ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at:www.ijdsir.com

Volume – 7, Issue – 6, November – 2024, Page No. : 64 - 72

Role of Diverse Imaging Modalities in the Assessment of Temporomandibular Joint Disorders - A Systematic Review

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Citation of this Article: Dr. Shriya R. Maknikar, Prof. Dr. Mahendra R. Patait, Dr. Kartikee V. Bhoir, “Role of Diverse Imaging Modalities in the Assessment of Temporomandibular Joint Disorders - A Systematic Review”, IJDSIR- November – 2024, Volume –7, Issue - 6, P. No. 64 – 72.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Introduction: Temporomandibular joint Disorders (TMDs) affect the Temporomandibular Joint, masticatory muscles, and head and neck musculoskeletal systems. While various diagnostic imaging approaches have been developed for TMJ imaging, there is no consensus on the "gold standard" for detecting lesions.

Aim: The study's aim was to identify the best standard imaging modality for the temporomandibular joint by focusing on the many imaging modalities utilized for it.

Objective: The objective of this systematic review was to evaluate the ability of different imaging techniques in the diagnosis of temporomandibular joint disorders.

Methods: Using PICO format a review question was formulated. A systematic search of PubMed, Cochrane, and Google Scholar using Medical Subject Heading terms (MeSH) was done from 1st Jan 2002 to 31st Dec 2022. The quality of assessment for the included studies was evaluated using “The Jonna Briggs Institute” tool (JBI) for cross sectional, cohort and case control studies.

Results: A total of 1678 articles **were found.** The relevant database searchers were PubMed 289 articles followed by Cochrane 1345, and Google scholar 44 articles**.** A final of 11 articles were included in the review.

Conclusions: The study concluded that MRI is preferred for identifying soft tissue changes, while USG can be used as an adjunct and CBCT for bony changes.

Keywords: Temporomandibular Joint Disorders, Magnetic Resonance Imaging, Cone-Beam Computed Tomography, Ultrasonography.

Introduction

The Temporomandibular joint (TMJ) is a diarthrodial joint. The squamous part of the temporal bone and the mandibular condyle combine to produce the Temporomandibular joint (TMJ). It articulates through an intervening disc of connective tissue and is encased in a fibrous capsule. [1,2]

A collection of craniofacial pain issues known as Temporomandibular joint disorders (TMDs) affect the Temporomandibular joint (TMJ), masticatory muscles, and related head and neck musculoskeletal systems. Patients with temporomandibular disorders often present with pain, limited to the jaw, temporomandibular joint area, and muscles of mastication, limited or asymmetric mandibular motion, and temporomandibular joint sounds. [3,4]

The clinical examination is the most crucial step in the diagnosis of Temporomandibular joint disorders (TMDs), however, due to its complex anatomy and pathology, specific imaging techniques are needed. The TMJ can be imaged with Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Cone Beam CT, Ultrasonography, and traditional radiography. [5]

Many diagnostic imaging techniques have been proposed till now to image the temporomandibular joint. However, there does not seem to be a general consensus as to which diagnostic imaging technique should be the ‘‘gold standard’’ in detecting these lesions in the TMJ.

Material and Methods

Identification and screening

For this study search strategy was developed for each electronic database which combined relevant keywords and phrases. The databases used were PubMed, Cochrane, and Google Scholar. In accordance with the 2019 PRISMA (Preferred Reporting Items for Systematic Reviews and meta-analysis) [6] guidelines, search protocol was designed.

Protocol and registration

The present systematic review was registered at the National Institute for Health Research PROSPERO[7]

Registration number: **CRD42023393053**

Formulating the review question

The research question was set following the PICO format (Population/ Sample characters, Intervention, Comparison, and Outcome) and is described in detail in Table 1.

Table 1: Selection criteria used for this study - PICO Model

Population/ Sample Characters	Patients with temporomandibular joint disorders
Intervention	Imaging of temporomandibular joint
Comparison	Not Applicable
Outcome	Best imaging technique for temporomandibular joint disorders

Research question

Which is the best imaging modality for temporomandibular joint disorders?

Inclusion Criteria

1. Peer-reviewed scientific journals from 2002 to 2022
2. Full articles in English.
3. Case studies, clinical trials, observational studies
4. Studies including both genders.

Exclusion Criteria

1. Articles with incomplete data.
2. Text book chapters, reviews and abstracts
3. Articles in other language than English.

Search methods for identification of studies

The Cochrane Library, PubMed, and Google Scholar electronic databases were looked up. Two reviewers were independently assigned to demarcate pertinent articles and any differences of opinion were discussed until they were all in accord.

Data collection and analysis

Study selection, data extraction, and quality assessment

Following the search, all identified citations were collected and uploaded into Zotero[8] and duplicates were removed. Potentially relevant studies were fully retrieved and thoroughly reviewed. Studies identified via citation searching were also screened.

The following details for each study were recorded on the data extraction form:

Author, place and year of study, subjects, image characteristics, and outcome measured. Described in detail in Table 2.

Table 2: Details of the studies analysed in the Review

Sr no	Article	Subjects	Image characteristics	Outcome
1	Jalal RA et al (2022) [9] Iran	40 Rheumatoid Athritis patients with 10 healthy adults (control cases).	**CBCT:** Sirona 3D machine (Galileos Comfort, Germany). **MRI:** 1.5 Tesla GE machine (made in USA)	CBCT was considered the most reliable method for assessing osseous injury when compared to MRI.
2	Dilek Yılmaz (2019) [10] Turkey	50 patients with temporomandibular disorders	**Ultrasound** (5–14 MHz) ACUSON S 2000 ultrasound machine (Siemens, Munich, Germany) with a “hockeystick” transducer when patients were in supine position. **MRI** were obtained by 1.5 Tesla machine (GE, Milwaukee, WI). In both closed and open mouth positions.	Ultrasound may be preferred as an adjunct imaging modalities in the assessment of TMJ. MR scans are the benchmark standard when combined with patient history and clinical examination findings.
3	Daniel Tălmăceanu (2018) [11] Cluj-Napoca, Romania	74 consecutive patients (148 TMJs) with signs and symptoms of TMD.	**USG**:- Hitachi EUB 8500	Although USG did not have the same diagnostic value as MRI, it might be a viable option for examining TMJ disc position and treatment outcomes.
4	Schnabl D (2018)[12] Germany	26 temporomandibular joints (TMJs) in 13 patients clinically diagnosed with TMJ arthralgia	**CBCT**: Picasso Trio (Vatech) **MRI** : imaging was performed in a lying position by the use of a high-resolution surface coil in a magnetic field of 1.5 tesla.	CBCT outperforms MRI in the visualization of osseous changes; hence, CBCT imaging is recommended for individuals clinically diagnosed with TMJ arthralgia.
5	Dora Zulema R. Díaz (2018)[13] Brazil	TMD group (n = 20): presence of clinical signs and symptoms of TMD for at least the last 6 months, with no treatment. Asymptomatic group (n = 12): absence of signs and symptoms of TMD.	The **USG** examination was performed with a high-resolution linear array transducer of 38 mm and 7-18 MHz (SSA-780A-APLIO MX [Toshiba Medical Systems Corporation, Otawara, Japan])	USG delivered imaging of the TMJ's anatomical features, however the articular abnormalities detected clinically could not be validated by the USG pictures.
6	Yasa Y et al (2017)[14] Ataturk University Turkey	200 patients which showed signs and symptoms consistent with TMD	**MRI :** NewTom 3G device (Quantitative Radiology, Verona, Italy).	CBCT is by far an ideal method for evaluating TMJ bone structures
7	Daniel Cortés et al (2016)[15] Chile	MRI and CT scans of 180 subjects with temporomandibular disorders (TMD) were examined.	**MRI:** (Phillips Intera 1.5 T, Sense Flex S Dual Coil, Eindhoven, Nederland) **CT:** scan was performed on all patients, using	MRI provides sufficient soft tissue contrast to detect the articular disk. MRI is the gold standard approach to identify internal derangements of the

			Bright Speed ELITE, General Electric, Milwaukee, with the patient in both closed-mouth and open-mouth positions.	temporomandibular joint because it is beneficial in determining the location, configuration, and form of the TMJ disk structure.
8	Paknahad M (2015)[16] Iran	There were two groups: symptomatic and asymptomatic, each with 30 individuals.	**CBCT :-** NewTom VGi (QR Srl, Italy)	CBCT provides the benefit of less radiation exposure and quicker scanning time compared to CT.
9	Burcu Bas (2011)[17] Turkey	182 temporomandibular joints (TMJs) of 91 patients who were referred for treatment.	**MRI** scans were carried out with a 0.5-T (Signa, General Electric, Milwaukee, WI) scanner using a 6- _ 8-cm diameter surface coil. At closed and maximum-opening mouth positions. **Ultrasonographic imaging** was done with a Toshiba Powervision 7000 (SSA-380; Osaka, Japan) instrument with a 10-MHz high-frequency transducer	The capability of USG to detect clinically normal joints was higher than with MRI.
10	M Alkhader et al (2010)[18] Japan	106 TMJs of 55 patients with temporomandibular disorder (TMD)	**MRI** :-1.5 T scanner (Magnetom Vision, Siemens Medical Systems, Erlangen, Germany) **CT**:- (Morita Corporation, Kyoto, Japan)	The capacity of MRI to identify osseous anomalies is currently regarded weak to moderate, requiring confirmation by CT or CBCT.
11	Serdar Uysal (2002)[19] Turkey	23 patients with a chief complaint of TMJ discomfort and a control group of 9 volunteers who had no sign of TMJ internal derangements.	**MRI** :-1.5 T Philips Gyroscan T5-NT (Philips, Best, The Netherlands) (mouth closed). **USG:-** Toshiba SSA-90A (Otowara, Japan) real B-mode ultrasound equipment with a 7.5-MHz probe.	MRI is the most effective tool for defining TMJ internal derangements since it displays disk location. US, like MRI, is an excellent tool for defining the disk, determining its location, and detecting TMJ interior derangements.

Assessment of the Risk of Bias in Clinical trial included studies.

The risk of bias was assessed using the **Joanna Briggs Institute Critical Appraisal tools** JBI (20) (21) for cross-sectional and case control research as shown in table III and IV. The objective of this critical appraisal was to evaluate the methodological quality of investigations and ascertain how much the included studies had reduced the likelihood of bias in their conception, execution, and analysis.

Table 3: Risk of Bias Assessment (Cross- sectional Study)

RISK OF BIAS ASSESSMENT (CROSS -SECTIONAL STUDY)

Studies (year)	Were the criteria for inclusion clearly defined	Were the study subjects and the settings described in detail	Was the exposure measured in a valid and reliable way	Were objective, standard criteria used for measurement of condition	Were confounding factors identified	Were strategies to deal with confounding factors stated	Were outcome measured in a valid and reliable way	Was appropriate statistical analysis used
M Alkhader et al 2010	+	?	+	+	+	+	?	?
Daniel Cortes et al 2011	+	−	+	+	?	−	+	+
Burcu Bas et al 2011	+	+	?	+	−	−	+	?
Daniel Talmaceanu et al 2017	+	+	+	+	?	+	+	?
Dagmar Schnabl et al 2017	+	−	+	+	−	−	+	+
Oden Yimaz et al 2019	+	+	+	+	−	−	+	+

+/green color: low risk of bias;

?/yellow color: some concerns; −/red color: high risk of bias

(Assessment done using Joanna Briggs Institute (JBI) for Cross Sectional Study)

Table 4: Risk of Bias Assessment (Case - Control Study)

RISK OF BIAS ASSESSMENT (CASE-CONTROL STUDY)

Studies (year)	1. Were the groups comparable other than the presence of disease in cases or the absence of disease in controls	2. Were cases and controls matched appropriately?	3. Were the same criteria used for identification of cases and controls	4. Was exposure measured in a standard, valid and reliable way	5. Was exposure measured in same way for cases and controls	6. Were confounding factors identified	7. Were strategies to deal with confounding factors stated?	8. Were outcomes assessed in a standard, valid and reliable way for cases and control?	9. Was the exposure period of interest long enough to be meaningful?	10. Was appropriate statistical analysis used?
[illegible] et al 2002	+	-	+	+	-	-	-	+	+	+
Maryam [illegible] et al [illegible]	+	-	+	+	?	-	-	+	?	+
Yasin Yasa et al 2017	+	+	?	+	-	-	-	?	+	+
[illegible] R Diaz et al [illegible]	+	+	+	+	?	+	+	?	+	?
[illegible] et al (2022)	+	?	+	+	+	+	?	?	+	+

+/green color: low risk of bias; ?/yellow color: some concerns; -/red color: high risk of bias

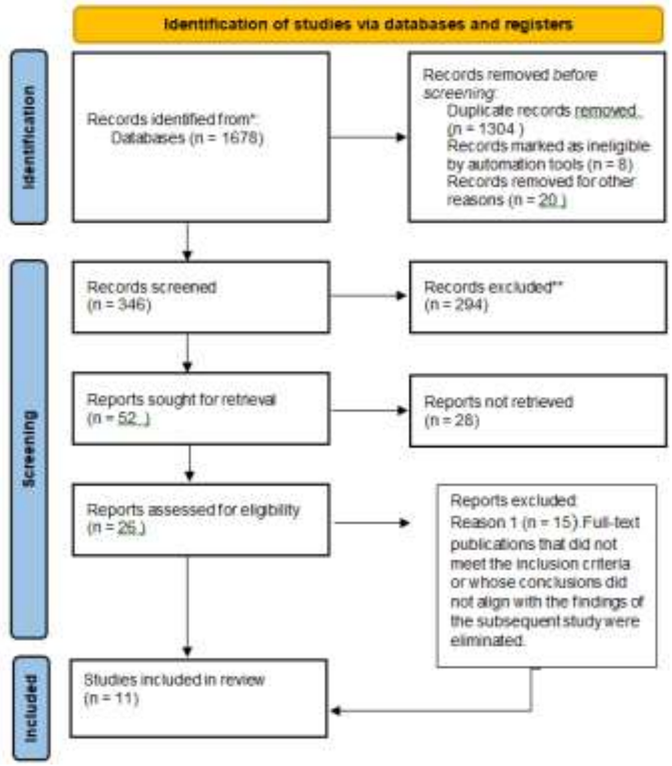
(Assessment done using Joanna Briggs Institute (JBI) for Case Control Study

Results

Study selection and Description of studies

We found 1678 publications in PubMed (289), Cochrane (1345), and Google Scholar (44). We then reviewed 346 non-duplicate, potentially relevant papers. After assessing the titles and abstracts, 294 of these papers were rejected and 52 were retained for further study. The primary and secondary reviewers evaluated the 26 publications in full-text, eliminating 15 articles **that** did not meet the inclusion criteria or whose conclusions did not align with the findings of the subsequent study were eliminated**.** Reviewers were left with 11 papers to consider, all of which were original research papers and were released between 2002 and 2022. Numerous study locations were looked at in this evaluation, including Iran,[9,16] Romania[11], Turkey,[10,14,17] Germany,[12] Japan,[18] Brazil[13] and Chile.[15]

Diagram 1: Flow Diagram of literature search and selection criteria (PRISMA 2020)



Discussion

Temporomandibular disorders (TMD) commonly affect the temporomandibular joint (TMJ) and associated muscles, presenting often with pain, limited jaw movement, and joint noise. They are notably prevalent in young to middle-aged women, potentially due to hormonal, anatomical, and psychosocial factors. For most cases, supportive therapies—such as physical therapy, medications, and behavioral interventions—are sufficient to alleviate symptoms. However, imaging becomes essential in cases where clinical assessment suggests severe joint pathology, like internal derangements, advanced arthritis, or the presence of tumors. Imaging is recommended for suspected severe internal disease, arthritis, failed medical treatment, unusual discomfort, sensory or motor impairment, or a palpable tumour. TMD imaging uses Dental Panoramic Tomography (OPG), Cone-Beam Computed Tomography (CBCT), Multidetector CT (MDCT), MRI, ultrasound, and nuclear medicine.[22]

Techniques for imaging the temporomandibular joint have been the subject of numerous studies. A few instances are:

Role of MRI

MRI uses strong magnetic fields and radiofrequency pulses to generate high-resolution images, allowing for clear differentiation of various TMJ disorders. This non-invasive imaging method is especially beneficial in evaluating the positioning, shape, and condition of the TMJ disc as well as surrounding soft tissues, which are critical in identifying abnormalities such as disc displacement or degeneration. Both closed- and open-mouth MRI scans provide valuable information on disc location, morphology, and the status of bone structures, making it a preferred choice in many clinical scenarios. Its advantages include high sensitivity, diagnostic accuracy, and the fact that it is radiation-free.[23] Studies evaluating MRI's diagnostic capabilities against CBCT for detecting osseous changes in the TMJ show MRI has a sensitivity of 75% and specificity of 84%, highlighting its strong performance, although CBCT may still be required for precise bone assessments. MRI's limitation lies in its moderate capacity to detect osseous abnormalities accurately, often necessitating confirmation via CT or CBCT to complete the diagnostic picture. This underscores MRI's role as an optimal modality for soft tissue evaluation rather than bony structures, where CBCT and CT excel.[9] MRI is the primary imaging tool because it is not associated with ionizing radiation, offers direct visualization of the disc, shows surrounding muscles and attachments with high resolution and provides a comprehensive idea about the general condition of TMJ. However, its ability to detect osseous abnormalities is still considered poor or moderate and confirmation with CT or CBCT is needed. [24]

MRIs can show the articular disc with appropriate soft tissue contrast, according to Daniel Cortés et al. As per Uysal[19] and Bas, the most effective imaging modality for TMJ soft tissue disease is MRI. [19]

Role of CBCT

Cone-Beam Computed Tomography (CBCT) is a highly effective imaging technique for visualizing the bony structures of the temporomandibular joint (TMJ) in three dimensions. CBCT produces volumetric, surface, and sectional images that provide a comprehensive view of the TMJ's osseous anatomy. This is invaluable for assessing bone morphology, joint alignment, and structural changes, such as those seen in degenerative joint disease, fractures, or congenital abnormalities. Its high-resolution images enable precise visualization of the condylar head, glenoid fossa, and other bony landmarks within the TMJ.

CBCT is recognized for its cost-effectiveness, making it more accessible for routine TMJ imaging. Additionally, CBCT has high sensitivity and specificity for detecting bony pathologies, which ensures reliable diagnostic outcomes in cases involving bone damage. However, CBCT's capabilities are limited to hard tissues; it cannot capture details of soft tissues such as the articular disc, muscles, or ligaments surrounding the TMJ. This makes it less suitable for cases where soft tissue pathology, like disc displacement or inflammation, is suspected.

Despite this limitation, CBCT remains the gold standard for assessing osseous TMJ conditions. Studies, such as those conducted by Jalal RA et al.[9] D Schnabl[12] and Paknahad M[16], have shown that CBCT is superior to MRI when evaluating bony structures, providing detailed insights into condylar shape, cortical integrity, and bone erosions. The high bone resolution offered by

CBCT enables detailed analyses of even subtle osseous changes, which is essential in early detection of conditions like osteoarthritis. According to Yasa et al, CBCT scans are quicker and utilize less radiation than CT.[14]

Role of USG

Diagnostic ultrasound (US) is a valuable imaging modality for evaluating the temporomandibular joint (TMJ), known for being non-invasive, affordable, and readily accessible. It provides high specificity for certain TMJ conditions, including disc displacement, cartilage issues, joint effusion, and condylar erosion.[22] Although ultrasound is generally less accurate than MRI, its ability to detect disc displacement and soft tissue changes has been shown to be effective, particularly in tracking therapy progress. Ultrasonography allows real-time imaging and dynamic assessment, which can be useful in evaluating joint movement and soft tissue responses. Dilek Yilmaz highlights that ultrasound can be a complementary tool in TMJ assessment alongside other imaging techniques, enhancing the clinician's understanding of TMJ pathology when combined with MRI and CBCT.[10][13] While MRI remains the gold standard for comprehensive TMJ evaluation—especially for soft tissue pathology when combined with patient data and clinical examination results—ultrasound has its strengths. As noted by Dora Zulema R. Daz, ultrasound can visualize the general anatomy of the TMJ, yet it may fall short in confirming certain articular anomalies identified clinically. Thus, while MRI offers unmatched detail, particularly for diagnosing and staging TMJ disorders, ultrasound provides a practical, supportive role, particularly for evaluating therapeutic responses and certain soft tissue abnormalities.[25]

Limitations

This systematic study focuses on a limited range of imaging modalities, primarily MRI, CBCT, and ultrasonography, for assessing the temporomandibular joint (TMJ). However, it is important to recognize that alternative imaging techniques, such as conventional radiography, bone scintigraphy, and nuclear medicine scans, also play significant roles in TMJ evaluation, each offering unique insights into various pathologies. Conventional radiography, for example, is a commonly used and accessible technique for initial screenings, while bone scintigraphy and other nuclear medicine imaging modalities provide valuable data on metabolic activity within the joint, aiding in the detection of active inflammation or bone turnover in TMJ disorders.

Additionally, this systematic review covers only a 20-year period, which inherently limits its scope. Studies and advancements in imaging techniques outside of this timeframe have not been included, potentially overlooking newer or evolving insights in TMJ imaging practices. Consequently, while this review provides valuable information on well-established modalities like MRI, CBCT, and ultrasound, further research encompassing a broader time frame and additional imaging methods may offer a more comprehensive understanding of TMJ imaging.

Conclusion

In conclusion, employing a range of imaging modalities is essential for a thorough assessment of temporomandibular joint (TMJ) disorders, as each technique offers unique advantages and limitations. Often, a combination of modalities is needed to capture the full spectrum of TMJ pathology, allowing for a more accurate diagnosis and targeted treatment approach. MRI is ideal for evaluating soft tissue structures, providing detailed images of the articular disc, joint capsule, and surrounding muscles. Ultrasound serves as a valuable adjunct, especially in assessing therapeutic progress and visualizing certain joint dynamics in real-time. CBCT, on the other hand, is preferred for examining bony changes, offering high-resolution images of the condyle and other osseous components. Together, these imaging tools enable healthcare professionals to establish an informed and effective management plan for patients with TMJ disorders.

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