RESEARCH ARTICLE

Ultrasonographically locating the mental foramen and its soft tissue relations

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Objectives: This ultrasound-based cross-sectional study aimed to visualize, locate and compare the position of the mental foramen with regard to its relationship to various soft tissue landmarks.

Methods: 100 Black and Caucasian subjects were included. An ultrasound transducer was used to locate the mental foramina. Distances to various landmarks were measured and compared.

Results: All mental foramina were visualized. The mean soft tissue distance of the entire group from the mental foramen on the right and left sides, respectively, were as follows: (a) 3.4 mm [standard deviation (SD) 1.7 mm] and 3.4 mm (SD 1.5 mm) lateral to a vertical line passing through the chelion; (b) 20.1 mm (SD 2.6 mm) and 20.1 mm (SD 2.6 mm) distal to a horizontal line bisecting the chelions; (c) 15.1 mm (SD 2.4 mm) and 15.0 mm (SD 2.4 mm) proximal to the inferior border of the mandible. We found no statistically significant differences between race groups, between gender group and between age categories with regard to the horizontal soft tissue distance from a vertical line passing through the chelion to the mental foramen on the right or left sides. There were statistically significant (but not clinically significant) differences between race groups and between gender groups but not between age groups with regard to the vertical soft tissue distance from a horizontal line bisecting the chelions to the mental foramen as well as from the inferior border of the mandible to the mental foramen on both the right and left sides.

Conclusions: This study suggests that ultrasound is a feasible imaging modality that can be utilized to locate the mental foramen. Differences in the position of the mental foramen with regard to various soft tissue landmarks are minor and clinically insignificant.

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Introduction

Ultrasound is an emerging field in point-of-care bedside medicine and is now regarded as the 21st century stethoscope of the emergency department.¹ Literature on the application of ultrasound imaging in dentistry is rather scarce. As a result, the role of ultrasound imaging in oral medicine has not yet been defined. The majority of published studies in this field either included small

sample sizes or were conducted in cadaver/non-human subjects. Despite this, ultrasound as an imaging modality still has potential in transforming the face of oral medicine.

Reported applications of ultrasound in oral medicine include the visualization of the alveolar ridge,² differentiating between periapical granulomas and cystic lesions,³ identification of dental cracks,⁴ diagnosis of periapical lesions,^{5,6} measurement of implant depth,^{7,8} measurement of enamel thickness⁹ and the identification of gingival inflammation.¹⁰ Only three

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studies have identified the mental foramen, the largest of which included just five subjects.^{8,11,12} Recently, Chan et al¹² in their proof of concept study concluded that sonographic findings correlated accurately with CBCT imaging. They clearly visualized the greater palatine nerve, mental foramen, lingual nerve and hard tissue surfaces such as enamel, root dentin and bone with ultrasound imaging.

The mental foramen is a highly important landmark not only in implant dentistry but also to oral maxillo-facial surgeons, other dental specialists, plastic surgeons and emergency physicians for procedures that include periapical surgery, orthognathic surgery, the repair of lower lip and chin lacerations, and facial reconstructive surgery.^{13,14} Surgical procedures in the vicinity of the mental nerve may be complicated by temporary or permanent sensory dysfunction and paraesthesia as a result of injury to the mental nerve.^{15,16} We recently published an in-depth review describing the position of the mental foramen and the various radiological modalities useful in locating this landmark.¹⁷ CBCT is currently regarded as the gold standard modality for its ability in defining orofacial anatomy in three dimensions.¹⁸ However, cost, time, radiation exposure and the impracticality of use during operative procedures are limiting factors. The fact that ultrasonography as an imaging modality is non-invasive, safe and radiation free and can be carried out in real time at the bedside/operating theatre makes it an appealing tool in dentistry and medicine.¹⁹

Variation in the anatomy and position of the mental foramen with regard to race, age and sex play an important role.^{13,20,21} To our knowledge, this study is the first to make use of ultrasonography in a study population to determine the position of the mental foramen in relation to soft tissue landmarks. Furthermore we have not come across any study that described the position of the mental foramen in relation to soft tissue landmarks on live human subjects. Only two prior studies described the position of the mental foramen in relation to soft tissue landmarks; however, both studies conducted their measurements on digitalized radiographs.^{22,23} With tooth loss and wear, variation in hard tissue landmarks such as the premolar teeth are expected.^{13,21} On the other hand, whilst it is noted that there is a decrease in facial skin turgor with advancing age, soft tissue landmarks such as the chelion are more likely to remain static and perhaps may even be more accurate when used as a landmark in locating the mental foramen. This ultrasound-based study aimed to visualize, locate and compare the position of the mental foramen with regard to its relationship to various soft tissue landmarks.

Methods and materials

In this cross-sectional study conducted at the Charlotte Maxeke Johannesburg Academic Hospital Emergency

Department (ED), we enrolled 100 adult Black and Caucasian (White and Asian) patients, who were 18 years and older. Based on an expected difference in population mean of 2.5 mm with regard to the vertical distance from the mental foramen to the inferior border of the mandible, an estimated standard deviation of 3.5 mm, a power of 0.8 and a significance level $p \leq 0.05$, the required sample size was calculated as 84 subjects. Subjects were randomly selected from the ED queue at a time convenient to the researcher. Subjects, who consented to participate in the study, were asked to lie in the supine position in an examination cubicle. We used a Toshiba diagnostic ultrasound system (model SSA-510A; Toshiba, Tokyo, Japan) and a high-frequency (8-MHz) transducer (PLF-805ST; Toshiba, Tokyo, Japan). After smearing ultrasound conductive gel, the transducer with the probe marker directed cranially was applied on the lower part of the face just lateral to the mentum. We identified the mental foramen and marked its position on the skin with a non-toxic body marker. A calliper and ruler were used to measure the horizontal and vertical distances to the chelion and the vertical distance to the inferior border of the mandible. Participants were asked to maintain a neutral facial expression throughout the study so as to not distort measurements. The above procedure was repeated on the opposite side of the face. Any difficulties experienced during the investigation were documented. Individuals with congenital/acquired facial distortion, a history of mandibular surgery or trauma and with missing mandibular teeth between the right and left lower first molars were excluded from the study. As part of the same study we also described the relationship of the mental foramen to hard tissue landmarks as well as the mandibular premolar teeth. These results have been reported separately.^{24,25}

Ethics

Permission to conduct the study was obtained from the head of department of the Charlotte Maxeke Johannesburg Academic Hospital ED and the hospital management. Ethical clearance was obtained from the Human Research Ethics Committee of the University of the Witwatersrand (certificate no. M110920). Patient confidentiality was respected at all times. Data were stored in a password-protected computer that was only accessible to the researchers.

Statistical analysis

All data were captured from the data collection sheets by the primary investigator and entered into an electronic spreadsheet (Microsoft Excel[®]; Microsoft, Redmond, WA). STATA[®] v. 12.1 software (StataCorp LP, College Station, TX) was utilized to analyze our data. Each volunteer was placed into an age category: (a) 18–30 years, (b) 31–40 years, (c) 41–50 years, (d) 51–60 years and (e) 61–70 years. Mean and standard deviation were calculated for the various measurements. Normal (Gaussian) distribution and equal variance of

the data were confirmed using the Kolmogorov–Smirnov and Barnett’s tests, respectively. Where appropriate, one-way ANOVA, Student’s *t*-test and Bonferroni *post hoc* analysis were performed. The level of significance was set at $p = 0.05$, CI = 95%. Study reporting conformed to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.²⁶

Results

The total sample of 100 subjects comprised 50 Blacks (27 males and 23 females) and 50 Caucasians (23 males and 27 females). The Caucasians were further subdivided into 25 Asians, all of South Asian origin (13 males and 12 females) and 25 Whites, all of Northern and Central European origin (10 males and 15 females). The overall gender distribution was equal (50 males and 50 females). The overall mean age of the study population was 35.7 years (SD 1.9 years).

We identified all (100%) mental foramina with ultrasound imaging. Figures 1 and 2 describe the mean distances from the mental foramen to various soft tissue landmarks for all 100 subjects who were studied. Table 1 describes the impact of race, gender and age on the position of the mental foramen with regard to distances to various soft tissue landmarks.

We found significant differences between Blacks and Asians, Blacks and Whites, and males and females for the vertical soft tissue distance from a horizontal line bisecting the chelion to the mental foramen (VCh) and the vertical soft tissue distance from the inferior border of the mandible to the mental foramen (VM) bilaterally. There were no significant differences for the horizontal soft tissue distance from a vertical line passing through

the chelion to the mental foramen with regard to these groups. We also did not find any significant differences between Asians and Whites or between age groups for any of the measured distances.

Discussion

We identified 100% of mental foraminae with ultrasound imaging. By applying the ultrasound probe just lateral to the mentum, the mental foramen was easily recognized as a break in the continuity of the bone (Figure 3). There are no other similar ultrasonographic structures that may be confused with the mental foramen in this region. Earlier studies using panoramic and apical radiographs reported detection of the mental foramen in 46–94% of cases.^{27–29} Therefore, ultrasound imaging may be regarded as superior to panoramic and periapical films in its ability to detect the mental foramen.

We found no statistically significant differences between groups with regard to the horizontal soft tissue distance from a vertical line passing through the chelion to the mental foramen (HChR and HChL). The overall mean distance lateral to the chelion was 3.4 mm bilaterally. Guo et al²² indirectly measured the horizontal distance from the chelion to the mental foramen on digitalized photographs. A mean distance of 3.55 mm (SD 1.70 mm) mesial to the chelion in the frontal view and 7.19 mm (SD 3.03 mm) lateral to the chelion on the lateral view was recorded. Song et al²³ also conducted their measurements indirectly on digitalized photographs and documented the mean position of the mental foramen as 3.3 mm (SD 2.9 mm) mesial to the chelion on the frontal view. However, digitalized photography does not account for angling and curvature of the mandible. One must also exercise caution when interpreting panoramic radiographs as these are prone to symmetry ratio and linear measurement errors.²⁸

Although there were some statistically significant differences between race groups and between gender groups for the vertical soft tissue distance from a horizontal line bisecting the chelion to the mental foramen (VChR and VChL), the overall differences were minimal at around 3 mm. The overall mean distances were 20.1 mm (SD 2.60 mm) bilaterally. In their study using

Figure 1 Frontal view of the lower face showing the various soft tissue measurements performed. Chelion, corner of the mouth where the upper and lower lips meet; HChL, horizontal soft tissue distance from a vertical line passing through the chelion to the mental foramen on the left; HChR, horizontal soft tissue distance from a vertical line passing through the chelion to the mental foramen on the right; VChL, vertical soft tissue distance from a horizontal line bisecting the chelions to the mental foramen on the left; VChR, vertical soft tissue distance from a horizontal line bisecting the chelions to the mental foramen on the right; VML, vertical soft tissue distance from the inferior border of the mandible to the mental foramen on the left; VMR, vertical soft tissue distance from the inferior border of the mandible to the mental foramen on the right.

Figure 2 Frontal view of the lower face showing the various mean soft tissue measurements for the entire group of participants. Chelion, corner of the mouth where the upper and lower lips meet.

Table 1 The impact of race, gender and age group on the position of the mental foramen with regard to soft tissue relations

Measured distance to mental foramen			Race			Gender		Age group (years)				
			All patients	Black	Asian	White	Female	Male	18–30	31–40	41–50	51–60
HChR	Mean (mm)	3.4	3.6	3.0	3.5	3.4	3.4	3.3	3.8	2.8	3.5	3.0
	SD (mm)	1.7	1.5	1.4	1.4	1.8	1.6	1.3	1.6	1.2	1.4	2.8
HChL	Mean (mm)	3.4	ANOVA ($p = 0.2868$)			t -test ($p = 0.8348$)		ANOVA ($p = 0.1710$)				
	SD (mm)	1.5	1.5	1.5	1.3	1.4	1.5	1.3	1.6	1.4	1.3	2.8
VChR	Mean (mm)	20.1	ANOVA ($p = 0.2766$)			t -test ($p = 1.0000$)		ANOVA ($p = 0.2308$)				
	SD (mm)	2.6	21.3	19.0	18.7	18.6	21.6	19.9	21.0	20.1	19.0	18.5
VChL	Mean (mm)	20.1	ANOVA: Bonferroni			t -test ($p = 0.0000$)		ANOVA ($p = 0.1626$)				
	SD (mm)	2.6	Blacks and Asians ($p = 0.000$)									
VMR	Mean (mm)	15.1	Blacks and Whites ($p = 0.000$)									
	SD (mm)	2.4	Asians and Whites ($p = 1.000$)									
VML	Mean (mm)	15.0	21.2	19.2	18.6	18.5	21.6	19.9	20.8	20.0	19.1	18.5
	SD (mm)	2.6	2.5	2.3	1.9	1.8	2.3	2.6	2.5	3.1	2.1	0.7
VMR	Mean (mm)	15.1	ANOVA: Bonferroni			t -test ($p = 0.0000$)		ANOVA ($p = 0.2880$)				
	SD (mm)	2.4	Blacks and Asians ($p = 0.001$)									
VChL	Mean (mm)	15.1	Blacks and Whites ($p = 0.002$)									
	SD (mm)	2.4	Asians and Whites ($p = 1.000$)									
VChL	Mean (mm)	15.1	ANOVA: Bonferroni			t -test ($p = 0.0000$)		ANOVA ($p = 0.2869$)				
	SD (mm)	2.4	Blacks and Asians ($p = 0.002$)									
VChL	Mean (mm)	15.1	Blacks and Whites ($p = 0.039$)									
	SD (mm)	2.4	Asians and Whites ($p = 1.000$)									
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	SD (mm)	2.4	Asians and Whites ($p = 1.000$)									
VChL	Mean (mm)	15.1	ANOVA: Bonferroni			t -test ($p = 0.0000$)		ANOVA ($p = 0.2869$)				
	SD (mm)	2.4	Blacks and Asians ($p = 0.002$)									
VChL	Mean (mm)	15.1	Blacks and Whites ($p = 0.039$)									
	SD (mm)	2.4	Asians and Whites ($p = 1.000$)									
VChL	Mean (mm)	15.1	ANOVA: Bonferroni			t -test ($p = 0.0000$)		ANOVA ($p = 0.2869$)				
	SD (mm)	2.4	Blacks and Asians ($p = 0.002$)									
VChL	Mean (mm)	15.1	Blacks and Whites ($p = 0.039$)									
	SD (mm)	2.4	Asians and Whites ($p = 1.000$)									
VChL	Mean (mm)	15.1	ANOVA: Bonferroni			t -test ($p = 0.0000$)		ANOVA ($p = 0.2869$)				
	SD (mm)	2.4	Blacks and Asians ($p = 0.002$)					</				

HChL, horizontal soft tissue distance from a vertical line passing through the chelion to the mental foramen on the left; HChR, horizontal soft tissue distance from a vertical line passing through the chelion to the mental foramen on the right; SD, standard deviation; VChL, vertical soft tissue distance from a horizontal line bisecting the chelions to the mental foramen on the left; VChR, vertical soft tissue distance from a horizontal line bisecting the chelions to the mental foramen on the right; VML, vertical soft tissue distance from the inferior border of the mandible to the mental foramen on the left; VMR, vertical soft tissue distance from the inferior border of the mandible to the mental foramen on the right.

digitalized photographs, Guo et al²² recorded mean distances of 23.38 mm (SD 2.00 mm) on the frontal view and 23.59 mm (SD 2.11 mm) on the lateral view. Song et al²³ reported a mean distance of 20.40 mm (SD 3.9 mm) on the frontal view in their study. Unlike our study, these two studies did not compare race, gender or age.

There is no previous report in the literature with regard to the vertical soft tissue distance from the inferior border of the mandible to the mental foramen (VMR and VML). Our study recorded statistically significant

differences between groups for this measurement, although differences were minimal at around 3 mm.

Results of our study indicate that the overall mean distances to soft tissue landmarks may be useful as a guide when blindly trying to locate the mental foramen (e.g. for purposes of administering local anaesthesia). Whilst, it is understood that oral care clinicians regularly perform mental nerve blocks with good success rates using the blind technique, these landmarks may still be useful to other clinicians such as plastic surgeons or emergency physicians who less frequently perform mental nerve blocks. Previous studies have predominantly studied the position of the mental foramen with regard to its relationship to the premolar teeth. The mental foramen is most commonly reported to be either in line with the long axis of the second premolar tooth or between the first and second premolar teeth. The most common position of the mental foramen in Caucasian and Middle Eastern populations is reported as between the first and second premolars, whereas the mental foramen is generally reported to be more posterior in Black and Mongoloid populations.^{13,20,25,31} In our study, we recorded minor differences in measured distances between race groups (<2.7 mm). Although

Figure 3 Ultrasound image of the mental foramen (white arrow). The mental foramen is easily identified as a break in the continuity of the bone in the vicinity just below the corner of the mouth.

many of the measurements obtained in our study reached statistical significance, they were, however, minimal and regarded as insignificant from a practical and clinical point of view. This implies that the position of the mental foramen varies minimally with regard to soft tissue landmarks, and it is rather the position of the premolar teeth that varies across ethnic groups. Hence from our study, it can be concluded that using soft tissue landmarks to determine the position of the mental foramen may be more reliable across race, gender and age as opposed to using hard tissue landmarks. However, these findings need to be replicated in larger scale studies involving other population groups.

Whilst it is acknowledged that the soft tissue in the vicinity of the mental foramen may be stretched, retracted or even raised as a flap during procedures, soft tissue landmarks may yet be utilized as a guide to more accurately localizing the position of the mental foramen. Once the position of the mental foramen is determined using soft tissue landmarks with the patient maintaining a neutral facial expression, a fixed hard tissue landmark (e.g. relationship to premolar tooth) may be marked off prior to soft tissue manipulation. Although still investigational, current developments in the field of intraoral ultrasonography may eventually reveal the ultimate solution to real-time ultrasound imaging for these type of procedures.³² Salmon and Le Denmat³³ have recently developed a novel high-frequency ultrasound probe specifically designed for intraoral application that has shown promise in evaluating various anatomical structures.

Operator dependency is a general limitation to the use and interpretation of ultrasound imaging.³³ With this in mind, we ensured that all ultrasound examinations were conducted by a certified point-of-care ultrasound practitioner. The study was further fully supervised by a faculty member aligned with the division of point-of-care emergency ultrasound. Studies have shown that a directed 1-day ultrasound-based training course is sufficient to equip the non-radiologist clinician with the necessary skill in evaluating limited anatomy of interest.^{35–36} A limitation to our study is that

individuals with facial distortion, previous mandibular surgery/trauma or missing teeth between the lower first molars were excluded. Perhaps, the mental foramen may have been subject to distortion or shift and hence difficult to visualize in these patients. In fact, advanced age, tooth wear and missing teeth have been associated with positional change in the mental foramen.^{13,21,37–38} Our study showed no age differences; however, most subjects in our study were below the age of 40 years. Age-related skin changes with regard to the position of the mental foramen and its soft tissue relations have not been previously reported. Future studies specifically concentrating on the geriatric population and subjects who were excluded in this study will settle these uncertainties.

Bedside and hand-held point-of-care ultrasound devices³⁹ and recent advances in three-dimensional^{40–41} and intraoral ultrasonography³³ have great potential to complement and revolutionize the practice of oral medicine. Despite the above-mentioned limitations, it is hoped that this study paves the way and stimulates more interest and research in the growing use of ultrasonography and its application in the field of oral health. Although this study predominantly concentrated on the mental foramen, we hope that others will embark on similar and larger scale studies, involving various anatomical landmarks relevant to the field of oral medicine.

Conclusions

Results of our study imply that ultrasound is a feasible imaging modality when attempting to locate the mental foramen. Differences in the position of the mental foramen with regard to various soft tissue landmarks are minor and clinically insignificant.

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