Dentomaxillofacial Radiology (2019) 48, 20180252

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RESEARCH ARTICLE

Is ultrasonography sufficient for evaluation of mental foramen?

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Objectives: To assess the efficacy of ultrasonography (USG) in morphological and morphometric evaluation of the mental foramen (MF) compared to cone beam CT (CBCT).
Methods: The measurements were established on 60 MFs of 30 patients (16 males, 14 females) with a mean age of 30.70 ± 9,23 years. The vertical and the horizontal diameters, distance to the alveolar crest of the MF was measured by both CBCT and USG. Results obtained with CBCT and USG were statistically compared. And also the blood flow of the MF determined by Doppler USG.
Results: All of the MFs could be detected by CBCT and USG. The vertical and the horizontal diameter measurements were compatible with each other by CBCT and USG. However, the distance to the alveolar crest was lower in USG than CBCT ($p < 0.0001$). The blood flow could be detected in all patients by Doppler USG that was weak in 8 MFs and strong in 52 MFs. Also there was no statistically significant association between the blood flow and age or gender. Furthermore, the blood flow was related with the horizontal diameter of the MF; however, it was not related with the vertical diameter and the distance to the alveolar crest.
Conclusions: USG is quite effective in showing the shape, size, and the location of the MF easily and rapidly. However, it is not as accurate as CBCT in measuring the distance from the MF to alveolar crest. And also it allows to examine the flow rate of mental artery with its Doppler modes.
Dentomaxillofacial Radiology (2019) **48**, 20180252. doi: 10.1259/dmfr.20180252

Cite this article as: Çağlayan F, Sümbüllü MA, Akgül HM. Is ultrasonography sufficient for evaluation of mental foramen?. *Dentomaxillofac Radiol* 2019; **48**: 20180252.

Keywords: cone beam CT; mandible; ultrasonography

Introduction

The mental foramen (MF) is an opening located on the anterior surface of the mandible. It transmits the terminal branches of the inferior alveolar nerve and the mental artery. The mental nerve supplies sensory fibers to the skin overlying the mandible and the lower lip and the mental artery supplies the chin at the MF. The location of the MF and also the course of the neurovascular bundle must be identified precisely before any surgical or endodontic procedures to avoid possible damages.

Many methods may be used to examine the MF such as direct examinations on dry skulls and radiological examinations established by conventional radiography (panoramic or periapical), CT, Cone Beam CT(CBCT), and MRI.[1–4] Conventional radiographic techniques collapse a three-dimensional structure onto a two-dimensional plane. So, the resulting superimposition of anatomical structures complicates image interpretation and landmark identification, and this distortion and magnification may lead to errors of identification.[5] Although MRI is not a method used in practice in dental radiology, it is stated that it can be used to determine mandibular nerve when the mandibular canal cannot be seen with the CBCT.[1] Namely, while the nerve tissue is hyperintense in the MRI, the mandibular canal cortical walls are hypointense T_1 weighted MRI images.

The CBCT which was also used in the present study is capable of providing accurate, submillimeter resolution images in three-dimensional visualization of the complexity of the maxillofacial region with lower radiation dose in comparison with medical CT.[6] CBCT allows accurate measurements in all three planes and

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Received 02 July 2018; revised 24 October 2018; accepted 07 November 2018

oblique sections with its isotropic cubic voxels and high resolution.[7] The MF can be clearly identified on axial, panoramic, or cross-sectional images by CBCT.[3]

Ultrasonography (USG) is used in dentistry generally for several purposes such as: salivary gland diseases, cervical lymphadenopathy, various soft tissue mass, masticatory, and neck muscles, as well as novel usage areas such as: maxillofacial fractures, periapical lesions, temporomandibular joint, tongue tumors, dental tissue's decay, cracks and fractures, mucosal lesions, periodontal tissues, implant planning, and orthodontic procedures.[8] Compared to other prominent methods of medical imaging, USG has several advantages: it provides images in real-time, is portable, inexpensive, radiation free, non-invasive, and unaffected by metal artifacts, such as dental restorations.[8–11] It also allows identification of the vascularity via its power Doppler and color Doppler facilities and is capable of differentiating cystic lesions from solid lesions.[10,11] The drawbacks of USG include limitations with respect to its field of view, such as physical condition and co-operation of patient, difficulty in imaging structures behind bone and air, and its dependence on a skilled operator.

Normally, the structures behind the bone cannot be examined by USG as known. There are many studies showing that USG can be used in bone and hard tissue evaluations in maxillofacial region, such as intraosseous jaw lesions,[12,13] temporomandibular joint studies,[14] bone fractures[15] or palatal suture evaluations.[16] When the intraosseous lesions cause thinning or perforation on the cortical bone surface, their content becomes visible with USG. In the same way, discontinuities on the bone surface such as foramens or fracture lines may be examined with USG due to the deterioration of the bone continuity.[9] Normally, the bone cortex, which is fully integrated, has a single line in the USG, must not have any curb or interruption. In this way, the MF which is an anatomical foramen on the facial side of the mandible, can be examined morphometrically by USG.

In the literature there are few studies about the USG determination of the MF. To our knowledge there is no other study in the literature about the morphometric and morphological features of MF comparing two radiological techniques that were the CBCT and the USG. The aim of the present study was to assess the efficacy of USG in determination of anatomorphometry of MF compared to CBCT and so on to determine if the USG is sufficient for evaluation of MF without radiation in real-time, instead of CBCT.

Methods and materials

Study design

This study was carried out in the Oral and Maxillofacial Radiology Department and was approved by the ethical committee of faculty (Decision No: 84). The study involved a total of 30 patients older than 18 years (16 males, 14 females), and the group's mean age was 30.70 ± 9.23 years. The observers had at least 10 years of experience with CBCT and 4 years of experience with USG. They were calibrated with each other about the measurements before the study. They used previous CBCT scans and USG trials for practice and applied measurements together and discussed the method with each other. Subsequently, only one of the researchers conducted the measurements on 60 mental foramen of 30 patients used in the study.

The patients who underwent CBCT for different reasons were included in the study. And also the CBCT scans with the whole mandible and the mandibular premolar teeth were complete included the study. The patients were asked for USG examination after CBCT shooting with their informed consent. USG measurements were established in real-time during the examination. CBCT measurements were made on another day, after the creation of the appropriate study reconstruction for the study and blind of USG results.

Imaging procedures and measurements

USG was applied using an Aplio-300 device (Toshiba Corporation, Tokyo, Japan) and an 8 MHz linear array transducer. The examinations were carried out with the patients in the rest position. During the examinations, the MF region was scanned on the horizontal and vertical planes by trans-cutaneus approach. The MF was easily identified as a break on the continuity of the mandible. The horizontal and the vertical diameter of the MF was measured by holding the probe horizontally and vertically (Figures 1 and 2). The distance to the alveolar crest was also measured in the vertical plane up to the upper limit of the alveolar bone visible on the USG (Figure 2). After capturing the best view of MF, the image was frozen and measurements were made with the caliper on the control panel. The shape of the MF was determined according to the vertical and horizontal diameter.

The vascularization of the MF was also examined by Doppler USG (Figure 3). The blood flow was

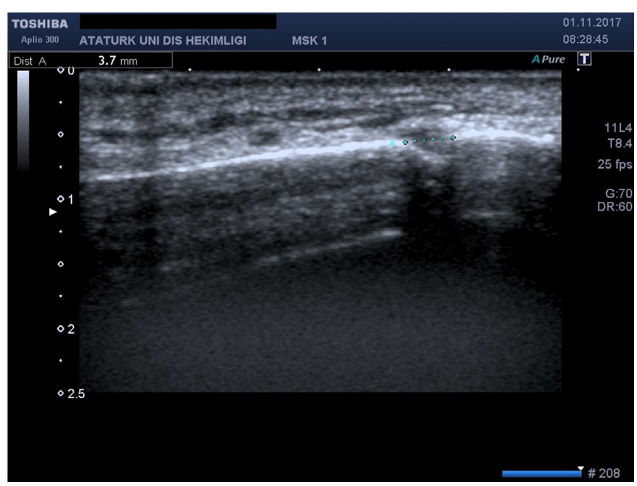

Figure 1 The measurement of the horizontal diameter of the MF by USG. MF, mental foramen; USG, ultrasonography.

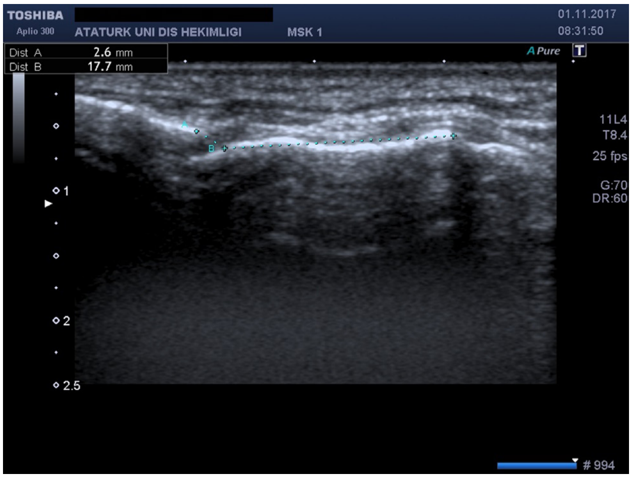

Figure 2 The measurement of the vertical diameter and the distance to the alveolar crest of the MF by USG (Dist A: Vertical diameter, Dist B: distance to the alveolar crest). MF, mental foramen; USG, ultrasonography.

classified as no flow, weak flow, and strong flow similar to the method applied by Baladi et al.[17] When systolic velocity is not clearly depicted in the spectral Doppler time–velocity graph, it was assessed as *weak flow*. When a clearly visible spectral Doppler time–velocity graph providing numerical data was obtained, it was assessed as *strong flow*. Also cases with no signal were considered as *no flow* naturally.

The cone beam images were taken with a NewTom 3G (Quantitative Radiology, Verona, Italy) flat panel-based CBCT device. The scanner operated with a maximum output of 110 KV, 15 mAs, 0.16 mm voxel size, and 5.4 s typical exposure time. Radiographic parameters were determined automatically from scout views by the NewTom FP. The horizontal plan review of MF was evaluated on the axial slices, for which the slice thickness and intervals were 0.5 mm, parallel to the lower edge of the mandible. The vertical plan review of MF was performed on cross-sectional slices, which are slices with a thickness of 1 mm derived from indirect reconstructions of axial slices. Cross-sectional sections were created on the axial section where the MF is seen in its widest form and measurements were made on the cross-section crossing the middle of the MF.

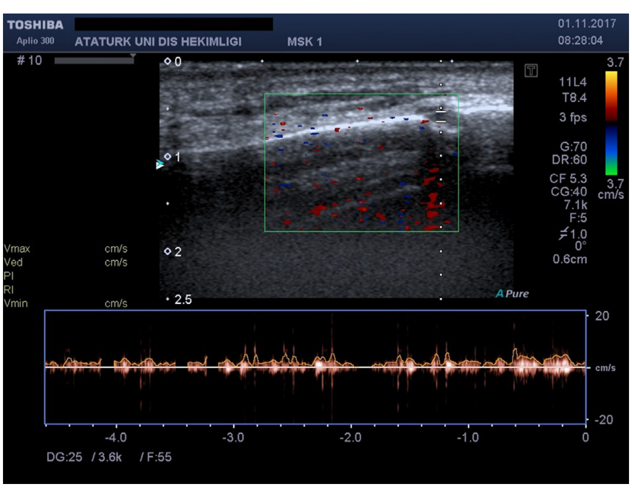

Figure 3 The blood flow of the MF by power Doppler USG. MF, mental foramen; USG, ultrasonography.

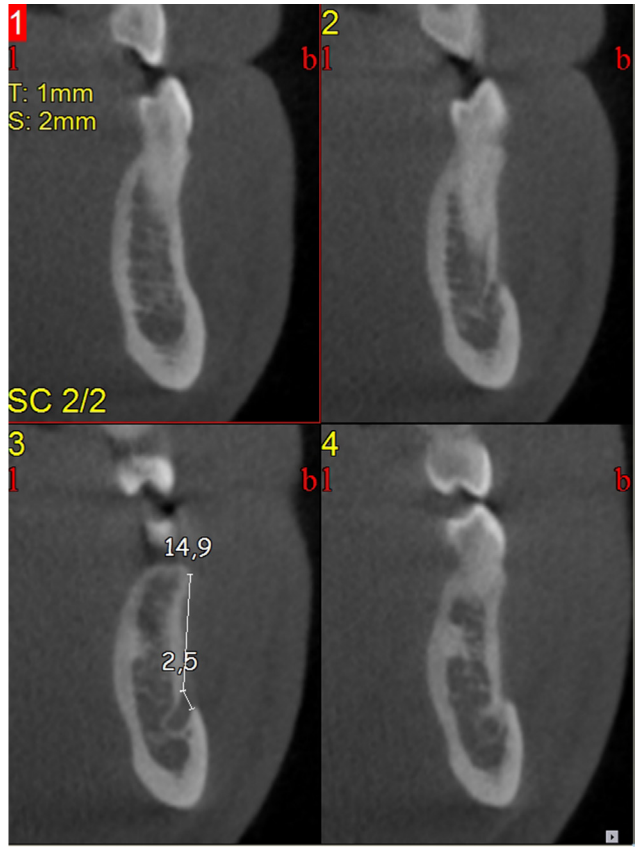

Figure 4 The measurement of the vertical diameter and the distance to the alveolar crest of the MF on cross-sectional CBCT slice. CBCT, cone beam CT; MF, mental foramen.

The vertical diameter of MF measured obliquely the upper and lower cortical edge peaks of the foramen on the cross-sectional slices (Figure 4). The horizontal diameter of MF measured obliquely the mesial and distal cortical margin peaks of the foramen on the axial slices (Figure 5). The distance to the alveolar crest was measured obliquely between the superior cortical margin peak of the foramen and the peak of the buccal cortical surface of alveolar bone (Figure 4). That is, measurements were made up to the top of the surface of the buccal cortical bone not to the alveolar crest peak. Because we can see the buccal cortical bone surface only with USG so that the measurements in both methods are intended to be compatible.

Statistical analyses

The statistical analyses were conducted with SPSS® software (SPSS v. 20.0 for Windows, SPSS Inc., Chicago, IL). The homogeneity of data was evaluated by Levene's test

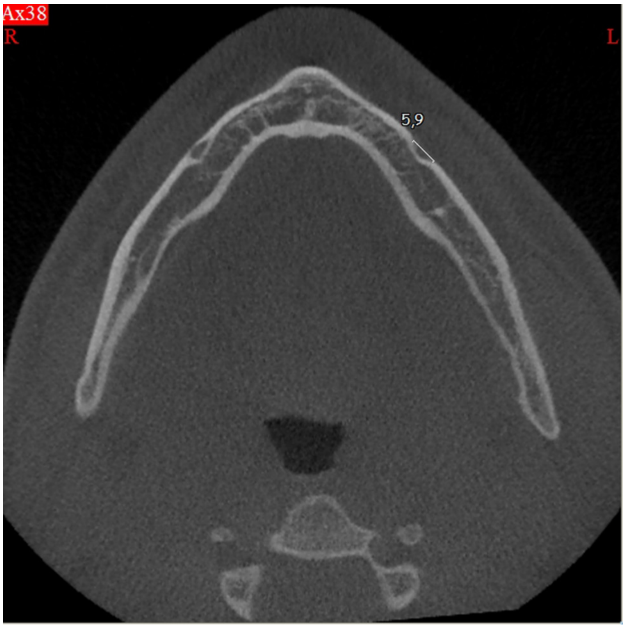

Figure 5 The measurement of the horizontal diameter of the MF on axial CBCT slice. CBCT, cone beam CT; MF, mental foramen.

for parametric measurements and Student's *t*-test was used to determine the differences in groups. The chi-square test was used to determine the differences of non-parametric results such as blood flow according to gender. A *p*-value of 0.05 was considered statistically significant.

Results

All of the MFs could be detected by CBCT and USG. When USG and CBCT measurements were compared, there was no statistically significant differences in vertical and horizontal diameter of MF in both techniques. That is, the diameter measurements were compatible with each other in both techniques. In addition, according to the horizontal and vertical diameters measured by CBCT and USG, we can say that all of the MFs exhibited an oval shape. However, the distance to alveolar crest was approximately 1–2 mm lower in USG than CBCT as seen in Table 1 ($p < 0.0001$).

The blood flow could be detected in all patients by Doppler USG that was weak in 8 MFs and strong in 52 MFs. There was no significant difference in the mean age of the groups in which the blood flow was strong and weak. So blood flow of the MF did not change depending on age. Furthermore, the horizontal diameter mean of MFs with weak blood flow was found higher than MFs with strong blood flow (Table 2, $p < 0.05$). There was no statistically significant differences in vertical diameter and distance to alveolar crest of MFs with weak and strong blood flow.

There was no significant difference in the blood flow of the MF between males and females due to gender as seen in Table 3. Although the measurements were all higher in males, these differences were statistically significant only for the distance to alveolar crest (USG measurement) and the vertical diameter (CBCT measurement) of MF.

Discussion

There are many CBCT[1,3,5,18] studies in the literature determining the MF morphometrically and also USG[2,19–22] studies. The present study differs from other studies on this subject in the literature by comparing the USG and the CBCT measurements. There is no other study in the literature about the morphometric and morphological features of MF comparing two radiological techniques that were the CBCT and the USG.

It was mentioned that the diameter, position, location, and the distance to the anatomical landmarks of MF can be detected by USG easily.[2,19,21] Laher et al[21] mentioned that the overall mean time taken to locate the mental foramen was 16.1 s by USG. Laher and Wells[22] mentioned in another study that USG may also be used to locate the MF with regard to various soft tissue landmarks. In another USG study Laher et al[2] found the mean alveolar bone height higher than the present study. However, this discrepancy was normal, because they had measured until the cusp of the teeth. We have measured until the top of the alveolar bone visible on the USG. Moystad et al[19] mentioned that the damage of the inferior alveolar nerve may lead to degeneration of the mental nerve and they showed the MF shrinkage by measuring the diameter of MF with USG.

In the present study, the vertical and horizontal diameter measurements of the MF did not show any difference between USG and CBCT. The measurements were consistent with both techniques. As known, the periphery of the mental foramen is surrounded by thick cortical bone. In this way, the foramen field could be fully distinguished on the USG section and the vertical and the horizontal diameters were measured similar to CBCT.

Table 1 Comparison of CBCT and USG measurements

	n	*CBCT measurements*	*USG measurements*	*t*	*p*
Vertical diameter	60	3.30 ± 0.80	3.30 ± 0.55	0.026	0.979
Horizontal diameter	60	4.39 ± 1.03	4.27 ± 0.94	0.636	0.526
Distance to alveolar crest	60	14.15 ± 1.80	12.80 ± 1.80	4.121	0.000[a]

CBCT, cone beam CT; USG, ultrasonography.
$p < 0.0001$.

Table 2 Comparison of the USG measurements according to blood flow

	n	*Strong flow*	*n*	*Weak flow*	*t*	*p*
Vertical diameter	52	3.23 ± 078	8	3.75 ± 0.87	1.74	0.087
Horizontal diameter	52	4.28 ± 1.02	8	5.13 ± 0.91	2.22	0.030[a]
Distance to alveolar crest	52	14.02 ± 1.72	8	15.05 ± 2.16	1.490	0.142

USG, ultrasonography.
$p < 0.05$.

In the present study, the distance between the MF and the alveolar crest measured about 1–2 mm lower with USG than CBCT. So this measure was not compatible with CBCT and USG (p›0.05). As known, alveolar crest gets thinner and becomes sharp as it approaches the top of the alveolar bone. And also the alveolar bone loses its apparent cortical surface in this region. This affects the exact visibility of the surface of the bone by USG in this region, resulting in lower measurements. In other words, the fact of the low measurement in this region was actually expected by USG.

Also sometimes, the inadequacy of the footprint of the ultrasound probe, or the exostosis or undercut on the facial surface of the mandibular bone may have caused this measurement not to be made clearly in this area. But as a result we can say that the distance to the crest of the MF was measured 1–2 mm lower by USG. This is sometimes even thought of as an area of concern, especially in implant applications, the USG does not show exactly right results in the measurement of the distance between the MF and the crest top. CBCT is already accepted as the gold standard in dimension measurements especially in implant procedures. CBCT is a useful tool for morphometric and morphological examinations of the maxillofacial hard tissues as well as anatomical landmarks and also MF. CBCT has been recommended for the imaging of anatomical landmarks before surgical procedures.[23] The efficacy of the CBCT in measurements in all planes with its isotropic cubic voxels and its low radiation dose is now accepted all over the world.[5–7] On the other hand, the use of USG in dental radiology is becoming widespread. The examination of MF by USG may be useful in emergencies, to avoid ionizing radiation especially for children and pregnant patients. Mental nerve damage can be prevented through USG in surgical procedures such as plastic and reconstructive, endodontic or periodontal surgery procedures and also MF can be quickly localized in mental nerve blocks and traumatic injuries.

When some studies in the literature are analyzed for shape, they declared that MF has an oval rather than a round shape.[3,24] According to the horizontal and vertical diameters in the present study, we can say that all of the MFs exhibited an oval shape on both sides as well consistent with the literature. In the present study, the measurements were all higher in males; these differences were statistically significant only for the distance to alveolar crest (USG measurement) and the vertical diameter (CBCT measurement) of MF. Already, measurements are expected to be higher in males naturally and the literature also supports this.[3] Although the location and diameter of mental foramen can be seen exactly with USG, the opening angle of the MF cannot be examined. The opening angle of MF angle is also important in the operations of this area especially in implants as well as diameters and distances.[24] The size and position of the implant may need to be changed depending on the angle. Çağlayan et al[3] measured the opening angle of the MF on CBCT sections in a previous study and they emphasized the importance of the opening angle of MF.

The mental artery escapes with the mental nerve at the mental foramen, supplies the chin, and anastomoses with the submental and inferior labial arteries. MF blood flow can also be affected by many factors such as age, systemic diseases or smoking.[20] In the present study we found that the MF blood flow was only related

Table 3 Comparison of the measurements based on gender

		n	*Male*	*n*	*Female*	*t*	*p*
Vertical diameter (CBCT)		32	3.44 ± 0.60	28	3.14 ± 0.47	2.135	0.037[a]
Horizontal diameter (CBCT)		32	4.35 ± 0.97	28	4.18 ± 0.92	0.712	0.479
Distance to alveolar crest (CBCT)		32	13.11 ± 1.66	28	12.43 ± 1.91	1.464	0.148
Vertical diameter (USG)		32	3.36 ± 0.77	28	3.22 ± 0.85	0.691	0.492
Horizontal diameter (USG)		32	4.41 ± 1.07	28	4.36 ± 1.00	0.153	0.879
Distance to alveolar crest (USG)		32	14.75 ± 1.65	28	13.46 ± 1.74	2.926	0.005[b]
Blood flow	Strong signal (%)	32	27(84.4)	28	25(89.3)	[c]p›0.05	
	Weak signal (%)		5 (15.6)		3 (10.7)		

CBCT, cone beam CT; USG, ultrasonography.
$p < 0.05$
$p < 0.005$
Chi square test

to the horizontal diameter of the foramen. There was only a numerical relationship with the vertical diameter, the difference was not significant statistically. There are studies in the literature that show an association between MF blood flow and alveolar bone resorption. Eiseman et al[20] Baladi et al[17] mentioned that diminished mental artery flow causes to the resorptıon of alveolar bone by USG studies. However, we could not find any association between the blood flow of the MF and the distance to the alveolar crest in the present study.

The limitation of the present study was being inadequate in assessing the blood flow of the MF. Namely, it did not show the specific blood flow velocity. And also, there is a need for more extensive studies with more patients, which regards factors such as age, systemic diseases or smoking that may affect blood supply. However, based on the present study we can clearly say that blood flow of the MF can be clearly seen by Doppler USG. Thus, the blood flow has been detected in all of the MFs by Doppler USG in the present study and the majority of them were strong flows. Already the main aim of the present study was to assess the efficacy of USG in the determination of morphometry of MF compared to CBCT. The data of the blood flow was used as an additional finding. However, these findings may lead to more extensive studies about the blood supply of the MF in the future.

In conclusion, USG is quite effective in detecting the shape, size, and the location of the MF easily and rapidly free of ionizing radiation. However, it is not as accurate as CBCT in measuring the distance from the MF to alveolar crest. And also it allows to examine the flow rate of mental artery with its Doppler modes.

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