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Assessment of Meniscal Pathologies and Meniscal Volume Quantification in Individuals with and without Radiographic Osteoarthritis

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Abstract

Objective: The purpose of this study is to determine whether osteoarthritis (OA) is associated with meniscus volume and pathologies in young and middle-aged individuals.

Methods: This study assessed 155 knee magnetic resonance images (MRIs) and X-rays from 138 participants aged 18-65. The knee X-ray examination was employed to identify OA, whereas the knee MRI was utilized to evaluate meniscal diseases. The volume of the meniscus was measured using ITK-SNAP software.

Results: There was a strong correlation between age and OA ($P < .001$). A link was identified between medial and lateral meniscus disease and age ($P < .001$, $P = .002$, respectively). Osteoarthritis was identified as being linked to both medial and lateral meniscus diseases ($P < .001$, $P = .007$ respectively). Medial meniscus extrusion was identified as being correlated with OA ($P < .001$). Neither medial nor lateral meniscus volumes showed significant correlations with OA ($P = .236$, $P = .501$ respectively). The inter-reader agreement for meniscal volume measurements was assessed using intraclass correlation coefficients (ICCs). ICCs for inter-reader agreement was 0.84.

Conclusion: In cases of meniscal disorders, including meniscal extrusion, even in the absence of OA symptoms, the patient should be considered at risk for OA and monitored accordingly. Given the aging population that is predicted to rise over the next several years, this strategy will also help to manage the condition more affordably.

Keywords: ITK-SNAP, meniscus volume, osteoarthritis

INTRODUCTION

Knee osteoarthritis (OA) is a complex, multifactorial condition that impacts the entire joint and is a leading cause of disability globally.[1] Osteoarthritis, a prevalent degenerative musculoskeletal disorder, is associated with numerous risk factors including advanced age, female sex, malalignment, obesity, genetic predispositions, and trauma.[2,3] Osteoarthritis is a prevalent source of pain and impairment in the aged population.[4] Given the rising older population due to increased life expectancy, the significance of this disease will escalate in the coming decades. An essential first step in preventing this disease, which impacts both individuals and society, is to comprehend it and identify its risk factors and causes.

The growing acknowledgment of the relationships among the structural tissues of the knee joint has led researchers to classify several OA phenotypes based on biochemical and imaging results.[5] Articular cartilage degeneration and changes in subchondral bone are the leading biomarkers of OA.[6] The meniscus is a fibrocartilaginous structure that is crucial for absorbing, transferring, and dispersing mechanical stress within the knee joint. It has been demonstrated that the lack of a functional meniscus exposes the knee's articular cartilage to pathologic stresses, leading to degeneration.[7,8] A robust causal link between meniscus injury and the structural development of OA is well acknowledged.[9] Therefore, especially when investigating knee OA, it is important to evaluate the joint space, subchondral sclerosis, and osteophytes, as well as assess meniscus pathologies, particularly in early-stage cases.

Research has been attempted to elucidate the influence of meniscal modifications on the start of OA, emphasizing factors such as volume, extrusion, thickness (height), and tibial coverage that describe meniscal architecture.[10-12] In the magnetic resonance imaging (MRI) Osteoarthritis Knee Score, extrusion and meniscal morphology were rated as semi-quantitative parameters.[13] However, meniscus volume is not yet included in this scoring system.

Liu et al[14] and Atik et al[15] have conducted studies revealing the relationship between meniscus structure, pathologies, and OA in elderly patients. Given that advanced age is a risk factor for OA, the study was designed to focus on young and middle-aged adults. Thus, the aim was to examine the correlation between meniscus pathology and OA while controlling for the positive impact of age on the progression of OA. The purpose of this study is to determine whether OA is associated with meniscus volume and pathologies in young and middle-aged individuals.

METHODS

Study Population

This is a single-center, retrospective, and cross-sectional study. This research has been approved by the ethical committee of Bandırma Onyedi Eylül University School of Medicine(Decision: January 2, 2025, no: 2024-12-05). The study was conducted in acordance with the Declaration of Helsinki. Written informed consent was obtained from patients who participated in this study.

Patients who underwent knee MRI at the hospital from December 2023 to June 2024 were retrospectively examined using Picture Archiving and Communication Systems. Patients aged 18-65 who had both knee MRI and knee radiography (RG) were identified. The study excluded trauma patients, individuals who had knee surgery for any reason, those with metabolic disorders, osteoporotic patients, oncology patients, and patients with suboptimal imaging quality. The screening resulted in the inclusion of 155 knee MRIs and knee X-rays from 138 participants aged 18-65 in the research.

Radiological Evaluation

This study analyzed Anteroposterior (AP) knee RG in the extended position. The RGs were evaluated using the Kellgren Lawrence (KL) classification system for OA. Accordingly, grade 0 is normal; grade 1 is suspicious osteophyte formation; grade 2 is significant osteophyte formation with normal joint space; grade 3 is osteophytes, narrowing of the joint space, and subchondral sclerosis; grade 4 is a reduction in joint space or ankylosis with multiple osteophytes, significant sclerosis, and erosion.[16] Patients were classified as having knee OA if their KL score was greater than or equal to 2. Patients were categorized into 2 groups according to the presence or absence of OA (Figure 1). The assessment was performed by 2 experienced radiologists. In instances of interpretative inconsistency or ambiguous cases, the images were re-assessed, and a consensus final decision was reached. The knee RG was used to measure the joint space.

Magnetic resonance imaging (MRI) was used to assess meniscus diseases. All MR images were acquired using a 1.5 Tesla MRI device (GE 1.5T, 60 cm, SIGNA™ Creator/Explorer, China, 2017). The MRI evaluation was conducted with the knee in an extended posture. The assessment was performed utilizing a knee MRI protocol including coronal T1, sagittal fat-suppressed proton-weighted, coronal fat-suppressed proton-weighted, and axial fat-suppressed proton-weighted sequences. The anterior and posterior horns of the lateral and medial menisci were assessed individually for each knee. Patients were categorized into 3 groups according to the condition of their meniscus: normal, degenerated, or torn. In addition, the presence of extrusion in the meniscus was evaluated with the coronal plane of MRI. Unaware of the patients' clinical and X-ray scans, 2 experienced radiologists prospectively reinterpreted each MRI. When there were uncertain or inconsistent interpretations, the images were reexamined, and a final conclusion was made by consensus.

The ITK-SNAP software was employed to evaluate the volume of the meniscus.[17] Magnetic resonance scans were uploaded to the software, and measurements were obtained using a three-dimensional (3D) region of interest. Measurements were obtained in the sagittal plane and subsequently validated with additional sequences. Segmentation was conducted from lateral to medial on all sections where the meniscus was visible (Figure 2). The volume measures were conducted independently by 2 radiologists who were oblivious to the patient's radiological results.

Statistical Analysis

Descriptive statistics were applied to analyze the baseline characteristics. The Chi-square (χ^2) test and Fisher's exact χ^2 test were applied in the evaluation of qualitative data. After testing for normality, statistical significance was calculated using an independent sample t-test for comparisons between 2 groups or one-way ANOVA for comparisons among 3 or more groups when the data were normally distributed. For non-normally distributed data, the Mann–Whitney *U* test was used for 2-group comparisons, and the Kruskal–Wallis test was applied for 3 or more groups. The Pearson correlation test was used to assess the linear relationship between normally distributed continuous variables, while the Spearman correlation test was used for those without a normal distribution. Interobserver agreement was assessed using the intraclass correlation coefficient (ICC). The significance of the ICC values was interpreted as follows: <0.50 poor, 0.50-0.75 moderate, 0.75-0.90 good, and >0.90 excellent reliability. All statistical analyses were performed using IBM SPSS software (IBM SPSS Corp.; Armonk, NY, USA, version 23), and a significance level of $P < .05$ was considered.

RESULTS

There were 57 (36.7%) male patients and 98 (63.2%) female patients. In this investigation, radiographic evidence of knee OA was identified in 84 (54.1%) of the 155 cases evaluated (KL grade ≥ 2). The characteristics of the study group are presented in Table 1.

There was a strong correlation between age and OA ($P < .001$). It was found that as people age, OA becomes more common. There was a correlation found between gender and OA ($P = .004$). Osteoarthritis is more frequently detected in females. A link was identified between medial and lateral meniscus disease (degeneration and tear) and age ($P < .001$, $P = .002$, respectively). The prevalence of medial meniscus disease was higher. Osteoarthritis was identified as being linked to both medial and lateral meniscus diseases ($P < .001$, $P = .007$ respectively). Medial meniscus extrusion was identified as being correlated with OA ($P < .001$). Lateral meniscus extrusion was not significantly associated with OA ($P = .5$). Medial meniscus diseases and medial joint space

MAIN POINTS

- Osteoarthritis is a prevalent source of pain and impairment in the aged population.
- An essential first step in preventing this disease, which impacts both individuals and society, is to comprehend it and identify its risk factors and causes.
- In cases of meniscal disorders, including meniscal extrusion, even in the absence of osteoarthritis symptoms, the patient should be considered at risk for osteoarthritis and monitored accordingly.

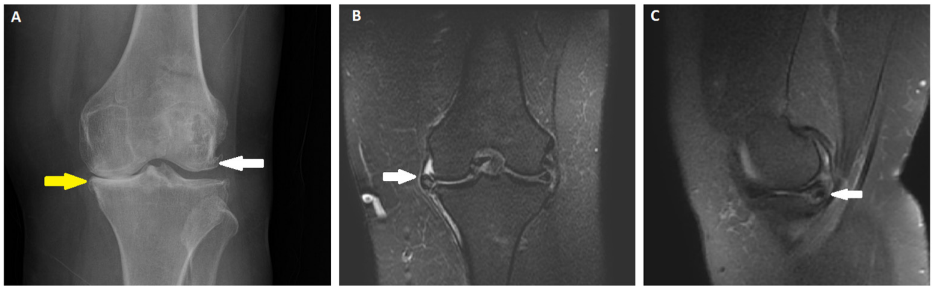

Figure 1. A 56-year-old female patient. The RG of the knee showed OA (A). Subchondral sclerosis (yellow arrow), joint space narrowing (yellow arrow), and osteophyte formation (white arrow) are noted. The fat-suppressed proton density-weighted MR sequence indicates medial meniscus extrusion in the coronal plane (B) and a horizontal tear of the posterior horn of the medial meniscus in the sagittal plane (C), as shown by arrows.

were found to be significantly correlated ($P < .015$). A correlation was demonstrated between gender and the volume of the medial and lateral meniscus ($P < .001$). The volume of the meniscus was determined to be larger in males. Neither medial nor lateral meniscus volumes showed significant correlations with OA ($P = .236$, $P = .501$ respectively) (Table 2). The inter-reader agreement was assessed for meniscal volume measurements using ICCs. Intraclass correlation coefficient for interreader agreement was 0.84.

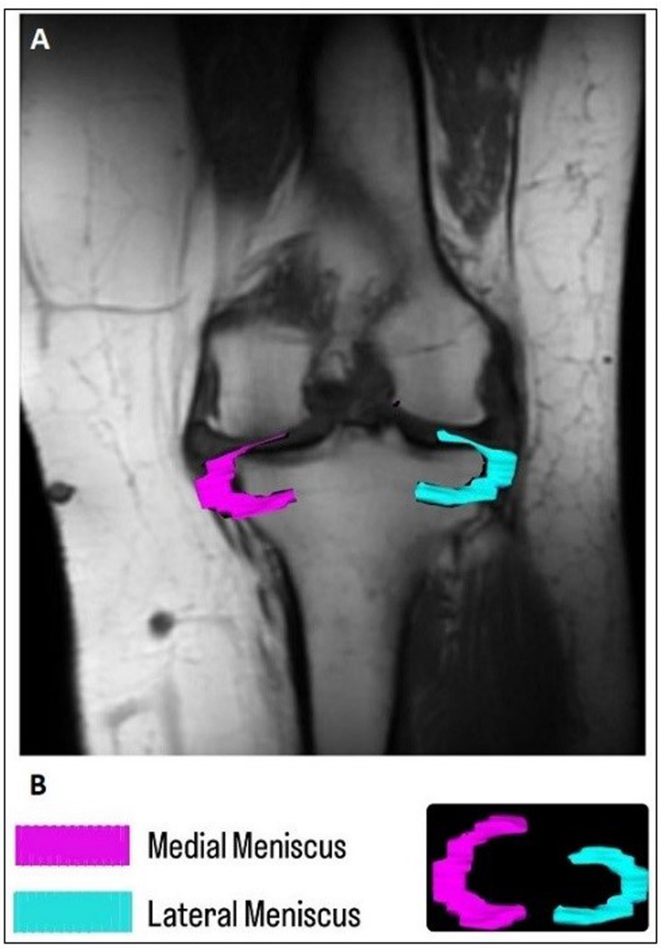

Figure 2. Example of meniscus segmentation. (A) Three-dimensional representation of the left knee and coronal perspective of meniscus segmentation. (B) Meniscus in 3D from segmentation (lateral meniscus is blue; medial meniscus is purple).

DISCUSSION

Knee OA is a degenerative musculoskeletal disease that can be caused by a variety of reasons. Radiography is used to make the diagnosis of OA. Osteoarthritis results can also be assessed using MRI. Meniscus diseases present a substantial risk for the onset and advancement of OA and are relatively common in knee MRI studies.[18]

Radiography was used to evaluate knee OA in this study. Knee OA was diagnosed in 54.1% of patients, with a notable increase in frequency associated with advancing age. This study revealed that women exhibited OA outcomes more frequently than males. It was discovered that these findings aligned with previous research.[2,3,15]

In this study, it was discovered that meniscus diseases are more common in people with OA than in those without OA, and they also increase with age. It was found that 54.9% of individuals without OA had meniscus pathology, whereas 82.1% of patients with OA had meniscus pathology. In studies that include elderly patients in the study group, these rates are elevated.[15,19] In contrast to these studies, the

Table 1. Patient Characteristics and Features of the Knee Joint

Characteristics	n = 155
Age, mean (range) years	45.6 (19-64)
Gender female/male (%)	98 (63.2%)/57 (36.7%)
OA (%)	
Yes	84 (54.1%)
No	71 (45.8%)
Medial joint space, mean (range) mm	5.2 (1.53-12.8)
Lateral joint space, mean (range) mm	6.1 (2.28-11.3)
Medial meniscus (%)	
Normal	47 (30.2%)
Degeneration	71 (45.8%)
Tear	37 (23.8%)
Lateral meniscus (%)	
Normal	126 (81.2%)
Degeneration	20 (12.9%)
Tear	9 (5.8%)
Medial meniscus extrusion	
Yes	34 (21.9%)
No	121 (78%)
Lateral meniscus extrusion	
Yes	2 (1.2%)
No	153 (98.7%)
Medial meniscus volume, mean (range) mm^3	1745 (964-3822)
Lateral meniscus volume, mean (range) mm^3	1317 (552-2905)

OA, osteoarthritis.

Table 2. The Relationship Between Osteoarthritis and the Other Parameters

	Patient with OA N[a], Mean[b]	Patient without OA N[a], Mean[b]	*P*
Age[b]	52	37	<.001*
Gender[a]			
Female	62	36	.004*
Male	22	35	
Medial meniscus disease[a]	69	39	.007*
Lateral meniscus disease[a]	23	6	<.001*
Medial meniscus volüme (mm^3)[b]	1793	1689	.236
Lateral meniscus volume (mm^3)[b]	1298	1341	.501
Medial meniscus extrusion[a]	31	3	<.001*
Lateral meniscus extrusion[a]	2	0	.5

OA, osteoarthritis.

**P* < .05.

There are numbers and average values in this data. For example, among those marked with a, there are 62 women with oa, while the average age ofpatients with oa (marked with b) is 52.

I noticed a mistake in the numbers in the age line. I corrected that too.

reduced prevalence of meniscus pathology in patients without OA in this research can be attributed to the fact that the patients were under 65 years of age.

The prevalence of medial meniscus pathology was higher than that of lateral meniscus diseases. Compared to the lateral meniscus, the medial meniscus is more vulnerable to injury and extrusion because of its anatomical characteristics and relative lack of mobility.[20] The increased prevalence of medial meniscus diseases relative to the lateral meniscus in the current study has been linked to this condition.

A strong correlation between OA and medial meniscus extrusion was discovered. Medial meniscus extrusion was seen more often in patients with OA than in those without the condition. In a review made by Ghouri et al[21], it was identified that meniscal extrusion is a risk factor for knee OA cartilage structural progression independently of age, gender, and BMI.

Osteoarthritis and both medial and lateral meniscus volume did not significantly correlate in the current research. Previous studies indicate that a greater initial meniscal volume and alterations in volume over time are associated with OA.[22,23] Individual anatomical variations in the meniscus have been documented in healthy knees.[24] To the authors' knowledge, there is no established normal range for meniscus volume for this reason. Given the absence of a standard range for meniscus volume, it was determined that a solitary measurement in a cross-sectional study would be inadequate and that temporal changes would provide more significant knowledge. This has been assumed to be the cause of the lack of any correlation between OA and meniscus volume.

A theory states that the extruded meniscus outside the joint edge has the chance to expand since the bones that comprise the joint do not compress it.[25] Okazaki et al[26] and Nebelung et al[27] established that alterations in meniscus volume, both in vitro and in vivo, could be triggered by variations in load on the meniscus. Baseline meniscus extrusion was positively correlated with changes in meniscus volume, according to Xu et al[23], but they found no correlation between changes in meniscus volume and radiographic knee OA. It can be concluded from this data that changes in meniscus volume are not the mechanism by which meniscus extrusion affects OA. Therefore, it is possible to think that an extrusion of the meniscus first leads to a larger meniscus, which then causes radiographic knee OA. According to Xu et al[23], this theory requires testing in cohorts with younger participants.

The findings of this investigation, which excluded those aged 65 and older, confirm that meniscal extrusion influences OA before alterations in meniscus volume occur. Nevertheless, due to the retrospective nature of this investigation, the impact of extrusion on meniscus volume could not be assessed. This hypothesis requires validation through extensive randomized controlled studies, including young patients.

There were several limitations to this study. The main limitation of this study is its retrospective design. The impact of temporal variations in meniscus volume on OA was not detected. The second limitation is that clinical findings and concerns from patients were not included in the study. Thirdly, the actual incidence of meniscal extrusion may be understated because all MRI studies evaluated extrusion while the subject was supine and not bearing any weight.

Osteoarthritis impacts the entire joint and is a leading cause of disability globally. Thus, it is critical to identify it early and restrict its progression. In cases of meniscal disorders, including meniscal extrusion, even in the absence of OA symptoms, the patient should be considered at risk for OA and monitored accordingly. Given the aging population that is predicted to rise over the next several years, this strategy will also help to manage the condition more affordably.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study was approved by the Ethics Committee of Bandırma Onyedi Eylül University School of Medicine (Approval no.: 2024-12-05; Date: January 20, 2025).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Ö.T.; Design – Ö.T.; Supervision – E.K.; Resources – B.T.; Materials – Ö.T., E.T.; Data Collection and/or Processing – Ö.T., B.T.; Analysis and/or Interpretation – Ö.T., E.T., E.K.; Literature Search – Ö.T., B.T.; Writing Manuscript – Ö.T.; Critical Review – E.T., E.K.

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REFERENCES

1. Gao KT, Xie E, Chen V, et al. Large-scale analysis of meniscus morphology as risk factor for knee osteoarthritis. *Arthritis Rheumatol*. 2023;75(11):1958-1968. [CrossRef]
2. Jang S, Lee K, Ju JH. Recent updates of diagnosis, pathophysiology, and treatment on osteoarthritis of the knee. *Int J Mol Sci*. 2021;22(5):2619. [CrossRef]
3. Magnusson K, Turkiewicz A, Snoeker B, Hughes V, Englund M. The heritability of doctor-diagnosed traumatic and degenerative meniscus tears. *Osteoarthr Cartil*. 2021;29(7):979-985. [CrossRef]
4. Anderson AS, Loeser RF. Why is OA an age-related disease? *Best Pract Res Clin Rheumatol*. 2010;24(1):15-26. [CrossRef]
5. Roemer FW, Collins J, Kwoh CK, et al. MRI-based screening for structural definition of eligibility in clinical DMOAD trials: Rapid Osteoarthritis MRI Eligibility Score (ROAMES). *Osteoarthr Cartil*. 2020;28(1):71-81. [CrossRef]
6. Shrive NG, O'Connor JJ, Goodfellow JW. Load-bearing in the knee joint. *Clin Orthop Relat Res*. 1978 Mar-Apr;(131):279-287. [CrossRef]

7. Hede A, Larsen E, Sandberg H. The long term outcome of open total and partial meniscectomy related to the quantity and site of the meniscus removed. *Int Orthop*. 1992;16(2):122-125. [CrossRef]
8. Jaureguito JW, Elliot JS, Lietner T, Dixon LB, Reider B. The effects of arthroscopic partial lateral meniscectomy in an otherwise normal knee: a retrospective review of functional, clinical, and radiographic results. *Arthroscopy*. 1995;11(1):29-36. [CrossRef]
9. Sharma L, Eckstein F, Song J, et al. Relationship of meniscal damage, meniscal extrusion, malalignment, and joint laxity to subsequent cartilage loss in osteoarthritic knees. *Arthritis Rheum*. 2008;58(6):1716-1726. [CrossRef]
10. Siorpaes K, Wenger A, Bloecker K, Wirth W, Hudelmaier M, Eckstein F. Interobserver reproducibility of quantitative meniscus analysis using coronal multiplanar DESS and IWTSE MR imaging. *Magn Reson Med*. 2012;67(5):1419-1426. [CrossRef]
11. Wirth W, Frobell RB, Souza RB, et al. A three-dimensional quantitative method to measure meniscus shape, position, and signal intensity using MR images: a pilot study and preliminary results in knee osteoarthritis. *Magn Reson Med*. 2010;63(5):1162-1171. [CrossRef]
12. Bowers ME, Tung GA, Fleming BC, Crisco JJ, Rey J. Quantification of meniscal volume by segmentation of 3T magnetic resonance images. *J Biomech*. 2007;40(12):2811-2815. [CrossRef]
13. Hunter DJ, Guermazi A, Lo GH, et al. Evolution of semi-quantitative whole joint assessment of knee OA: MOAKS (MRI Osteoarthritis Knee Score). *Osteoarthr Cartil*. 2011;19(8):990-1002. [CrossRef]
14. Liu Y, Du G, Liu J. Meniscal anterior and posterior horn heights are associated with MRI-defined knee structural abnormalities in middle-aged and elderly patients with symptomatic knee osteoarthritis. *BMC Musculoskelet Disord*. 2022;23(1):1-10. [CrossRef]
15. Atik I, Gul E, Atik S. Evaluation of the relationship between Knee osteoarthritis and meniscus Pathologies. *Malawi Med J*. 2024;36(1):48-52. [CrossRef]
16. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis*. 1957;16(4):494-502. [CrossRef]
17. Yushkevich PA, Piven J, Hazlett HC, et al. User-guided 3D active contour segmentation of anatomical structures: significantly improved efficiency and reliability. *Neuroimage*. 2006;31(3):1116-1128. [CrossRef]
18. Aylanç N, Ertem ŞB. Medial meniskal ekstrüzyon İLE dejeneratİf artrİtİn NEDEN SONUÇ İLİŞKİSİ bakimindan İncelenmesİ investigation of the cause-effect relationship between degenerative arthritis and medial meniscal extrusion. *Bozok Tıp Derg*. 2020;10(2):16-22. [CrossRef]
19. Özdemir M, Kavak R. Meniscal lesions in geriatric population: prevalence and association with knee osteoarthritis. *Curr Aging Sci*. 2019;12(1):67-73. [CrossRef]
20. Papalia GF, Za P, Saccone L, et al. Meniscal extrusion: risk factors and diagnostic tools to predict early osteoarthritis. *Orthop Rev (Pavia)*. 2023;15:74881. [CrossRef]
21. Ghouri A, Muzumdar S, Barr AJ, et al. The relationship between meniscal pathologies, cartilage loss, joint replacement and pain in knee osteoarthritis: a systematic review. *Osteoarthr Cartil*. 2022;30(10):1287-1327. [CrossRef]
22. Xu D, Van Der Voet J, Hansson NM, et al. Association between meniscal volume and development of knee osteoarthritis. *Rheumatology (Oxford)*. 2021;60(3):1392-1399. [CrossRef]
23. Xu D, van der Voet J, Waarsing JH, et al. Are changes in meniscus volume and extrusion associated to knee osteoarthritis development? A structural equation model. *Osteoarthr Cartil*. 2021;29(10):1426-1431. [CrossRef]
24. Fox AJS, Wanivenhaus F, Burge AJ, Warren RF, Rodeo SA. The human meniscus: a review of anatomy, function, injury, and advances in treatment. *Clin Anat*. 2015;28(2):269-287. [CrossRef]
25. Wenger A, Wirth W, Hudelmaier M, et al. Meniscus body position, size, and shape in persons with and persons without radiographic knee osteoarthritis: quantitative analyses of knee magnetic resonance images from the osteoarthritis initiative. *Arthritis Rheum*. 2013;65(7):1804-1811. [CrossRef]
26. Okazaki Y, Furumatsu T, Yamauchi T, et al. Medial meniscus posterior root repair restores the intra-articular volume of the medial meniscus by decreasing posteromedial extrusion at knee flexion. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(11):3435-3442. [CrossRef]
27. Nebelung S, Dötsch L, Shah D, et al. functional MRi Mapping of Human meniscus functionality and its Relation to Degeneration. *Sci Rep*. 2020;10(1):2499. [CrossRef]