The Role of Ultrasound in Evaluation of Knee Joint Meniscal Injuries Compared to MRI Results

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Abstract

Background: Sports knee injuries result in pain, swelling, and limited mobility. Endoscopy is common but doesn't provide a complete diagnosis. MRI is costly and less accessible. Ultrasound is an emerging, portable, and cost-effective alternative for diagnosing meniscal and ligament injuries.

Objectives: To compare between the accuracy of Ultrasound and MRI in diagnosis and evaluation of knee joint meniscal injures.

Patients and methods: This prospective study evaluated 100 patients with knee meniscal injuries referred from an orthopedic clinic to the Diagnostic and Interventional Radiology department at Qena University. Patients underwent comprehensive examinations, including ultrasound for anterior and posterior knee assessment, and MRI with various sequences.

Results: Ultrasonography demonstrated 33.33% sensitivity and 91.46% specificity for degeneration with an 81% overall accuracy. For tear detection, it showed 91.46% sensitivity and 66.67% specificity, with an 81% overall accuracy. When assessing different sites, ultrasonography exhibited high sensitivity (89.83% for PHMM, 100% for PHLM, and AHMM), excellent specificity (92.68% for PHMM, 98.82% for PHLM, and 88.89% for AHMM), and strong accuracy (91% for PHMM, 99% for PHLM, and 91% for AHMM). Positive predictive values (PPV) ranged from 67.86% to 94.64%, and negative predictive values (NPV) were between 86.36% and 100% for the various sites compared to MRI diagnosis that used as a reference standard.

Conclusion: Ultrasound has 81% sensitivity for tears and 13% for degeneration. Ultrasound excels in detecting lesions in the posterior horn of the medial and lateral meniscus with good sensitivity, specificity, and accuracy.

Keywords: Ultrasound; Knee joint; Meniscal injuries; MRI.

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Introduction

In sports, knee injuries, particularly those affecting the meniscus, are widespread and can result in significant impairments, marked by symptoms like pain, swelling, and a limited range of motion. Although clinical indications point towards the necessity of surgical intervention, they fail to provide a complete comprehension of meniscal tears. Advanced imaging methods, predominantly magnetic resonance imaging (MRI), are considered the standard for precise diagnosis and effective treatment planning. Nevertheless, MRI is associated with limitations, including its high cost, time-consuming procedures, restricted availability, and the potential for misdiagnosis. Therefore, an increasing demand exists for supplementary diagnostic tools to ensure a thorough evaluation of meniscal injuries **(Adams et al., 2021; Kopf et al., 2020).**

Ultrasound has emerged as a promising substitute for the diagnosis of meniscal injuries. Despite MRI remaining the foremost choice for imaging, ultrasound offers distinct advantages, such as portability, safety, cost-effectiveness, and wide accessibility. It can efficiently identify various types of meniscal injuries and, when used in conjunction with dynamic techniques, can also aid in the diagnosis of ligament tears **(Yaseen and Gorial, 2019; Ahmad et al., 2022).**

The main aim of the study was to compare between the accuracy of Ultrasound and MRI in diagnosis and evaluation of knee joint meniscal injures.

Patients and methods

This prospective study aimed to assess 100 patients of both sex with mean age of 38.54 ± 9.88with knee meniscal injuries who were referred from an orthopedic clinic to the Diagnostic and Interventional Radiology department at Qena University. The study involved a two-step process, starting with ultrasound examination of the knee, followed by MRI.

Inclusion Criteria

1. Post-traumatic patients suspected of having meniscal injuries.
2. Patients experiencing knee pain (acute or chronic) accompanied by symptoms like clicking sounds, swelling, knee locking, or stiffness.
3. Clinical suspicion of a meniscal injury considered if patients exhibited joint line tenderness, a positive Mc Murray test, or a positive Apley grinding test.
4. Inclusion irrespective of whether there was a history of knee trauma.

Exclusion Criteria

1. Patients with general contraindications for MR Imaging. Examples include those with cardiac pacemakers or claustrophobia.
2. Patients with a previous history of knee issues.
3. Exclusion of patients with inflammatory arthropathy.
4. Exclusion of patients unwilling to participate in the study.

In this study, a comprehensive approach was applied to all patients. Firstly, informed consent was obtained from each patient to ensure compliance with ethical standards. Following this, an extensive medical history was meticulously gathered to gain insight into each patient's health status and potential risk factors. Subsequently, a comprehensive examination was conducted, encompassing both general and focused assessments.

Examination Process

- General health checkup.
- Patients positioned supine for localized knee joint assessment to

detect asymmetry, muscle wasting, edema, crepitus, and deformities.

- Hip joint assessment, including internal/external rotation and flexion maneuvers.

Imaging procedures

- Two main diagnostic approaches for detailed knee joint evaluation:

1. Knee Ultrasound (Fig 1, 2):

- Utilized Logic P7 ultrasound device with a 7.5 to 15-MHz linear probe.
- Anterior knee examination in a supine position with knee flexed (20°-30°).
- Posterior knee examination in a prone position with the knee extended (cruciate ligament flexed at 60°-70°).
- Meticulous assessment of components like the medial meniscus, involving external leg rotation and slight flexion.
- Identification of the medial collateral ligament, distinguishing between hyper-echoic fibrillar outer layer and inner layer.
- Recognition of the medial meniscus as the hyper-echoic wedge structure between the femur and tibia.

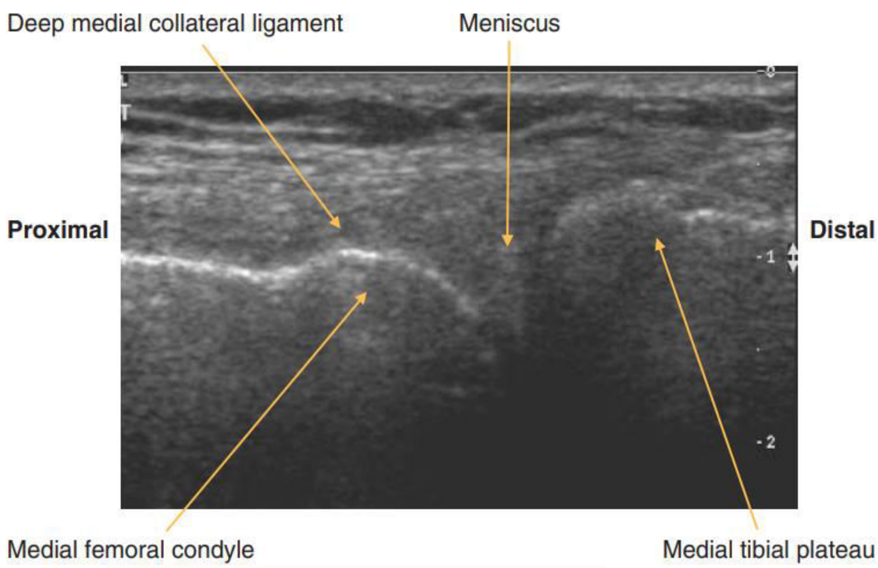

Fig 1. Lateral side of medial meniscus.

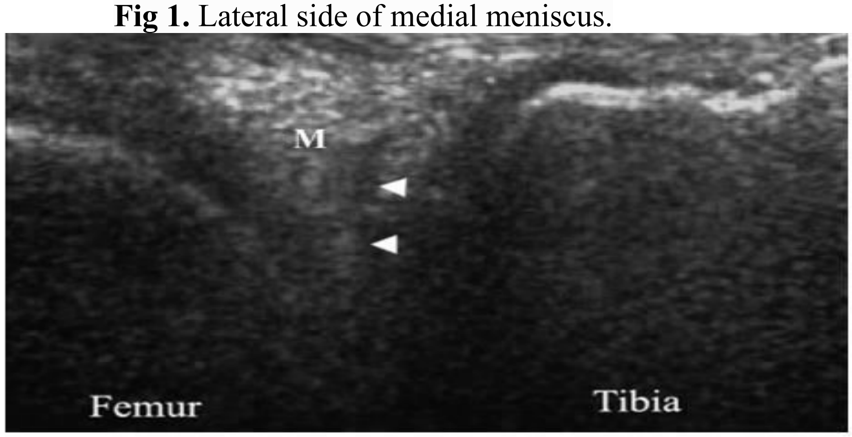

Fig 2. Longitudinal ultrasonography obtained through the posterior horn of the medial meniscus showing a discrete hypoechoic cleft extending to the tibial articular surface of the hyperechoic meniscus.

Lateral Meniscus Examination (Fig. 3):

- Internal rotation of the leg with slight knee flexion (20°-30°) for lateral meniscus assessment.
- Valgus stress was applied for evaluating the medial meniscus, while varus stress used for assessing the lateral meniscus.
- Obtained longitudinal and transverse grayscale ultrasonographic images of the menisci.

Fig.3. Tear in posterior horn of lateral meniscus extending to inferior surface demonstrated on US.

- **Ultrasound Criteria for Meniscal Injury:**
  - Criteria for meniscal injury included the presence of a distinct hypoechoic or anechoic cleft extending to the articular surfaces.
  - Detection of a defect in the hyperechoic meniscus served as an indicator of meniscal injury.
- **Knee MRI Investigations (Fig .4):**
  - Conducted using a Philips Achieva MRI device with a 1.5-Tesla superconducting magnet.
  - Multiple sequences employed for a comprehensive assessment:
    - PD-weighted sequences (sagittal, coronal, optional axial)
    - PD-weighted (fat-saturated) sequences (sagittal, coronal, optional axial)
    - Fat-saturated T2-weighted sequences (coronal, optional axial)
    - T1-weighted sequences (axial or coronal)
  - Pulse sequences used a spin echo (SE) technique with parameters set at a repetition time/echo time (TR/TE) of 600-1,800/15-80 ms.
  - T1-weighted images, proton density images, and T2-weighted images acquired in sagittal, coronal, and axial planes.
  - Thorough evaluation of each lesion based on images obtained from two planes with 5-mm thick slices and no interslice gaps.
  - A 256 × 256 matrix and an extremity surface coil were used to ensure precise imaging.

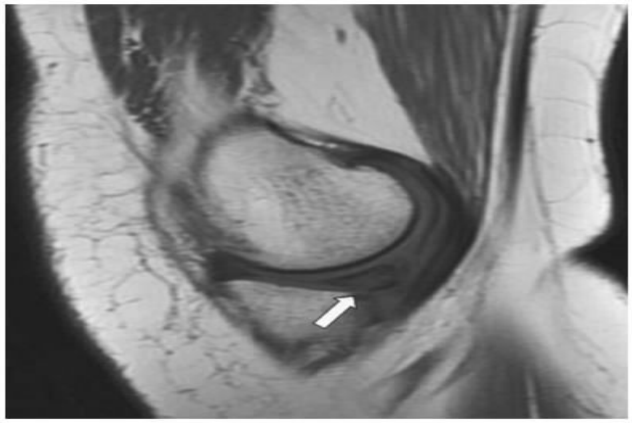

Fig 4. A sagittal T1-weighted image depicts a tear in posterior horn of medial meniscus extending to inferior surface.

Research outcome measures: To compare sensitivity, specificity, and accuracy of Knee Ultrasound studies in the detection of Meniscal Injuries compared to MRI results that used as a gold standard.

Statistical Analysis

IBM-SPSS version 24 was used for data analysis (May 2016). Kristall-Wallis and Wilcoxon's tests, as well as Spearman's correlation and logistic regression analysis, were used to determine statistical significance. Based on the type of data it contained, each variable was analysed (parametric or not). We considered results statistically significant if the P-values were less than 0. 05.(five percent).

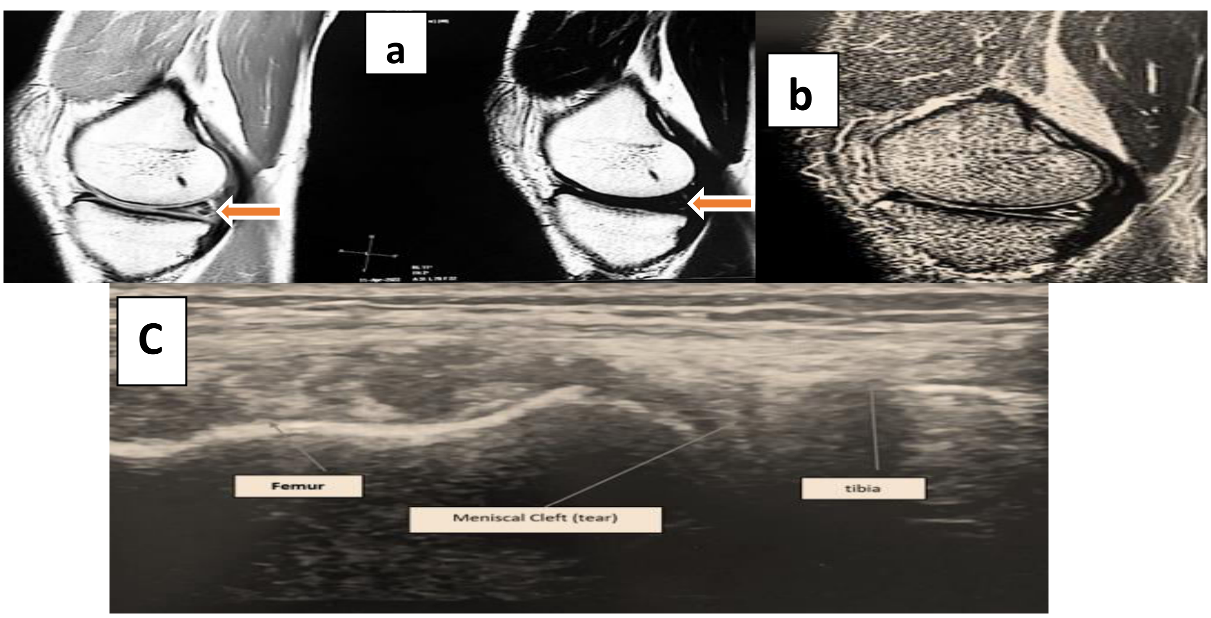

Fig.5. A 23 years Male patient Complain of left knee pain and click with history of trauma since 1 year. **MRI exam. :** (a) Sagital **PDWI and T2WI** Showed abnormal signal intensity at posterior horn of medial meniscus reaching to articular surface denoting tear. (b) Sagital **STIR** Showing branching tear within posterior horn of medail meniscus. **Ultrasonsography** (c) showing fluid filled gaped (cleft) seen within medial meniscus indicate a meniscus tear .

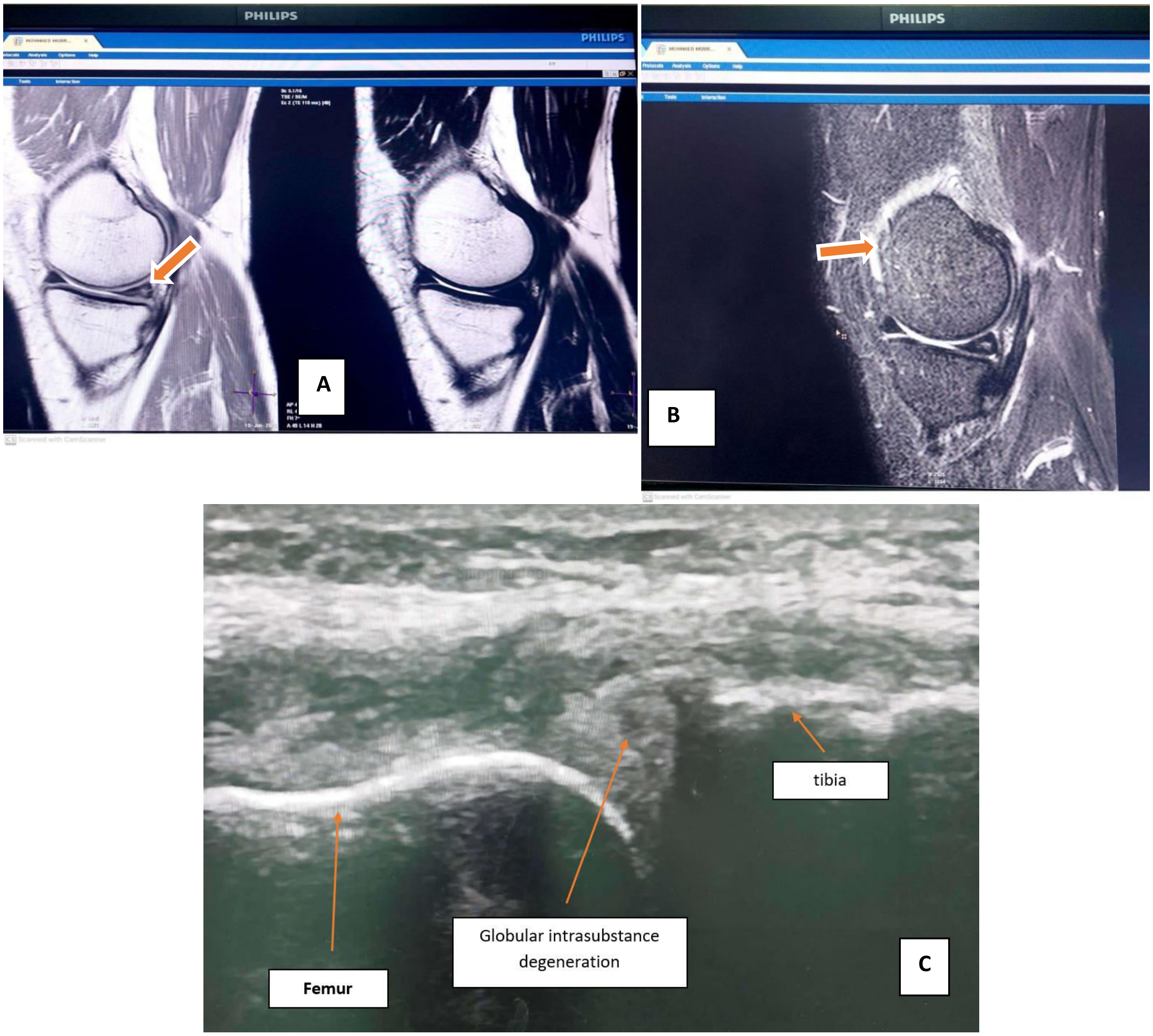

Fig.6. A 47-year-old male patient comes with left knee pain and click**. MRI exam:** (a) sagittal **T2WI** and **PDWI** Showing abnormal signal intensity within posterior horn of medial meniscus not reaching to articular surface denoting degeneration. (b) sagittal **STIR** Showing bone marrow edema. **Ultrasonography**: Fig (c) Showing irregularities and intra substance area of fluid filled (degeneration) seen within medial meniscus.

Results

(**Table.1**) presents general data for the 100 patients. Their mean age was 38.54 ± 9.88, with 72% being male. The average BMI was 28.62 ± 1.92. 58% had issues on the right. The most common mode of injury was sports trauma (66%). All patients reported symptoms of pain, tenderness, and swelling (100%), along with positive clicks (68%) and giving away (74%). Ultrasonography (US) findings showed hypoechoic areas and fluid-filled gaps in 62% of patients, effusion in 72%, globular hypoechoic areas in 12%, calcification in 10%, and a heterogeneous echo pattern in 11%. Using MRI, vertical tears were the most common lesion affecting 40%. ACL tears (57%) was the most common associated lesion followed by joint effusion (50%).

Table 1. General data of included patients.

Variables	**Value (N = 100)**
Age	38.54 ± 9.88
Sex	
• **Male**	72 (72%)
• **Female**	28 (28%)
BMI	28.62 ± 1.92
Knee side	
• **Right**	58 (58%)
• **Left**	42 (42%)
Mode of injury	
• **Road Accident**	28 (28%)
• **Senile Changes**	6 (6%)
• **Sports Trauma**	66 (66%)
Symptoms	
• **Pain**	100 (100%)
• **Tenderness**	100 (100%)
• **Swelling**	100 (100%)
• **Positive Click**	68 (68%)
• **Giving away**	74 (74%)
US Findings	
• **Hypoechoic areas fluid filled gap (tear)**	62 (62%)
• **Effusion (Edema)**	72 (72%)
• **Globular hypoechoic areas (Synovitis)**	12 (12%)
• **Calcification (Crystal Deposition)**	10 (10%)
• **Heterogeneous echo pattern (Arthritis)**	11 (11%)
MRI diagnosis of meniscal lesions	
• **Degeneration Grade 2**	17 (17%)
• **Vertical tear**	40 (40%)
• **Horizontal tear**	14 (14%)
• **Bucket handle tear**	7 (7%)
• **Complex tear**	10 (10%)
• **Branched tear**	5 (5%)
Different association of lesions	
• **Para meniscal cyst**	48 (48%)
• **Ganglion cyst**	49 (49%)
• **Joint Effusion**	50 (50%)
• **ACL tear**	57 (57%)
• **Osteoarthritic changes**	14 (14%)

(**Table.2**) displays a comparison between US and MRI findings for the included subjects. The diagnosis of tears showed no significant difference, with 81% agreement between both methods (p = 0.8555). For degeneration, US identified 13%, while MRI showed 18%, which was not statistically significant (p = 0.3286). However, a significant increase was observed in the "Normal" category, with 6% in US compared to none in MRI (p = 0.0289). Concerning the site of the lesion, there was a non-significant difference between US and MRI for the PHMM, PHLM, and AHMM sites, with p-values of 0.999, 0.845, and 0.8755, respectively. Also, a significant increase in lesion detection by MRI was noted for the AHLM site, with US showing none and MRI revealing lesions in 7% of cases, yielding a p-value of 0.014. Ultrasonography displayed a sensitivity of 33.33% and specificity of 91.46% for degeneration (N = 13), with a PPV of 46.15% and NPV of 86.21%, resulting in an 81% overall accuracy. For tear detection (N = 81), ultrasonography had a sensitivity of 91.46% and specificity of 66.67%, along with a PPV of 92.59% and NPV of 63.16%, yielding an 81% overall accuracy as well. In the assessment of different sites, ultrasonography (US) showed highest sensitivity (100%) with PHLM and AHLM, highest specificity for PHLM (98.82%), highest PPV with PHMM (94.64%) and highest NPV with both PHLM and AHMM (100%) (**Table.3, Fig.7,8**).

Table 2. Comparison between both US and MRI findings among included subjects

Variables	US Evaluations (N = 100)	MRI Evaluations (N = 100)	P. Value
Diagnosis			
• **Tear**	81 (81%)	82 (82%)	0.8555
• **Degeneration**	13 (13%)	18 (18%)	0.3286
• **Normal**	6 (6%)	0	0.0289*
Site of lesion			
• **PHMM**	56 (56%)	56 (56%)	0.999
• **PHLM**	16 (16%)	15 (15%)	0.845
• **AHMM**	28 (28%)	29 (29%)	0.8755
• **AHLM**	0	7 (7%)	0.014*

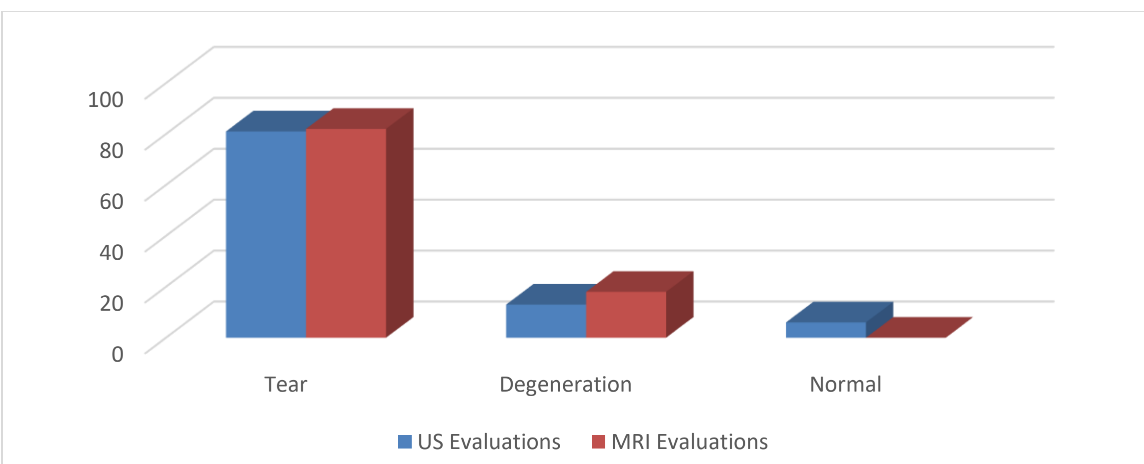

Fig.7. Comparison between both US and MRI diagnosis

Table 3. Accuracy measures of ultrasonography regarding type of lesion

MRI examination	US			Total	Sensitivity	Specificity	PPV	NPV	Accuracy
	Degeneration (N = 13)	Tear (N = 81)	Normal (N = 6)						
Degeneration	6 (6%)	6 (6%)	6 (6%)	18 (18%)	33.33	91.46	46.15	86.21	81
Tear	7 (7%)	75 (75%)	0	82 (82%)	91.46	66.67	92.59	63.16	81
Total	13 (13%)	81 (81%)	6 (6%)	100 (100%)					
	PHMM (N = 56)	PHLM (N = 15)	AHMM (N = 29)						
PHMM	53 (53%)	0	6 (6%)	59 (59%)	89.83	92.68	94.64	86.36	91
PHLM	0	15 (15%)	0 (0%)	15 (15%)	100	98.82	93.75	100	99
AHMM	0	0	19 (19%)	19 (19%)	100	88.89	67.86	100	91
AHLM	3 (3%)	1 (1%)	3 (3%)	7 (7%)					
Total	56 (56%)	16 (16%)	28 (28%)	100 (100%)					

Discussion

In our study, the participants mean age was 38.54 years (SD: 9.88) and ranged from 29 to 65 years. Of 100 individuals, 72% were male (n=72) and 28% female (n=28). The average BMI was 28.62. We found similar results to prior ultrasonography (USG) research on meniscal injury diagnosis. **Mir et al. (2021)** compared USG's sensitivity, specificity, and accuracy to MRI in 60 17-59-year-olds.

All 100 participants in our research had meniscal tear symptoms as pain, soreness, and edema. 68% of respondents reported a good click sensation, and 74% experienced knee joint giving away. Our findings supported **Mostafa et al. (2019),** who compared MRI and ultrasound for knee meniscal tear diagnosis. The research included 50 patients. All patients had discomfort, edema, and stiffness/resistance.

In our study, ultrasound (US) detected meniscal tears (81% sensitivity) and degeneration (13% sensitivity) in our investigation. In 62% of instances, hypoechoic regions and fluid-filled spaces indicated tears. MRI and US were similar, with 82% identifying tears and 18% degeneration. The posterior horn of the medial meniscus was most usually impacted (56%), followed by the anterior (29%) and posterior (15%) horns. US, a non-invasive and accessible approach, agrees with MRI for identifying meniscal injury. We observed posterior horn meniscal lesions to be common, as did **Sheikh et al. (2021).** They vary from **Chianget al. (2007),** who had trouble identifying meniscal degeneration from tears using ultrasonography. **Elshimy et al. (2023)** also found that ultrasonography could diagnose meniscal and collateral ligament injuries, although it missed certain rips seen during arthroscopy, suggesting limits.

MRI is the gold standard for soft tissue visualization, whereas US provides real-time, dynamic imaging during joint mobility. US is cheaper, available, and radiation-free. This investigation supports the benefits of both imaging methods **(Bianchi et al., 2003; Heron & Hine, 2003; Hussain, 2022).**

Our results match **Anjum (2021),** who found high-frequency ultrasound to diagnose meniscal injuries with 81.3% sensitivity and 38% specificity. **Farag et al. (2023)** found ultrasonography accuracy of 85.2% for meniscal tear and 70.6% for degeneration.

Our findings contradict **Mostafa et al. (2019),** who found ultrasound insufficient for tear type classification and recommended MRI. Our work emphasizes ultrasound's ability to identify tears and degeneration, whereas Mostafa et al. emphasize the MRI's superiority in tear type classification.

Study limitations: Ultrasound accuracy and interpretation depend on operator expertise, and ultrasound and MRI protocols may not be standardized, limiting comparability. Diagnostic errors are possible, but MRI reliability assumes perfect accuracy. Meniscus injuries were the only focus of the study, which may have missed other knee pathologies. The study's single center may limit generalizability. Ultrasound versus MRI knee joint meniscal injury evaluations in multi-center studies with larger sample sizes and standardized protocols would be more robust and comprehensive.

Conclusion

Ultrasound surpasses MRI in assessing knee meniscal damage, with 81% sensitivity for tears and 13% for degeneration. It detects various features and has intermediate sensitivity (33.33%) and high specificity (91.46%) for degenerative changes, and moderate specificity (66.67%) for meniscal tears, yielding 81% accuracy. Ultrasound is non-invasive, widely accessible, cost-effective, offering real-time dynamic evaluation during joint movement. MRI is preferred for soft tissue contrast and multiplanar capabilities. Ultrasonography excels in detecting lesions in the posterior horn of the medial and lateral meniscus with good sensitivity, specificity, and accuracy.

Abbreviations

ACL	Anterior Cruciate Ligament
AHLM	Anterior Horn of The Lateral Meniscus
AHMM	Anterior Horn of The Medial Meniscus
MRI	Magnetic Resonance Imaging
PHLM	Posterior Horn Of The Lateral Meniscus
PHMM	Posterior Horn Of Medial Meniscus
US	Ultrasound

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