuries in knee joint associated with MMPR tears.

Discussion

Menisci play a crucial role in knee biomechanics, and currently, meniscus tears are a common injury with increasing prevalence among all age groups due to factors such as trauma or arthritis.[9] Recent advancements have significantly contributed to the diagnosis and management of this condition. A comprehensive evaluation involving a detailed patient's history, physical examination, and an assessment of meniscal tear characteristics enhances our understanding of pathogenesis and treatment options.[10] Radiologic imaging is commonly employed to confirm a meniscal tear. Although X-rays cannot be used to directly visualize a meniscus tear due to its cartilaginous composition, these images eliminate other potential causes of symptoms akin to a meniscus tear. Consequently, MRI has emerged as the predominant imaging modality for diagnosing meniscal tears, boasting favorable sensitivity and specificity. On MRI, an abnormal meniscus shape and heightened signal intensity in contact with the surface edge are observable indicators of a tear.[11]

This study aimed to assess the impact of MMPR tears on concurrent cartilage, bone, ligament lesions, meniscal protrusions, and subchondral cysts. The findings revealed that all patients exhibited damage to MFC and MTP cartilage. Regarding subchondral cysts, a quarter of patients presented with this injury, while more than half had bone marrow edema. Additionally, the results highlighted that degeneration was the most prevalent outcome in patients with damage to the PCL and ACL ligaments, whereas incomplete tears were the predominant damage to the TCL ligament. A comparison of the frequency of MFC damage in meniscus tears revealed that in the minor tear group, most patients experienced low-grade MFC damage, while in the major tear group, a majority experienced high-grade MFC damage. Similar results were observed when comparing meniscal tears with MTP injuries.

The estimated incidence of meniscal tears is approximately 60 per 100,000 people, and this rate is on the rise, due to increased sports activity and advancements in diagnostic tools. Consequently, meniscal surgery has become one of the most prevalent orthopedic procedures, with an incidence of 17 per 100,000 in the United States. Individuals with meniscal injuries encounter heightened cartilage wear, rendering them prone to early degenerative changes and diminished long-term performance. Notably, more than 75% of patients who experience symptomatic osteoarthritis exhibit concurrent meniscal damage.[11]

Concerning extrusion, Bin et al. reported that absolute medial meniscus extrusion was significantly greater in patients with extensive gaps.[12] In patients with MMPR tears, studies have reported mean meniscal extrusion values of 4.02 mm by Kim et al.[13], 3.8 mm by Choi et al.[14], and 4.4 mm by Krych et al.[7] In our study, the extrusion length in the minor tear group was significantly shorter than that in the major tear group. In the investigation by Mete et al. the mean extrusion in the minor group was 3.51 mm, and in the major group, it was 4.52 mm.[8] These findings suggest that increased tear length is related to greater extrusion. Following an MMPR tear, the shock-absorbing function of the meniscus is compromised, leading to impaired management of hoop stress resulting from axial loading on the knee. This impairment reduces the tibiofemoral contact area and increases peak stress in the region.[15]

While numerous studies have explored the connection between the degree of meniscal extrusion and cartilage damage[15,16] there are few studies that have directly investigated the relation between the extent of the tear gap formed due to MMPR tears and cartilage damage.[12,17]

Kim et al.[13] and Bin et al.[12] observed that a larger tear gap resulting from MMPR rupture was related to increased cartilage damage in the MFC. Similarly, in our study, among all patients with MFC damage, the ones with the major tear group predominantly experienced severe MFC damage. Consistent with our findings, the study by Mete et al. revealed a significant difference in the prevalence of MFC cartilage damage between tear groups, with a greater occurrence in the major group ($P = 0.002$).[8] These results suggest that the cumulative physiological stress on the knee may contribute to the widening of the tear gap and escalating cartilage damage in the years following the initial MMPR tear. The biomechanics of the knee joint, featuring enhanced femoral movement on the meniscus compared to the tibia, might accentuate cartilage damage, particularly in the medial femoral condyle.

In both the minor and major groups of this study, the majority of individuals did not exhibit subchondral cysts. Furthermore, in both the minor and major tear groups, most patients presented with bone marrow edema, with no significant difference between the two groups. Conversely, in the investigation by Mete et al., although there was a greater incidence of osteophytes, bone marrow edema, and subchondral cysts in patients with major tears, there was no statistically significant difference between the minor and major groups.[8] It is essential to note that the absence of a significant difference between these groups does not negate the consideration of MMPR rupture as a potential risk factor for subchondral bone changes.

In our investigation, 49.4% of the patients exhibited ACL ligament injury, primarily characterized by incomplete tears (18.8% or 30 individuals). Additionally, 28.7% of the patients had PCL ligament injury, with degeneration being the predominant form (23.8% or 38 individuals). Furthermore, 91.3% of the patients presented with TCL injury, with incomplete tears being the most prevalent (48.8% or 78 individuals). Similarly, Mete et al. noted that MMPR rupture might induce asymmetric pressure changes on ACL, PCL, and TCL due to the joint's disrupted load distribution.[8] However, consistent with our findings, no significant difference in the tear gap was observed among ACL, PCL, and TCL tears in the presence of MMPR tears.

Nevertheless, in a study comparing medial and lateral meniscal root tears, the frequency of ACL, PCL, and TCL tears did not significantly increase in the presence of medial meniscus root tears. Conversely, ACL tears were significantly more prevalent in the presence of lateral meniscal root tears.[5]

Miller et al. discovered a noteworthy association between lateral meniscus extrusion and ACL tears, yet no such relation was identified between medial meniscus extrusion and ACL tears.[6]

Despite being able to investigate a sufficient number of patients with meniscal tears, our study has several limitations. Specifically, all participants in this study, predominantly middle-aged women, had degenerative MMPR rupture. Consequently, our findings may not be applicable to injuries in younger patients. To address these limitations, conducting multicenter studies with larger sample sizes across diverse age groups and exploring additional influencing factors could prove beneficial.

Conclusion

The findings concerning the association between the gap caused by medial meniscus posterior root tears and diverse structural injuries in the knee joint suggest that the nature of the meniscus tear can influence the occurrence and nature of cartilage and ligament injuries. Consequently, these results can enhance the ability of clinicians to diagnose and treat patients with meniscus injuries and other joint-related issues more efficiently and effectively.

Declarations

- Abbreviations:
  1. MMPR: medial meniscus posterior root
  2. MRI: magnetic resonance imaging
  3. MTP: medial tibial plateau
  4. MFC: medial femoral condyle
  5. ACL: anterior cruciate ligament
  6. PCL: posterior cruciate ligament
  7. TCL: tibial collateral ligament
- Ethical approval and consent to participate: Written informed consent was obtained from the patients. This study was approved by the ethics committee of Guilan University of Medical Sciences (ethical code: IR.GUMS.REC.1402.423).
- Consent for publication: Not applicable.
- Availability of data and materials: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.
- Competing interest: The authors declare that they have no competing interests.
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- Authors' contribution: M-MR made the conception and statistical analysis. FA drafted and interpreted the patient's data. AA supervised the findings of this work. NSh wrote the manuscript in consultation with AA. All authors read and approved the final manuscript.
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