

MRI ASSESSMENT OF POPLITEUS TENDON VARIATIONS AND THEIR ASSOCIATION WITH LATERAL MENISCUS ABNORMALITIES IN ADULTS

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Abstract

Background The popliteus tendon plays an important role in the stabilization of the posterolateral aspect of the knee joint. Some anatomic relationships exist between the popliteus tendon, the lateral meniscus, and the meniscopopliteal fascicles. There are some morphological variations in the popliteus tendon that are associated with abnormalities in the lateral meniscus and may be diagnosed by MRI.

Objectives To assess the morphologic changes of the popliteus tendon with MRI examination and its relationship to lateral meniscal lesions in adult population.

Methods The descriptive cross-sectional research was carried out in radiology units of selected tertiary care hospitals in Lahore. 96 patients were selected by using non-probability consecutive sampling technique and their knee MRI was performed. Morphological characteristics of popliteus tendon, meniscopopliteal fascicles, and lateral meniscal abnormalities including degeneration, Stoller signal intensity grade, tear type, and extrusion were identified with the help of MRIs. Data were analyzed by using statistical package for social sciences (SPSS) version 26. Descriptive statistics were computed and relationships among categorical variables were determined by the chi-square test. P value <0.05 was taken as statistically significant.

Results Mean age of participants was 40.53 ± 13.67 years with age range being 18-63 years. Normal morphology of the popliteus tendon was observed in 55 (57.3%) cases, while 18 (18.8%) cases had accessory slip, 14 (14.6%) had bifid tendon and 9 (9.4%) had split tendons. Meniscal degeneration was present in 65 (67.7%) patients; Grade III Stoller signal intensity score was observed in 39 (40.6%) patients. Significant associations were observed between popliteus tendon morphology and degenerative changes of meniscus ($\chi^2=24.914$, $df=3$, $p<0.001$); Stoller signal intensity score ($\chi^2=48.952$, $df=9$, $p<0.001$); meniscal tear pattern ($\chi^2=58.813$, $df=12$, $p<0.001$); meniscal extrusion ($\chi^2=42.784$, $df=3$, $p<0.001$); and meniscocapsular separation ($\chi^2=32.105$, $df=3$, $p<0.001$).

Conclusion Significant correlations were observed between morphological differences of the popliteus tendon and different MRI results of the lateral meniscus. In the MRI analysis of lateral knee injury, consideration should be given to the evaluation of the morphology of the popliteus tendon and its accompanying structures. Further multicenter studies are needed to clarify their clinical significance.

1. INTRODUCTION

The knee is a weight-bearing joint characterized by the need for stability, provided by the interplay of osseous, ligamentous, tendinous, and meniscal tissues. Several stabilizing tissues are located in the posterolateral area of the knee joint and serve as the basis for its rotational and translational stability. The tendon of the popliteus muscle is one of the anatomical structures having a close connection with the lateral meniscus. [1]

The popliteus muscle-tendon complex participates in the dynamic stability of the knee joint and contributes to knee flexion from the position of full extension.[2] As for its anatomical and functional connections, the popliteus tendon is related to posterolateral structures of the knee joint and participates in tibial rotation regulation. [2] The lateral meniscus is less fixed than the medial meniscus because of the presence of the popliteal hiatus. [3-5]

The popliteus tendon is very closely connected to the lateral meniscus via the popliteomeniscal fascicles. Such tissues are important for stabilizing the posterior horn and lateral meniscus when the knee joint move. Anatomical variation within the popliteus tendon and its associated structures has been described, including accessory and other variant tendon configurations. [6,7]

MRI provides multiplanar visualization of the soft-tissue structures of the knee and is widely used for assessment of meniscal, ligamentous, and posterolateral knee abnormalities. [8-10] MRI can demonstrate changes in meniscal signal intensity, degeneration, tears, extrusion, and abnormalities of the popliteomeniscal structures.

Previous studies have described the anatomy and biomechanics of the popliteus tendon and lateral meniscus; however, the relationship between morphological variations of the popliteus tendon and different MRI manifestations of lateral meniscal pathology has received comparatively limited attention. [6,7,11]

The lateral meniscus may also demonstrate instability or abnormal mobility in association with abnormalities of the popliteomeniscal fascicles and other posterolateral stabilizers. Recent imaging and biomechanical literature

suggests that abnormalities of these structures may be relevant to lateral meniscal pathology, although MRI assessment of lateral meniscal instability remains challenging. [12-14]

Therefore, the present study was conducted to assess morphological variations of the popliteus tendon on MRI and determine their association with abnormalities of the lateral meniscus in adults.

2. Materials and Methods

2.1 Study Design and Setting

This cross-sectional analytical study was carried out at the radiology departments of selected tertiary care hospitals of Lahore, Pakistan. This research was completed within a period of six months, which included data collection, MRI interpretation, data analysis, and reporting.

2.2 Study Population and Sample Size

The target population consisted of adult patients with MRI evaluation of the knee joints.

The sample size was determined by the single-proportion method of the population with 95% confidence level, population proportion of 0.5, and 10% margin of error, resulting in a sample of 96 individuals. Though the intended sample size was 100 MRIs, the analyzed data consisted of 96 individuals.

2.3 Sampling Technique

Non-probability consecutive sampling was used. Eligible MRI examinations were included consecutively according to the predefined selection criteria.

2.4 Inclusion Criteria

Participants were eligible if they:

- were adults aged 18–63 years;
- had undergone knee MRI for a clinical indication;
- had symptoms such as knee pain, suspected meniscal injury, or degenerative changes; and
- had MRI images of adequate quality for assessment of the popliteus tendon and lateral meniscus.

2.5 Exclusion Criteria

MRI examinations were excluded in the presence of:

- severe grade IV osteoarthritis;
- recent acute knee injury within six months;
- incomplete MRI examinations; or
- systemic joint condition in the knee, like rheumatoid arthritis.

2.6 Ethical Considerations

Ethical approval was obtained from the institutional review boards of the respective hospitals before conducting the research. Anonymity was guaranteed, and personal information was not captured during the data collection process.

2.7 MRI Protocol and Image Assessment

MRI scans were conducted using either 1.5T or 3.0T MRI machines. This consisted of acquiring axial, sagittal, and coronal fat saturated proton density images together with T1-weighted images. Slice thickness ranged from 3–4 mm, with no interslice gap.

MRI examinations were assessed for:

1. Popliteus tendon morphology
2. Popliteus tendon appearance
3. Meniscopopliteal fascicles
4. Lateral meniscal signal intensity
5. Meniscal degeneration
6. Meniscal tear pattern
7. Meniscal extrusion
8. Meniscocapsular separation

Popliteus tendon anatomy was divided into single tendon, accessory slip, bifid tendon, and split tendon.

Appearance of the tendon was graded as normal, tendinosis, and tendon thickening.

Meniscopopliteal fascicles were categorized as intact or disrupted.

Lateral meniscal signal intensity was assessed using the Stoller grading system. Meniscal extrusion greater than 3 mm was considered abnormal according to the study protocol.

2.8 Data Collection

The demographic and clinical data collected comprised age, gender, body mass index (BMI), complaint on presentation, duration of complaints, prior trauma history, swelling, locking, instability, and surgery.

MRI findings were documented by means of a data collection form.

2.9 Statistical Analysis

Statistical Package for the Social Sciences (SPSS) was used in data analysis, version 26. For continuous variables, mean and standard deviation was used as the summary statistics whereas categorical variables were summarized using frequency and percentage. Association between popliteus tendon morphology variation and lateral meniscal abnormalities was determined using Pearson's Chi Square test where $p < 0.05$ was considered statistically significant.

3. Results

3.1 Demographic Characteristics

A total of 96 participants were included in the final analysis. The mean age was 40.53 ± 13.67 years, with a range of 18–63 years.

There were 48 (50.0%) male and 48 (50.0%) female participants.

Regarding BMI, 36 (37.5%) participants had a normal BMI, 52 (54.2%) were overweight, and 8 (8.3%) were obese.

Table 1. Demographic characteristics of participants

Variable	Category	n (%)
Sex	Male	48 (50.0)
	Female	48 (50.0)
BMI	Normal	36 (37.5)
	Overweight	52 (54.2)
	Obese	8 (8.3)

3.2 Clinical Characteristics

The most common presenting complaint was knee pain, reported in 41 (42.7%) participants, followed by sports/trauma-related pain in 22 (22.9%). Pain with swelling and mechanical symptoms were each reported in 10 (10.4%) participants.

A history of trauma was present in 44 (45.8%) participants. Swelling was reported in 75 (78.1%), locking in 37 (38.5%), and instability in 42 (43.8%) participants. Previous knee surgery was reported in 15 (15.6%).

3.3 Popliteus Tendon MRI Findings

Normal single tendon morphology was the most frequent finding, observed in 55 (57.3%) participants. An accessory slip was identified in 18 (18.8%), bifid tendon in 14 (14.6%), and split tendon in 9 (9.4%).

Regarding tendon appearance, 49 (51.0%) participants had normal tendon appearance, 26 (27.1%) demonstrated tendinosis, and 21 (21.9%) demonstrated tendon thickening.

Meniscopopliteal fascicles were intact in 64 (66.7%) participants and disrupted in 32 (33.3%).

Table 2. Popliteus tendon MRI findings

MRI finding	Category	n (%)
Tendon morphology	Normal single tendon	55 (57.3)
	Accessory slip	18 (18.8)
	Bifid tendon	14 (14.6)
	Split tendon	9 (9.4)
Tendon appearance	Normal	49 (51.0)
	Tendinosis	26 (27.1)
	Tendon thickening	21 (21.9)
Meniscopopliteal fascicles	Intact	64 (66.7)
	Disrupted	32 (33.3)

3.4 Lateral Meniscus MRI Findings

Meniscal degeneration was present in 65 (67.7%) participants.

According to the Stoller grading system, Grade 0 was observed in 12 (12.5%), Grade I in 19

(19.8%), Grade II in 26 (27.1%), and Grade III in 39 (40.6%) participants.

Horizontal tears and complex tears were each observed in 11 (11.5%) participants, radial tears in 9 (9.4%), and vertical tears in 8 (8.3%). Fifty-seven

(59.4%) participants had no Grade III tear pattern.

Meniscal extrusion greater than 3 mm was present in 39 (40.6%) participants, while meniscocapsular separation was identified in 24 (25.0%).

Table 3. Lateral meniscus MRI findings

Variable	Category	n (%)
Stoller grade	Grade 0	12 (12.5)
	Grade I	19 (19.8)
	Grade II	26 (27.1)
	Grade III	39 (40.6)
Meniscal degeneration	No	31 (32.3)
	Yes	65 (67.7)
Tear type	No Grade III tear	57 (59.4)
	Horizontal	11 (11.5)
	Vertical	8 (8.3)
	Radial	9 (9.4)
	Complex	11 (11.5)
Extrusion >3 mm	No	57 (59.4)
	Yes	39 (40.6)
Meniscocapsular separation	No	72 (75.0)
	Yes	24 (25.0)

3.5 Association Between Popliteus Tendon Morphology and Meniscal Degeneration

A statistically significant association was observed between popliteus tendon morphological variation and meniscal degeneration ($\chi^2=24.914$, $df=3$, $p<0.001$).

Meniscal degeneration was present in 26 (47.3%) participants with normal single tendon morphology, 17 (94.4%) with an accessory slip, 14 (100%) with a bifid tendon, and 8 (88.9%) with a split tendon.

Table 4. Association between popliteus tendon morphology and meniscal degeneration

Popliteus tendon morphology	No degeneration n (%)	Degeneration n (%)	Total
Normal single tendon	29 (52.7)	26 (47.3)	55
Accessory slip	1 (5.6)	17 (94.4)	18
Bifid tendon	0 (0.0)	14 (100.0)	14
Split tendon	1 (11.1)	8 (88.9)	9

Pearson $\chi^2=24.914$, $df=3$, $p<0.001$.

3.6 Association with Stoller Signal Intensity

A statistically significant association was observed between popliteus tendon morphology and Stoller signal intensity grade ($\chi^2=48.952$, $df=9$, $p<0.001$). Grade III signal intensity was observed in 8 (14.5%) participants with normal single tendon morphology, 10 (55.6%) with an accessory slip, 14 (100%) with a bifid tendon, and 7 (77.8%) with a split tendon.

3.7 Association with Meniscal Tear Type

Popliteus tendon morphological variation was significantly associated with meniscal tear type ($\chi^2=58.813$, $df=12$, $p<0.001$).

Complex tears were observed particularly frequently among participants with bifid tendon morphology, where 6 (42.9%) participants demonstrated complex tears.

3.8 Association with Meniscal Extrusion

A statistically significant association was identified between popliteus tendon morphology and meniscal extrusion greater than 3 mm ($\chi^2=42.784$, $df=3$, $p<0.001$).

Extrusion was present in 8 (14.5%) participants with normal single tendon morphology, 10 (55.6%) with an accessory slip, 14 (100%) with a bifid tendon, and 7 (77.8%) with a split tendon.

3.9 Association with Meniscocapsular Separation

A statistically significant association was observed between popliteus tendon morphology and meniscocapsular separation ($\chi^2=32.105$, $df=3$, $p<0.001$).

Meniscocapsular separation was present in 6 (10.9%) participants with normal single tendon morphology, 2 (11.1%) with an accessory slip, 10 (71.4%) with a bifid tendon, and 6 (66.7%) with a split tendon.

4. Discussion

This study investigated morphological variations of the popliteus tendon on MRI and relationship with lateral meniscal degenerative changes in adult population. The study established statistically significant relationships between morphology of popliteus tendon and meniscal degeneration, Stoller signal intensity, type of tear, meniscal extrusion and meniscocapsular separation.

MRI is one of the most common imaging methods used in evaluating the knee joint anatomy because of high accuracy of visualization of internal knee structures without the need for invasive procedure. Popliteus tendon and its surroundings may be studied with help of multiplanar MRI. [8,10,15]

Single tendon morphology was the most common popliteus tendon structure observed in this study and accounted for 57.3% of patients. Accessory slip, bifid tendon and split tendon morphology were also detected. Anatomical studies reported significant variability of popliteus tendon morphology and its importance for diagnostic and surgical purposes. [6,16,17]

A significant correlation between popliteus tendon anatomy and meniscal degeneration was

shown in this study. 47.3% of the individuals with normal single tendon were seen to have meniscal degeneration while 94.4%, 100%, and 88.9% of the individuals with popliteus tendon accessories such as accessory slip, bifid tendon, and split tendon had degeneration of the menisci.

Anatomical association between the popliteus tendon structure and lateral meniscus forms the basis for studying this correlation. Lateral meniscus is supported by popliteus tendon, popliteomeniscal fascicles, joint capsule, and other surrounding structures. Variations or abnormalities within this stabilizing complex may be relevant to the mechanical environment of the lateral meniscus. [3,5,12]

A significant association was also observed between popliteus tendon morphology and Stoller signal intensity. Grade III signal intensity was more frequent among participants with variant tendon morphology. Because Grade III signal represents signal extending to the articular surface and is associated with meniscal tearing, this finding is consistent with the observed association between tendon morphology and meniscal structural abnormalities.

The association between popliteus tendon morphology and meniscal tear type was also statistically significant. Complex tears were particularly frequent in participants with bifid tendon morphology. Previous literature has emphasized that lateral meniscal pathology may be influenced by the interaction of the meniscus with the surrounding posterolateral stabilizers rather than by isolated meniscal abnormalities alone. [12-14]

Meniscal extrusion greater than 3 mm was significantly associated with popliteus tendon morphology in the present study. Extrusion was identified in 14.5% of participants with normal single tendon morphology compared with 55.6% of those with accessory slip, 100% with bifid tendon, and 77.8% with split tendon morphology. The association between popliteus tendon morphology and meniscocapsular separation was similarly significant. Meniscocapsular separation was observed in 71.4% of participants with bifid tendon morphology and 66.7% with split tendon

morphology, compared with 10.9% with normal single tendon morphology.

These findings are relevant to the established role of the popliteomeniscal fascicles in maintaining lateral meniscal stability. Di Vico et al. reported that tears involving the popliteomeniscal fascicles may be associated with lateral meniscus instability, while Suganuma and Mochizuki demonstrated that abnormalities of the popliteomeniscal fascicles may be associated with abnormal mobility of the posterior horn of the lateral meniscus. [12,14]

These results are in agreement with the literature which describes the hypermobility and instability of the lateral meniscus, as well as the role of the popliteus tendon and related structures for stabilizing the lateral meniscus. [12,13,18]

Azzopardi et al. emphasized the importance of correctly identifying normal and pathological structures related to the popliteus, while D'Addona et al. described the importance of the popliteomeniscal fascicles. [19,20]

The statistical significance of the associations found in the current study does not mean that the results are causal. The cross-sectional design of the study is unable to determine whether there is a chronological relation between the development of popliteus tendon morphology alterations and the pathology of the meniscus. Also, anatomical variations may be considered as part of anatomic variability of structures, not a pathological condition. It was noted in previous studies. [6,13,17]

The results can have implications for MRI reporting as well. Traditionally, the evaluation of knee MRIs is done based on ligaments and any significant meniscal injuries that are noted. Abnormalities related to the popliteus tendon, popliteomeniscal fascicles, and meniscocapsular connections should be considered in cases of lateral knee pain and mechanical symptoms or when lateral meniscal instability is suspected. [13,14]

This study provides MRI data about the relationship between the morphological features of the popliteus tendon and several lateral meniscal abnormalities. Still, additional

multicenter studies are required to prove the clinical relevance of such relationships.

5. Conclusion

The associations between variations in the morphology of the popliteus tendon and MRI-detected features of the lateral meniscus have been shown to be statistically significant, including degeneration of the meniscus, Stoller signal intensity, type of tear, meniscus extrusion, and meniscocapsular separation.

Normal single tendon morphology was seen in most cases, while accessory slip, bifid tendon, and split tendon were the main variations found.

These results highlight the significance of a comprehensive evaluation of the popliteus tendon and its posterior lateral attachments in MRI examination of the lateral knee. Nevertheless, due to the nature of the study, these associations should not be considered to be causative.

6. Limitations

This study has several limitations. First, the sample size was quite small, and subjects were selected from tertiary-care centers in Lahore.

Second, this study has a cross-sectional design, thus making it difficult to establish temporal or causal association between popliteus tendon morphology and lateral meniscal pathology.

Third, the findings on MRI were not compared with those on arthroscopy, which could have served as a confirmatory technique for intra-articular lesions.

Fourth, no functional assessment of the clinical outcome was made; thus, no correlation could be established between MRI and clinical features.

7. Recommendations

Further research should use populations that are larger and multicentric in nature in order to confirm the relationships found.

Prospective studies could provide more information on the relationship between time and popliteus tendon morphology versus lateral meniscal abnormalities.

The correlation of MRI results with those found arthroscopically will also help to understand the

importance of popliteus tendon variations in clinical practice.

Also, future MRI studies need to focus on assessing the popliteus tendon, popliteomeniscal fascicles, and meniscocapsular structures in patients with lateral meniscal instability.

8. Declarations

Ethics Approval

Ethical approval was gained through the institutional review boards of the participating hospitals prior to data collection. Confidentiality of patients was ensured during the research process.

Informed Consent

Informed consent was obtained from the participants in accordance with the research protocol.

Funding

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Conflict of Interest

The authors declare no conflict of interest related to this study.

Author Contributions

Author contributions should be completed according to the actual contribution of each author before submission.

Data Availability

Data availability should be stated according to the policies of the target journal and the requirements of the participating institutions.

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