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REVIEW ARTICLE

THE RELIABILITY OF IMAGING IN THE DIAGNOSIS OF TEMPOROMANDIBULAR JOINT DISORDERS; A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The aim of this study is to assess the reliability of imaging in the diagnosis of TMJ disorders, namely, MRI, Cone Beam and and Ultrasonography. This systematic review has allowed an analysis of the scientific literature in the period 2005 to September 2015. This study is based on approved publications that assess the sensitivity, specificity and reliability of each type of imaging technics in the diagnosis of ATM components disorders, their benefits and limitations; and comparison with other imaging technics not discussed in this study. Our research allowed collecting 29 relevant articles from a total of 682 treating the subject over a period of 10 years. This lack of valid articles is disproportionate with the importance and value of the imagery in the diagnosis of temporomandibular joint disorders. Based on the results, a discussion allowed us to conclude that MRI is the most reliable imaging to determine disc movements compared to the condyle, and to diagnose joint effusions. The Ultrasonography has an acceptable reliability in the diagnosis of anterior disc displacement, but it is not reliable for detecting lateral movement of the disc. There is not enough evidence- based studies showing the validity and reliability of these imaging in the diagnosis of all joint disorders, such as joint effusions. In conclusion, further studies in the same subject must be conducted in order to clarify the value of these complementary examinations.

INTRODUCTION

The temporomandibular joints, small symmetrical joints concealed under the base of the skull, have a very complex role, some essential functions of life (mastication, swallowing, phonation) depend on their health.In view of the complexity of the anatomy of this region and the diversity of clinical manifestations and symptoms of disorders of this joint, the practitioner must carry out a clinical examination and supplement it with a radiological examination in order to clarify the diagnosis and thus determine the treatment.Indeed, several studies have shown that clinical examination alone is not sufficient to diagnose TMJ disorders. In addition, different imaging modalities are used to assess the integrity of joint structures, to confirm the stage of progression of disorders and to evaluate the effects of treatments.In this systematic review, based on the literature published between 2005 and 2015, we aimed to evaluate the reliability of imaging in the diagnosis of temporomandibular joint disorders, namely Magnetic Resonance Imaging MRI), Cone Beam (CBCT) and Ultrasonography.

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MATERIALS AND METHODS

The research strategy consisted of querying the PubMed data base to obtain references from publications on the reliability of imaging in the diagnosis of ATM disorders without language restrictions.To query Medline, we used the keywords; Temporomandibular Joint, Magnetic Resonance Imaging, Diagnosis, Computed Tomography, Temporomandibular Joint Disorders, Ultrasonography, CBCT.The articles to be included in the study had to fulfil two essential criteria: to be published between 2005 and 2015, and to treat the reliability, sensitivity and specificity of TMJ imaging, namely Magnetic Resonance Imaging (MRI), Cone Beam (CBCT) and Ultrasonography, in the diagnosis of temporomandibular disorders (TMDs).We excluded articles evaluating other types of imaging in the diagnosis of TMDs (such as arthroscopy, scintigraphy, conventional radiography, etc.) and articles dealing with TMJ tumour's.This strategy was carried out by two of the authors in a consensual manner. It identified 29 articles, only 19 of which were in the form of randomized studies (Fig. 1).The data was extracted by applying an analysis form to each study selected in the final file. The extracted data are: type of imaging, age, sex, sample criteria, type of joint disorder, articular structure studied, study protocol, imaging criteria, the analytical tool, the

results of the study, the advantages of imaging, the limits of the imagery, the biases of the study.

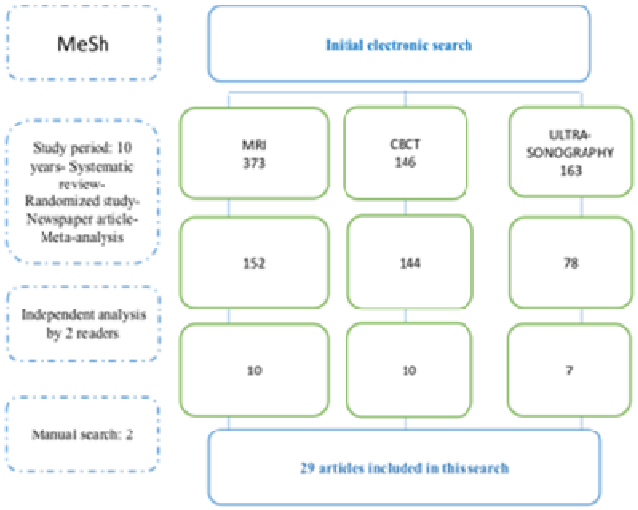

Fig. 1. Article selection strategy

RESULTS

The studies available on the reliability of imaging in the diagnosis of temporomandibular joint disorders are mainly performed on patients (16 studies) with a dispersion ranging from 10 to 180 patients. Women predominated in all studies that mentioned this criterion. The average age range is in the range of 14 to 60 years.

Results by Imaging Type

Magnetic Resonance Imaging: MRI

Overall, only six studies used MRI in the diagnosis of TMJ disorders.

MRI Criteria

Five studies (Arayasantiparb Raweewan and Tsuchimochi, 2010 ; Galhardo *et al*., 2013; Park *et al*., 2012; Summa*et al*., 2014; Widmalm*et al*., 2006) carried out MRI examinations in the closed mouth and open mouth positions. Only the study of Moen (De Boer *et al*., 2014) did the MRI examination only in the closed mouth position.Five studies (De Boer *et al*., 2014; Arayasantiparb Raweewan and Tsuchimochi, 2010; Widmalm *et al*., 2006; Galhardo *et al*., 2013; Summa *et al*., 2014) used images weighted in T1 and T2 and perpendicular to the horizontal axis of the mandibular condyle in both sagittal and coronal planes. Only a study conducted by Park *et al*. (2012) did not specify the cutting plans of the TMJ images.

Methods of analysis of radiological images

Four studies (Arayasantiparb Raweewan and Tsuchimochi, 2010; Galhardo *et al*., 2013; De Boer *et al*., 2014; Park*et al*., 2012) described the normal position of the disc in opening and closing (position 11:30 to 12 o'clock). Each disc movement is considered to be an earlier displacement of the disc. The other studies did not mention this point.The analysis of the radiological images concerning the articular position was described by two studies using two methods of analysis.The study by Kurita *et al*. explained in the article by Raweewan and al. (2010) uses bone points to determine the position of the condyle and disc by measuring:

- the disc movement,
- and the angle formed between the posterior edge and the vertical line passing through the center of the condylar head in the anteroposterior direction in the position of opening and closing of the mouth.

When there is a displacement (DD) with reduction, the comparison of the disc position in the mouth opening in symptomatic and asymptomatic patients shows no significant difference. While in the case of a displacement without reduction, the posterior point of the disc is more superior in asymptomatic patients than in the symptomatic patients, in the position of buccal closure.The other study (Summa*et al*., 2014) evaluated the relationship between clinical examination and radiological data obtained by MRI using the technique described by Drace and Enzmann, which measures the condylar axis, the angle of the articular eminence and disc position.Clinical evaluation and radiological images found partial but satisfactory congruence (77%), a correlation between clinical and radiological data (80%) of the static and dynamic images, especially for patients with displacement with reduction (47%), and a good correlation for patients with a displacement without reduction (51%).By specifying a sensitivity of the MRI images of 0.80 to 0.87 and a specificity of 0.63 to 0.80.

Validity of MRI in the diagnosis of temporomandibular joint disorders

Two studies have identified the value of MRI in the diagnosis of TMJ disorders, by assessing the agreement and correlation between the diagnostic criteria for temporomandibular disorders (RDC / TMD) and the MRI results:

- The results of the Park and al (2012) study, show that Cohen's kappa value was 0.336 showing overall disagreement between RDC/TMD group II and MRI diagnoses ($P<0.001$)
- The results of the study of Galhardo show that, of the 67 patients, 44 were diagnosed with temporomandibular disorders (TMD) according to RDC/TMD, but 21 (32%) of the diagnoses were not confirmed by MRI.
- The RDC/TMD sensitivity was 83.0%, specificity was 53.0%, and the positive likelihood ratio was 1.77, whereas the negative likelihood ratio was 0.32 ($P = 0.16$).

Cone beam (or CBCT "tomography composed by cone beam")

Six studies have used Cone Beam in the diagnosis of TMJ disorders. All studies have reported that Cone Beam allows visualization of the bone component of TMJ in the three planes without superposition of adjacent structures (De Boer *et al*., 2014; Talaat *et al*., 2015; Yadav *et al*., 2015; Al-Ekrish *et al*., 2015; Honey *et al*., 2007; Summa *et al*., 2014). Two studies (Talaat *et al*., 2015; Yadav *et al*., 2015) show the reliability of Cone Beam in the diagnosis of TMJ osteoarthritis. According to

the study of Honey (Honey *et al*., 2007), CBCT images provide superior reliability and greater accuracy than TOMO and TMJ panoramic projections in the detection of condylar defects.Studies by Al-Ekrish *et al*. (2015) and Al-Saleh *et al*. (2015) find that the Cone Beam is the most reliable imaging for the detection of cortical erosion of the condyle. This last study shows a very high reliability of 95% to detect these minor anomalies.According to the study of Boer *et al*. (2014), the degree of certainty was rated by the clinician before and after the cone-beam had been assessed. The primary diagnosis was changed in 32 patients (25%), additional diagnosis procedures were changed in 57 patients (45%), and the treatment was changed in 15 patiens (12%). The study by Junior *et al*. mentioned in the study by Talaat *et al*. (2015) found that 83% of patients with idiopathic juvenile arthritis had degenerative changes in the bone component of ATM. They also found that Cone Beam has a high degree of precision in the evaluation of degenerative bone. In contrast, the study of Talaat *et al*. (2015) declares the inability of this imaging to show the total articular surface of the ATM and the high cost that limits its use. The study by Yadav *et al*. (2015) shows that the Cone Beam may exhibit artifacts that may interfere with the interpretation of the images.

and the most anterior point of the condyle is not reliable for the evaluation of the disc displacement.

Comparison between different imaging techniques

The study of Alkhader *et al*. (2010) showed excellent agreement between the two radiologists on the reliability of Cone Beam in the diagnosis of bone changes (condylar erosion, osteophyte, subcortical cyst, or generalized sclerosis) and an acceptable agreement on the reliability of the MRI in the diagnosis of bone abnormalities, except for the sclerosis of the joint pit where they found a bad agreement.The study of Kaya *et al*. (2009) reported that no significant difference was found between MRI and Ultrasonography with respect to demonstrating ADD, ADD with reduction, ADD without reduction, and effusion, and the findings of the two methods were found to be in agreement with each other regarding all assessments (p. 0.05).Ultrasonography was shown to give quite accurate results in the determination of disc position anomalies. Researchers have shown the reliability of US in the diagnosis of disc displacement, although it fails to display the medial face of condyle. However, MRI is widely regarded as a gold standard for diagnostic accuracy studies.

Table I. Sensitivity, specificity, PPV, NPV and reliability of Ultrasonography and MRI in the diagnosis of disc displacement

	Ultrasonography	MRI
Sensitivity (%)	69	85
Specificity (%)	80	62
Positive predictable value (PPV) (%)	92	88
Negative predictive value (NPV) (%)	42	54
Reliability (%)	71	80

Table II. Comparison of some types of imaging techniques in the diagnosis of certain joint disorders

	Osteoarthritis	Erosions	disc displacement	Effusion
IRM	Acceptable Panoramic<MRI<Conventional tomography (Alkhader *et al*., 2010; Ahmad *et al*., 2009)		Excellent MRI> Ultrasonography (Bas *et al*., 2011)	Good MRI> Ultrasonography (Larheim *et al*., 2015)
CBCT	Excellent(Summa *et al*., 2014)	Good Conventional tomography <Panoramic < CBCT (Honey *et al*., 2007)		
Ultrasonography			Acceptable Ultrasonography<MRI (Bas *et al*., 2011)	Faible Ultrasonography <MRI (Kaya *et al*., 2010)

Ultrasonography

Four studies (Bas*et al*., 2011; Cakir-Ozkan*et al*., 2010; Elias*et al*., 2006; Kaya*et al*., 2010) have used Ultrasonography in the diagnosis of ATM disorders. According to these studies, Ultrasonography is a reliable method in evaluating the position of the disc in TMJ disc derangements. Compared with the DRC / TMD(Bas*et al*., 2011), Ultrasonography showed a sensitivity of 69%, specificity of 80%, and accuracy of 71% in the detection of internal derangements. Thepositive predictable value, negative predictive value, and likelihood ratio were 92%, 42%, and 3.45, respectively. In the study of Kaya, the accuracy of Ultrasonography were found to be 82% in the assessment of anterior disc displacement (ADD), 57% in ADD with reduction, and 76% in ADD without reduction. The results of this study showed that ultrasonography is reliable in detecting disc displacement, but is not precise enough to determine the type of disc displacement. The results of Cakir-Ozkan *et al*. (2010) showed that the measurement of the distance between the most anterior point of the articular capsule

It has an accuracy of 95%, a sensitivity of 0.9, and a specificity of 1.0 in detecting disc displacement because it can display clearly the different parts of a disc, including coronal, sagittal, and transverse sections.

DISCUSSION

TMD is defined as a subgroup of craniofacial pain problems that involve the TMJ, masticatory muscles and associated head and neck musculoskeletal structures.The diagnosis of TMD is based mainly on medical history, clinical examination, and radiologic assessment. The conditions can be diagnosed based on clinical features, but require confirmation by imaging studies. Several TMDs present similar clinicalsymptoms and are difficult to diagnose differentially, resulting in misdiagnosis. For example, several studies reported accuracies of 43% to 90% for a clinical diagnosis of disc displacement because of unclear symptoms or no symptom. Therefore, imaging detection techniques are important for confirmation.Even though there are an extensive number of

publications that deal with TMJ disorders, not many have focused on imaging techniques to diagnose TMD. Over a period of 10 years, from 2005 to 2015, selection criteria were applied to exclude papers with a minimal methodological validity, and only 29 articles were left. Most of them are more than two decades old, or are dealing with small samples.which can constitute a bias of sampling or representativity, and therefore validity of the results of the studies.

Concerning Magnetic Resonance Imaging:

All examinations are performed in the closed mouth and open mouth positions.The closed mouth view is said to be most suitable for MRI to determine disc displacement (De Boer *et al*., 2014; Aiken *et al*., 2012; Moen *et al*., 2010), and it is suitable for comparing and quantifying displacement.Based on the studies in this review, T1 or protondensity sequences should be used in combination with T2 images.Aiken *et al*. (2012), Limchaichana, Chaput, Peterson, and Rohlin (Chaput*et al*., 2012; Limchaichana *et al*., 2006) found that the combination of T1 and T2 is the best condition for evaluating anterior displacement.Calibration of the observers seemed to improve interobserver agreement. Although the observers in many clinical studies conducted on an international basis are not calibrated, calibration is desirable not only to improve interobserver agreement but also to facilitate comparison of the results of different studies using MRI. Therefore, it is better to have sessions of collective work between the specialists for the interpretation of the radiological images.The RDC/TMD consists of guidelines and procedures that help the examiner to gain adequate inter-observer reliability by using diagnostic criteria for investigating muscle origin pain, disc displacement, arthralgia and degenerative bone change of the temporomandibular joint (TMJ).Park *et al*. (2015) showed that there is a discrepancy between RDC/TMD based diagnosis and MRI findings.Studies by Galhardo *et al* (2012) and Gedrange *et al*. (2013) confirms these results.

These authors explain this divergence by:

- A plausible explanation for the diagnostic mistake made was the presence of clicks as a diagnostic criterion for disk displacement according to the RDC/TMD algorithms. In fact, the literature shows that joint noises are perhaps no more than a case of biological variability of the TMJ rather than one of internal derangement because asymptomatic individuals may present such clinical signs.
- The possibility of MRI overdiagnosis for disk displacement.

RDC/TMD is more likely to make a false-positive diagnosis for TMDs, thereby to unnecessary treatments for individuals with a healthy TMJ, as pointed out by Galhardo *et al*. (2011) and Ahmad *et al*. (2010). We thus consider RDC/TMD as a tool of easy reproducibility but not necessarily of adequate accuracy, making it appropriate for use in large surveys, but less so in clinical practice. The evolution of MRI reliability in the diagnosis of TMJ disorders, based on the DRC / TDG tool as a diagnostic tool, has not been examined by any systematic review. Further studies are necessary to improve the accuracy of the RDC/TMD. If made with maximum reliability, an early diagnosis of disease results in effective treatment. MRI, perhaps the gold standard for diagnosing TMD (Aiken *et al*., 2012), can aid in the early diagnosis of TMJ disorders. 66% of studies considered MRI to be the most reliable imagery for giving information about soft tissue structure and determining disc displacements. However, an MRI machine is expensive and not always available, except in large cities (Park *et al*., 2012; Galhardo *et al*., 2013). It should only be indicated when there is a real need according to Ribeiro *et al*. (2012), while bearing in mind its limitations for the diagnosis of TMJ's bone abnormalities. Thus, the clinical examination of the patient is still the main assessment method, but it must be carried out judiciously.

About the Cone Beam

Several studies show that a small field of view and a small voxel size increase the effectiveness of Cone Beam in the diagnosis TMJ's bone disorders.Several studies (Al-Ekrish *et al*., 2015; Al-Saleh *et al*., 2015; Honey *et al*., 2007; Talaat *et al*., 2015) found that the Cone Beam has a very high reliability in detecting erosions, osteophytes, flattened condylar surfaces, surface irregularities of the condyle and Ely's cysts. According to Westesson *et al*. cited in the Petersson study (Ribeiro-Rotta *et al*., 2011), sensitivity (75%) and specificity (50%) are higher than those of MRI, confirming the high reliability of Cone Beam and the limitations of MRI in the diagnosis of bone changes. The study of Boer *et al*. (2014) shows that the diagnosis has changed in more than half of patients with TMJ disorders after Cone Beam use. Hence the value of this imagery and its considerable impact on the decision-making for these patients. These results are explained by the ability of the Cone Beam to have several para-sagittal plans and by high contrast and without structural overlay or tomographic blur unlike other types of imagery.According to some works (Honey *et al*., 2007; De Boer *et al*., 2014; Talaat *et al*., 2015), the Cone Beam should be prescribed only when its indication is necessary, in order to not expose the patient to excessive radiation.

About Ultrasonography

Three studies (Bas *et al*., 2011; Elias *et al*., 2006; Kaya *et al*., 2010) have shown that the transducer must be positioned over the TMJ perpendicularly to the zygomatic arc in a transverse and longitudinal plane, for better visualization of the disc. Ultrasonography has been used in the diagnosis of disc displacement of the TMJ in many recent studies, but some investigators have realized that ultrasonography has disadvantages. On ultrasonographic images, the TMJ disc appears as a narrow linear area between the glenoid fossa and condyle and is difficult to distinguish from the TMJ capsule and surrounding soft tissue. The disc generally appears as a hypoechoic or isoechoic band, but always appears as a hyperechoic in patients with a TMD. Such a change might be caused by inflammation and structural changes in disc composition, and such changes might influence the diagnoses unless inflammation in the TMJ is excluded. Also, the methods of examination may produce differences. So further researches are needed to clarify this point (Li *et al*., 2012; Kundu *et al*., 2013).The study by Bas *et al*. (2011) and the study by Kaya *et al*. (2010) found a sensitivity of 69% and 91% respectively, a specificity of 80% and 16% and a reliability of 71% and 82%, respectively, in the diagnosis of anterior disc displacement. While the study by Cakir-Ozkan *et al*. (2010) has shown that

the US measurement of the distance between the most anterior point of the articular capsule and the most anterior point of the condyle can be used to assess disc displacement in diseased joints but is not yet able to replace MRI. Reproducibility and interobserver and intraobserver agreement of TMJ US are low.Studies by Hansa Kundu *et al*. (2012) and Li *et al.* (2010) found that ultrasonography had acceptable reliability in the diagnosis of anterior disc displacement. However, the positive results of this imaging must be confirmed by MRI, which has more sensitivity and reliability than Ultrasonography to determine the type of displacement. And according to the same studies Ultrasonography does not present any reliability in the diagnosis of the lateral disc displacements (Chaput *et al*., 2012).

Conclusion

The objective of this paper was to use some reliable and reproducible imaging means allowing exploration of TMJ and all its components : bone, capsulo-ligament.The obtained results do not leave any doubt on the importance of imaging for the diagnosis of TMJ disorders. Each imaging treated in this work has a certain reliability ans sensitivity for some articular structures and therefore some reliability in the diagnosis of disorders of the TMJ disorders. MRI is the most reliable imagery for determining disc displacement regarding the condyle. Its reliability is excellent in the diagnosis of joint effusions, and acceptable in the diagnostic of osteoarthritis. While the Cone Beam is the most reliable imaging in the diagnosis of bone changes. Ultrasonography is a non-invasive and easy to perform technique for visualizing the disc- condyle relationship. However, it is not able to replace MRI in the anterior disc displacement.

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