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ORIGINAL ARTICLE

Comparison of the diagnostic accuracy of Ultrasonography and CBCT for detection of mandibular condyle erosion (an in-vitro study)

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INTRODUCTION

Temporomandibular joint (TMJ) is one of the most important, unique and structurally has the highest complex synovial system in the body (1, 2). TMJ, encompassing the temporal bone, mandibular condyle and articular disc, is a diarthrodial joint. As a collective form, Temporomandibular Joint Disorders (TMD) is often with multifactorial etiologies, and these diseases can more commonly affect the soft-tissue components of the TMJ including the articular disc and posterior attachment, the osseous components of the TMJ and also the related muscles (3, 4). The most common cause of the regional orofacial pain of non-dental origin is a result of TMD. Additional symptoms may include TMJ sounds such as clicking, pumping, limited or asymmetric mandibular movement (5). As TMJ is covered by a layer of fibrocartilage, unlike other joints in the human body, the mandibular condyles can be damaged due to cartilage degeneration. In addition, arthritis can also be initiated because of the particular dynamics in the maxillofacial area (6). TMD's are frequently associated with degenerative bone changes which can involve the bone structures of the TMJ such as erosion, flattening, osteophytes, subchondral bone sclerosis and pseudocysts (7). To correctly diagnose the dysfunctions associated with the disease and for adequate treatment planning Knowledge about these bone changes is fundamental (8).

A clinical examination alone is insufficient to adequately assess the osseous and soft tissue component changes of the TMJ. Therefore, a radiographic examination is an important part of the clinical assessment routine for conditions of TMJ dysfunction (9). Many imaging modalities have been used to assess the morphological changes of the TMJ For the diagnosis and treatment of TMD. For the observation of the soft tissue of the TMJ, magnetic resonance imaging (MRI) is considered the gold standard because of providing excellent soft tissue contrast (10). At the same time, CBCT imaging has become the gold standard imaging tool to evaluate TMJ osseous structural changes. Pathological changes such as condylar erosion, ankylosis, fractures, dislocation and osteophytes are most favorably viewed on CBCT (11-13). Nabih and Speculand who first reported Visualization of the TMJ and the disc with ultrasonography with a 3.5-MHz transducer in 1991 (14). As an alternative diagnostic method in the imaging of TMJ disorders ultrasonography has been suggested since 1992, because of being non-ionizing, non-invasive, less expensive and providing real-time imaging and also to view the joint in a continuum without discomfort, alteration of the patient's normal head posture, or interference with condylar motion (15).

Many medical data have been suggested that ultrasonography assessment of bone pathologies was less accurate than that for soft tissues. In TMJ, ultrasonography diagnosis of condylar erosion was commonly based on an interruption of the echogenicity of the cortical surface. The medial aspect of the condyle can hardly be depicted because of the limited acoustic window which is composed of bony structures. On the contrary, osteophyte formation and condylar erosion were more commonly seen in the anterior or lateral aspects of the condyle, and thus ultrasonography might easily depict those bone abnormalities. According to the review article, the diagnostic accuracy of ultrasonography in assessing the presence of condylar defects compared with MRI ranged from 56% to 94%, sensitivity and specificity ranged from 67% to 94% and accuracy from 26% to 100% (16). Rudisch et al. showed that condylar erosion was detected using ultrasonography with a sensitivity of 95%, specificity of 90% and accuracy of 93% compared with autopsy specimens (16). This data made up a representative insight into the potentiality of ultrasonography to assess bone abnormalities of the TMJ. Since there is insufficient evidence to advocate using ultrasonography for assessment of bone changes of the TMJ, this study has been designed with the aim of evaluating diagnostic reliability of ultrasound compared with CBCT for detection of mandibular condyle erosion.

MATERIALS AND METHODS

In this in-vitro study, the sample consisted of 12 TMJs from 6 dried human skulls. They have been obtained from the library and Anatomy Department, Tehran University of Medical Sciences, Iran. Demographic data were not available for the skull samples. Sex, age or ethnicity did not identify them. Condyles of the 12 TMJ samples were morphologically evaluated and reported to be free from apparent erosion or fracture.

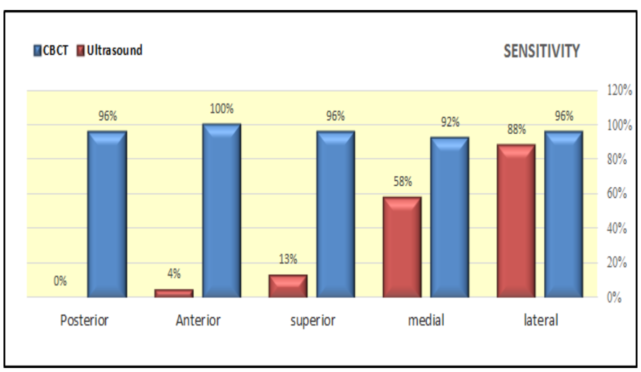
Case definitions: The following definitions were applied to evaluate the mandibular condyles:
No defect: intact cortical boundaries
Defect: interruption of cortical bone integrity

Six mandibular condyles will be randomly assigned with a defect on it. Five possible surfaces: Medial pole, lateral pole, anterior, posterior and superior surface. We have assigned 0.5, 1, 1.5,2 millimeters (mm) defects or left it intact as the control. A periodontist using a dental drill with four sizes (0.5, 1, 1.5, 2mm) of round bur has been used for all the lesions (fig.1). The defects have been checked in size with periodontal cullies. Due to the difficulty in finding dry human mandibles, at first, we created the 0.5mm defect, after ten days, the same defects were subsequently enlarged to 1,1.5 and 2 mm.in total we had 30 defect for each size, and also 24 defect for each surface. To simulate the soft-tissue anatomy in the area and to decrease the contrast, fresh meat was used. The fresh meat was placed in the glenoid fossa between the squamous part of the temporal bone and the condyle as well as around the joint. The condyle will be laid in the appropriate position guided by the natural occlusion of the teeth by aligning the maxillary and mandibular teeth and the application of light Force and fixing it with registration bite was made from rose wax (fig. 2) We coded the defected condyles number 1,3,5,7,9 and 11 and the normal ones 2,4,6,8,10 and 12. Defect being on the left or right condyles was not a variable in our study. Two calibrated blinded, oral and maxillofacial radiologists observer A, B examined together with the volumetric CBCT data. One general radiologist and well trained oral and maxillofacial radiologist (two calibrated blinded) Observer C, D evaluate together the real-time ultrasound images. The two observer for each modality checked the images together. Therefore, we only tested the intraobserver agreement for their first evaluation and second time ten days later.

The CBCT scans were taken with Alphard VEGA 3030 (Asahi Rontgen Ind. Co., Ltd, Kyoto, Japan), with the exposure protocol of voxel size=0.2mm, 80 KVP, 4mA, scan time 17s. The imaging field of view size was 10x10 cm. TMJ exposure mode was chosen. CBCT images were observed by using the NEO 3D software (Asahi Rontgen Ind., Co., Ltd., Kyoto, Japan). The images were displayed on a 17 inch Samsung monitor (Sync Master 740 N, Korea) with color set to the 32-bit depth and the screen resolution set at 1280×1024 pixels.

US were performed with an L12-4 probe on Philips Affinity 50 machine (USA).

Statistical analysis: The diagnostic performance of CBCT and US for detecting mandibular condyle erosion was evaluated by calculating its sensitivity and specificity. Data was analyzed using the McNamara's test. The intra-observer agreement was calculated with weighted Kappa coefficient. These results were interpreted consistently with the criteria of Landis and Koch:22 0.81 (very good. or excellent), 0.61– 0.80 (good or substantial), 0.41–0.60 (moderate), 0.21– 0.40 (fair) and 0.20 (poor) agreement. The result was statistically compared with a confidence interval of 95%, and the results were also considered significant when the P-value was less than or equal to 0.05.



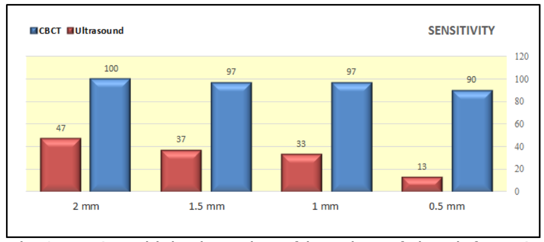


Fig 3. A: Sensitivity in order of location of the defect. Sensitivity in order of size of the defect.

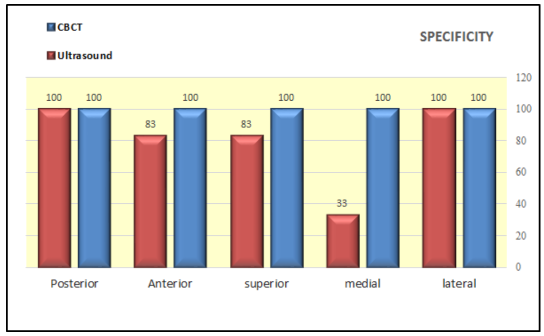


Fig 4.Comparison of CBCT and Ultrasound specificity:

Fig.2. Position of the skull and mandible to mimic TMJ for this study.

Table 1:

Position of defect	CBCT		Ultrasound		p-value
	%	N	%	N	
Lateral	100%	6	100%	6	1.000
Medial	100%	6	33%	2	0.125
Superior	83%	5	100%	6	1.000
Anterior	100%	6	83%	5	1.000
Posterior	100%	6	100%	6	1.000

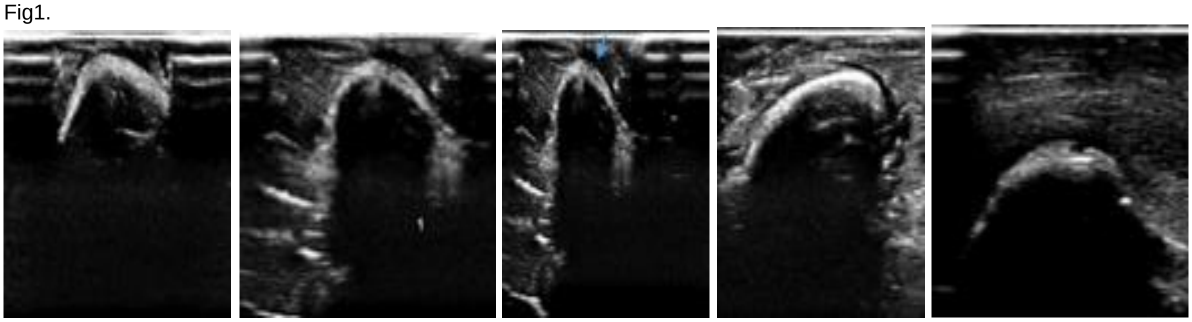
Table 2:

Position of effect	defect size	CBCT		Ultrasound		p-value
		%	N	%	N	
Lateral	0.5mm	83%	5	50%	3	0.625
	1mm	100%	6	100%	6	1.000
	1.5mm	100%	6	100%	6	1.000
	2mm	100%	6	100%	6	1.000
Medial	0.5mm	83%	5	17%	1	0.125
	1mm	100%	6	50%	3	0.250
	1.5mm	83%	5	67%	4	1.000
	2mm	100%	6	100%	6	1.000
Superior	0.5mm	100%	6	0%	0	0.031
	1mm	83%	5	17%	1	0.125
	1.5mm	100%	6	17%	1	0.063
	2mm	100%	6	17%	1	0.063
Anterior	0.5mm	100%	6	0%	0	0.031
	1mm	100%	6	0%	0	0.031
	1.5mm	100%	6	0%	0	0.031
	2mm	100%	6	17%	1	0.063
Posterior	0.5mm	83%	5	0%	0	1.000
	1mm	100%	6	0%	0	0.031
	1.5mm	100%	6	0%	0	0.031
	2mm	100%	6	0%	0	0.031

Table 3. table above shows specificity of two image modalities. Table below shows Sensitivity of CBCT AND US in respect of size and location of the defect

	Correct answer of observer		Correct answer of observer after 10 days		Percent of agreement	Kappa value	P-value
	%	N	%	N			
Ultrasound	42.7%	64	44%	66	93.3%	0.864	0.000
CBCT	96%	144	98.7%	148	96%	0.235	0.001

Fig1.



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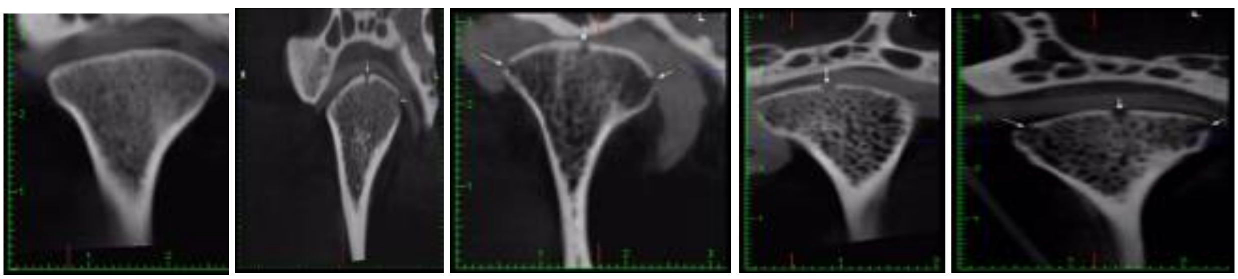

F G H I J

Fig 1.Ultrasound images from TMJs. a: no defect, b:0.5mm defect, c:1mm defect, d:1.5mm defect, e :2mm defect
Fig 2.CBCT images from TMJs. F: no defect. G: 0.5mm defect, H: 1mm defect, I: 1.5mm defect, J: 2mm defect

RESULT

Herein study with Mc nemar's exact test the sensitivity of two modalities reveals statistically significant differences (p=0.000) CBCT with sensitivity 95% was superior at detecting the defect of mandibular condyle than ultrasonography with sensitivity 33%. However, the result for specificity shows no statistically significant difference (p=0.22) CBCT with specificity 96% and Ultrasonography was 87%.

The specificity and sensitivity of the two modalities for the two observations have been listed in table 1. Figure 3 shows the sensitivity of two modalities in term of the position and the size of the defect. Figure 4 shows examples of correctly detected defects using each modality.

Intra observer reliability for the CBCT, the first and second reading was significantly correlated. (p= 0.001; k =0.235 with agreement of 96%). For the US Intraobserver reliability the first and second evaluation were also significantly correlated. (p=0.000; k=0.864 with agreement of 93.3%).

DISCUSSION

Usually, clinical examinations alone are not sufficient for diagnostic evaluation of different conditions compromising the normal morphology and function of TMJ (imaging diagnosis of the temporomandibular joint). The current imaging techniques in the assessment of osseous components changes of the TMJ include conventional tomography, panoramic radiography, MDCT, CBCT (17). Tsiklakis et al. in 2003 assessed five patients TMJs using CBCT. They concluded CBCT provides a complete radiographic evaluation of the bony structure of the TMJ with high diagnostic quality reconstructed images. The patient dose is lower and the examination time is shorter than that with conventional CT. Therefore, CBCT was considered as the imaging technique of choice when examination of an osseous component of the TMJ is required. Magnetic resonance imaging (MRI) is known as the gold standard method for the assessment of the soft tissue component of the TMJ. However, its limited since it has high costs and low availability. Likewise, for the patient with a contraindication to MRI, the use of Ultrasonography examination can be a convenient alternative in the evaluation of internal dysfunction of TMJ, joint effusion and disk displacement (16). Therefore, it has become one of the most recommended modality in recent decades because of its non-ionizing and non-invasive ability in evaluating the correlation and integrity of the soft and hard tissues of the TMJ through dynamic and static evaluations (18).

US diagnosis of erosions is usually based on the detection of absence or interruption of the echogenicity of the cortical bone lining. Longitudinal scans give the best view of Condylar morphology. Although transverse examination can assure the examiner's that the condyle has osteoarthrosis (19).

This study aimed to compare the diagnostic accuracy of Ultrasonography with CBCT for the detection of the simulated erosion of mandibular condyle. To the best knowledge of the authors, no previous study has investigated in this comparison. Therefore, there are no previous articles that can be directly related to the results.

In this present study, diagnostic accuracy of the CBCT was significantly higher than Ultrasonography taking all the size of the defect into account. Similarly, these results comprise of the location of the defects except the lesions located at the lateral pole of the condyle which reveals no statically significant difference between these two modalities. (p=0.625). The size of the defect affected the accuracy of detection for the US, for simulated erosion size of 0.5,1,1.05,2 mm the sensitivity for the US was 13%,33%,37% and 47% respectively. Intraobserver reliabilities for US (p=0.000) and for CBCT (p=0.001) showed significant agreement.

In 2012, Zain-Alabdeen et al.(20) Assessed that cone beam CT (CBCT) images were accurate and reliable compared with multidetector CT (MDCT) images for the detection of surface osseous changes in temporomandibular joints (TMJs). The sensitivities of both modalities were low and similar whereas the specificities were high and comparable. Intraobserver reliabilities for CBCT (p=0.0005) and for MDCT (p=0.0001) showed significant agreement. Interobserver reliability was higher for CBCT than for MDCT. Although there was a high agreement in Intraobserver reliability, the kappa value for CBCT was low. (k=0.2-0.4, which represents fair agreement). This result is in accordance with this present study. In spite of high agreement in intraobserver reliability, the kappa value for CBCT was low. (k=0.235). Conversely, the diagnostic accuracy for detection of mandibular condyle erosion for CBCT was high with sensitivity 95%.

In 2006, Honda et al. (20) compared the diagnostic accuracy of MDCT with CBCT in detecting erosion and osteophyte of the TMJ in autopsy material. Although CBCT had a slightly superior sensitivity (0.8) compared with MDCT sensitivity (0.7), both modalities show the same specificity (1.0) for detection of osseous changes in TMJ. They concluded that CBCT was similar to MDCT and that both techniques were highly reliable.

Y. Sirin et al. in 2010 studied the evaluation of condylar fractures in an experimental study on sheep; by that it was confirmed that CBCT had a diagnostic accuracy compared with MDCT (21)

Marques ET al16 demonstrated that the sensitivity of CBCT for assessing osseous defects was dependent on the size of defects and it was confirmed by Patel et al17 in their investigations of simulated condylar lesions. They concluded Minimal defects, <2 mm, showed to be difficult to detect,17 however, the sensitivity for detecting condylar bone defects was fairly high: 72.9–87.5%; while our study concluded that even small defects (0.5,1.1.5mm) proved to be easily detected with CBCT with overall sensitivity 95% (22).

S. Sharifi Shooshtari et al. Compared the sensitivity of CBCT for assessing bone defects dependent on the site of the lesions. They concluded that the results showed the sensitivity of CBCT was minimum in the lateral surface (27%) and maximum in the superior, posterior and anterior surfaces (100%). The specificity of CBCT was minimum in the medial and lateral surfaces (94%) and maximum in the superior, posterior and anterior surfaces (100%). However, our result showed the sensitivity of CBCT was 96% in the lateral surface. The specificity of CBCT was minimum in the superior surface (83%) and maximum in other surfaces (100%). The differences between our results and the above studies are probably related to the wide range of imaging protocols and equipment which were used.

In our study, Bone defects were simulated in dry mandibular condyles, using four sizes of drill bits. This is the same methodology used in the study by Marques et al., Zain-Alabdeen et al. and S. Sharifi Shooshtari. This methodology was selected to obtain a reference method, which simplifies the results comparison received by the observer as well as allowing for statistical treatment.

A study by U.M. Dohn et al. showed an overall moderate sensitivity of 44% and very high specificity of 95% for US in the detection of erosions of metacarpophalangeal (MCP) while using CT as the reference method. However, the sensitivity improved significantly when only areas with easy US accessibility were included (71%). Their data are in correlation with U.M. Dohn earlier study. Results in which US had an overall moderate sensitivity of 42% for erosion detection in MCP joints stay consistent (23). They concluded that US is a reliable and, in areas with good accessibility, a sensitive method for detecting bone erosions in RA MCP joints. US accuracy to detect bone erosions which encompasses a CT-determined bone volume loss more than 10%. However, in this present study, the small size of defect was not easily detected by US.

Another study reported by Alasaarela et al. proved US showed more erosion than CT in the humeral head of 26 patients with rheumatoid arthritis (RA).

The difference between our study and studies mentioned above is that US is expected to have less diagnostic accuracy concerning erosion detection when it comes to more complicated joints such as the TMJs. The reason for lower sensitivity in our study has been explained as such: some areas of the joints are inaccessible. Our study showed the sensitivity of US for detecting mandibular condyle defect range between 0 to 88% with the minimum amount at the superior surface and maximum at the lateral pole of the condyle.

According to the autopsy reported A. Rudisch et al. Study osteophyte formation and condylar erosion of the lateral or anterior aspect of the condyle were more detectable by ultrasonography than those positioned medially. Furthermore, they reported that condylar erosion with ultrasonography was detected with a sensitivity and specificity of 95% and 90% respectively.

Brandlmaier et al. reported the possibility of diagnosis of many osteoarthritis changes with Ultrasonography while they were not visible with MRI which pointed that MRI is an imperfect standard of reference. These results point to the potentiality of US to evaluate osteoarthritic changes within the TMJ.

Our study showed that the condylar erosion of the lateral aspect of the condyle were more detectable by ultrasonography although the defects of the anterior, posterior, superior and medial aspect were not easily detected. A condylar defect with ultrasonography was detected with a sensitivity and specificity of 33% and 87% respectively.

As far as study limitations are concerned, in this in-vitro study, the erosive lesions were simulated with round bur with well-defined margins that would not usually be observed in a clinical situation. Since the simulated lesions were not the same as the actual disease conditions, the diagnostic accuracy of these imaging modalities in this study might be slightly higher compared with an in-vivo evaluation. Other limiting factors in our study were represented by a reduced comparability of the dry skull and the fresh meat used to simulate x-ray attenuation by soft tissue with the TMJs in the clinical setting. Also, CBCT and Ultrasound assessments were made only in the closed jaw views. In clinical situations, both closed and open views are usually obtained. Superimpositions are not considered during CBCT evaluations; however, when using Ultrasonography, some lesions might be more easily detected in the open view in which the position of the condyle is outside the glenoid fossa.

Moreover, the correct use of equipment and the accuracy of results depend on the skills of the operator. Consequently, to achieve a diagnostic image by the US, an expert, a well-oriented radiologist is required.

It is apparent that ultrasound images have less spatial resolution than that of CBCT's, especially in imaging the bone. Therefore, US is more frequently applied for examination of soft tissue examinations. However, in the recent study of K. Degen et al. (degan) Ultrasound showed high potential to supplement CBCT in measuring the cortical bone thickness. These encouraging results support efforts to further developing of accessible osseous assessments by US.

CONCLUSION

Since the diagnostic accuracy of US in detection of the mandibular condyle erosion is lower than CBCT, now with the available resources US it is not useful for the mentioned proposed.

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