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Magnetic Resonance Imaging as a Gold Standard Imaging Modality in Comparison to X-Ray Imaging and Ultrasound in the Diagnosis, Evaluation, and Follow-up of Hip Joint Osteoarthritis

Sabah Hasan Shindakh[1], Fernando Ruiz Santiago[2], Ali Falah Zbalah[3], Thair Wali Ali[4], Mustafa Karam Alfawadi[5], Haydar Raheem Hmoud[6*]

[1]Radiologist, Head of Radiation Protection Center, Ministry of Health and Environment, Baghdad, Iraq; [2]Head of Radiology Department, Hospital of Traumatology, Carretera de Jaen SN, 18014 Granada, Spain; [3]Rheumatologist, Al-Kindy College of Medicine, University of Baghdad, Iraq; [4]Pathologist, College of Medicine, Al-Qadisiyah University, Iraq; [5]Medical Physicist, Private International Medical Center, Baghdad, Iraq; [6]Department of Family and Community Medicine, Al-Kindy College of Medicine, University of Baghdad, Iraq

ABSTRACT

Objective: In patients with hip osteoarthritis (OA), this study sought to assess and contrast the diagnostic efficacy of magnetic resonance imaging (MRI), the gold standard, with conventional radiography (X-ray) and ultrasound (US). Methods: A mean age of 52.8 ± 7.6 years was obtained from 63 patients (126 hip joints). The participants were all subjected to X-ray, US, and MRI of the hip. The OA presence characteristics (joint space narrowing (JSN) and bony changes on X-ray and joint effusion and soft tissue examination on US) were compared with the related MRI results. The sensitivity, specificity, positive and negative predictive values (PPV, NPV), accuracy and Kappa statistics were used to evaluate diagnostic performance. ROC analysis, association, using Phi coefficient (φ) and agreement by the Bland-Altman analysis were conducted. Results: X-ray showed high levels of specificity (94.3%) but moderate levels of sensitivity (64.3%) to detect JSN compared to MRI (Kappa=0.62). US had moderate sensitivity (65.9%), and specificity (63.6%) values compared to MRI (Kappa=0.27). Analysis of ROC indicated that X-ray had a moderate diagnostic performance in the detection of JSN (AUC=0.728) and US in the detection of bone effusion (AUC=0.748). The correlation between OA diagnoses between modalities was moderate in all cases (X-ray vs. MRI φ =0.329; US vs. MRI φ =0.386; X-ray vs. US φ =0.320). According to the Bland-Altman analysis, there was a systematic bias and broad limits of agreement between the conventional imaging and MRI and there is no interchangeability of the two methods in individual patient measurements. Conclusion: MRI is the most multifunctional modality in the evaluation of hip OA; nevertheless, X-ray and US may play an important and complementary role. X-ray is very specific in bony changes and US with regard to visualization of the soft-tissue pathology. A combined X-ray and US methodology can offer a feasible and efficient diagnostic plan to hip osteoarthritis first screening and treatment in a resource-constrained environment, including remote communities or hospitals with no MRI services.

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1. Introduction

The most frequent disease affecting human joints worldwide is osteoarthritis, which is a principal reason for joint discomfort and pain (Chen et al., 2017; Litwic et al., 2013; Yunus et al., 2020). The disease is often called age-associated arthritis, degenerative joint illness, or wear and tear arthritis (Lespasio et al., 2018). The cartilage of joints and surrounding tissues are the main tissues impacted by the illness. Osteophytes, thickening of the subchondral bone, gradual loss and degradation of articular cartilage, hypertrophy of the joint capsule, ligament degeneration, and varying degrees of synovial inflammation were among the pathological alterations (Berenbaum & Walker, 2020; He et al., 2020). In terms of etiology, the disease is a manifestation of various contributors, including genetic factors, the aging process, increased weight, and joint injury (Goldring & Goldring, 2007; Krasnokutsky et al., 2007; Loeser, 2009).

CONTACT Sabah Hasan Shindakh

This degenerative joint disease can be generally categorized as primary and as secondary type. The primary one mainly affects older adults, targeting multiple articular sites, and is often of undetermined causes (idiopathic) (Rossignol et al., 2005). The secondary type is usually confined to a single joint that has been previously affected by a well-defined disorder such as trauma (Figueiredo et al., 2016). One of the body's biggest weight-bearing joints, the hip joint is often impacted by osteoarthritis (Damen et al., 2019). Although the disease affects the entire joint, the degenerative process mostly affects the articular cartilage. Despite being the initial study modality, radiography is not very sensitive to early alterations in soft tissues, cartilage, or bone marrow (Sakellariou et al., 2017).

The pathological changes in hip OA will include subchondral cysts, progressive degradation of the articular cartilage, formation of osteophytes, muscle weakness, laxity of ligaments surrounding the arthroplasty, and inflammatory processes of the synovia. Osteoarthritis of major joints in lower extremities particularly hips may result in loss of independence and increasing dependency on medical services due to reduced mobility and high level of physical impairment (Lespasio et al., 2018).

Osteoarthritis may be combined with other diseases, including osteonecrosis, rapid-progression arthritis, inflammatory and viral arthropathies, which may manifest them in a similar or identical manner. Imaging is performed as a part of radiographic evaluation and reveals the signs of joint space narrowing, sclerosis, osteophytes, and bony distortions. The CT scans can be reformatted in multiplanar views which can give a complete study of the hip. MRI can perform tests of the existence of labral anomalies, degeneration of articular cartilage, and bone marrow indicators (Walsh & Walz, 2022).

In the country of Iraq particularly in the rural and remote areas, high diagnostic issues are witnessed in hip osteoarthritis patients due to acute shortage and high cost of the Magnetic Resonance Imaging (MRI). It causes healthcare disparity whereby high level of diagnostic provision is concentrated in the urban regions, and as such, the primary care physicians of rural regions have minimal facilities in effecting proper diagnoses and follow up.

Therefore, the present study aimed to evaluate whether conventional X-ray and ultrasound, as the most widely available imaging modality in primary health centers across Iraq, can serve as a reliable alternative to MRI, for diagnosing and monitoring hip osteoarthritis by comparing their findings in a sample of Iraqi patients.

2. Study Design and Ethical Considerations

Between June 2022 and February 2023, the Baghdad Governmental Hospital hosted a prospective, cross-sectional study on diagnostic accuracy. The Institutional Review Board of Baghdad Medical City examined and approved the study protocol (Approval No: RFB22-165; Date of Approval: 3/5/2022). Prior to their registration in the trial, each subject provided written informed consent.

2.1 Patient Selection and Eligibility Criteria

A consecutive sample of 63 patients presenting with chronic hip pain was recruited from rheumatology and orthopedic clinics.

2.1.1 Inclusion Criteria

- Adult patients between the ages of 40 and 67.
- Hip osteoarthritis is diagnosed clinically using the American College of Rheumatology's (ACR) clinical criteria (Altman et al., 1991), which usually include hip pain and two or more of the following: rate of erythrocyte sedimentation (ESR) radiographic joint space narrowing, radiographic femoral or acetabular osteophytes, or less than 45 mm/h.
- Willingness to take part in the research

2.1.2 Exclusion Criteria

- History of autoimmune inflammatory arthritis (e.g., rheumatoid arthritis, spondyloarthritis).
- Previous hip surgery or major trauma to the hip within the last 6 months.
- Contraindications to MRI (e.g., non-MRI compatible implants, severe claustrophobia).
- Secondary causes of osteoarthritis other than trauma (e.g., avascular necrosis, septic arthritis, Paget's disease).
- Pregnancy.

2.2 Study Setting and Patient Pathway

All participants underwent a standardized imaging protocol within a 4-week period:

- Plain Radiography (X-ray): Performed first as the standard-of-care.
- Magnetic Resonance Imaging (MRI): Performed as the reference standard.
- Ultrasound (US): Used to evaluate soft-tissue elements, such as joint surfaces and cartilage.

The images from each modality were interpreted separately by two radiologists with over 5 years of musculoskeletal experience to avoid interpretation bias.

2.3 Radiographic Assessment

The Tonnis classification system was used to determine the degree of osteoarthritis in hip joints in addition to individual radiographic features (Tönnis, 1987). One way to describe the Tonnis scale is as follows:

Grade 0: No osteoarthritis symptoms (>4mm).

Grade 1: Mild osteoarthritis, increased sclerosis, a minor reduction in joint space, and either no loss of the femur's sphericity (2.5–4 mm) or a slight loss.

Grade 2: Small cysts, moderate joint space loss, and moderate head sphericity loss (1.5mm–2.5mm) are the hallmarks of moderate osteoarthritis.

Grade 3: This severe form of osteoarthritis is characterized by massive cysts, complete or severe joint space loss or disappearance, and significant femur head deformation (less than 1.5 mm or bone on bone). It was evaluated by a musculoskeletal radiologist (fellowship-trained) who was not aware of ultrasound and MRI findings.

2.4 Radiological Techniques

2.4.1 Magnetic Resonance Imaging (MRI)

- Scanner: Philips, Achieva 1.5 Tesla
- Patient Positioning: Supine, feet first, with a body matrix coil centered over both hip joints.
- Imaging Protocol: All patients underwent the following sequences:
- Coronal T1-weighted Spin Echo (TR: 1100-1200 ms, TE: 24 ms)
- Coronal T2-weighted Spin Echo (TR: 3500 ms, TE: 120 ms)
- Coronal Short Tau Inversion Recovery (STIR) (TR: 2500-3500 ms, TE: 55 ms)
- Coronal Gradient Echo (TR: >650 ms, TE: 18 ms)
- Axial T1-weighted Spin Echo (TR: 1100-1200 ms, TE: 24 ms)
- Axial T2-weighted Spin Echo (TR: 3500-5500 ms, TE: 110-115 ms)
- Coronal Proton Density (PD) Fat-Saturated
- Sagittal PD Fat-Saturated
- Parameters Common to all sequences: Slice thickness: 4-5 mm, Gap: 1 mm, Field of view: 35-50 cm.

MRI Findings:

1.-Acetabular subchodral cyst.
2.-Greatest size of the acetabular cyst: numerical (mm)
3.-hip joint space: numerical (mm)
4.-Acetabular cartilage defects. (0=No, 1=Yes)
5.-Location of acetabular cartilage defects: anterior, medium, posterior
6.-femoral subchondral cyst. (0=No, 1=Yes)
7.-Greatest size of femoral subchondral cyst: numerical (mm)
8.-Bone edema. (0=No, 1=Yes)
9.-Bone spurs. (0=No, 1=Yes)
10.-Center-edge Wiberg angle: numerical (degrees)
11.-Alpha angle: numerical (degrees)
12.-Labral tear. (0=No, 1=Yes)
13- Joint effusion. (0=No, 1=Yes)

2.4.2 Ultrasound (US)

- Device: High-end ultrasound system GE Voluson E6, hospital type with a high-frequency linear transducer (7-12 MHz).

- Examination: Bilateral examination of the hips and trochanteric regions was performed regardless of unilateral symptoms. Patients were examined supine with 15°–20° of external hip rotation for the anterior joint, and in the lateral decubitus position for the

trochanteric region. Predefined settings were used, with adjustments for depth, gain, and focus.

Ultrasound Findings

1. Bone spurs. (0=No, 1=Yes)
2. Joint effusion. (0=No, 1=Yes)
3. Synovitis. (0=No, 1=Yes)
4. Labral tear. (0=No, 1=Yes)
3. Plain Radiography (X-ray)

- For every patient, a frog-leg lateral view of the hip and a standard anteroposterior (AP) view of the pelvis were acquired. In order to profile the femoral head-neck junction, the frog-leg view was performed with the patient supine, the afflicted knee bent to 30°–40°, and the hip abducted to around 45°.

X-ray Findings: The radiologist used a threshold of ≤ 2.0mm at the narrowest point of the superior compartment to define the presence of JSN (1=Yes). Measurements were performed using the digital caliper tool on the PACS (Picture Archiving and Communication System), but for the purpose of the Tönnis Grading and statistical correlation, the data was recorded as a binary presence/absence variable.

1. Bone cyst (0=No, 1=Yes)
2. Severe deformity of femoral head (0=No, 1=Yes)
3. Osteosclerosis (0=No, 1=Yes)
4. Osteophyte (0=No, 1=Yes)
5. Femoral head deformity (0=No, 1=Yes)
6. Joint space narrowing (0=No, 1=Yes)

2.5 Data Collection and Variables

A standardized case report form was utilized in the data collection and comprised:

- Demographics Age, gender, occupation, residence.
- Clinical Presentation: Suffering, gait problem, stiffness, swelling, movement inhibition, etc.
- Findings of Imaging: MRI, X-ray, and ultrasound all qualitative and quantitative findings were captured.

2.6 Statistical Analysis

IBM SPSS Statistics Windows version 26.0 was used to analyze the data. Descriptive statistics (mean ± standard deviation, frequencies, and percentages) were used to summarize the data. Using ROC curve analysis, the diagnostic performance of X-ray and ultrasound was assessed against MRI as the reference standard, determining the Area under the Curve (AUC), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Cohen's Kappa (κ) was used to evaluate the degree of agreement between modalities for categorical findings. Statistical significance was defined as a p-value of less than 0.05.

3. Results

3.1 General Characteristics

A total of 63 patients (126 hip joints) were enrolled in this study. The cohort had a mean age of 52.8 ± 7.6 years, ranging from 40 to 67 years, with all participants being nonalcoholic. Baseline characteristics are presented in Table 1.

Table 1: General Characteristics of Patients

Characteristic		N (%)
Age, Years	52.8± 7.6	63 (100)
Gender	Male	35 (55.6)
	Female	28 (44.4)
Occupation	Governmental employee	31 (49.2)
	Self-employed	19 (30.2)
	Housewife	13 (20.6)
Sport Habit	Yes	9 (14.3)
	No	54 (85.7)
Severity of Osteoarthritis	Tönis I	14 (22.2)

	Tönis II	18 (28.6)
	Tönis III	23 (36.5)

3.2 Clinical Features of Patients with Osteoarthritis of Hip Joint

The clinical features of patients with hip joint osteoarthritis are shown in Table 2. Pain and gait difficulty, deformity, nodules and tophi, were reported in all patients, swelling and effusion were seen in 55 (87.3%), limitation and joint of movement was observed in 47 (74.6%), weakness was seen in 44 (69.8%), redness and warmth were seen in 38 (60.3%), and joint stiffness was seen in 6 (9.5%) as shown in Figure 1. Bursae and extra-articular manifestations were not reported.

According to the number of joints involved, patients were categorized into 96.7% and 3.3% as having mono-articular and poly-articular disease respectively.

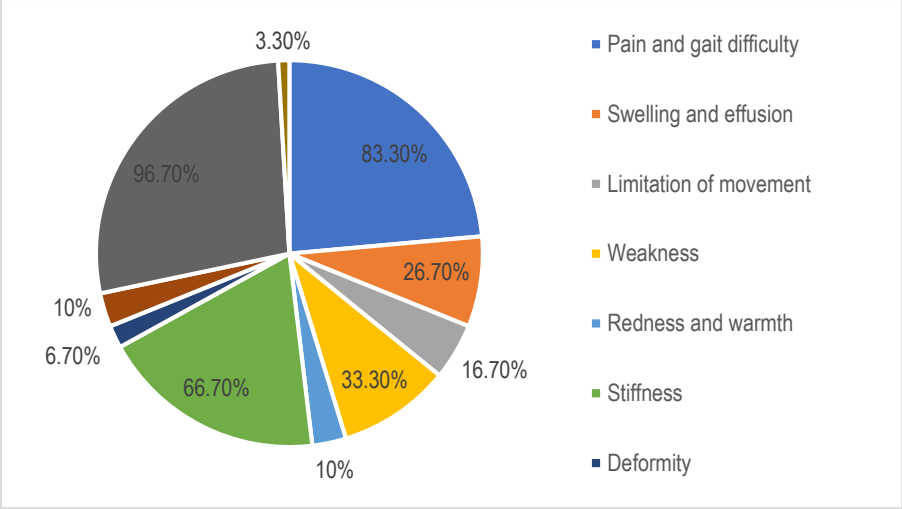


Figure 1: Clinical Features of Patients with Osteoarthritis

3.3 MRI Findings in Patients with Osteoarthritis of the Hip Joint

Qualitative MRI findings in patients with osteoarthritis of the hip joint enrolled in this study are shown in Figure 2.

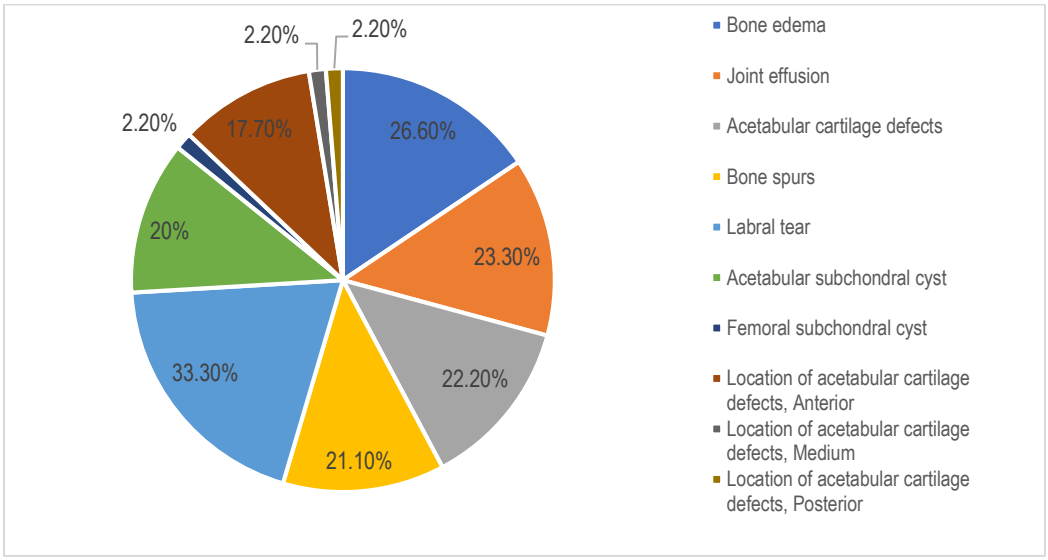


Figure 2: Qualitative MRI Findings in Patients with Osteoarthritis of the Hip Joint

Quantitative MRI findings in patients with osteoarthritis of the hip joint enrolled in this study are shown in Table 2. The mean, standard deviation, and range of Hip joint space, Center-edge Wiberg angle, and Alpha angle are shown in the table.

Table 2: Quantitative MRI Findings in Patients with Osteoarthritis of the Hip Joint

Characteristic	Mean ±SD	Range (Minimum-Maximum)
Hip Joint Space (mm)	3.2 ±0.9	1-5
Center-Edge Wiberg Angle	31.8±3.5	20-40
Alpha Angle	60.6±5.0	50-70

A comparison of ultrasound to x-ray findings in patients with hip osteoarthritis is shown in Table 3. Bony lesions, such as bone cysts and bone spurs, can be detected using MRI and X-ray, whereas soft tissue lesions, such as labrum tears and joint effusion, can be seen using MRI and Ultrasound.

Table 3: Comparison of Ultrasound to X-Ray Findings in Patients with Hip Osteoarthritis.

Characteristic	X-ray		US		MRI	
	n	%	n	%	n	%
Bone Cyst	1	1.6	7	11.1	3	4.8
Increased Osteosclerosis	38	60.3			45	71.4
Minor or Moderate Loss of Femoral Head Sphericity	42	66.7				
Joint Space Narrowing	24	38.1			12	19.0
Deformity of Femoral Head	29	46				
Bone Spurs	12	19.2	8	12.7	30	47.6
Joint Effusion			45	71.4	44	69.8
Labrum Tear			30	47.6	20	31.7
Synovitis			26	41.3	44	69.8
Osteoarithritis	41	65.1	36	57.1	49	77.8

3.4 Agreement Between Individual Imaging Features and MRI Reference

To assess the modality-specific diagnostic performance beyond overall osteoarthritis diagnosis, we analyzed the agreement of individual pathological features between conventional imaging and MRI. Table 4, 5, and 6 present the concordance for two key diagnostic features: joint space narrowing on radiography and joint effusion on ultrasound, using corresponding MRI findings as the gold standard respectively.

Table 4: Association Between X-Ray Joint Space Narrowing and MRI Hip Joint Space Findings

	MRI Hip Joint Space +	MRI Hip Joint Space -	P-value
X-ray JSN +	18	2	< 0.001
X-ray JSN -	10	33	

Table 5: Association Between Ultrasound Joint Effusion and MRI Joint Effusion Findings

	MRI Joint Effusion +	MRI Joint Effusion -	P-value
US Effusion +	27	8	0.024
US Effusion -	14	14	

Table 6: Comparative Diagnostic Performance of X-Ray Joint Space Narrowing with MRI Joint Space and US Joint Effusion and MRI Joint Effusion

Feature	Sensitivity	Specificity	PPV	NPV	Accuracy	Kappa	P-value
X-ray	64.3%	94.3%	90.0%	76.7%	81.0%	0.62	<0.001
US	65.9%	63.6%	77.1%	50.0%	65.1%	0.27	0.023

3.5 ROC Analysis Results

X-ray showed moderate diagnostic performance for detecting joint space narrowing to MRI, with an AUC of 0.728 (p-value: 0.015, 95% Confidence Interval: 0.568-0.888). The best balance of sensitivity and specificity was achieved at a cutoff of 0.5, yielding 75.0% sensitivity and 29.4% specificity (Figure 3).

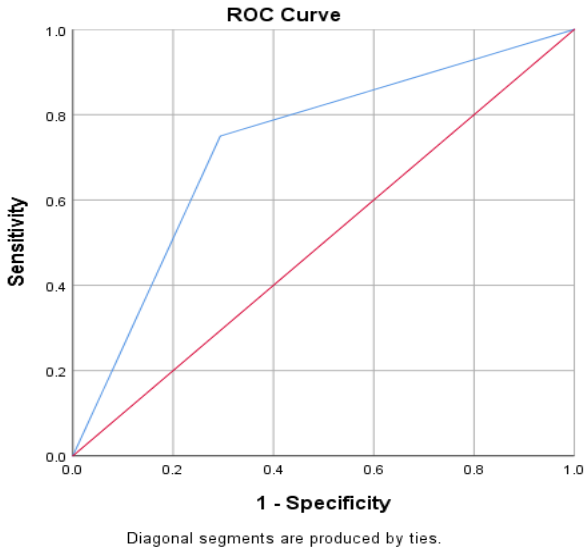


Figure 3: Performance of X-Ray in Detecting Joint Space Narrowing Compared to MRI by ROC Test.

US showed moderate diagnostic performance for detecting bone effusion compared to MRI, with an AUC of 0.748 (p-value: 0.002, 95% Confidence Interval: 0.604-0.891). The best balance of sensitivity and specificity was achieved at a cutoff of 0.5, yielding 86.4% sensitivity and 36.8% specificity (Figure 4).

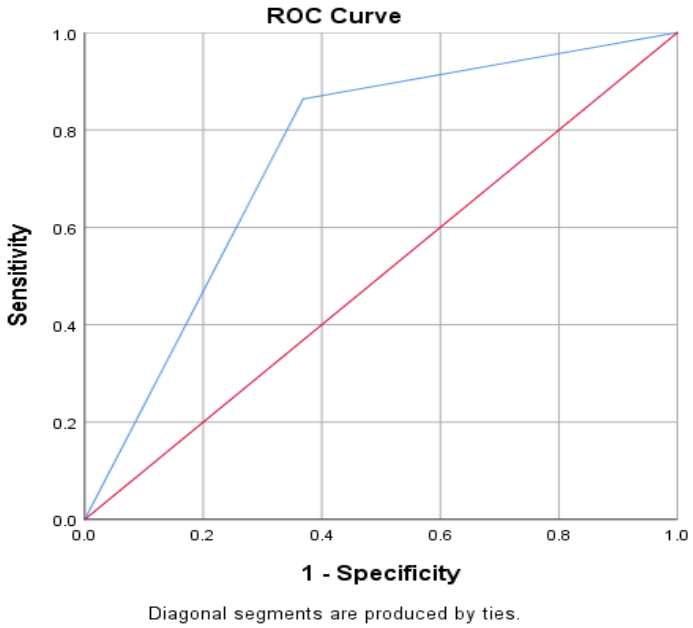


Figure 4: Performance of US in Detecting Joint Effusion Compared to MRI by ROC Test.

3.6 Association Analysis of OA across imaging modalities

The association between osteoarthritis diagnoses across imaging modalities was assessed using Phi coefficient (φ), which measures the strength of association in 2×2 contingency tables. This analysis complements agreement measures by evaluating the relationship strength between binary outcomes from different imaging techniques (Table 7). For X-ray vs Ultrasound comparison, sensitivity and specificity represent agreement proportions rather than diagnostic performance against a reference standard.

Table 7: Association Between Diagnoses Modalities of OA

Comparison	φ	p-value	Strength	Sensitivity	Specificity	Accuracy
X-Ray and MRI	0.329	0.009	Moderate	73.5%	64.3%	71.4%

US and MRI	0.386	0.002	Moderate	67.3%	78.6%	69.8%
X-Ray and US	0.320	0.010	Moderate	68.3%	71.4%	68.3%

3.7 Bland-Altman Analysis of Method Agreement

The analysis of agreement between imaging modalities was done using the Bland-Altman analysis to determine both the systematic bias (mean) and random variability (95% limits of agreement). This analysis presents in-depth data regarding the possibility of interchangeability of procedures to clinical use as illustrated in Table 8 and Figures 5, 6 and 7.

Table 8: Bland-Altman Analysis of Agreement Between Imaging Modalities

Comparison	Bias, (points)	Std	Lower LoA	Upper LoA	Agreement Range, (points)
X-Ray and MRI	-0.91	1.838	-4.51	+2.70	7.21
US and MRI	-1.19	1.712	-4.55	+2.17	6.71
X-Ray and US	+0.29	1.091	-1.85	+2.43	4.28

- Std: Standard Deviation
- LoA: Level of Agreement

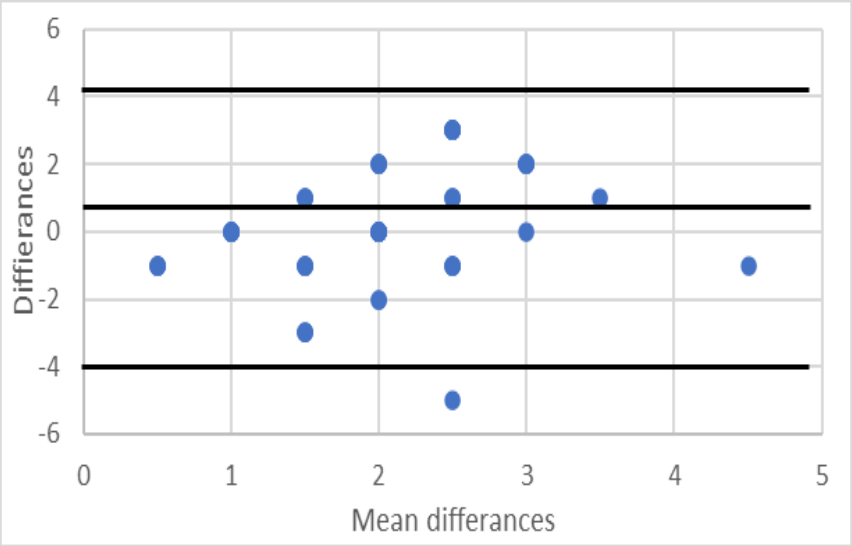


Figure 5: Level of Agreement between X-ray and MRI by Bland-Altman Test

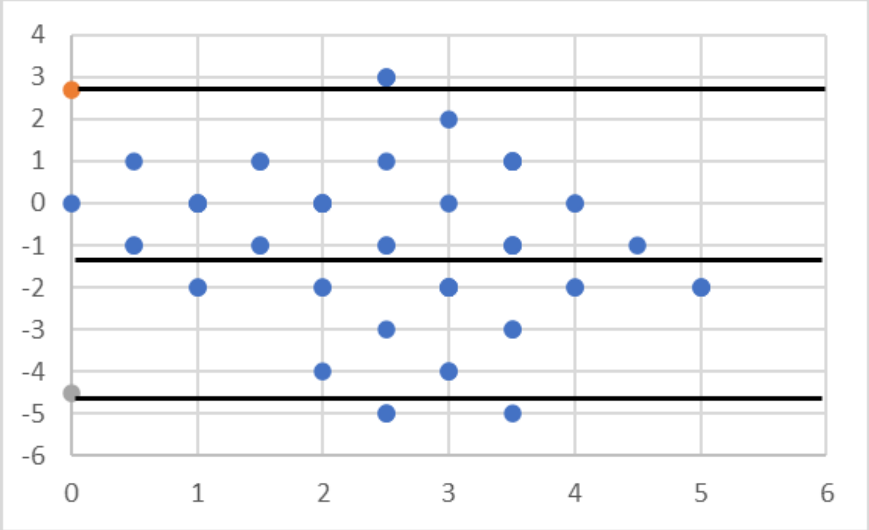


Figure 6: Level of Agreement between US and MRI by Bland-Altman Test

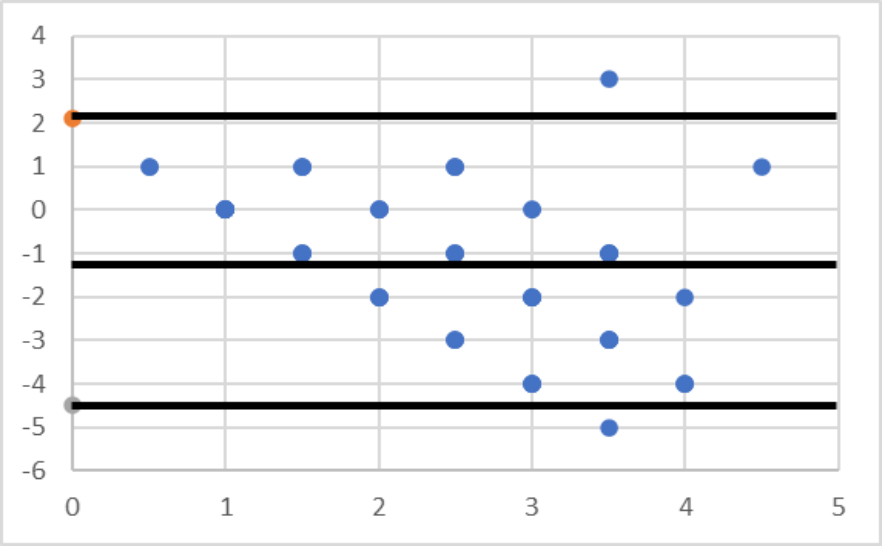


Figure 7: Level of Agreement between X-ray and US by Bland-Altman Test

4. Discussion

This paper gives a close comparative examination of traditional radiography (X-ray) and ultrasonography (US) versus the magnetic resonance imaging (MRI) as the standard of measuring hip osteoarthritis (OA). The results of our study clarify the specific diagnostic patterns of the two modalities, which supports the idea that the two modalities provide complementary information and not redundant in the clinical evaluation of hip OA.

Pain and gait difficulty were the clinical features of our cohort and were observed universally, in line with the symptomatic characteristic of advanced hip OA (Mobasheri & Henrotin, 2015). The prevalence of swelling/effusion (87.3%) and limitation of movement (74.6%) further indicates the high prevalence of major effect of the disease on the functioning of the body. It is interesting that the prevalence of mono-articular disease (96.7%) in our sample was enormous and could indicate a certain etiological or phenotypic pattern among this group of patients, which could have been caused by factors of biomechanics and not necessarily the occurrence of a systemic inflammatory process.

The strengths of X-ray and US are well defined by the modality-specific detection of the pathological features as outlined in Table 3. Radiography helped to detect traditional bony changes of OA, including the severity of osteosclerosis (60.3%), the disappearance of femoral head sphericity (66.7%), and the decrease of the joint space (38.1%). Ultrasonography on the other hand did better in visualizing soft-tissue pathologies, finding an effusion of the joint in a high percentage of patients (71.4%), and a significant number of labrum tear (47.6%) and synovitis (41.3%) tear. This concurs with the X-ray and US modalities roles that have been in place since the beginning of times, in which the X-ray provides the structural bony outcome of OA, and the US a dynamic perspective of the inflammatory and soft-structural aspects of the disease (Braun & Gold, 2012).

The analysis of the agreement with MRI was an important source of information about the validity of these traditional tools. In the case of the most significant radiographic change of joint space narrowing (JSN), X-ray only showed the changes to be quite specific (94.3%) and positive predictive value (90.0%), indicating that, when JSN appears in an X-ray, it is indeed a very reliable indicator of actual cartilage loss as evidenced by MRI. Nevertheless, it had a moderate level of sensitivity (64.3%), which resulted in a high number of false negatives. It highlights a basic weakness of radiography, its failure to show early cartilage degeneration before it can be seen as a loss of joint space on a plain film (Roemer et al., 2011). High specificity but constrained by this restricted sensitivity are, therefore, the reason behind the substantial agreement (Kappa=0.62).

The same trend was followed in ultrasound when used to detect effusion in a joint. Although US demonstrated moderate sensitivity (65.9%), it also exhibited lower specificity (63.6%), which led to fair agreement with MRI only (Kappa=0.27). It means that US can identify effusion, however, it can be confused with other pathologies or over-declare its presence, or the other way round, complex or localized fluid collections that cannot be conclusively detected by MRI.

These relationships were also further quantified by the ROC curve analysis. X-ray showed a moderate general aptitude (AUC=0.728) to differentiate patients with and without MRI-confirmed JSN. Interestingly, US demonstrated the moderate AUC (0.748) in the occurrence of joint effusion than MRI, which had high sensitivity (86.4%), but low specificity (36.8%). This result has clinical implications, with bone marrow lesions (BMLs) being closely related to pain and having predictive capacity of structural changes in OA

(Felson et al., 2003). The sensitivity is so high that US may be useful as a sensitive, readily available, screening method to suspect BMLs, but due to its low specificity the test should be followed up by a definitive diagnosis using MRI.

The correlation between the total diagnoses of OA in the various modalities as captured by the Phi coefficient was all moderate (φ ~0.32-0.39). This statistically significant, but moderate correlation proves the assumption that X-ray, US and MRI are interconnected in the conclusions made in the diagnoses, but intrinsically, they are examining different aspects of the OA paradigm. They cannot be global used interchangeably but are chosen according to the clinical question--X-ray, synovitis and effusion, and thorough assessment of all the structures of the joints including cartilage and bone marrow of MRI.

Lastly, the Bland-Altman analysis showed some significant quantitative differences. The systematic bias, especially the negative bias between US and MRI (-1.19) and X -ray and MRI (-0.91) means that both traditional modalities have a consistent trend of exaggerating the severity of the disease when compared to the gold standard MRI. The broad margins of the agreement of all comparisons indicate a significant random variation between approaches to individual patients. This is an important practical lesson: the measurements provided in one modality cannot be accurately translated into values in another in a clinical context, which is why the same type of modality should be used when serial measurements of the disease progression in a patient are necessary (Giavarina, 2015).

5. Conclusion

Our finding supports a multimodal imaging of hip OA. Radiography is still the investigation of bony morphology and joint space with the first line. The ultrasonography is a special, dynamic, and non-ionizing technique of assessing the inflammatory condition and defects of soft tissue. MRI is however the most complete modality, which is able to identify early and pre-radiographic disease, including cartilage integrity and bone marrow pathology. Imaging selection must be based on the clinical scenario at hand and the advantages and disadvantages of each method will be known. Most importantly, in resource-restricted locations like remote locations or in small hospitals where MRI is not widely available, our results prove the sensible application of a composite X-ray and US strategy. This easily available and affordable combination is capable of giving strong diagnostic data: X-ray to determine bony alterations and joint-space compressibility, and US to determine active inflammatory elements such as effusion and synovitis. Such a combined protocol has the potential to dramatically increase diagnostic confidence and initial management decisions and ensure a wider access to the necessary imaging of hip OA patients in a wide variety of healthcare settings.

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