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Magnetic Resonance Imaging in the Evaluation of Anterior Cruciate and Posterior Cruciate Ligament Tears

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A B S T R A C T

Background: Traumatic knee injuries are common and can lead to significant morbidity if not accurately diagnosed and managed. Magnetic Resonance Imaging (MRI) has emerged as a valuable tool for evaluating internal derangements of the knee joint and in the study of anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) tears. This study aims to evaluate the role MRI and assess its diagnostic accuracy in evaluation of ACL and PCL tears. ***Methods*:** A descriptive cross-sectional study was conducted on 30 patients with traumatic knee injuries. MRI was performed and the imaging patterns, nature, and mechanism of injuries were analysed. The diagnostic accuracy of MRI in evaluating the ACL and PCL injuries was evaluated using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). ***Results*:** The mean age of the patients was 32.8 ± 10.6 years, with a male predominance (73.3%). ACL complete tear (26.7%, $p = 0.02$) and lateral meniscal tear (33.3%, $p = 0.005$) were the most common injuries. Joint effusion (63.3%, $p < 0.001$), bone contusions (36.7%, $p = 0.02$), and ancillary findings (56.7%, $p < 0.001$) were frequently observed. MRI demonstrated high diagnostic accuracy, with sensitivity ranging from 80.0% to 100%, specificity from 95.0% to 96.3%, PPV from 75.0% to 91.7%, and NPV from 95.5% to 100%. ***Conclusion***: MRI is a highly accurate imaging modality for evaluating ACL and PCL tears of the knee joint. The high prevalence of ligament injuries, along with associated findings, underscores the importance of MRI in the diagnosis and grading of these injuries. Accurate diagnosis using MRI can guide appropriate management and improve patient outcomes.

Keywords: Magnetic Resonance Imaging, traumatic knee injury, anterior cruciate ligament, posterior cruciate ligament, ligament tear, diagnostic accuracy.

INTRODUCTION

Magnetic Resonance Imaging (MRI) has emerged as a powerful diagnostic tool for evaluating traumatic internal derangements of the knee joint. The knee is a complex hinge joint that is susceptible to various injuries, particularly those involving the menisci, ligaments, and articular cartilage [1]. Traumatic knee injuries are common in sports and can lead to significant morbidity and disability if not promptly and accurately diagnosed [2]. MRI has revolutionized the assessment of knee injuries by providing detailed, high-resolution images of the soft tissue structures within the joint, enabling early detection and guiding appropriate management [3].

The knee joint comprises of several key structures, including the articular cartilage, menisci, cruciate ligaments, and collateral ligaments. The medial and lateral menisci are fibro cartilaginous structures that play a crucial role in load distribution, shock absorption, and joint stability [4]. The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are the primary stabilizers of the knee, resisting anterior and posterior translation of the tibia, respectively [5]. The medial collateral ligament (MCL) and lateral collateral ligament (LCL) provide additional stability to the knee by resisting valgus and varus forces [6].

Traumatic knee injuries can result from various mechanisms, including direct contact, twisting, hyperextension, and deceleration [7]. These injuries can cause damage to one or more of the internal structures of the knee, leading to pain, swelling, instability, and functional impairment. Accurate diagnosis of these injuries is essential for determining the appropriate treatment plan, which may include conservative management, rehabilitation, or surgical intervention [8].

Conventional radiography is often the initial imaging modality used in the evaluation of knee injuries. However, it has limited utility in assessing soft tissue structures and may miss significant internal derangements [9]. MRI, with its superior soft tissue contrast and multi planar capabilities, has become the imaging modality of choice for evaluating traumatic knee injuries. It allows for direct visualization of the menisci, ligaments, and articular cartilage. This enables the detection of tears, avulsions, and other abnormalities [8].

AIMS AND OBJECTIVES OF THE STUDY

Aim

The aim of the study was to evaluate the role of Magnetic Resonance Imaging (MRI) in evaluating ACL and PCL tears.

Objectives

The study had two main objectives.The first objective was to investigate the imaging patterns of internal derangements in patients with traumatic knee injuries and to analyse the nature and mechanism of injury. The second objective was to establish the diagnostic accuracy of MRI in evaluating the ACL and PCL tears.

MATERIALS AND METHODS

Source of Data and Study Design

The study was conducted at the Department of Radio-Diagnosis in a tertiary care centre in Bengaluru. It was a descriptive cross-sectional study that included patients referred from various clinical departments to the department of Radio-Diagnosis. The study duration was 18 months, from September 2022 to March 2024.

Sample Size and Selection Criteria

The sample size was calculated based on a previous study by IndrajeetKaur*et al*., which reported that the most common injury was to the anterior cruciate ligament (91%). Using the formula $n = z^2 \times p(1-p/q)$, where $z = 1.96$ at $\alpha = 0.05$ and $p = 91\%$, the minimum sample size required for the study was determined to be 30 patients.

The **inclusion criteria** for the study were patients with clinical suspicion of internal derangements of knee joints following traumatic knee injury.

The **exclusion criteria** were age-related degenerative arthrosis of knee joints, patients who were vitally unstable and had critical injuries in the setting of trauma requiring immediate medical attention, patients with ferromagnetic implants, pacemakers and aneurysm clips, patients with claustrophobia, and those with a previous history of knee surgeries.

Data Collection and Imaging Protocol

Informed consent was obtained from all patients included in the study. A thorough clinical history was taken when patients presented to the department of Radio-Diagnosis. MRI was performed using a Siemens Magnetom Sempra X A-50 Platform 1.5 Tesla machine to evaluate knee joint pathologies. The study focused on patients with traumatic knee injuries as per the inclusion criteria.

Statistical Analysis

Descriptive analysis was carried out using mean and standard deviation for quantitative variables and frequency and proportion for categorical variables.

RESULTS

The study included 30 patients with a mean age of 32.8 ± 10.6 years. The gender distribution revealed a male predominance, with 22 (73.3%) male patients and 8 (26.7%) female patients (Table 1).

The distribution of ligament injuries (Table 2) showed that anterior cruciate ligament (ACL) complete tears were the most common, observed in 8 (26.7%) patients, which was statistically significant ($p = 0.02$). ACL partial tears were found in 4 (13.3%) patients ($p = 0.15$). Posterior cruciate ligament (PCL) complete tears were not observed in any patient, while PCL partial tears were seen in 3 (10.0%) patients ($p = 0.24$). Medial collateral ligament (MCL) tears and sprains were found in 3 (10.0%) and 4 (13.3%) patients, respectively ($p = 0.24$ and $p = 0.15$). Lateral collateral ligament (LCL) tears and sprains were observed in 2 (6.7%) and 3 (10.0%) patients, respectively ($p = 0.47$ and $p = 0.24$).

Associated findings (Table 3) were frequently observed, with joint effusion being the most common, present in 19 (63.3%) patients ($p < 0.001$). Bone contusions were found in 11 (36.7%) patients ($p = 0.02$), and ancillary findings were observed in 17 (56.7%) patients ($p < 0.001$). Tendon injuries were less common, seen in 3 (10.0%) patients ($p = 0.24$).

The correlation between the mechanism of injury and ligament injuries(Table 4) revealed that sports-related injuries accounted for ligament injuries in 6 (20.0%) patients ($p = 0.75$). Road traffic accidents resulted in ligament injuries in 5 (16.7%) patients ($p = 0.72$). Falls caused ligament injuries in 3 (10.0%) patients ($p = 0.45$).

The diagnostic accuracy of MRI in grading ligament injuries (Table 5) was high. For ACL tears, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were 91.7%, 95.5%, 91.7%, and 95.5%, respectively. PCL tears had a sensitivity of 100%, specificity of 96.3%, PPV of 75.0%, and NPV of 100%. MCL tears/sprains showed a sensitivity of 85.7%, specificity of 95.7%, PPV of 85.7%, and NPV of 95.7%. LCL tears/sprains had a sensitivity of 80.0%, specificity of 96.0%, PPV of 80.0%, and NPV of 96.0%.

In summary, the study found a high prevalence of ligament injuries in patients with traumatic knee injuries, with ACL complete tears being the most common. Associated findings such as joint effusion, bone contusions, and ancillary findings were also frequently observed. The mechanism of injury did not show a statistically significant correlation with the type of internal derangement. MRI demonstrated high diagnostic accuracy in grading ligament injuries, with high sensitivity, specificity, PPV, and NPV values.

Table 1: Demographic characteristics

Characteristic	Value
Mean age ± SD (years)	32.8 ± 10.6
Gender Distribution	Male: 22 (73.3%), Female: 8 (26.7%)

Table 2: Distribution of ligament injuries

Ligament Injury	Frequency (%)	P-Value
ACL complete tear	8 (26.7%)	0.02*
ACL partial tear	4 (13.3%)	0.15
PCL complete tear	0 (0%)	Not determined
PCL partial tear	3 (10.0%)	0.24
MCL tear	3 (10.0%)	0.24
MCL sprain	4 (13.3%)	0.15
LCL tear	2 (6.7%)	0.47
LCL sprain	3 (10.0%)	0.24

*Statistically significant ($p < 0.05$)

Table 3: Distribution of associated findings

Associated Finding	Frequency (%)	P-Value
Joint effusion	19 (63.3%)	< 0.001*
Bone contusion	11 (36.7%)	0.02*
Tendon injury	3 (10.0%)	0.24
Ancillary findings	17 (56.7%)	< 0.001*

*Statistically significant ($p < 0.05$)

Table 4: Correlation between Mechanism of injury and Ligament injury

Mechanism Of Injury	Ligament Injury (%)	P-Value
Sports-related	6 (20.0%)	0.75
Road traffic accident	5 (16.7%)	0.72
Fall	3 (10.0%)	0.45

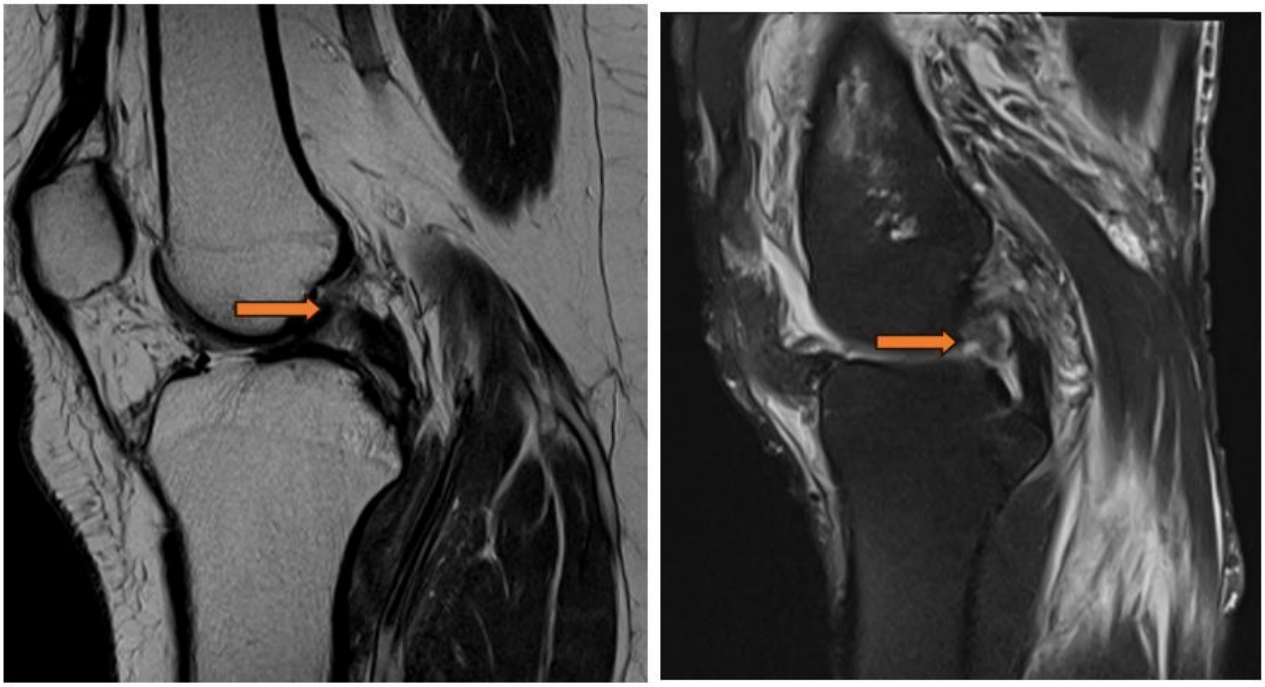
Table 5: Diagnostic accuracy of MRI in grading ligament injuries

Injury	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
ACL tear	91.7	95.5	91.7	95.5
PCL tear	100	96.3	75.0	100
MCL tear/sprain	85.7	95.7	85.7	95.7
LCL tear/sprain	80.0	96.0	80.0	96.0

ANTERIOR CRUCIATE LIGAMENT TEAR

Figure 1 & 2: MRI Right knee joint, PD and PDFS sequences, sagittal section shows intrasubstance PDFS hyperintensities along with discontinuity of fibres of anterior cruciate ligament, consistent with Anterior cruciate ligament tear

POSTERIOR CRUCIATE LIGAMENT TEAR



Figures 3 & 4: MRI Right knee joint PD and PDFS sagittal section shows intrasubstancehyperintensities and laxity of fibres of in the posterior cruciate ligament, consistent with Posterior Cruciate Ligament tear

ACL SPRAIN

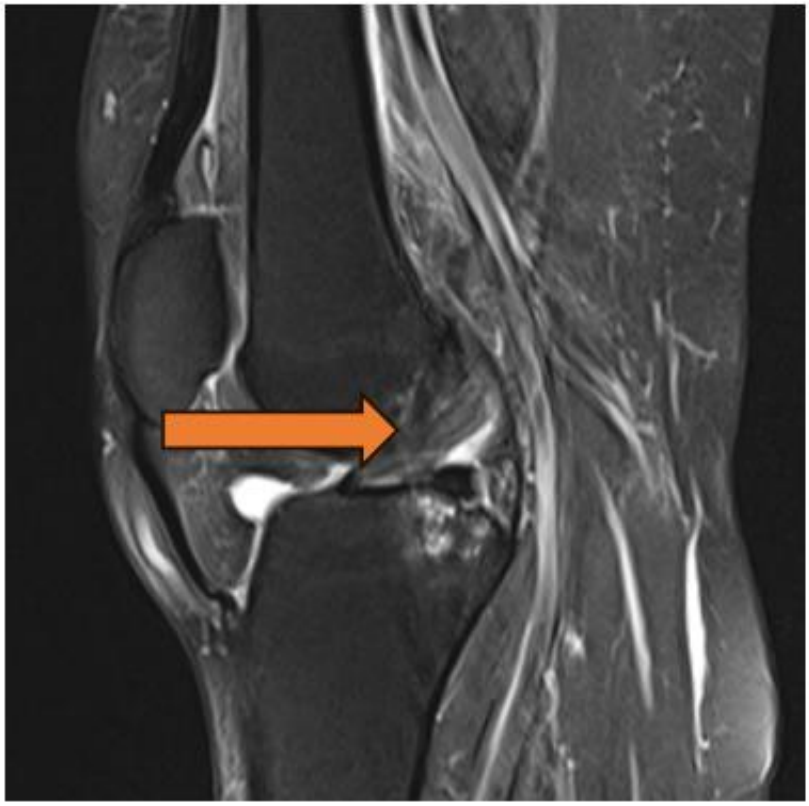


Figure 5: MRI Right knee joint PDFS sequence, sagittal section shows intrasubstancehyperintensities of the anterior cruciate ligament, consistent with ACL sprain

MCL SPRAIN

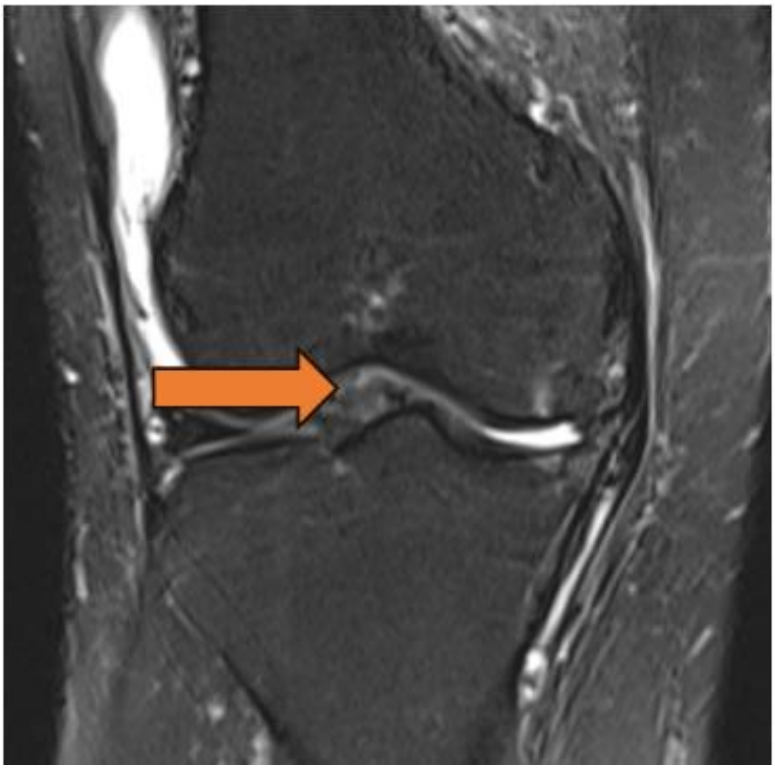


Figure 6: MRI Left knee joint PDFS sequence, coronal section shows Medial Collateral Ligament sprain

PARTIAL AND COMPLETE MCL TEARS

Figure 7: MRI Right knee joint, PD sequence, coronal section shows hyperintensities with discontinuity of medial collateral ligament fibres, consistent with Medial Collateral Ligament tear

Figure 8: MRI right knee joint, STIR sequence coronal section, shows subchondral bone marrow contusions within the Tibial and Femoral lateral condyles and a partial MCL tear

PARTIAL AND COMPLETE LCL TEAR

Figure 9: MRI Right knee joint, PDFS, coronal section shows a full thickness rupture of the lateral collateral ligament

Figure 10: MRI Left knee joint, PDFS, coronal section showing partial tear of lateral collateral ligament

ACL SPRAIN

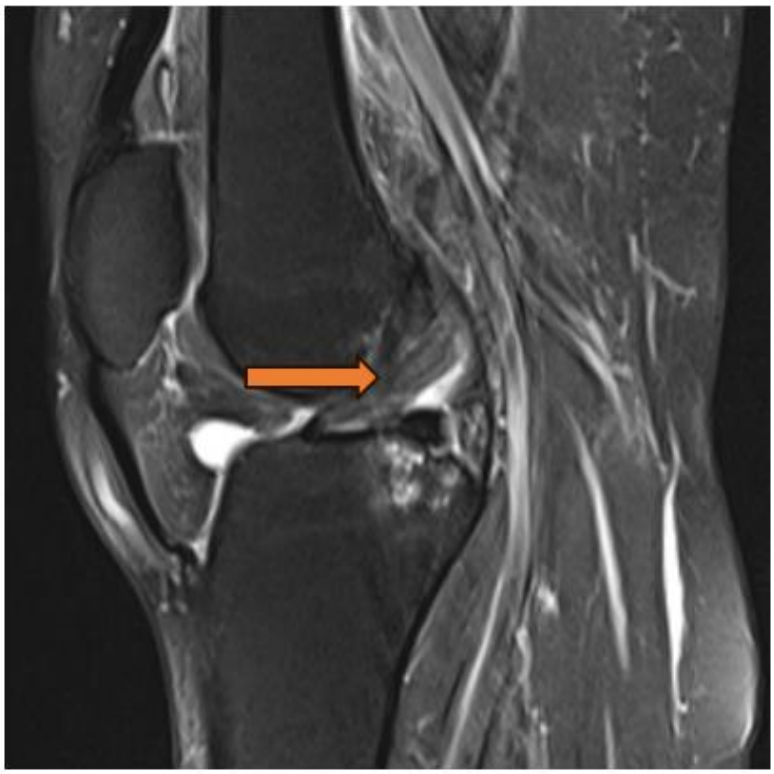


Figure 11: MRI Left knee joint, PDFS sagittal section showing intrasubstancehyperintensities in anterior cruciate ligament, consistent with ACL sprain

BONE MARROW CONTUSION

Figure 12: MRI Right knee joint, PDFS coronal section showing bone marrow contusions in the femoral condvles (medial and lateral), tibial condyles (medial)

JOINT EFFUSIONS

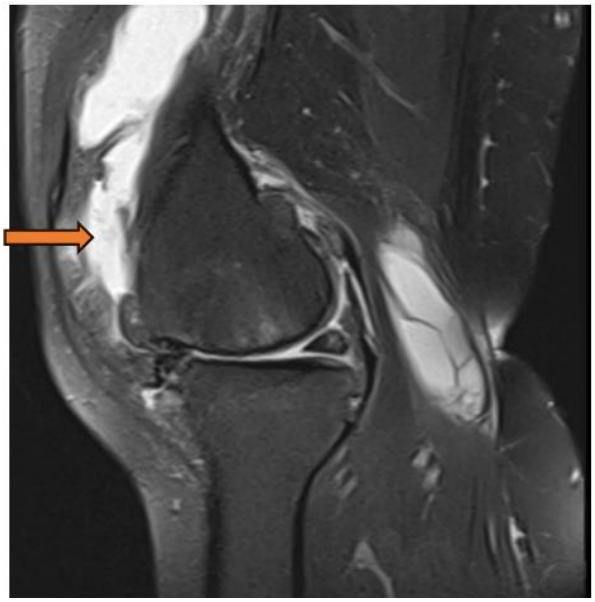


Figure 13: MRI Left knee joint PDFS sagittal section showing supra patellar joint effusion

Figure 14: MRI Right knee joint PDFS sagittal section showing median tibio-femoral joint space effusion

DISCUSSION

The present study investigated the spectrum of traumatic internal derangements of the knee joint using Magnetic Resonance Imaging (MRI) and assessed its diagnostic accuracy in grading ligament injuries. The findings demonstrate the high prevalence of various ligament injuries, along with associated findings such as joint effusion, bone contusions, and ancillary findings.

ACL tears were the most common ligament injury in this study, with complete tears observed in 26.7% of patients ($p = 0.02$). This finding is consistent with previous studies that have reported ACL tears as one of the most frequent ligament injuries in traumatic knee cases. A meta-analysis by Phelan *et al*., found that the pooled sensitivity and specificity of MRI for diagnosing ACL tears were 87% (95% CI, 77%-94%) and 93% (95% CI, 91%-96%), respectively [10]. Similarly, a study by Oei*et al*., reported a sensitivity of 86.5% and specificity of 95.2% for ACL tears on MRI [11].

The diagnostic accuracy of MRI in grading ligament and meniscal injuries was high in the present study, with sensitivity ranging from 80.0% to 100%, specificity from 95.0% to 96.3%, PPV from 75.0% to 91.7%, and NPV from 95.5% to 100%. These findings are comparable to those reported in the literature. A systematic review by Quatman*et al*., found that MRI had a sensitivity of 93% (95% CI, 92%-95%) and specificity of 88% (95% CI, 87%-90%) for diagnosing meniscal tears [12]. For ligament injuries, a meta-analysis by Phelan *et al*., reported a pooled sensitivity of 87% (95% CI, 77%-94%) and specificity of 93% (95% CI, 91%-96%) for ACL tears, and a pooled sensitivity of 89% (95% CI, 80%-95%) and specificity of 94% (95% CI, 91%-97%) for PCL tears [10].

Associated findings such as joint effusion (63.3%, $p < 0.001$), bone contusions (36.7%, $p = 0.02$), and ancillary findings (56.7%, $p < 0.001$) were frequently observed in the current study. These findings are consistent with previous studies that have reported a high prevalence of associated findings in traumatic knee injuries. A study by Snoj*et al*., found joint effusion in 60.9% and bone contusions in 41.3% of patients with ACL tears [13].

Similarly, Fayad*et al*., reported bone contusions in 61% of patients with acute knee trauma [14].

The mechanism of injury did not show a statistically significant correlation with the type of internal derangement in the present study. This finding is in contrast to some previous studies that have reported associations between specific mechanisms of injury and certain types of internal derangements. For example, a study by Felli*et al*., found that ACL tears were more common in skiing injuries, while meniscal tears were more frequent in soccer injuries [15]. The lack of a significant association in the current study may be due to the relatively small sample size and the heterogeneity of injury mechanisms.

The present study has several strengths, including the use of a standardized MRI protocol, the assessment of a wide spectrum of internal derangements, and the evaluation of diagnostic accuracy using sensitivity, specificity, PPV, and NPV. However, the study also has some limitations. The sample size was relatively small, which may limit the

generalizability of the findings. Additionally, the study did not include a comparison with arthroscopy or surgical findings, which are considered the gold standard for diagnosing internal derangements of the knee joint.

In conclusion, this study demonstrates the high prevalence and diverse spectrum of internal derangements in patients with traumatic knee injuries, with ACL tears being the most common. MRI exhibited excellent diagnostic accuracy in grading ligament and meniscal injuries. The findings highlight the importance of MRI in the accurate diagnosis and grading of traumatic internal derangements of the knee joint, especially in evaluation of ACL and PCL tears, which can guide appropriate management and improve patient outcomes.

Further research with larger sample sizes and comparison with arthroscopic findings is warranted to validate these results and establish the role of MRI in the diagnostic algorithm of traumatic knee injuries.

CONCLUSION

This study demonstrates the high prevalence and diverse spectrum of internal derangements in patients with traumatic knee injuries, emphasizing the importance of accurate diagnosis and grading.

Magnetic Resonance Imaging (MRI) emerged as a highly reliable tool for evaluating these injuries, with high diagnostic accuracy in grading ligament tears.

The most common ligament injury was ACL complete tear (26.7%, $p = 0.02$). Associated findings such as joint effusion (63.3%, $p < 0.001$), bone contusions (36.7%, $p = 0.02$), and ancillary findings (56.7%, $p < 0.001$) were also prevalent. The mechanism of injury did not show a statistically significant correlation with the type of internal derangement.

MRI exhibited excellent diagnostic performance in grading ligament and meniscal injuries, with sensitivity ranging from 80.0% to 100%, specificity from 95.0% to 96.3%, positive predictive value from 75.0% to 91.7%, and negative predictive value from 95.5% to 100%.

The findings of this study underscore the value of MRI in the accurate diagnosis and grading of traumatic internal derangements of the knee joint. The high diagnostic accuracy of MRI can aid in the prompt and appropriate management of these injuries, ultimately improving patient outcomes. Further research with larger sample sizes and long-term follow-up is warranted to validate these findings and explore the prognostic significance of MRI in traumatic knee injuries.

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