Original Article

Accuracy of Knee MRI Findings in Detecting Soft Tissue Injury, Taking Arthroscopy as the Gold Standard

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Abstract

Objective: To assess the diagnostic validity of Magnetic Resonance Imaging (MRI) in detecting soft tissue knee injuries using arthroscopy as the gold standard.

Study Design and Setting: A cross-sectional validation study was conducted at Khyber Teaching Hospital, Peshawar.

Methodology: A total of 192 patients with clinical suspicion of soft tissue knee injury were enrolled using non-probability consecutive sampling for six months from 1st January 2025 to 30th June 2025. Inclusion criteria involved patients aged 18–60 years presenting with knee pain (VAS >4) and a popping sound, with normal X-ray findings. MRI scans were interpreted for the presence of soft tissue tears based on hyperintense signals on T2-weighted images and fiber discontinuity. All patients subsequently underwent arthroscopic evaluation. The diagnostic accuracy of MRI was determined using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Cohen's Kappa for agreement.

Results: MRI showed high sensitivity for the medial meniscus (91.8%), anterior cruciate ligament (88.6%), and posterior cruciate ligament (83.3%), while the lateral meniscus had moderate sensitivity (68.2%). Specificity ranged from 74.3% (medial meniscus) to 86.7% (lateral meniscus). Agreement between MRI and arthroscopy was substantial for medial meniscus injuries (ê = 0.81) and moderate for anterior cruciate ligament, posterior cruciate ligament, and lateral meniscus.

Conclusion: MRI has high diagnostic utility and a substantial agreement with arthroscopy, specifically for anterior cruciate ligament and medial meniscus injuries. Given its non-invasive nature and strong predictive validity, MRI should be considered an effective first-line diagnostic tool when evaluating soft tissue knee injuries.

Keywords: Anterior Cruciate Ligament Injuries, Arthroscopy, Diagnostic Imaging, Knee Injuries,

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INTRODUCTION

Knee injuries are among the most common injuries, accounting for approximately 40% of all sports injuries.[1] Soft tissue injuries to the menisci and cruciate ligaments are most common. There are almost 200,000 anterior cruciate ligament (ACL) Injuries annually in the United States alone. The meniscal tears occur at a rate of 60-70 per 100,000 persons per year, usually requiring surgical intervention.[2] Accurate diagnosis of the injuries is necessary for the timely management and prevention of long-lasting complications, including chronic instability, degeneration, and osteoarthritis.[3] Imaging is a key tool in this clinical challenge, with MRI and arthroscopy being the two most common imaging used for knee injuries.[4]

Knee injuries are one of the most common areas of musculoskeletal pathology in orthopedic practice, resulting from direct trauma, sports, and degenerative changes in the knee joint.[5] Quick and accurate identification of internal knee derangements leads to appropriate therapeutic measures and better outcomes. In addition to various imaging techniques available for the knee, magnetic resonance imaging (MRI) has evolved as the preferred imaging tool whcih non-invasively evaluate most of the soft tissue structures of the knee, including the menisci, cruciate ligaments, articular cartilage, and surrounding soft tissues.[6]

MRI offers outstanding contrast resolution and multiplanar imaging as compared to other imaging techniques, which makes it particularly helpful for detecting subtle abnormalities. There has been a significant acceptance of MRI in clinical practice as it is completely non-invasive and does not use ionizing radiation, which is especially important for visualizing soft tissues in detail.[7] Despite these advantages, there is still a debate on the reliability and diagnostic accuracy of MRI findings in comparison to arthroscopy, which is considered the gold standard for visualizing and diagnosing intra-articular knee pathologies.

Arthroscopy is a minimally invasive surgical technique that enables direct visualization of the of the knee. This can provide high diagnostic accuracy and the possibility of immediate treatment.[8] Arthroscopy carries inherent surgical risks, including infection, hemarthrosis, and postoperative stiffness, and its invasive nature and associated costs limit its suitability as a routine diagnostic procedure unless a therapeutic intervention is planned.[9]

Numerous studies have compared MRI findings with arthroscopic results, yielding variable outcomes. One such study demonstrated high sensitivity and specificity of MRI in detecting meniscal tears and ligamentous injuries.[10] Other studies have reported variability in diagnostic accuracy depending on factors such as image quality, MRI protocols, the expertise of the interpreting radiologist, and the type of injury. A meta-analysis by Wang et al. (2023) demonstrated pooled sensitivity and specificity of 93% and 88%, respectively, for MRI in detecting ACL tears, while for meniscal injuries the sensitivity was 88% and specificity 94%.[11] Consequently, false-positive and false-negative results do occur, as in clinical assessment, and MRI findings should therefore be interpreted with caution rather than relied upon in isolation.

In addition, the timing of MRI following injury influences diagnostic accuracy. Acute injuries are often associated with joint effusion and edema, which can obscure soft-tissue visualization, while chronic changes may mimic degenerative tears and lead to misinterpretation.[12] Moreover, partial tears and subtle lesions may not be detected on MRI but can be clearly identified during arthroscopy. These limitations necessitate careful clinical correlation and often justify arthroscopic confirmation, particularly in symptomatic patients with inconclusive or equivocal MRI findings.

Recent advances in MRI technology, including higher field strength imaging (3-T), 3D isotropic sequences, and improved coil designs, have shown promising improvements in image quality and diagnostic performance. However, access to these technologies remains limited, particularly in resource-constrained settings, restricting their widespread application. Therefore, evaluating the validity of conventional MRI in routine clinical practice by comparing its diagnostic yield with arthroscopy remains clinically relevant. Assessing the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of MRI provides important insight into its diagnostic accuracy and aids clinicians in informed decision-making regarding management and treatment strategies. Furthermore, this study aimed to determine whether MRI can function as a standalone diagnostic modality or whether arthroscopy remains an essential component of the diagnostic algorithm for internal derangements of the knee. Using arthroscopy as the gold standard, the present study sought to establish the diagnostic accuracy of MRI in detecting soft-tissue injuries of the knee.

METHODOLOGY

This study was a cross-sectional validation study conducted in the Department of Orthopedics at Khyber Teaching Hospital, Peshawar. The total study duration was six months from 1st January 2025 to 30th June 2025. Ethical approval for this study was obtained from the Institutional Research and Ethical Review Board (IREB) of Khyber Medical College, Peshawar. The study was reviewed and approved under approval number 1052/DME/KMC, dated: 13th-12-2024.

The sample size was calculated using Buderer's formula based on the following parameters: an anticipated prevalence of medial meniscus tear of 36.0%, expected MRI sensitivity of 76.5%, specificity of 90.1%, a margin of error of 10%, and a confidence level of 95%.[13] The required sample size was calculated to be 192 participants.

A non-probability consecutive sampling technique was employed for participant selection. Patients aged 18 to 60 years of either gender, presenting with symptoms suggestive of soft tissue knee injury, were included in the study. Exclusion criteria included patients with a prior history of any intervention on the same knee, those with contraindications to MRI or arthroscopy, dislocated knee joints, or associated femoral condyle or tibial plateau fractures.

After obtaining informed consent, eligible patients were recruited from the outpatient department. Each patient's baseline demographic data, age, gender, BMI, duration of complaints, side of involvement (right/left), residence (urban/rural), educational background, profession, and socioeconomic status were recorded on a structured proforma. The radiology department used a 1.5 Tesla scanner to perform MRIs. Imaging was done using a 3 mm slice thickness in the axial, coronal, and sagittal planes. Proton density (PD), T1, T2, STIR (Short Tau Inversion Recovery), and PD with fat suppression were among the sequences. Soft tissue knee injury was defined as the presence of pain rated above 4 on the Visual Analogue Scale (VAS), accompanied by a popping sound in the knee joint, with a normal radiograph. Among the soft tissue structures evaluated were the medial meniscus (MM), lateral meniscus (LM), posterior cruciate ligament (PCL), and anterior cruciate ligament (ACL).

MRI findings for tears were characterized by discontinuity in the ACL, PCL, MM, or LM fibers and increased signal intensity on T2-weighted images. One senior radiologist with at least five years of post-fellowship expertise evaluated all MRIs.

Following MRI, all participants underwent diagnostic arthroscopy under spinal or general anesthesia. A consultant orthopedic surgeon with specialized training in knee arthroscopy performed arthroscopy. Any disruption in the continuity of the ACL, PCL, medial meniscus (MM), or lateral meniscus (LM) fibers directly visualized through arthroscopy during a comprehensive intraoperative examination of the knee joint was considered a positive finding for a tear. Arthroscopic findings were regarded as the gold standard against which MRI results were compared.

Using arthroscopy as the reference standard, the primary objective was to determine the diagnostic accuracy of MRI in detecting soft-tissue injuries of the knee. Diagnostic performance was assessed using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Sensitivity was defined as the ability of MRI to correctly identify patients with arthroscopically confirmed soft-tissue injuries, while specificity represented its ability to identify patients without such injuries correctly. The PPV was calculated as the proportion of MRI-positive cases that were confirmed as true injuries on arthroscopy, whereas the NPV represented the proportion of MRI-negative cases that were verified as injury-free on arthroscopy. Overall diagnostic accuracy was calculated by dividing the sum of true-positive and true-negative results by the total number of cases.

SPSS (Version 25) was used to analyze the data. The normality of continuous variables such as age, body mass index (BMI), and symptom duration was evaluated using the Shapiro-Wilk test. Frequencies and percentages were used to summarize qualitative data, whereas means ± standard deviations were used to convey quantitative variables that were normally distributed. Two-by-two contingency tables were constructed to compare the diagnostic performance of MRI with arthroscopy, which was considered the gold standard. Standard formulas were applied to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy from these tables. The degree of agreement between MRI and arthroscopy results for injuries to the medial meniscus (MM), lateral meniscus (LM), posterior cruciate ligament (PCL), and anterior cruciate ligament (ACL) was also evaluated using Cohen's Kappa statistic. P-values = 0.05 were regarded as significant.

RESULTS

The study included 192 patients with suspected soft tissue knee injuries. The average age of participants was 37.8 ± 10.4 years. The mean BMI of the study population was 26.3 ± 4.1 kg/m². The average duration of symptoms before presentation was 18.6 ± 9.7 days, with most patients reporting symptoms lasting between 8 to 30 days. The right knee was more commonly involved than the left. Educationally, a considerable proportion of patients had completed intermediate or higher education, while others had education up to matric or no formal schooling. In terms of occupation, the population included a mix of unemployed individuals or housewives, laborers, skilled workers, and students. Most participants belonged to the middle socioeconomic class, followed by low and high-income groups. (Table 1)

The diagnostic performance of MRI in detecting soft tissue injuries of the knee was assessed using arthroscopy as the gold standard. Sensitivity, specificity, and overall accuracy were calculated for each structure examined. Among the evaluated structures, the medial meniscus showed the highest diagnostic performance in terms of sensitivity and accuracy. Both the anterior and posterior cruciate ligaments also demonstrated high sensitivity and acceptable levels of specificity. The lateral meniscus showed relatively lower sensitivity but maintained a high specificity. (Table 2)

Further evaluation of diagnostic metrics, including positive predictive value (PPV) and negative predictive value (NPV), revealed that MRI consistently demonstrated good predictive capabilities across all structures, particularly for the anterior cruciate ligament and medial meniscus. Despite some variation, the values for the posterior cruciate ligament and lateral meniscus also remained within clinically acceptable ranges. (Table 3)

The agreement between MRI and arthroscopy in diagnosing soft tissue knee injuries was evaluated using Cohen's Kappa statistic. The analysis revealed substantial to almost perfect agreement across all evaluated structures. The highest level of agreement was observed for the medial meniscus, followed by strong concordance for the anterior cruciate ligament, lateral meniscus, and posterior cruciate ligament. All comparisons demonstrated statistically significant agreement. (Table 4)

DISCUSSION

In the current validation investigation, which compared MRI and arthroscopy for the detection of knee soft-tissue injuries such as ACL, PCL, medial meniscus (MM), and lateral meniscus (LM), we found strong performance in cruciate ligaments and LM (ê ? 0.53–0.70) and significant agreement for MM (ê ? 0.81). These findings align closely with recent evidence in the literature. A study conducted by Dawkins et al. (2022) reported pooled sensitivity/specificity values of approximately 94%/79% for medial meniscal tears and 81%/87% for lateral meniscus, while ACL injuries achieved 92% sensitivity and nearly 99% specificity. Our sensitivity (91.8%) for MM and specificity (86.7%) for LM are consistent with those pooled estimates, supporting that MRI remains highly accurate for meniscal pathology in modern protocols.[10]

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population (n = 192)

Variable	n (%)/ Mean ± SD
Age (years)	37.8 ± 10.4
18–30	58 (30.2%)
31–45	81 (42.2%)
46–60	53 (27.6%)
Gender	
Male	124 (64.6%)
Female	68 (35.4%)
BMI (kg/m^2)	26.3 ± 4.1
< 18.5 (Underweight)	12 (6.3%)
18.5–24.9 (Normal)	71 (37.0%)
25.0–29.9 (Overweight)	66 (34.4%)
= 30 (Obese)	43 (22.4%)
Duration of Symptoms (days)	18.6 ± 9.7
= 7 days	49 (25.5%)
8–30 days	96 (50.0%)
> 30 days	47 (24.5%)
Side of Involvement	
Right	109 (56.8%)
Left	83 (43.2%)
Residence	
Urban	112 (58.3%)
Rural	80 (41.7%)
Educational Background	
No formal education	39 (20.3%)
Primary to Matric	72 (37.5%)
Intermediate or above	81 (42.2%)
Profession	
Unemployed/Housewife	61 (31.8%)
Laborer	37 (19.3%)
Office/Skilled worker	48 (25.0%)
Student	46 (24.0%)
Socioeconomic Status	
Low	73 (38.0%)
Middle	95 (49.5%)
High	24 (12.5%)

Table 2: Relationship between MRI and Arthroscopy in the Diagnosis of Soft Tissue Knee Injuries (n = 192)

Structure	Sensitivity (%)	Specificity (%)	Accuracy (%)
MM	91.8	74.3	85.4
LM	68.2	86.7	79.2
ACL	88.6	80.2	84.4
PCL	83.3	78.6	81.8

Abbreviations:
MM stands for medial meniscus, LM for lateral meniscus, PCL for posterior cruciate ligament, and ACL for anterior cruciate ligament.
Kappa Meaning:

Table 4: Agreement Between Arthroscopy and MRI in Diagnosing Soft Tissue Knee Injuries (n = 192)

Structure	Kappa Value	Level of Agreement	p-value
ACL	0.72	Substantial	(p = 2.22×10?^{23})
PCL	0.66	Substantial	(p = 3.68×10?$^{2°}$)
MM	0.81	Almost Perfect	(p = 3.54×10?$^{2?}$)
LM	0.70	Substantial	(p = 2.05×10?^{22})

Abbreviations:
MM stands for medial meniscus, LM for lateral meniscus, PCL for posterior cruciate ligament, and ACL for anterior cruciate ligament.
Kappa Meaning:
Moderate agreement is between 0.41 and 0.60; substantial agreement is between 0.61 and 0.80.
0.80 indicates nearly complete agreement.
Cohen's Kappa statistic was used to evaluate agreement, and the Z-test based on the standard error of Kappa was used to compute p-values.
The agreement is considered statistically significant if the p-value is less than 0.05

Table 3: Detailed Diagnostic Accuracy of MRI Compared to Arthroscopy (n = 192 knees)

Structure	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
ACL	88.6	80.2	84.4	85.5	83.8
PCL	83.3	78.6	81.8	80.1	82.5
MM	91.8	74.3	85.4	86.2	83.9
LM	68.2	86.7	79.2	78.4	80.1

Abbreviations:
MM stands for medial meniscus, LM for lateral meniscus, PCL for posterior cruciate ligament, and ACL for anterior cruciate ligament.
Kappa Meaning:

A single-center prospective study from Pakistan in 2021–22 (Jinnah Hospital Lahore) reported considerably lower specificity as low as 45% for MM and around 65% for LM, despite decent sensitivity.[14] The discrepancy appears attributable to differences in MRI field strength, reporting standards, and patient population. In contrast, our values suggest superior diagnostic fidelity, reflecting optimized MRI protocols and experienced radiological interpretation. Another study focusing on combined injuries in BMC Musculoskeletal Disorders 2021 found MRI to perform well for detecting cruciate ligament injuries, but markedly less reliable for meniscus tears in the setting of multi-ligament injury, especially for peripheral posterior horn tears.[15] Similarly, our slightly lower sensitivity for LM (68%) aligns with known limitations in detecting subtle or posterior horn tears, particularly when ACL or PCL is involved.

A 2024 observational cohort by Bin Abd Razak et al. in Annals of Translational Medicine showed nearly perfect MRI reliability for ACL and strong performance for PCL, but moderate sensitivity (76–77%) and accuracy (up to ~92%) for meniscal tears. That study highlighted decreased PPV for LM and MM tears limited to the posterior horn.[13] Our results parallel these patterns, suggesting our MRI protocol effectively captures moderate-to-severe lesions but may underperform in subtle presentations. A study by Vo et al 2024 reported moderate agreement for meniscal tears when accompanied by ACL injuries, attributing discrepancies to postoperative effusion and injury-induced signal alterations on MRI. Our substantial ê for MM and moderate ê for LM also reflect that imaging in the context of acute injuries remains challenging, particularly for LM.[16]

Across the literature, false negatives tend to occur in peripheral longitudinal or root tears involving the posterior horn, positions often obscured by anatomical artifacts and edema, leading to variable detection rates even with high-field MRI.[17] This may underlie our comparatively lower LM sensitivity and modest PPVs for certain structures. A recent systematic review by Botnari et al. (2024) utilizing deep learning approaches demonstrated improved diagnostic consistency, with weighted ê values surpassing 0.80 for ACL classification and comparable accuracy for meniscal tears, suggesting potential future enhancement through AI assistance.[18] While our current study did not employ machine learning, it underscores that conventional MRI remains highly reliable under experienced interpretation. Finally, a prospective single-center study by Shantanu et al. (2021) documented MRI diagnostic accuracy of 88% for ACL and up to 100% for PCL injuries.[19] This closely mirrors our results (ACL 88.6%, PCL 83.3%), reinforcing that MRI, particularly high-field systems, performs well for cruciate ligaments.

Our findings, demonstrating substantial agreement between MRI and arthroscopy for the medial meniscus (MM; ê ? 0.81) and moderate agreement for ACL, PCL, and lateral meniscus (LM), are in line with contemporary literature. A prospective cohort of 150 knees using 1.5T MRI found ACL sensitivity significantly higher than cartilage injuries ($p = 0.0083$), reinforcing the robust performance of MRI for cruciate ligaments and menisci in routine clinical settings.[20] Similarly, a prospective study of 50 knee trauma patients reported perfect sensitivity for ACL and PCL and moderate sensitivity for LM (90.1%), while specificity for MM was modest (69.7%).[21] These results reflect the common challenge in imaging subtle meniscal tears and support our observation of lower LM sensitivity.

A retrospective review at Kenyatta National Hospital reported MRI sensitivity of 100% for ACL and PCL tears, with specificity of 96.6% and 98.5% respectively. However, sensitivity for PCL was low (50%), and the lowest accuracy was seen for MM (80.5%).[22] This variability mirrors our context, where MM specificity (74.3%) and LM sensitivity (68.2%) are lower than for cruciate ligaments, likely reflecting tear location and imaging complexity.

A systematic logistic regression analysis of over 5,600 MRI-arthroscopy correlations revealed that false negatives for MM were more common in younger, higher-BMI patients and partial tears ($p < 0.001$).[23] Similarly, LM false negatives were significantly associated with partial tears and female sex ($p < 0.05$). These findings help explain our lower LM sensitivity and emphasize the need for careful interpretation in specific patient subgroups.

In a machine learning–assisted imaging study, DL algorithms achieved an AUC of 0.96 for MM and 0.99 for ACL detection, while physician sensitivity improved from 83% to 91% with AI assistance.[24] Though our study did not utilize AI, this underlines the potential to enhance MRI performance further. Lastly, a recent observational study reported MRI accuracy of 94% for ACL and PCL injuries, and 96% for MM detection, confirming MRI as a highly reliable imaging tool.[25] Our results, ACL accuracy 84.4%, PCL 81.8%, and MM 85.4%, closely align, albeit showing slightly lower performance, possibly due to tear complexity or reader variability.

In summary, our findings are consistent with the latest evidence demonstrating that modern MRI protocols yield high sensitivity, specificity, and substantial agreement with arthroscopy for key knee structures, especially ACL and MM. Lower sensitivity for LM highlights persistent limitations in imaging posterior horn tears. MRI should continue to be considered a highly valid non-invasive modality for diagnosing knee soft-tissue injuries, with the caveat that arthroscopy remains indispensable in equivocal or complex cases.

The findings of this study reinforce the role of MRI as a highly effective, non-invasive diagnostic tool for evaluating soft tissue knee injuries, particularly in identifying tears of the ACL, PCL, and menisci. Its high sensitivity and substantial agreement with arthroscopic findings support its use as a reliable first-line investigation in patients presenting with knee trauma. Incorporating MRI into diagnostic algorithms may reduce the need for unnecessary diagnostic arthroscopies, lower procedural risks, and guide precise preoperative planning. This is particularly valuable in resource-limited settings where surgical facilities may not be readily accessible.

Despite its strengths, the study has several limitations. Being conducted at a single tertiary care center may limit the generalizability of the findings to other populations or healthcare settings. MRI interpretations were performed by a single radiologist, which could restrict inter-observer reliability assessment and introduce potential observer bias. Additionally, the inherent limitations of conventional MRI sequences may have hindered the detection of subtle or complex tears, particularly in the posterior horn of the lateral meniscus. Future multicenter studies employing standardized imaging protocols and blinded, multi-observer evaluations are recommended to strengthen the validity and applicability of the results.

CONCLUSION

MRI demonstrates excellent diagnostic performance and strong concordance with arthroscopy in the evaluation of knee soft-tissue injuries, particularly those involving the ACL and medial meniscus. Its high accuracy, noninvasive nature, and wide availability make it an essential diagnostic modality in orthopedic practice. Although arthroscopy remains the gold standard, MRI serves as a highly valuable and patient-friendly alternative that can facilitate timely diagnosis, reduce unnecessary invasive procedures, and optimize treatment strategies, thereby improving overall patient outcomes in musculoskeletal care.

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Authors Contribution:
Zeeshan Haider: Introduction + Discussion, data collection+ conclusion
Abbas Ali: Review article + dissuasion
Shehryar Khan: Data Collection + review article
Luqman Khan: Data Collection + review article
Ubaid Ullah: Data Collection + data analysis
Waqas Ahmad: Review article and dissociation

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