Analysis of the Size and Position of the Mental Foramen Using the CS 9000 Cone-beam Computed Tomographic Unit

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Abstract

Introduction: The mental foramen (MF) houses vital neurovascular structures, thus making it an anatomic landmark of great importance for many dental procedures. Because the size and position of the MF can vary, proper planning is necessary beforehand to prepare the strategy of treatment. The purpose of this retrospective observational study was to determine and compare the size and position of the MF using the CS 9000 CBCT unit (Carestream Dental, Rochester, NY) to the findings from similar studies. **Methods:** Tangential, axial, and coronal CBCT images of 106 patients were retrospectively evaluated to determine the size and position of the MF with respect to the mandibular second premolar apex and the cementoenamel junction. Distinguishing characteristics of sex, age, and race were evaluated. **Results:** Regarding location, 53.7% of the MFs were located mesial, 45.3% distal, and 1% coincident to the apex of the mandibular second premolar. Males had a significantly greater coronal height and tangential height measurement than females. Black patients had a significantly greater distal horizontal distance from the cementoenamel junction than white patients. The mean width of the MF was 4.08 mm (axial) or 4.12 mm (tangential), whereas the mean height was 3.54 mm (tangential) or 3.55 mm (coronal). **Conclusions:** The present study shows that the size and position of the MF can be reliably measured using limited field of view CBCT technology. The findings are similar to previous studies when considering the averages and ranges of the measurements. *(J Endod 2015;41:1032–1036)*

Key Words

Cone-beam computed tomographic imaging, CS 9000, limited field of view, mandibular anatomy, mental foramen

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The mental foramen (MF) houses vital neurovascular structures, thus making it an anatomic landmark of great importance for many dental procedures. The MF serves as the portal for vascularization and innervation to the skin and mucosa of the lower lip, cheeks, chin, and teeth (1). Accurate identification of the foramen is critical to avoid damage to the neurovascular bundle while obtaining appropriate access to accomplish the procedure with excellence. Dental surgical procedures in the posterior mandible, such as endodontic microsurgery, implant surgery, genioplasty, and bone harvesting, require keen awareness of all anatomic structures including the MF. Because the size and position of the MF can vary, proper planning is necessary beforehand to prepare the strategy of treatment (2).

The MF has historically been studied using various techniques. Phillips et al (3–5) conducted a series of 3 studies in which MFs were measured on dry skulls directly, with periapical radiographs, and with panoramic radiographs. Moiseiwitsch (6) used regional dissections of cadavers to measure the position of the MF in North Americans. Fishel et al (2) conducted a retrospective study using periapical radiographs from patients and found that the position of the MF varies; 53% of the time it could not be found. Other studies have been conducted using similar materials and methods but incorporating various ethnicities to determine if any variation exists (7–9). Also, studies have shown that accessory MFs can exist (10). These are small foramina that surround the primary MF but can contain neurovascular structures.

These studies establish baseline knowledge for the practitioner to estimate where the MF may reside. However, with the advent of cone-beam computed tomographic (CBCT) imaging, many practitioners are using this technology for their pretreatment surgical planning. Thus, it is important to know how the identification of the MF using CBCT imaging compares with historic studies that primarily used 2-dimensional radiography. CBCT imaging offers a high-resolution, 3-dimensional rendering of a patient's anatomy. It has been shown to be an appropriate and accurate modality for measuring anatomic structures (11). A recent literature review by Aminoshariae et al (12) concluded that CBCT imaging is the best current imaging technology for detection of the MF. Of note, the majority of the reviewed studies used large field of view volumes for their analysis. Von Arx et al (13) recently studied the MF using a small field of view with the 3D Accuitomo unit (Morita, Kyoto, Japan) and found the measurements to be consistent with previous radiographic studies regarding the size and position of the MF and the distances between the MF and adjacent anatomic structures. Within the endodontic dental specialty specifically, the CS 9000 CBCT unit (Carestream Dental, Rochester, NY) is frequently used because of its high resolution and limited field of view (LFOV), which decreases radiation exposure to the patient. This allows a clear focus on the area of interest while decreasing the radiation risk to the patient (14). Aminoshariae et al's review referenced no studies that used the CS 9000 CBCT unit. The purpose of this retrospective observational study was to determine and compare the size and position of the MF using the CS 9000 CBCT unit with findings from similar studies.

Materials and Methods

This study was designed as a retrospective analysis of CBCT images taken with the LFOV CS 9000 CBCT unit at Texas A&M University Baylor College of Dentistry and a private endodontic practice in Dallas, TX. Because of the retrospective design of this study, it was approved for institutional review board exemption. CBCT-scanned volumes that incorporated the mandibular premolar region and fit the inclusion criteria were obtained. The sample size was empirically determined from previous similar studies. All scans were taken using the CS 9000 CBCT unit using a voxel size of 0.076 mm. The scans were viewed on a Dell Optiplex 9010 all-in-one desktop with a 23-inch monitor (Dell, Plano, TX) in the native viewing software under typical clinical lighting conditions. The scans were measured in their maximized slice window but were not otherwise zoomed in during evaluation. The scans were measured using the orthogonal and curved slicing views. The vertical height and horizontal width of the MF were measured as well as its position in relationship to the apex and cementoenamel junction (CEJ) of the mandibular second premolar. Inclusion criteria for the study were as follows:

1. Mandibular first premolar, second premolar, and first molar teeth must be present.
2. Teeth are in a reasonably normal position and alignment.
3. Patient must be 18 years or older.

Patients were excluded if a significant *malocclusion* existed, which was defined as rotation greater than 45° from the arch form or overlap of teeth greater than 2 mm as measured on CBCT imaging.

One hundred six CBCT scans that met the study criteria were obtained. This resulted in a total of 212 measurements in each category. Measurements were obtained and recorded by a single viewer. To analyze intraobserver agreement, 2 measurements were repeated at 2 different time points for each scanned volume. The following measurements were performed using the scanned volumes:

1. In the axial view, the maximum width (AxialW) of the MF was measured (Fig. 1*A*).
2. In the axial view, a curved line was drawn along the external border of the mandible at the level where the greatest extent of the MF was visible. This curve served as a reproducible landmark to reference for measurements across all scanned volumes. It also determined the corrected tangential plane and corrected coronal plane (90° to the corrected tangential plane).
3. In the tangential view, the maximum height (TangentialH) and width (TangentialW) of the MF was measured (Fig. 1*B*).
4. In the coronal view, the maximum height (CoronalH) of the MF was measured (Fig. 1*C*).
5. In the tangential view, a center point of the MF was marked with the axial and coronal marking lines in the viewing software (Fig. 2*A*). The coordinates (a, b) at this location were recorded. The coronal view was then moved in space until the apex of the mandibular second premolar was visible. The axial and coronal marking lines were then moved until they centered over the apex of the mandibular second premolar (Fig. 2*B*). The coordinates (c, d) at this location were recorded. The difference of the 2 measurements gave the vertical and horizontal position difference in millimeters to the hundredth of a millimeter (VertApex: c − a, HorzApex: d − b).
6. The same procedure was used to obtain measurements from the foramen center to the buccal CEJ (VertCEJ, HorzCEJ) (Fig. 2*C* and *D*).
7. The same procedure was used for any accessory foramina located in the scanned volumes. Additional vertical and horizontal measurements were also recorded from the centers of the accessory foramina themselves.

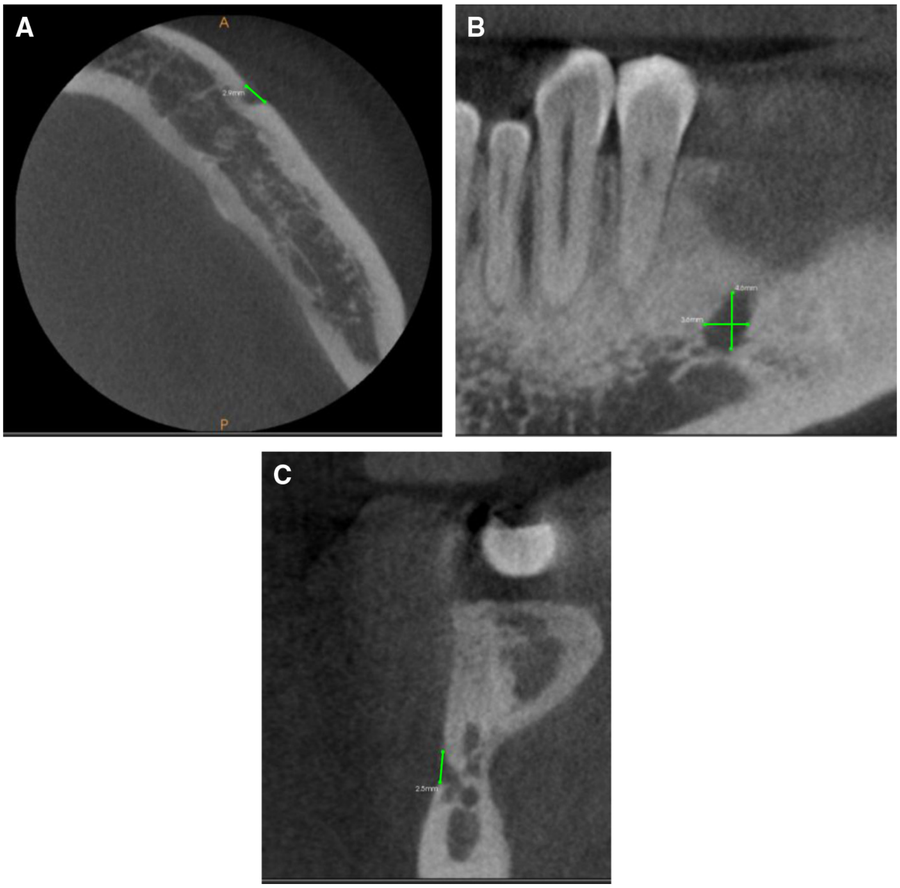

Figure 1. (*A*) Width of the MF in the axial view. (*B*) Height and width of the MF in the tangential view. (*C*) Height of the MF in the coronal view.

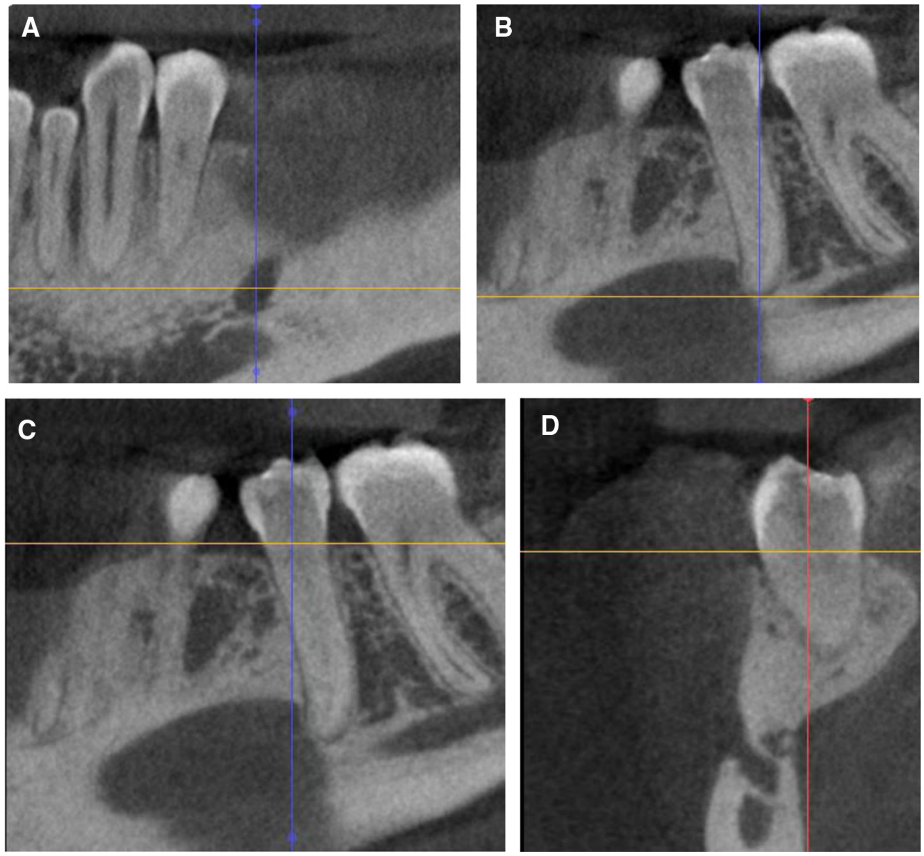

Figure 2. (*A*) The center point of the MF marked with the axial and coronal marking lines in the tangential view. (*B*) The center point of the mandibular second premolar apex marked with the axial and coronal marking lines in the tangential view. (*C*) The buccal CEJ marked with the axial and coronal marking lines in the tangential view. (*D*) The buccal CEJ marked with the axial marking line in the coronal view.

To determine intraexaminer reliability for the measurements, intraclass correlation was applied to the 2 measurements in each category. The 2 measurements were then averaged for each patient and category. Descriptive statistics were then obtained for all data. To detect significant differences in the measurements based on sex, age, and race, the Kruskal-Wallis and Mann-Whitney *U* tests were applied. For the analysis of age, the data were divided into 3 categories (ie, 18–29 years, 30–49 years, and ≥50 years). This was a retrospective study in which race was not indicated by the patient. Because the literature indicates that the position of the MF does vary by race, an attempt was made to define race by subjective visualization of the patient's photographs, which were included in each record. If a photograph was not available or there was lack of subjective clarity, the race was deemed unknown (6–9). Kruskal-Wallis analyses of variance were used for detecting overall differences among age and racial groups ($P < .05$). These were followed up by pair-wise Mann-Whitney *U* tests. Bonferroni-corrected significance levels were used for these post hoc tests to defend against type 1 errors; for detecting differences between pairs of age groups and differences between pairs of racial groups, significance levels of 0.0167 and 0.0083, respectively, were used. Sex differences were evaluated with the Mann-Whitney *U* test ($P < .05$).

Results

Regarding distinguishing characteristics, the sample population consisted of heterogeneity within sex, age, and race (Table 1). The intraclass correlation measure (>0.90) indicated that intraexaminer reliability was excellent. With regard to the location of the MF, 53.7% (57/106) were located mesial, 45.3% (48/106) distal, and 1% (1/106) coincident to the mandibular second premolar apex. For sex, males had a statistical difference compared with females with a greater average for coronal height and tangential height measurements (Table 2). No statistical differences were found for any measurement regarding age. For race, there was a statistical difference in that black patients had a significantly greater distal horizontal distance from the foramen center to the CEJ compared with white patients (Table 3). Because distance measurements were measured from the foramen to the apex/CEJ, all vertical distance measurements with a positive value indicate the foramen was inferior to the mandibular second premolar apex, whereas negative values indicate the foramen was superior. For all horizontal measurements, positive values indicate the foramen was

TABLE 1. Demographics (no. of patients)

	No. of patients	%
Sex		
Female	76	71.7
Male	30	28.3
Age		
18–29	4	3.8
30–49	33	31.1
≥50	64	60.4
Race		
Asian	9	8.5
Black	13	12.3
Unavailable	10	9.4
White	74	69.8

TABLE 2. Mental Foramen Measurements (mean ± standard deviation in millimeters)

	AxialW	TangentialH	TangentialW	CoronalH
Sex				
Male	4.35 ± 1.25	3.94 ± 0.80*	4.36 ± 1.24	3.94 ± 0.83*
Female	3.97 ± 0.92	3.38 ± 0.75*	4.02 ± 0.94	3.39 ± 0.77*
Age (y)				
18–29	3.7 ± 0.16	3.45 ± 0.78	3.60 ± 0.27	3.45 ± 0.76
30–49	4.13 ± 0.99	3.49 ± 0.83	4.16 ± 0.97	3.54 ± 0.89
≥50	4.08 ± 1.09	3.57 ± 0.79	4.12 ± 1.10	3.56 ± 0.80
Race				
Asian	3.92 ± 0.69	3.42 ± 0.77	3.93 ± 0.71	3.34 ± 0.74
Black	4.32 ± 1.36	3.42 ± 0.91	4.45 ± 1.40	3.51 ± 0.91
Unavailable	3.81 ± 0.81	3.48 ± 0.76	3.76 ± 0.76	3.46 ± 0.85
White	4.09 ± 1.04	3.59 ± 0.80	4.13 ± 1.03	3.59 ± 0.82
Overall	4.08 ± 1.03	3.54 ± 0.80	4.12 ± 1.04	3.55 ± 0.82

AxialW, maximum width in the axial view; CoronalH, maximum height in the coronal view; TangentialH, maximum height in the tangential view; TangentialW, maximum width in the tangential view.
*P = .002 for TangentialH and CoronalH between males and females.

mesial to the mandibular second premolar, whereas negative values indicate the foramen was distal. Also, 6 patients had single identified accessory foramina, and 1 patient had 2 identified accessory foramina. Because of the small number identified, statistical analysis could not be performed. Their respective descriptive measurements and distances are summarized in Table 4.

Discussion

This study evaluated the size and position of the MF with respect to the mandibular second premolar using CBCT radiographic technology. Because the MF is an important anatomic landmark for various dental surgical procedures, it is valuable to have information on its size and position. Although many studies have been conducted using cadavers, periapicals, and panoramic radiographs, CBCT technology has been shown to be the most advantageous modality for this purpose (12). It is important to be attentive when comparing results of studies that use differing modalities because of the differing methodologies and interpretations (13). Considering this, the present study would most appropriately be compared with the von Arx et al study (13), which had the most similar methodology. In that study, the MF had a mean height of 3.0 mm and a mean width of 3.2 mm. It was also reported that no significant difference was found among sex and age for the location of the MF. There was also no significant difference among age groups for the dimensions of the MF. However, in line with the present study, there was a statistically significant difference for sex regarding the height of the MF in which male patients exhibited greater values than females (13). Kalender et al (15) conducted a CBCT study reporting an MF mean height of 3.7 mm and a mean width of 3.4 mm. Phillips et al (3–5) reported MF measurements with a mean height of 3.4 mm and a mean width of 4.6 mm in the cadaver study, a mean height of 2.3 mm and a mean width of 2.6 mm in the periapical radiograph study, and a mean height of 2.5 mm and a mean width of 2.9 mm in the panoramic radiograph study. In the cadaver study, Phillips et al (3) also reported the average position of the MF with respect to the long axis of the mandibular second premolar crown and found it to be located mesial 18% of the time, intersecting 62.7% of the time, and distal 19.3% of the time. In the radiographic studies, Phillips et al (4, 5) reported the average position of the MF with respect to the mandibular second premolar apex and found it to range from 3.8 mm mesial to 2.7 mm distal and 2.0 mm superior to 3.5 mm inferior in the periapical radiographic study and a range from 2.5 mm mesial to 2.9 mm distal and 2.4 mm superior and 3.9 mm inferior in the panoramic radiographic study. The advantage of a cadaver study is that the findings are anatomically accurate versus a radiographic study, which is an image-processed approximation. However, the disadvantage of the Phillips cadaver study is that the apices of the premolars were housed in bone and thus not visible. This prevented measurements to the apices from being obtained, whereas radiographic methods, such as CBCT imaging, are able to visualize the apices and measure the relative distance to the foramina. The differences in the findings between this current study and other studies can be potentially attributed to the differences in methodology and patient population.

TABLE 3. Mental Foramen Distances (mean ± standard deviation in millimeters)

	VertApex	HorzApex	VertCEJ	HorzCEJ
Sex				
Female	3.30 ± 3.48	0.33 ± 2.99	17.58 ± 3.35	−0.57 ± 3.70
Male	2.61 ± 2.58	−0.12 ± 2.84	16.30 ± 2.43	−1.42 ± 3.59
Age (y)				
18–29	2.17 ± 3.89	−1.26 ± 5.13	16.62 ± 2.99	−3.64 ± 1.96
30–49	3.73 ± 2.57	−0.34 ± 2.69	17.11 ± 2.18	−1.26 ± 4.05
≥50	2.40 ± 2.88	0.24 ± 2.83	16.45 ± 3.01	−1.00 ± 3.46
Race				
Asian	4.13 ± 2.08	−0.82 ± 2.55	17.46 ± 2.61	−2.96 ± 3.93
Black	3.35 ± 1.54	−1.14 ± 1.65	17.85 ± 1.35	−3.66 ± 3.10*
Unavailable	3.17 ± 2.54	1.50 ± 3.60	17.69 ± 3.03	−0.47 ± 4.57
White	2.50 ± 3.12	0.11 ± 2.92	16.22 ± 2.86	−0.62 ± 3.34*
Overall	2.80 ± 2.86	0.01 ± 2.88	−16.66 ± 2.77	−1.18 ± 3.62

HorzApex, horizontal distance from the center of the mental foramen to the apex of mandibular second premolar; HorzCEJ, horizontal distance from the center of the mental foramen to the cementoenamel junction of mandibular second premolar; VertApex, vertical distance from the center of the mental foramen to the apex of mandibular second premolar; VertCEJ, Vertical distance from the center of the mental foramen to the cementoenamel junction of mandibular second premolar.
*P = .006 for HorzCEJ between black and white patients.

TABLE 4. Accessory Foramina Measurements and Distances (mean ± standard deviation [SD] in millimeters)

Accessory foramina measurements (mean ± SD in millimeters)			
AxialW	TangentialH	TangentialW	CoronalH
1.79 ± 0.54	1.49 ± 0.42	1.83 ± 0.43	1.45 ± 0.48
Accessory foramina distances (mean ± SD in millimeters)			
VertApex	HorzApex	VertCEJ	HorzCEJ
1.70 ± 2.67	−4.36 ± 3.01	16.39 ± 2.89	−5.69 ± 1.85

AxialW, maximum width in the axial view; CoronalH, maximum height in the coronal view; HorzApex, horizontal distance from the accessory foramina to the apex of mandibular second premolar; HorzCEJ, horizontal distance from the accessory foramina to the cementoenamel junction of mandibular second premolar; TangentialH, maximum height in the tangential view; TangentialW, maximum width in the tangential view; VertApex, vertical distance from the accessory foramina to the apex of mandibular second premolar; VertCEJ, vertical distance from the accessory foramina to the cementoenamel junction of mandibular second premolar.

The use of CBCT imaging is becoming more frequent, and it is important to know its advantages and limitations. Based on the results and their comparative similarities to prior studies, one may have a reasonable expectation of the size and location of the MF based on the average measurements reported. Also, a CBCT volume of an area may prove useful in aiding in the identification of a patient's individualized foramen size and location because the measurements were shown to be repeatable. For surgical planning, the location of the foramen in relationship to the mandibular second premolar is perhaps the more important finding because its proximity will typically have more of an effect than its size. Assessing the existing literature and the present study, CBCT volumes seem to be a reliable way to determine the size and location of the MF. This could greatly aid a clinician in preparation before an operation to ensure no iatrogenic errors occur to the nearby neurovascular structures.

Some concerns about the present study include the uneven distribution of the sample population with respect to sex, age, and race, which may impact the results. From a measurement standpoint, because the 2 independent measurements were so similar a third measurement was not included. However, to increase accuracy of the intraobserver agreement, a third independent measurement may be beneficial in future studies. The subjective nature of race assignment is also problematic. It would be ideal to have the patient self-designated race assignment, which would require a prospective study or records that included this information. Finally, the study is purely radiographic so there is no confirmation that the measurements were indeed accurate with relationship to their anatomic reality. Therefore, the results need to be validated with subsequent studies, larger sample sizes, and more evenly distributed samples.

Conclusion

The present study shows that the size and position of the MF can be reliably measured using LFOV CBCT technology. Within the limitations of this study, the CBCT analysis of the MF showed that the MF's size on average is approximately 3.5 mm in height and 4.1 mm in width and on average is located approximately 2.8 mm inferior and 0.01 mm mesial to the apex of the mandibular second premolar. It also showed MFs in males had greater heights than females. Finally, black patients had MFs located significantly more distal in relationship to the CEJ of the mandibular second premolar than white patients. The findings are similar to previous studies when considering the averages and ranges of the measurements.

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The authors deny any conflicts of interest related to this study.

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