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Review Article

Ultrasonography Versus MRI for the Diagnosis of Temporomandibular Joint Internal Derangement: A Systematic Review

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Abstract

Introduction: Magnetic resonance imaging (MRI) is the gold standard for the diagnosis of internal temporomandibular joint (TMJ). However, it is frequently expensive, time-consuming, and not readily available. Furthermore, ultrasonography (US) has been suggested as a non-invasive, easy-to-access, and cost-effective alternative, but its accuracy as a diagnostic tool is debatable. Thus, this systematic review aimed to assess the current evidence regarding the use of US for diagnosing internal TMJ disorders compared to MRI.

Methods: PubMed, Web of Science, and Scopus international databases were searcherd for studies published from December 2000 to March 2022. A multiple search strategy involved the use of keywords, medical subject headings, and terms related to TMJ disorders (TMJ, internal derangement, and disc displacement), imaging modalities (ultrasound, Doppler, and MRI), and diagnostic accuracy using Boolean operators. Surveys comparing the accuracy of diagnosis between ultrasound and MRI were employed as a reference standard. No review articles, case reports, or studies were included in cases where data were inadequately provided to calculate diagnostic accuracy indices. The QUADAS-2 tool was utilizeds to evaluate the methodological quality and risk of bias of studies. References of relevant articles were also reviewed manually.

Results: The database searches identified 576 records. After removing 148 duplicates, 428 records remained for screening. Following tilte and abstract screening based on the eligibility criteria, 29 articles were assessed for full-text eligibility. Eventually, 19 articles were included and evaluated using the STARD checklist, which all achieved an acceptable score (at least 12 out of 27).

Conclusion: US may serve as an initial diagnostic modality for TMJ disorders. However, MRI remains warranted for confirmation in cases with abnormal disc position, surgical indications, or suspected medial disc displacement not excluded by US findings.

Keywords: Ultrasonography, Magnetic resonance imaging, Internal derangement, Temporomandibular joint, Systematic review

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Introduction

The temporomandibular joint (TMJ) is a complicated joint in the body that has a fundamental role in mandibular movements, including chewing, speaking, and swallowing (1). A range of structural and functional abnormalities of the TMJ, masticatory muscles, and surrounding tissues can affect the TMJ, referred to as TMJ disorders, which present a variety of symptoms, such as pain, restricted motion, and/or abnormal sounds from the joint. These disorders are very common and may impact the patients' quality of life (2, 3).

Among different types of TMJ disorders, internal derangement (ID) is one of the most prevalent pathological patterns. It involves the inability of the articular disc to move back into normal position, whether the disc is reduced or whether the articular disc is displaced into normal position. Accordingly, accurate diagnosis of ID is crucial to select the right treatment, improving prognosis while preventing the progression of structural changes. Imaging is, therefore, important in the diagnostic process and is suggested as a complementary module in the clinical assessment (4, 5).

Magnetic resonance imaging (MRI) is the reference standard for assessing the condition of the TMJ disc and soft tissues and is currently the most widely reliable method for diagnosing ID. However, MRI has limitations, such as high cost, time-consuming nature, unavailability in many centers, and inability to be used in some patients. Although other imaging modalities (e.g., computed tomography, cone-beam computed tomography, and arthrography) are also applicable, they are mainly suitable for evaluating bony structures and have limited ability to examine the articular disc in detail (6, 7).

As a non-invasive, low-cost, rapid, and readily available method, ultrasonography (US) has attracted increasing attention in the field of diagnosing TMJ disorders in recent years. This technique can be employed in dental settings and is more tolerable for patients compared to other imaging modalities. However, the available evidence regarding the accuracy and efficacy of US in diagnosing ID is inconsistent. Different studies have reported promising results and found its diagnostic accuracy inadequate. This heterogeneity in findings highlights the need for a critical and comprehensive evaluation of the available evidence (1, 4, 8, 9).

Given the lack of scientific consensus concerning the role of US in the diagnosis of internal TMJ disorders, this study has been designed to systematically review the evidence available to evaluate the utility, reliability, and diagnostic efficacy of US in comparison to MRI, as the reference standard. The present study offers higher clarity regarding the clinical role of this imaging method.

Materials and Methods

Study Type

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (2020).

Search Strategy

PubMed, Web of Science, and Scopus databased were searched for articles published from December 2000 to March 2022, without language restrictions. Our search for studies was limited to the mentioned period, as studies before this time could not be compared with the new studies in terms of reporting standards, diagnostic methodology, and technologies used, which could have introduced great heterogeneity in the results of the search. A combination of keywords, MESH terms, and Boolean operators was used in the search. Moreover, relevant journals and references of the included articles were manually reviewed to investigate the gray databases (Table 1). The search and selection process was independently performed by two authors. They independently searched all the above-mentioned databases and then screened the titles and abstracts. Additionally, conflicts were discussed and mutually agreed upon at each stage. If agreement was not reached, the third opinion was employed as the final one.

Study Selection

Retrieved studies were imported into EndNote software, duplicates were removed, and then a content analysis of titles and abstracts was used to identify studies. Furthermore, the full-texts of eligible or potentially relevant studies were reviewed to resolve final eligibility.

Inclusion and Excluded Criteria

Inclusion Criteria

Observational (cross-sectional, case-control, and cohort) studies and clinical trials were included in this review. In addition, –evaluation on the diagnostic efficacy of US for disc dislocation (DD) and patients with clinical signs/symptoms of any DD, irrespective of the type of displacement, gender, age, socioeconomic status, and so forth, were considered as the critera for inclusion in this review. Using MRI as the a gold standard and reporting an accuracy index (sensitivity, specificity, accuracy, or validity indices), at least one, were the other inclusion criteria.

Exclusion Criteria

Review articles and case reports (1), duplicate publications (2), and data analyses were excluded from this review.

Data Extraction

The data were extracted by two authors in the form of an Excel file (Microsoft Excel 2021) for selected articles. The obtained data included name of the first author, publication year, number of patients and TMJs examined, number of patients' gender (male and female), age range (minimum and maximum) of subjects, type of ultrasonic device, number of true and false positive, number of true and false, sensitivity, specificity, accuracy, positive predictive value, and negative predictive value for each

Table 1. Search Strategy in the Current Study

Database	Search Strategy
PubMed	((temporomandibular* OR TMJ* OR TMD* OR craniomandibular*) AND (displacement* OR "disc displacement*" OR "joint dislocation*" OR dislocation OR "internal derangement" OR "abnormal disc position")) AND (US OR ultrasonography OR ultrasound OR Doppler* OR ultrasonics) AND (MRI OR "magnetic resonance imaging")
Web of Science	TS = (((temporomandibular* OR TMJ* OR TMD* OR craniomandibular*) AND (displacement* OR "disc displacement*" OR "joint dislocation*" OR dislocation OR "internal derangement" OR "abnormal disc position")) AND (US OR ultrasonography OR ultrasound OR Doppler* OR ultrasonics) AND (MRI OR "magnetic resonance imaging"))
Scopus	TITLE-ABS-KEY(((temporomandibular* OR TMJ* OR TMD* OR craniomandibular*) AND (displacement* OR "disc displacement*" OR "joint dislocation*" OR dislocation OR "internal derangement" OR "abnormal disc position")) AND (US OR ultrasonography OR ultrasound OR Doppler* OR ultrasonics) AND (MRI OR "magnetic resonance imaging"))

Note. Data range: December 2000-March 2022.

mouth positions (open and closed). A table for the STARD (Standards for Reporting Diagnostic Accuracy Studies) scores was also created for each study.

Quality Assessment of Reporting

As per the STARD checklist, the quality of the studies was included in the analyses. This tool was utilized only for transparency and completeness in reporting rather than as an exclusion criterion. Two independent reviewers completed the assessment.

Data Analysis and Statistical Synthesis

All analyses were accomplished using Stata software (version 16). The between-study heterogeneity was accounted for by using a random-effect model. Moreover, heterogeneity was evaluated by I^2 statistic and Cochran's Q test. Likewise, diagnostic accuracy measures (sensitivity, specificity, positive and negative likelihood ratios, and diagnostic odds ratio) were computed with 95% confidence intervals. Similarly, the overall diagnostic performance was determined by the summary receiver operating characteristiccurves. A metaregression analysis was also performed to investigate the possible sources of heterogeneity. Finally, narrative (qualitative) synthesis was conducted when quantitative analysis was impossible, and heterogeneity was considered statistically significant when the P-value was < 0.05.

Results

Search Results

Through database searches (87 articles from Scopus, 63 from Web of Science, and 426 from PubMed, 576 in total) were initially identified (Figure 1). After the removal of 89 duplicate articles, there were 487 unique titles; then, 372 titles were removed because they were irrelevant to the project. Of the remaining 116 articles, 87 were excluded as they were not in line with the inclusion criteria. All 29 articles were eligible for full-text review, and 19 met all the predefined inclusion criteria and were included in the qualitative synthesis accordingly. All the 19 included studies were assessed on their reporting quality using the STARD checklist. Ultimately, 17 out of 27 studies scored ≥ 12, demonstrating the acceptability of the quality of reporting.

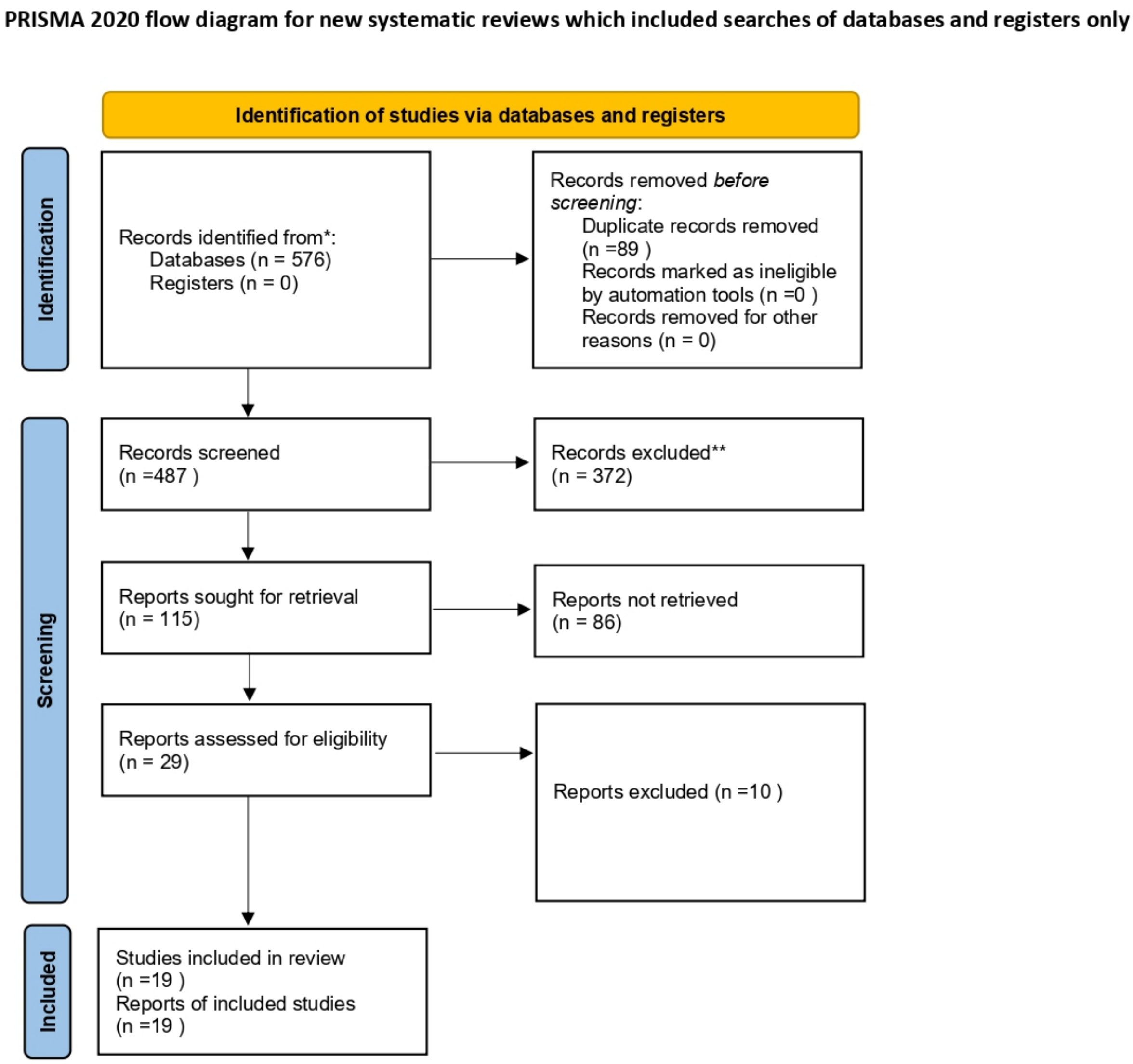

Figure 1. PRISMA 2020 Flow Diagram
Note. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Risk of Bias and Applicability

The quality of methodology and the reporting transparency of the eligible studies were evaluated using STARD. Of 34 checklist items, seven did not apply to our review and from scoring, resulting in a maximum possible score of 27. Two authors independently assessed all the 19 included studies. Each item was scored as "1" if adequately reported and "0" if inadequately reported or not reported. Additionally, disagreements were resolved through discussion, and when necessary, consultation with a third reviewer. Studies (n = 19) that met the inclusion criteria were considered for the review and synthesized qualitatively. The scores considered for STARD ranged from 10 to 23 out of 27. All the 19 studies scored ≥ 12, reflecting generally acceptable reporting quality, while two studies demonstrated lower completeness of reporting. Importantly, no study was excluded based on the STARD score. It should be noted that the STARD assessment was used solely to evaluate reporting quality and assist in interpreting the robustness of the findings (Figure 2).

Characteristics of the Studies

Of the 18 end-of-the-period selected articles, 14 were clinical trials, 1 was a case-control study, 2 were prospective studies, and 1 was a retrospective study. In different studies, the applied ultrasonics were between 7 Hz and 20 Hz. In 17 cases, 1.5-T MRI scanners were used, with one case employing a 2.2-T scanner and two cases using 3-T scanners. Other study characteristics are presented in Table 2.

Diagnostic Accuracy of Ultrasonography Versus Magnetic Resonance Imaging

US was compared with MRI (the reference standard

	Azlağ Pekince, K 2020	Brandlmaier, I. 2003	Çakir-Özkan, N 2010	Chalkoo, A. H 2015	(disc ...) Emshoff, R 2002	(are...) Emshoff, R 2002	Fernando de Mello Junior, C 2011	Friedman, S. N 2020	Habashi, H 2015	Jank, S 2005	Jank, S. 2001	Kaya, K 2010	Landes, C. A 2006	Landes, C. A 2007	Razek, A. A. K. A. 2015	Talmaceanu, D. 2020	Talmaceanu, D. 2018	Tognini, F. 2005	Yilmaz, D. 2019
1	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	+	+	+	+	+	-	-	+	+	+	-	+	+	+	+	+	+	+	+
4	-	-	+	-	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+
5	-	-	-	-	+	+	-	-	-	+	+	+	-	+	+	-	-	-	-
6	-	-	+	+	-	-	-	-	+	+	-	-	-	-	-	+	-	+	+
7	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
8	+	+	+	+	-	+	-	-	+	+	-	-	+	+	-	-	+	+	+
9	-	+	+	-	+	-	-	-	+	+	-	+	+	+	+	+	+	-	-
10a	+	+	-	+	+	+	-	+	+	-	-	+	+	+	+	+	+	+	+
10b	+	+	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+
11	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
13a	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
13b	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14	+	+	+	+	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
18	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	+	-	-	-	-	+	-	+	+	-	-	-	+	+	-	-
21a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
24	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
26	+	+	+	-	+	+	+	+	+	+	+	-	-	+	+	-	+	+	+
27	+	+	-	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Score (27)	15	16	15	16	16	15	10	13	19	18	12	16	16	19	17	18	18	17	18

Figure 2. Assessing Risk of Bias Of Studies

Table 2. Information Extracted From Studies Investigating the Accuracy of Ultrasonography Versus Magnetic Resonance Imaging in Diagnosing TMJ Internal Derangement

First Author	Ref.	Year	Female	Male	Number of Patients	Number of TMJs	Mean Age	Minimum Age	Maximum Age	US Transducer (MHz)	MRI Scanner (T)
Pekince, K	(10)	2020	42	13	55	110	28.2±10.2	18	63	A 12-MHz linear probe	1.5-T and 3-T scanners
Brandlmaier, I	(11)	2003	35	13	48	192	38	17	67	Real-time 12 MHz linear-array scanners	A 1.5-T MR-scanner
Chalkoo, A. H	(12)	2015	12 (case: 7 control: 5)	7 (case: 4 control: 3)	19 (case: 11 control: 8)	19 (case: 11 control: 8)	case: 40.2±12.87 control: 39.4±13.98	Case: 24 Control: 23	Case: 70 Control: 65	A 17 MHz linear probe	A 1.5-T MRI system
Emshoff, R	(13)	2003	55	9	64	128	35.5	17	65	Real-time 12 MHz linear-array scanners	A 1.5-T MR scanner
Emshoff, R	(14)	2002	23	6	29	58	29	19	62	A 12-MHz linear array transducer	A 1.5-T MR scanner
Friedman, S. N	(8)	2020	18	43	61	61	40	13	67	A 15–7 MHz transducer	1.5-T
Jank, S	(15)	2005			100	200		16		(sono-CT)	A 2.2-T MR-scanner
Jank, S	(16)	2001	51	15	66	132	38.2	13	78	A real-time 12-Mhz linear-array scanner	A 1.5-T MR-scanner
Kaya, K	(17)	2010	47	5	52	52	28.30 ± 10.76	-	-	A 7.5-Mhz linear probe	A 1.5-T scanner
Landes, C. A	(18)	2006	44	24	68	136	32	14	77	An 8- to 12.5-MHz linear array	A 1.5-T MRI
Landes, C. A	(19)	2007	23	10	33	66	34	14	77	An 8–12.5MHz linear array	A 1.5-T MR scanner
Tognini, F	(20)	2005			41	82	-	-	-	8–20 MHz transducers	A 1.5-T scanner
Çakir-Özkan, N	(21)	2010	19	9	28	56	32.82	16	51	A 12-MHz linear array transducer	A 1.5-T magnet
Habashi, H	(22)	2015	26	13	39	78	37.23 ± 16.26	18	77	A high-resolution (5–17 MHz) linear array transducer	A 3-T MRI machine
Razek, A. A. K. A.	(23)	2015	17	3	20	40	26.1	-	-	A real-time linear array high frequency (12 MHz) transducer	A 1.5-T scanner
Talmaceanu, D	(24)	2020	42	8	50	100	29	15	61	20 MHz US	A 1.5-T MRI
Talmaceanu, D	(25)	2018	60	14	74	148	29	13	69	A 6.5-13 MHz linear transducer	1.5-T MRI equipment
Yılmaz, D	(26)	2019	35	15	50	100	30.61 ± 1.856	17	75	A 5–14 MHz high-resolution “hockey stick” probe	A 1.5-T scanner

Note. US: Ultrasonography; MRI: Magnetic resonance imaging; TMJ: Temporomandibular joint; Ref.: Reference; CT: Computed tomography.

for diagnosting TMJ ID) in 19 studies. In the geneal population, the sensitivity of US was reported as moderate to high across studies, particularly in detecting anterior disc displacement. The sensitivity and specificity tended to range 60–95% and 70–100%, respectively. Moreover, diagnostic performance was superior at higher frequencies (≥12 MHz). The clinical findings of better diagnostic accuracy in the closed-mouth position than in the open-mouth position were cited in several studies, especially with regard to an anterior DD without reduction. However, the ability of US to identify medical and/or lateral DD was poorer because of anatomical limitations and limited acoustic windows. MRI, 1.5-T and 3-T systems in particular, gave consistently better visualization of soft tissue structures, such as disc morphology, joint effusion, and retrodiscal tissues. Nonetheless, most studies employed 1.5-T MRI scanners; there are restricted data suggesting that 3-T MRI scanners offered enhanced spatial resolution, but with only minor changes in comparative results. Additionally, positive predictive and negative predictive values were dependent on study population and the prevalence of TMJ disorders. Further, figured accuracy for US was in the range of 65–90% as compared to MRI. In spite of variability in the study design and ultrasound equipment, most of the eligible studies reported that US is a useful, non-invasive, and cost-effective preliminary diagnostic tool. Nonetheless, MRI currently remains the gold standard imaging modality for the definitive diagnosis of the internal derangement of TMJ.

Discussion

The present systematic review revealed a great enhancement for the diagnosis of TMJ DD using US. Most studies had utilized 12–17-MHz probes, while some recent studies employed higher-resolution probes (20 MHz) and reported improved diagnostic accuracy. For instance, in the study by Talmaceanu et al using a 20-MHz probe, the US displayed highly desirable diagnostic performance in detecting DD (24). Several studies, including those performed by Azlağ Pekince al, Emshoff et al, Landes et al, and Jank et al, confirmed the ability of US to assess TMJ disc position (10, 13-16, 18, 19). In each of these studies, US was comparatively useful for the detection of anterior and lateral DD; nonetheless, it had its major drawback in detecting medial DD. Friedman et al also demonstrated that the US can have high sensitivity and specificity for the detection of a medial DD; however, MRI should be performed in cases with inconclusive US finindgs (8). Similarly, Habashi et al and Razek et al, have proven the usefulness of using US for detecting changes at the intra-capsular level, such as anterior and lateral displacement or intra-capsular changes, such as degenerative changes and joint effusion (22, 23). In addition, the main advantage of US over MRI is its ability to assess joint dynamics during mouth opening and closing, which is a capability that can be clinically important for disc motion analysis and the diagnosis of functional disorders. On the other hand, the results of studies conducted by Jank et al and Kaya et al revealed a significant false-positive rate and a high dependence on operator skill and device quality (15, 17), suggesting that standardizing imaging protocols and increasing operator training play an important role in improving the reliability of US.

Overall, the analysis of the reviewed studies demonstrated that most studies used 1.5 Tesla MRI as the reference standard, and the participants ranged in age from adolescents to older adults. They further reportedthat US is applicable in different groups. In most studies, the number of patients was between 20 and 100, and bilateral TMJ assessment was common. Moreover, high-frequency probes were found to be a key factor in increasing the diagnostic accuracy of US.

The review also suggested that US can be an efficient screening tool for diagnosing internal TMJ disorders, especially anterior and lateral disc displacement, but MRI remains necessary for medial displacement or when US findings are inconsistent with clinical symptoms. Furthermore, the high dependence of the US on operator skill and equipment quality underscores the need for the standardization of the examination method. Given the many advantages of US (i.e., availability, high speed, low cost, the ability to examine joint dynamics, and repeatability), this method can be employed as a valuable complement to imaging in the management of patients suspected of TMJ disorders in dental and specialized settings.

The present systematic review had several key strengths. The study included a wide range of studies and, with a focus on MRI as the gold standard, ensured the validity of comparing US with the reference method. Likewise, the data were organized in a structured manner using tables, allowing for direct comparison of findings across studies. Similarly, the examination of the impact of probe resolution and new US technologies provided a clear perspective on technological advances and clinical application of this method. The practical advantages of US (i.e., low cost, availability, non-invasiveness, and the ability to assess joint dynamics) are the other strengths of this review. However, in this study, there were restrictions that need to be taken into account. Due to heterogeneity in the study design, imaging protocol, diagnostic criteria, and US equipment, it was impossible to perform meta-analyses and provide statistical aggregates. Most of the studies were relatively small in scope; therefore, the findings may no be generalizable. Further, the accuracy of US is highly dependent on operator skill and equipment quality, and is limited in detecting medial disc displacement. Heterogeneity in protocols and probe frequencies used in the intended studies also increased the variability of findings. Accordingly, future research should focus on improving these limitations. Standardization of US protocols, including probe frequency, patient positioning, and image analysis methods, can increase the accuracy and reliability of the method. Moreover, larger, multicenter studies, the use of advanced techniques (e.g., three-dimensional and high-resolution US), and combined evaluation of US and MRI as screening and diagnostic confirmation tools can provide a practical and economical solution for patient management. In addition, training operators and increasing skill standards will play an essential role in reducing errors while improving diagnostic accuracy.

Overall, our findings demonstrated that US can be employed as an effective screening and complementary diagnostic tool for internal TMJ disorders, especially anterior and lateral disc displacement, while MRI remains necessary for definitive diagnosis and complex cases. Future studies could further define the role of the US in the diagnosis, monitoring, and management of patients with TMJ disorders and improve the clinical application of this method.

Conclusion

This systematic review demonstrated that high-resolution US is a non-invasive, low-cost, and readily available imaging modality that can play a complementary and effective role in diagnosing TMJ disorders, particularly anterior and lateral disc displacement. Additionally, it allows for the assessment of joint dynamics during mouth opening and closing and can be utilized as an initial screening tool in clinical settings, especially in dentistry and specialized centers. However, there are limitations to US. It is less accurate depending on the skill and experience of the operator and can only be used to detect medial DD. Thus, in dubious or problematic cases, or prior to deciding on invasive treatments, MRI remains the gold standard and is a critical examination technique. Ultimately, the current results indicate the need for future studies to standardize imaging protocols, train operators, and employ advanced imaging equipment to further clarify the role of US in the diagnosis of TMJ disorders.

Authors' Contribution
Conceptualization: Sajad Ghorbanizadeh
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Investigation: Sahar Azizi
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Project Administration: Sajad Ghorbanizadeh
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Software: Asma Sepahdar
Supervision: Sajad Ghorbanizadeh
Validation: Sajad Ghorbanizadeh
Visualization: Sajad Ghorbanizadeh
Writing–Original Draft: Asma Sepahdar
Writing–Review & Editing: Sajad Ghorbanizadeh

Competing Interests
The authors declared that they have no conflict of interests.

Ethical Approval
This research was approved by the Research Ethics Committee of Lorestan University of Medical Sciences, Lorestan, Iran (ethical No. IR.LUMS.REC.1402.090).

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