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Magnetic resonance imaging evaluation of knee joint disorders: Assessment of meniscal, ligamentous, cartilaginous, and bone marrow abnormalities with clinical correlation

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Abstract

Background: Knee joint disorders are common and may involve the menisci, ligaments, articular cartilage, bone marrow, and surrounding soft tissues. Magnetic resonance imaging (MRI) provides comprehensive evaluation of these structures and is valuable for detecting internal derangements.

Objective: To evaluate MRI findings of knee joint disorders with particular emphasis on meniscal, ligamentous, cartilaginous, and bone marrow abnormalities and to assess their correlation with clinical findings.

Materials and Methods: A hospital-based prospective observational study was conducted over a period of two years in the Department of Radiodiagnosis, Karnataka Medical College and Research Institute, Hubballi, Karnataka. A total of 100 patients with clinically suspected knee joint disorders were included. All patients underwent MRI examination using standard multiplanar sequences. Meniscal, ligamentous, articular cartilage, bone marrow, and associated abnormalities were systematically evaluated and correlated with clinical presentation.

Results: Of the 100 patients, 62% were males and 38% were females. Knee pain was the commonest clinical presentation (88%), followed by history of trauma (54%). Meniscal abnormalities were the most frequent structural abnormality (48%), followed by ligamentous abnormalities (36%), cartilage abnormalities (32%), and bone marrow abnormalities (28%). The ACL was the

most commonly affected ligament (28%), while medial meniscal tear was the commonest meniscal abnormality (26%). Joint effusion was the most frequent associated MRI finding (58%). Meniscal, ligamentous, and bone marrow abnormalities were more frequent among patients with a history of trauma.

Conclusion: MRI provides comprehensive and detailed evaluation of knee joint pathology, enabling accurate identification of meniscal, ligamentous, cartilage, and bone marrow abnormalities. Clinical correlation with MRI findings improves diagnostic assessment and helps in appropriate management of patients with suspected knee joint disorders.

Keywords: Magnetic Resonance Imaging, Knee Joint, Meniscal Tears, Ligamentous Injuries, Articular Cartilage, Bone Marrow Edema, Anterior Cruciate Ligament

Introduction

The knee joint is one of the largest and most complex synovial joints in the human body and plays an essential role in weight bearing, locomotion, and maintenance of lower-limb stability. Its complex anatomical composition, including the menisci, cruciate and collateral ligaments, articular cartilage, subchondral bone, and surrounding soft tissues, makes it susceptible to a wide range of traumatic and degenerative disorders. Knee pain is a common clinical presentation and may result from abnormalities involving one or more of these structures.

Accurate diagnosis of internal derangements of the knee is important for appropriate treatment planning and prevention of progressive joint dysfunction. Conventional radiography is useful for evaluating fractures, alignment, and degenerative osseous changes; however, its ability to demonstrate intra-articular soft-tissue abnormalities is limited. Ultrasonography can assess superficial structures and joint effusion but has limitations in evaluating deep intra-articular anatomy. Magnetic resonance imaging (MRI), owing to its excellent soft-tissue contrast and multiplanar imaging capability, provides comprehensive evaluation of the knee joint and has become an important non-invasive modality for the assessment of internal derangements.[1,2]

MRI allows detailed visualization of the menisci, cruciate and collateral ligaments, articular cartilage, bone marrow, synovium, tendons, and periarticular soft tissues. It can demonstrate meniscal tears, ligamentous injuries, cartilage defects, bone marrow edema, osteochondral lesions, and associated abnormalities in a single examination[2,3]. This comprehensive evaluation is particularly important because traumatic and degenerative knee disorders may involve multiple structures simultaneously.

Meniscal pathology is an important cause of knee pain and may occur following acute trauma or as a consequence of degenerative changes. MRI permits accurate identification of meniscal tears and characterization of their location and morphology. Abnormal intrameniscal signal extending to an articular surface is an important criterion for diagnosing a meniscal tear[3,4]. Ligamentous injuries, particularly anterior cruciate ligament (ACL) injuries, are also common causes of knee instability. ACL disruption may occur with associated meniscal, cartilage, and bone marrow abnormalities, making comprehensive MRI assessment important for determining the complete extent of injury[5].

Articular cartilage abnormalities range from mild thinning and surface irregularity to focal defects and complete cartilage loss. MRI can demonstrate cartilage

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morphology and associated subchondral abnormalities and is therefore valuable in the evaluation of traumatic and degenerative cartilage disease[6,7]. Bone marrow edema and bone contusions are also important MRI manifestations of acute knee injury and may provide information regarding the mechanism and severity of trauma[8,9].

Degenerative knee disease, particularly osteoarthritis, may involve cartilage loss, osteophyte formation, subchondral abnormalities, meniscal degeneration, and joint effusion. MRI provides information regarding multiple structural components involved in osteoarthritis and can demonstrate abnormalities that may not be adequately characterized by conventional radiography.[10]

Although clinical examination remains essential in the evaluation of knee disorders, symptoms such as pain, swelling, restricted movements, and instability may be non-specific and can result from abnormalities involving different structures. Correlation of clinical findings with MRI abnormalities can therefore improve diagnostic assessment and assist in treatment planning.

The present study was undertaken to evaluate MRI findings in patients with clinically suspected knee joint disorders, with particular emphasis on meniscal, ligamentous, articular cartilage, and bone marrow abnormalities, and to assess their correlation with clinical presentation. The study included 100 patients evaluated over a period of two years at Karnataka Medical College and Research Institute, Hubballi, Karnataka.

Materials and Methods

Study Design and Setting

A hospital-based, prospective observational study was conducted in the Department of Radiodiagnosis at Karnataka Medical College and Research Institute (KMCRI), Hubballi, Karnataka. The study was designed to evaluate the magnetic resonance imaging (MRI) findings of patients presenting with clinically suspected knee joint disorders, with particular emphasis on meniscal, ligamentous, articular cartilage, and bone marrow abnormalities, and to assess their correlation with clinical findings.

Study Duration

The study was conducted over a period of 2 years.

Study Population

The study population comprised patients presenting to the Radiology Department with knee pain, swelling, restricted movements, instability, history of trauma, or other clinical features suggestive of internal derangement or structural abnormality of the knee joint and referred for MRI evaluation.

Sample Size

A total of 100 patients fulfilling the predefined eligibility criteria were included in the study.

Inclusion Criteria

Patients were included if they met the following criteria:

1. Patients presenting with clinical symptoms or signs suggestive of knee joint pathology.
2. Patients referred for MRI evaluation of the knee joint.
3. Patients of either sex and all adult age groups.
4. Patients who provided informed consent for participation in the study.
5. Patients in whom adequate-quality MRI images of the knee joint could be obtained.

Exclusion Criteria

The following patients were excluded:

1. Patients with contraindications to MRI, such as non-compatible metallic implants or devices.

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2. Patients with severe claustrophobia who could not undergo MRI examination.
3. Patients who were unable to maintain the required position during imaging.
4. Patients with incomplete clinical information or inadequate MRI images.
5. Patients who declined participation in the study.

Clinical Evaluation

All enrolled patients underwent a detailed clinical assessment before MRI examination. Relevant demographic and clinical information was recorded, including age, sex, presenting symptoms, duration of symptoms, history of trauma, mechanism of injury where applicable, pain, swelling, restricted range of motion, joint instability, and previous history of knee surgery or other relevant knee disorders.Clinical findings were subsequently compared with MRI findings to determine the relationship between clinical presentation and structural abnormalities detected on imaging.

MRI Examination

MRI examination of the affected knee was performed using a dedicated knee coil with the patient positioned supine. Standard multiplanar MRI sequences were obtained in sagittal, coronal, and axial planes.

The imaging protocol included appropriate T1-weighted, T2-weighted, proton-density (PD), and fluid-sensitive fat-suppressed sequences, according to the institutional MRI protocol. Images were acquired with adequate coverage of the knee joint, including the menisci, cruciate and collateral ligaments, articular cartilage, bone marrow, joint space, and periarticular soft tissues.

MRI Assessment

MRI images were systematically evaluated for abnormalities involving the major structural components of the knee joint.

1.Meniscal abnormalities

Both medial and lateral menisci were assessed for:

- Meniscal degeneration
- Meniscal tears
- Horizontal, vertical, radial, complex, and root tears
- Meniscal extrusion
- Associated parameniscal abnormalities where present

Meniscal abnormalities were diagnosed based on abnormal intrameniscal signal extending to an articular surface or other established MRI criteria.

2.Ligamentous abnormalities

The following ligaments were evaluated:

- Anterior cruciate ligament (ACL)
- Posterior cruciate ligament (PCL)
- Medial collateral ligament (MCL)
- Lateral collateral ligament (LCL)

The ligaments were assessed for normal morphology and signal intensity, sprain, partial tear, complete tear, discontinuity, and associated ligamentous injuries.

3.Articular cartilage abnormalities

Articular cartilage over the medial and lateral femorotibial compartments and patellofemoral compartment was evaluated for:

- Cartilage thinning
- Focal cartilage defects
- Fissuring
- Partial-thickness loss
- Full-thickness cartilage loss
- Chondral degeneration

Associated subchondral changes were also documented.

4.Bone marrow abnormalities

The osseous structures forming the knee joint were examined for:

- Bone marrow edema

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- Bone contusions
- Subchondral changes
- Osteochondral lesions
- Fractures
- Other focal or diffuse marrow signal abnormalities

5.Additional MRI findings

Additional abnormalities, when present, were also documented, including:

- Joint effusion
- Synovial abnormalities
- Baker's cyst
- Osteophytes
- Bursitis
- Tendinous abnormalities
- Periarticular soft-tissue abnormalities

Image Interpretation

All MRI examinations were systematically reviewed by a radiologist experienced in musculoskeletal imaging. Findings were recorded using a structured data collection format. In cases with multiple abnormalities, each individual abnormality was documented separately.

The final MRI diagnosis was based on the overall imaging findings and was categorized according to the principal structural abnormality identified.

Clinical–Radiological Correlation

The MRI findings were correlated with the clinical presentation of the patients. Particular emphasis was placed on evaluating the association between specific clinical symptoms and structural abnormalities such as meniscal tears, cruciate ligament injuries, cartilage defects, and bone marrow edema.

Where available, relevant clinical findings such as joint-line tenderness, instability, restricted movement, and history of trauma were compared with corresponding MRI abnormalities.

Data Collection and Statistical Analysis

All relevant demographic, clinical, and MRI findings were entered into a structured data collection sheet and subsequently analyzed using appropriate statistical methods. Categorical variables were expressed as frequency and percentage, while continuous variables were summarized using mean and standard deviation or median and interquartile range, as appropriate.

Associations between clinical variables and MRI abnormalities were assessed using appropriate statistical tests, such as the Chi-square test or Fisher's exact test for categorical variables and appropriate tests for continuous variables. A p-value <0.05 was considered statistically significant.

Results and Observations

A total of 100 patients with clinically suspected knee joint disorders who fulfilled the inclusion criteria were evaluated by MRI during the study period. The MRI examinations were assessed systematically for abnormalities involving the menisci, ligaments, articular cartilage, bone marrow, and other associated structures. Clinical findings were subsequently correlated with the MRI findings.

Table 1: Age-wise distribution of study participants

Age group (years)	No. of patients	Percentage (%)
18–30	24	24.0
31–40	22	22.0
41–50	24	24.0
51–60	18	18.0
>60	12	12.0
Total	100	100.0

The majority of patients belonged to the 41–50 years age group (24%), followed by 18–30 years (24%) and 31–40 years (22%). Patients aged above 60 years constituted 12% of the study population.

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Table 2: Gender-wise distribution of study participants

Gender	No. of patients	Percentage (%)
Male	62	62.0
Female	38	38.0
Total	100	100.0

There was a male predominance in the study, with 62% males and 38% females, giving a male-to-female ratio of approximately 1.63:1.

Table 3: Distribution according to presenting clinical symptoms

Clinical presentation	No. of patients	Percentage (%)
Knee pain	88	88.0
Swelling	46	46.0
Restricted movements	38	38.0
History of trauma	54	54.0
Joint instability	28	28.0
Joint-line tenderness	42	42.0

Knee pain was the most common presenting symptom, observed in 88% of patients. A history of trauma was present in 54%, while swelling and restricted knee movements were reported in 46% and 38% of patients, respectively.

Table 4: Overall distribution of MRI abnormalities Baseline Severity of Hearing Loss

MRI abnormality	No. of patients	Percentage (%)
Meniscal abnormalities	48	48.0
Ligamentous abnormalities	36	36.0
Articular cartilage abnormalities	32	32.0
Bone marrow abnormalities	28	28.0
Joint effusion	58	58.0
Osteoarthritic changes	26	26.0
Other soft-tissue abnormalities	18	18.0

The most frequently identified structural abnormality was meniscal pathology (48%), followed by ligamentous abnormalities (36%) and articular cartilage abnormalities (32%). Joint effusion was the most frequent associated MRI finding, seen in 58% of patients.

Table 5: Distribution of meniscal abnormalities

Meniscal finding	No. of patients	Percentage (%)
Medial meniscal tear	26	26.0
Lateral meniscal tear	10	10.0
Both medial and lateral meniscal tears	4	4.0
Meniscal degeneration	12	12.0
Meniscal extrusion	6	6.0

Medial meniscal pathology was more frequently observed than lateral meniscal pathology. Medial meniscal tears were identified in 26% of patients, whereas lateral meniscal tears were seen in 10%.

Table 6: Distribution of ligamentous abnormalities

Ligament	Normal	Partial tear/sprain	Complete tear	Total abnormal
ACL	72 (72%)	10 (10%)	18 (18%)	28 (28%)
PCL	92 (92%)	5 (5%)	3 (3%)	8 (8%)
MCL	86 (86%)	10 (10%)	4 (4%)	14 (14%)
LCL	94 (94%)	4 (4%)	2 (2%)	6 (6%)

The ACL was the most commonly involved ligament, with abnormalities identified in 28% of patients.

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Complete ACL tears accounted for 18%, while partial tears/sprains accounted for 10%. PCL and LCL abnormalities were comparatively less frequent.

Table 7: Distribution of articular cartilage abnormalities

Cartilage finding	No. of patients	Percentage (%)
Cartilage thinning	14	14.0
Focal cartilage defect	8	8.0
Partial-thickness cartilage loss	6	6.0
Full-thickness cartilage loss	4	4.0
Total	32	32.0

Cartilage abnormalities were identified in 32% of patients. Cartilage thinning was the most frequent cartilage abnormality, accounting for 14% of the total study population.

Table 8: Distribution of bone marrow abnormalities

Bone marrow finding	No. of patients	Percentage (%)
Bone marrow edema/contusion	18	18.0
Subchondral marrow changes	6	6.0
Osteochondral lesion	3	3.0
Marrow abnormality associated with fracture	1	1.0
Total	28	28.0

Bone marrow abnormalities were observed in 28% of patients. Bone marrow edema or contusion was the most common finding, occurring in 18% of the study population.

Table 9: Distribution of associated MRI findings

Associated MRI finding	No. of patients	Percentage (%)
Joint effusion	58	58.0
Baker's cyst	14	14.0
Osteophytes	22	22.0
Synovial thickening	10	10.0
Bursitis	8	8.0
Tendinous abnormality	12	12.0

Joint effusion was the most frequent associated finding, present in 58% of patients, followed by osteophyte formation in 22% and Baker's cyst in 14%.

Table 10: MRI findings according to history of trauma

MRI abnormality	Trauma present (n=54)	No trauma (n=46)	Total
Meniscal abnormality	32 (59.3%)	16 (34.8%)	48
Ligamentous abnormality	30 (55.6%)	6 (13.0%)	36
Cartilage abnormality	12 (22.2%)	20 (43.5%)	32
Bone marrow abnormality	22 (40.7%)	6 (13.0%)	28
Joint effusion	38 (70.4%)	20 (43.5%)	58

Meniscal, ligamentous, and bone marrow abnormalities were more frequently observed among patients with a history of trauma. Ligamentous abnormalities were particularly common in the trauma group.

Table 11: Clinical–MRI correlation of knee pain and major MRI abnormalities

MRI finding	Knee pain present	Knee pain absent	Total
Meniscal abnormality	46	2	48
Ligamentous abnormality	34	2	36
Cartilage abnormality	30	2	32
Bone marrow abnormality	26	2	28
No corresponding major abnormality	6	2	8

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Knee pain showed a strong clinical association with structural abnormalities detected on MRI. Most patients with meniscal, ligamentous, cartilage, or bone marrow abnormalities presented with knee pain.

Table 12: Distribution of major MRI diagnoses

Principal MRI diagnosis	No. of patients	Percentage (%)
Meniscal tear/degeneration	36	36.0
ACL injury	28	28.0
Cartilage degeneration/defect	20	20.0
Bone marrow edema/contusion	18	18.0
Osteoarthritic changes	16	16.0
PCL/MCL/LCL injury	14	14.0
Other abnormalities	8	8.0

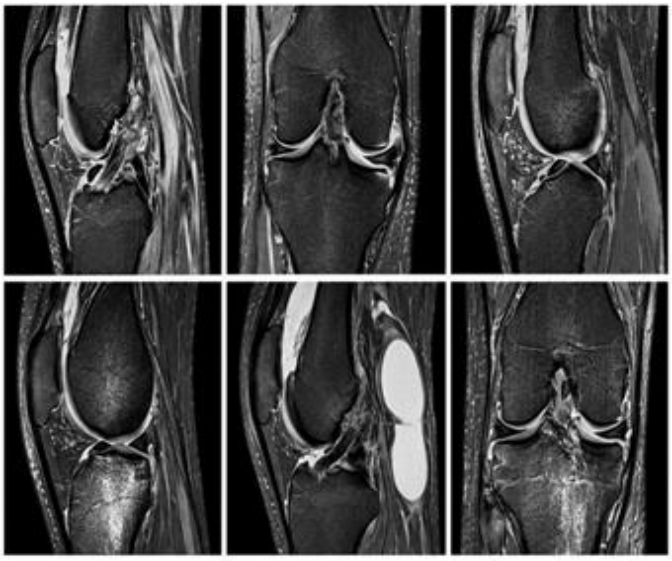

Figure 1: Complete ACL Tear Figure; 2 Medial Meniscal Tear Figure; 3Articular Cartilage Defect Figure; 4 Bone Marrow Edema/Contusion Figure; 5 Joint Effusion with Baker's Cyst Figure; 6; Combined Traumatic Internal Derangement

Discussion

The present study evaluated 100 patients with clinically suspected knee joint disorders using MRI, with systematic assessment of meniscal, ligamentous, articular cartilage, bone marrow, and associated abnormalities. Clinical findings were also correlated with the MRI findings. The multiplanar MRI protocol allowed comprehensive assessment of the major intra-articular and periarticular structures of the knee.

In the present study, males constituted 62% of the study population, while females constituted 38%, giving a male-to-female ratio of approximately 1.63:1. The higher proportion of males may be related to greater exposure to occupational, recreational, and trauma-related activities. Patients were distributed across different adult age groups, indicating that clinically significant knee abnormalities requiring MRI evaluation occur across a broad age range.

Knee pain was the most common clinical presentation, occurring in 88% of patients, followed by a history of trauma in 54%, swelling in 46%, joint-line tenderness in 42%, restricted movements in 38%, and joint instability in 28%. These findings demonstrate that the clinical manifestations of knee pathology are variable and may not always indicate the precise anatomical structure involved. MRI therefore provides important complementary information by directly demonstrating the underlying structural abnormality.

Meniscal abnormalities were the most frequently identified major structural abnormality, occurring in 48% of patients. Medial meniscal tears were observed in 26%, lateral meniscal tears in 10%, and combined medial and lateral meniscal tears in 4%. Meniscal degeneration and extrusion were identified in 12% and 6%, respectively. The greater involvement of the medial meniscus may be related to its relatively restricted mobility compared with the lateral meniscus. MRI is particularly useful for evaluating meniscal pathology

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because it demonstrates the location, morphology, and extent of tears and can simultaneously identify associated abnormalities [3,4]. In the present study, both medial and lateral menisci were systematically assessed for degeneration, different tear patterns, extrusion, and associated abnormalities.

Ligamentous abnormalities were identified in 36% of patients. The ACL was the most commonly affected ligament, with abnormalities detected in 28% of the study population. Complete ACL tears accounted for 18%, whereas partial tears or sprains accounted for 10%. PCL abnormalities were identified in 8%, MCL abnormalities in 14%, and LCL abnormalities in 6%. ACL injury is an important cause of knee instability and may be accompanied by meniscal, cartilage, and bone marrow abnormalities. MRI allows direct assessment of ligament morphology, continuity, and signal characteristics and facilitates differentiation between partial and complete injuries[5].

A marked relationship was observed between trauma and ligamentous abnormalities. Ligamentous pathology was present in 55.6% of patients with a history of trauma compared with 13.0% of patients without trauma. Meniscal and bone marrow abnormalities were also more frequent in the trauma group. These findings emphasize the importance of clinical history when interpreting MRI findings and demonstrate the value of MRI in identifying the complete pattern of traumatic internal derangement.

Articular cartilage abnormalities were detected in 32% of patients. Cartilage thinning was the most frequent abnormality, followed by focal cartilage defects, partial-thickness cartilage loss, and full-thickness cartilage loss. MRI is particularly useful for evaluating articular cartilage because it can demonstrate structural abnormalities that may not be adequately characterized by conventional radiography[6]. Progressive cartilage loss is an important component of degenerative knee disease and may contribute to pain, functional limitation, and osteoarthritis[7,10]. The present study assessed the femorotibial and patellofemoral compartments for cartilage thinning, defects, fissuring, and partial- or full-thickness loss.

Bone marrow abnormalities were observed in 28% of patients, with bone marrow edema or contusion being the most frequent finding. Subchondral marrow changes and osteochondral lesions were also identified. Bone marrow edema and contusions are important MRI manifestations of acute trauma and may occur in association with ligamentous and meniscal injuries. MRI is sensitive for detecting these abnormalities and can demonstrate occult osseous injury that may not be evident on conventional radiographs[8,9]. In the present study, bone marrow abnormalities were more frequent among patients with a history of trauma, occurring in 40.7% of patients with trauma compared with 13.0% of those without trauma.

Joint effusion was the most frequent associated MRI finding, being observed in 58% of patients. Osteophytes were present in 22%, Baker's cyst in 14%, tendinous abnormalities in 12%, synovial thickening in 10%, and bursitis in 8%. Joint effusion may accompany traumatic, degenerative, and other intra-articular disorders and therefore represents a common associated imaging finding. Osteophytes and other degenerative findings further contribute to the overall structural assessment of the knee.

The present study demonstrated a close relationship between knee pain and structural abnormalities detected on MRI. Knee pain was present in 46 of 48 patients with

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meniscal abnormalities, 34 of 36 patients with ligamentous abnormalities, 30 of 32 patients with cartilage abnormalities, and 26 of 28 patients with bone marrow abnormalities. This indicates that although knee pain is clinically non-specific, it was frequently associated with demonstrable structural abnormalities on MRI.

The distribution of MRI abnormalities according to trauma further demonstrated the clinical utility of MRI. Meniscal abnormalities were observed in 59.3% of patients with trauma compared with 34.8% without trauma. Ligamentous abnormalities were present in 55.6% and 13.0%, respectively, while bone marrow abnormalities were identified in 40.7% and 13.0%. These findings suggest a strong relationship between traumatic history and internal derangement involving the menisci, ligaments, and bone marrow.

Overall, the findings demonstrate that MRI provides comprehensive evaluation of knee joint pathology and can simultaneously identify abnormalities involving the menisci, ligaments, articular cartilage, bone marrow, and associated soft tissues. The occurrence of multiple abnormalities in individual patients highlights the importance of evaluating the knee as a whole rather than focusing on an isolated structure. Systematic MRI assessment combined with clinical correlation can therefore provide valuable diagnostic information and assist in the management of patients with suspected knee joint disorders.

Conclusion

MRI provided comprehensive evaluation of knee joint disorders, effectively identifying meniscal, ligamentous, cartilage, and bone marrow abnormalities. Meniscal pathology and ACL injuries were prominent findings, while trauma was strongly associated with ligamentous and bone marrow abnormalities. MRI with clinical correlation is therefore valuable for accurate diagnosis and characterization of knee joint pathology.

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