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ORIGINAL COMMUNICATION

Evaluation of the Mental Foramen and Accessory Mental Foramen in Turkish Patients Using Cone-Beam Computed Tomography Images Reconstructed From a Volumetric Rendering Program

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This study determined the occurrence and location of the mental foramen (MF) and accessory mental foramen (AMF) in Turkish patients using cone-beam computed-tomography (CBCT) with 3D-imaging software. CBCT scans of 386 sites in 193 (92 male, 101 female) patients were retrospectively analyzed to determine MF and AMF occurrence, sizes, and locations. Digital imaging and communications in medicine (DICOM) data were transferred to surface-rendering software to generate 3D images. Distances between the MF and AMF and from both foramina to the alveolar ridge and to the closest tooth were measured. Differences in AMF incidence by sex, side, and location were evaluated using chi-squared tests, and MF and AMF measurements were evaluated using Mann–Whitney *U*-tests. AMFs were observed in 6.5% of patients and were most commonly in an anteroinferior location. Mean AMF size did not differ significantly by sex or side [males: horizontal = 1.5 mm (1.0–2.4 mm), vertical = 1.4 mm (0.8–2.4 mm); females: horizontal = 1.5 mm (0.8–3 mm), vertical = 1.3 mm (0.8–2.1 mm); $P > 0.05$]. Males showed significantly greater mean vertical and horizontal MF dimensions compared with females [males: horizontal = 3.9 mm (1.0–7.0 mm), vertical = 3.6 mm (1.2–7.0 mm); females: horizontal = 3.5 mm (1.3–5.6 mm), vertical = 3.3 mm (0.8–5.8 mm); $P < 0.05$]. Awareness of the AMF is important to avoid mental nerve damage during surgical intervention and anesthetic applications. CBCT is useful for AMF detection, distributes less ionizing radiation, and allows 3D imaging. Clin. Anat. 25:584–592, 2012. © 2011 Wiley Periodicals, Inc.

Key words: accessory mental foramen; prevalence; cone-beam computed tomography; surface reconstruction

INTRODUCTION

The mental foramen (MF) allows one of the terminal branches of the inferior alveolar nerve to exit the body of the mandible on each side. This nerve supplies sensation to the lower lip, the buccal vestibule, and the gingiva mesial of the first mandibular molar

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(Moiseiwitsch, 1998). The locations of the MF and mandibular canal must be identified preoperatively to prevent confusion with bony pathosis defects. To avoid damage, the neurovascular bundle must be identified precisely before any surgical procedure. The location of the root apices in relation to the MF must also be determined before root-canal treatment of the premolars and molars. However, the presence of small foramina [e.g., bifid, double, accessory mental foramen (AMF), nutrient foramina] in the area surrounding the MF is often ignored or receives little attention in many anatomy textbooks (Kaufman et al., 2000).

Although AMF have been reported in the region surrounding the MF, they have not been clearly defined (Katakami et al., 2008; Naitoh et al., 2009a; Fuakami et al., 2011). The AMF, which is smaller than the MF, has been considered to be associated with the mental nerve and is presumed to be the result of branching of the mental nerve before its exit from the MF (Kaufman et al., 2000).

These anatomical variations can be detected in clinical practice using radiography. Conventional radiographs have several drawbacks, including errors of projection and errors of identification. Conventional radiographic techniques collapse a three-dimensional (3D) structure onto a two-dimensional plane. The resulting superimposition of anatomical structures complicates image interpretation and landmark identification, and this distortion and magnification may lead to errors of identification (Kumar et al., 2007; Nalcaci et al., 2010). Moreover, the MF becomes more difficult to identify on conventional radiographs as bone density increases (Ngeow and Yuzawati, 2003). Rouas et al. (2007) also noted that dental panoramic radiography has limitations with regard to the diagnosis of variations among mandibular canals.

The use of cone-beam computed tomography (CBCT) was first reported by Mozzo et al. (1998) and has been proposed in the last decade for maxillofacial imaging (Connor et al., 2007; Periago et al., 2008; Brown et al., 2009). A CBCT scan uses a different type of acquisition than that used in medical CT (MDCT). Rather than capturing an image as separate slices as in MDCT, CBCT produces a cone-shaped X-ray beam that allows an image to be captured in a single shot. The resultant volume can be reformatted to provide multiple reconstructed images (e.g., sagittal, coronal, axial) that are similar to traditional MDCT images (Mozzo et al., 1998; Lascala et al., 2004; Scarfe et al., 2006; Connor et al., 2007). CBCT thus offers the distinct advantage of a lower radiation dose than MDCT and the possibility of importing and exporting individualized, overlap-free reconstructions and Digital imaging in communications and medicine (DICOM) data to and from other applications (Ludlow and Ivanovic, 2008; Periago et al., 2008; Loubele et al., 2009; Ludlow et al., 2009; Liang et al., 2010).

The locations of the MF and AMF have been studied in several populations (Yosue and Brooks, 1989a,b; Shankland, 1994; Al Jasser and Nwoku, 1998; Moiseiwitsch, 1998; Ngeow and Yuzawati, 2003). Most of these studies were based on dental panoramic radiography. Although several studies (Oguz and Bozkir, 2002; Aktekin et al., 2003; Gungor et al., 2006; Yesilyurt et al., 2008) have intensively examined the MF in Turkish populations using dry skulls and conventional radiographs, no CBCT data can be found that describe the occurrence of the AMF or the relationships between these foramina and surrounding structures. Hence, the purpose of this study was to determine the occurrence and location of the MF and AMF using CBCT with 3D-rendering imaging software in a group of Turkish patients.

MATERIALS AND METHODS

Data from CBCT examinations of 386 sites in 193 (92 male, 101 female) patients who had been referred to our outpatient clinic during a 2-year period were analyzed retrospectively. The overall mean age was 38.6 years [range: 20–83 years, standard deviation (SD): 15.8 years]. Informed consent was obtained from all patients before CBCT examinations. The study group was divided into three subgroups: dentate (92 patients, 184 sides), partially edentulous (85 patients, 170 sides), and edentulous (16 patients, 32 sides). All partially edentulous patients were categorized as Kennedy Class I–III; this study included no Kennedy Class IV patient. Subjects with evidence of bone disease (especially osteoporosis), relevant drug consumption, or skeletal asymmetries or trauma were excluded from the study.

CBCT scans (NewTom 3G; Quantitative Radiology s.r.l., Verona, Italy) used a 9-inch field of view (FOV) to include the mandibular anatomy. Radiographic parameters (kV, mA) were determined automatically from scout views by the NewTom 3G. Depending on the size of the patient and the extent of beam attenuation, exposure varied up to 40%.

Axial slice thickness was 0.3 mm, and voxels were isotropic. The axial images were exported in a 512 × 512-matrix DICOM file format and then imported into Maxilim® software (ver. 2.3.0; Medicim, Mechelen, Belgium). All constructions and measurements were performed on a 21.3-inch flat-panel color-active matrix thin-film transistor medical display (Nio Color 3MP, Barco, Belgium) with a resolution of 2048 × 1536 pixels at 76 Hz and 0.2115-mm dot pitch operated at 10 bits. An oral and maxillofacial radiologist (K.O.) made high-quality 3D hard-tissue surface representations computed from several stages of the patients' CBCT datasets, a technique similar to that described in previous studies (Swennen et al., 2006; Periago et al., 2008; Ludlow et al., 2009), and examined all images. The bone and soft-tissue surface images were first segmented by applying a threshold to the acquired image volume of radiographic densities. An attempt was made to reduce noise without impacting the visibility of osseous anatomy. To begin the analysis, the segmented hard-surface representations of the skull were rendered in a virtual scene. After semiautomated virtual standardized positioning of the skull, high-quality 3D hard-tissue surface representations were computed from the patients' CBCT datasets. Axial, sagittal, and coronal CT radiographic slices were also superimposed over reconstructed 3D images (Fig. 1).

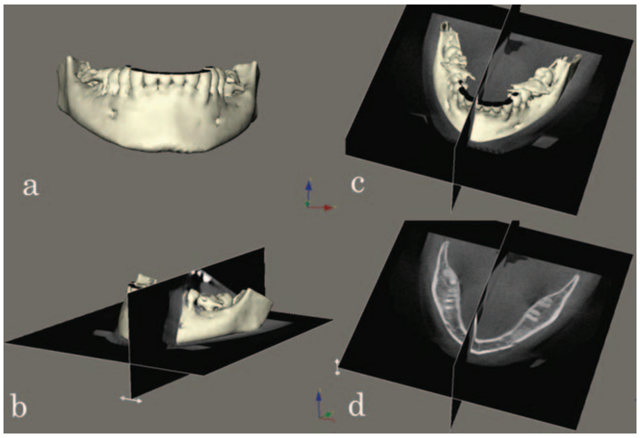

Fig. 1. **a:** 3D image generated by volumetric rendering software. **b, c:** Superimposition of axial and sagittal slices over the reconstructed 3D image. **d:** 3D image with only CBCT slices. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

The MF and AMF, which show continuity with the mandibular canal, were subsequently identified on each side of the mandibular body. As in previous studies (Katakami et al., 2008; Naitoh et al., 2009a), the AMF was defined strictly as a buccal foramen smaller than the MF and followed by the accessory branch of the mandibular canal before its exit from the MF regardless of its location. In this study, buccal foramina showing no continuity with the mandibular canal were also identified, but were excluded from the study due to their potential identities as nutrient foramina.

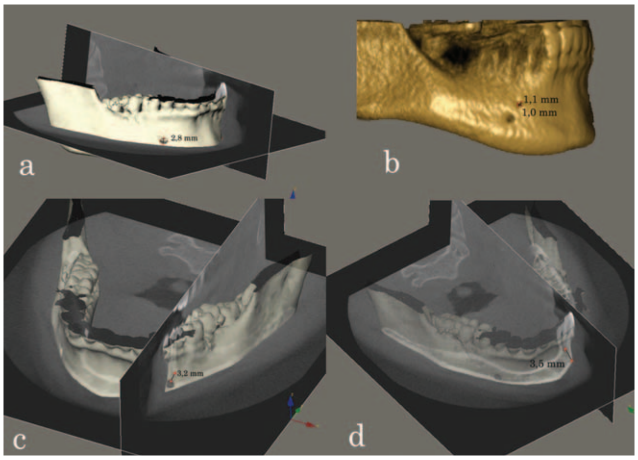

Fig. 2. Dimensions of the mental foramen (**a**), and the accessory mental foramen (**b**); distances between the closest tooth, the mental foramen (**c**), the accessory mental foramen (**d**) on 3D renderings with superimposed radiographic images created using volumetric rendering software. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

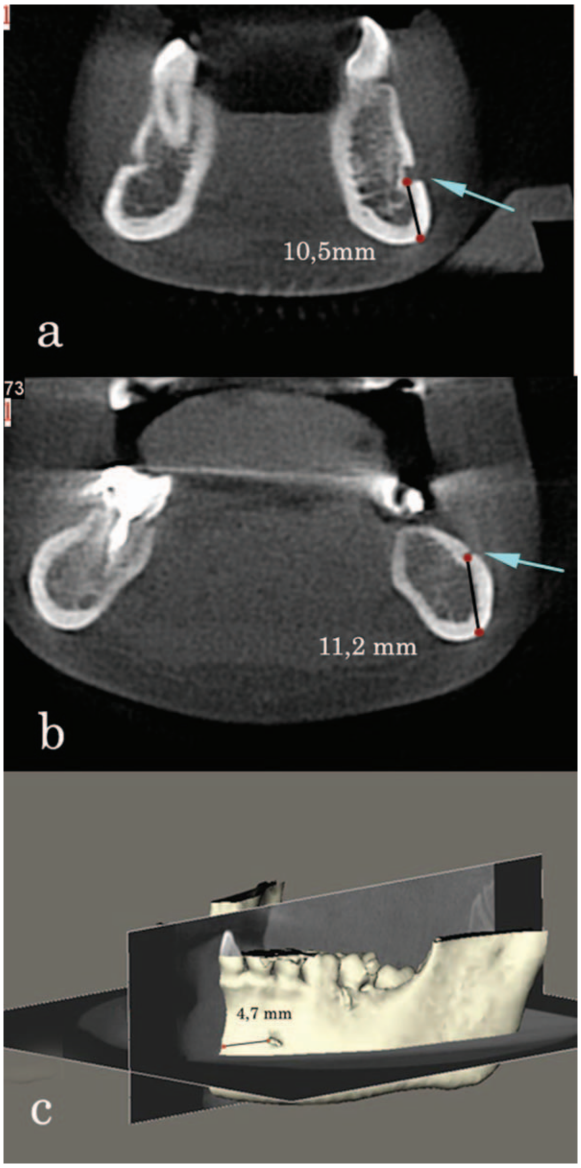

Fig. 3. **a:** Distances from the lower border of the mandible to (a) the mental foramen and (**b**) the accessory mental foramen. **c:** Shortest distance between the mental foramen and the accessory mental foramen. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

The position of the MF was recorded as (1) in line with the first molar, (2) between the second premolar and the first molar, (3) in line with the second premolar, (4) between the first and second premolars, (5) in line with the first premolar, or (6) anterior to the first premolar. The position of the AMF was recorded as posterosuperior, posterior, posteroinferior, superior, inferior, anterosuperior, anterior, or anteroinferior to the MF.

The dimensions of the MF and AMF were determined by measuring the maximum horizontal and vertical dimensions on the inner aspect of the cortical bone, as in previous studies (Katakami et al., 2008; Naitoh et al., 2009a; Fuakami et al., 2011). The shortest distance between each foramen and the

TABLE 1. Sex Distribution of Accessory Mental Foramen Position on Left and Right Sides

	AMF							
	Right			Left				
Positions	Total *n*(%)	Female *n*(%)	Male *n*(%)	Total *n*(%)	Female *n*(%)	Male *n*(%)	*P* value[a]	Total *n*(%)
Posterior	0	0	0	0	0	0	p > 0.05	0
Posterosuperior	1 (8.3)	0	1 (14)	2 (13.3)	2 (25)	0	p > 0.05	3 (11.1)
Posteroinferior	2 (16.6)	0	2 (29)	4 (26.6)	1 (12.5)	3 (42.8)	p > 0.05	6 (22.2)
Superior	2 (16.6)	2 (40)	0	2 (13.3)	1 (12.5)	1 (14)	p > 0.05	4 (16.6)
Inferior	2 (16.6)	2 (40)	0	1 (6.6)	1 (12.5)	0	p > 0.05	3 (11.1)
Anterosuperior	0	0	0	0	0	0	p > 0.05	0
Anterior	1 (8.3)	1 (20)	0	0	0	0	p > 0.05	1 (3.7)
Anteroinferior	4 (33)	0	4 (58)	6 (40)	3 (37.5)	3 (42.8)	p > 0.05	10 (37.0)
Total	12 (100)	5 (100)	7 (100)	15 (100)	8 (100)	7 (100)	p > 0.05	27 (100)

[a]Indicated statistical significance at level of *P* less than 0.05.

TABLE 2. Sex Distribution of Mental Foramen Position on Left and Right Sides

	MF							
	Right			Left				
Positions	Total *n*(%)	Female *n*(%)	Male *n*(%)	Total *n*(%)	Female *n*(%)	Male *n*(%)	*P* value[a]	Total *n*(%)
In line with the first molar	0	0	0	1 (0.51)	1	0	p > 0.05	1 (0,3)
Between the second premolar and first molar	6 (3,0)	2 (2.06)	4 (4.16)	10 (5.1)	6 (6)	4 (4.3)	p > 0.05	16 (4,2)
In line with the second premolar	56 (29,5)	30 (31)	26 (27.1)	64 (33.1)	30 (30)	34 (36.5)	p > 0.05	120 (30,4)
Between the first and second premolar	120 (61.5)	56 (57.7)	64 (66.6)	111 (57.5)	59 (59)	52 (55.9)	p > 0.05	231 (59,8)
In line with the first premolar	11 (5,5)	9 (9.27)	2 (2.08)	7 (3.6)	4 (4)	3 (3.2)	p > 0.05	18 (4,8)
Situated anterior to the first premolar	0	0	0	0	0	0	p > 0.05	0
Total	193 (100)	97 (100)	96 (100)	193 (100)	100 (100)	93 (100)	p > 0.05	386 (100)

[a]Indicated statistical significance at level of *p* less than 0.05.

closest tooth was also measured (Fig. 2). Distances between each foramen and the lower border of the mandible were measured on superimposed coronal images, and the distance between the MF and AMF was measured on 3D reconstructed images (Fig. 3).

All CBCT images were evaluated retrospectively by a single oral and maxillofacial radiologist with 12 years of experience (K.O.). Statistical analyses were performed using SPSS software (ver. 12.0.1; SPSS, Chicago, IL). Wilcoxon matched-pairs signed-ranks tests were used to assess the intraobserver reliability of repeated measurements and examinations. Differences in sex, side, AMF occurrence, and location were evaluated using chi-squared tests and MF and AMF measurements were evaluated using Mann–Whitney *U*-tests. Differences were considered significant when $P < 0.05$.

RESULTS

Repeated measurements of CBCTs showed no significant intraobserver difference ($P > 0.05$). Intraobserver consistency was 98.2% between two examinations and 100% for the detection of MF and AMF positions. Twenty-seven AMFs (6.5% of sides; 13 sides in 10 female patients, 14 sides in 13 male patients) were observed.

Tables 1 and 2 show the locations of AMFs and MFs. AMF incidence did not differ significantly between female and male patients ($P > 0.05$). AMFs were most commonly located anteroinferior to the MF, followed by locations posteroinferior to the MF. Bilateral AMFs anteroinferior to the MF were observed in a 24-year-old male patient. Three AMFs located anteroinferior, inferior, and posterosuperior to the MF were observed in a 19-year-old female patient. A 28-year-old male patient exhibited two AMFs inferior to the MF on the left side (Fig. 4). We found no significant difference between left and right sides according to sex or AMF location ($P > 0.05$).

One mandibular canal was found on each side in all patients. The most common position of the MF in this study was position 4, followed by position 3 (Table 2). MF position did not differ by side ($P > 0.05$), and posi-

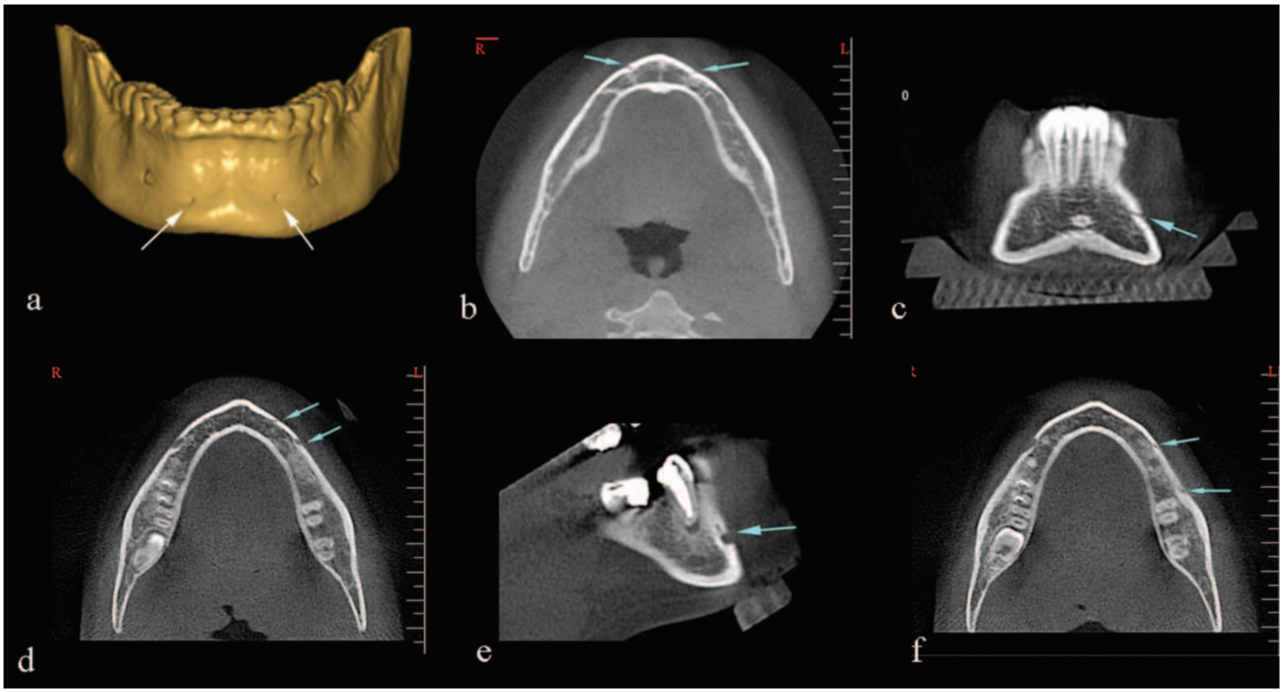

Fig. 4. (**a**) 3D and (**b**) axial CBCT images of the same patient showing bilateral accessory mental foramina. **c:** Coronal CBCT image of the same patient indicating the anteroinferior location of the accessory mental foramen. **d–f:** Axial and sagittal CBCT images showing three accessory mental foramina in the same patient located anteroinferior, inferior, and posterosuperior to the mental foramen. [Color 2figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

tion 4 was the most common position among males and females ($P > 0.05$). MFs were symmetrically located in 53.4% of cases (206 sides); of these symmetrically placed MFs, the most common location was position 4, followed by position 3. No MF was found in position 6, and one MF was found in position 1. No significant difference in symmetry was found between sexes ($P > 0.05$).

Table 3 shows the AMF and MF measurements. The mean vertical and horizontal dimensions of the AMF were 1.4 mm (range: 0.8–2.4 mm) and 1.6 mm (range: 0.8–3 mm), respectively. Among males, the mean horizontal size of the AMF was 1.5 mm (range: 1.0–2.4 mm), and the vertical size was 1.4 mm (range: 0.8–2.4 mm). Among females, the mean horizontal size of the AMF was 1.5 mm (range: 0.8–3 mm), and the vertical size was 1.3 mm (range: 0.8–2.1 mm). AMF sizes did not differ significantly by sex or side ($P > 0.05$).

The vertical and horizontal sizes of the MF were 3.7 mm (range: 1.0–7.0 mm) and 3.4 mm (range: 0.8–7 mm), respectively. Among males, the mean horizontal size of the MF was 3.9 mm (range: 1.0–7.0 mm), and the mean vertical size was 3.6 mm (range: 1.2–7.0 mm). Among females, the mean horizontal size of the MF was 3.5 mm (range: 1.3–5.6 mm), and the mean vertical size was 3.3 mm (range: 0.8–5.8 mm). The horizontal and vertical MF sizes were significantly greater in male patients than in female patients in this study group ($P < 0.05$).

The distance between the MF and AMF ranged from 1.3 to 15.4 mm, with a mean of 5.3 mm (SD: 4.4 mm). The distance between the MF and the lower border of the mandible ranged from 7.9 to 18.6 mm, with a mean of 12.4 mm (SD: 1.7 mm), and that between the AMF and the lower border of the mandible ranged from 7.5 to 20.6 mm, with a mean of 10.7 mm (SD: 2.3 mm). The MF was located closer to the alveolar area than the AMF. Distances did not differ significantly by side, but the distance between the MF and the lower border of the mandible was greater in male patients than in female patients ($P < 0.05$).

Measurements were also taken between each foramen and the closest tooth. Distances ranged from 2.1 to 12.5 mm (mean: 4.0 mm, SD: 2.4 mm) for the MF and 3.5 to 11.2 mm (mean: 6.3 mm, SD: 2.3 mm) for the AMF. These distances did not differ significantly by sex or side ($P > 0.05$).

Because the literature has indicated the influence of dental status on some anatomical parameters (Prado et al., 2010; Chrcanovic et al., 2011), we compared the parameters of dentate, partially edentulous, and edentulous patients (Table 4). We found no significant difference among groups for most measurements. However, the distance between the MF and AMF was significantly greater in dentate patients than in partially edentulous or edentulous patients, and the distance between the AMF and the closet tooth was significantly greater in partially edentulous patients than in dentate patients ($P < 0.05$).

TABLE 3. Comparison of Measurements Taken in Males and Females on Both Sides

	Left				Right			
Measurements (mean ± sd)	Total (mean ± s.d)	Male (mean ± s.d)	Female (mean ± s.d)	p value	Total (mean ± s.d)	Male (mean ± s.d)	Female (mean ± s.d)	p value
Horizontal dimension of MF	3.7±0.8	3.9±0.8	3.5±0.8	0.001[a]	3.8±0.8	4.0±0.8	3.6±0.8	0.031[a]
Vertical dimension of MF	3.4±0.7	3.6±0.8	3.3±0.7	0.001[a]	3.5±0.8	3.7±0.8	3.3±0.7	0.001[a]
Horizontal dimension of AMF	1.6±0.6	1.6±0.5	1.7±0.7	0.907	1.5±0.5	1.5±0.5	1.4±0.5	0.807
Vertical dimension of AMF	1.4±0.4	1.4±0.5	1.4±0.7	0.908	1.4±0.3	1.5±0.3	1.3±0.3	0.513
The distance between MF and AMF	5.1±4.4	5.8±5.1	4.1±3.2	0.942	5.5±4.5	6.1±5.3	4.0±2.9	0.566
The distance between MF and closest tooth	4.0±2.5	3.8±2.3	4.1±2.7	0.452	3.9±2.4	3.9±2.3	4.0±2.5	0.754
The distance between AMF and closest tooth	6.0±2.0	6.6±2.0	5.4±2.0	0.312	6.6±2.7	7.5±3.2	5.7±2.2	0.245
The distance between MF and lower border of mandible	12.6±1.7	13.1±1.6	12.2±1.6	0.017[a]	12.3±1.7	12.8±1.7	11.8±1.7	0.019[a]
The distance between AMF and lower border of mandible	10.9±2.4	10.8±2.4	11.0±2.4	0.561	10.5±2.2	10.6±2.4	10.4±2.3	0.193

[a] Indicated statistical significance at level of p less than 0.05.

TABLE 4. Comparison of Measurements Taken in Males and Females According to Dental Status

Measurements (mean ± sd)	Dentate $n=92$, sides 184 (mean ± s.d)	Partial edentulous $n=85$, sides 170 (mean ± s.d)	Edentulous $n=16$, sides 32 (mean ± s.d)	Dentate- partial edentulous *P* value	Dentate- edentulous *P* value	Partial edentulous- edentulous *P* value
Horizontal dimension of MF	3.8 ± 0.8	3.7 ± 0.8	3.6 ± 0.9	$p>0.05$	p>0.05	p>0.05
Vertical dimension of MF	3.4 ± 0.8	3.4 ± 0.7	3.4 ± 0.6	$p>0.05$	p>0.05	p>0.05
Horizontal dimension of AMF	1.7 ± 0.6	1.6 ± 0.4	1.5 ± 0.5	$p>0.05$	p>0.05	p>0.05
Vertical dimension of AMF	1.4 ± 0.4	1.4 ± 0.3	1.4 ± 0.3	$p>0.05$	p>0.05	p>0.05
The distance between MF and AMF	6.6 ± 4.2	4.4 ± 2.4	4.3 ± 2.6	0.001[a]	0.001[a]	P>0.05
The distance between MF and closest tooth	4.1 ± 2.9	3.9 ± 2.8	0	p>0.005	NA	NA
The distance between AMF and closest tooth	5.0 ± 1.4	7.1 ± 2.6	0	0.001[a]	NA	NA
The distance between MF and lower border of mandible	12.7 ± 1.9	12.6 ± 1.7	12.5 ± 1.6	p>0.05	p>0.05	p>0.05
The distance between AMF and lower border of mandible	10.7 ± 3.0	10.6 ± 3.1	10.6 ± 2.8	p>0.05	p>0.05	p>0.05

[a] Indicated statistical significance at level of p less than 0.05., NA indicates not applicable.

DISCUSSION

The positions of the MF and mandibular canal must be determined accurately when performing dental implant or periapical surgery in the posterior segment of the mandible. Previous reports (Aktekin et al., 2003; Gungor et al., 2006) have used panoramic radiographs to determine that the MF was most commonly located between the first and second premolars in a Turkish population, as found in our study. However, Oguz and Bozkir (2002) and Yesilyurt et al. (2008) found that the MF was most commonly located in line with the longitudinal axis of the second premolar in a Turkish population. Our finding is in accordance with data from some populations (Moiseiwitsch, 1998; Laster et al., 2005; Haghanifar and Rokouei, 2009) but not others (Oguz and Bozkir, 2002; Ngeow and Yuzawati, 2003; Ari et al., 2005; Igbigbi and Lebona, 2005; Apinhasmit et al., 2006; Yesilyurt et al., 2008). Ari et al. (2005) reported that traits such as the localization of the MF may differ not only between populations from different geographic environments but also among inhabitants of the same environment. The present study found bilateral symmetry in the position of the MF, as in previous studies (Shankland, 1994; Chinami et al., 2004; Apinhasmit et al., 2006), and like other studies, showed no sex differences in MF distribution (Moiseiwitsch, 1998; Ngeow and Yuzawati, 2003; Apinhasmit et al., 2006).

Our results indicated that the vertical and horizontal sizes of the MF were 3.7 mm (range: 1.0–7.0 mm) and 3.4 mm (range: 0.8–7 mm), respectively. These findings support those of previous reports. Neiva et al. (2004) found a mean MF height of 3.47 mm (range: 2.5–5.5 mm) and mean width of 3.59 mm (range: 2–5.5 mm). Yosue and Brooks (1989a) noted that the mean diameter of the MF was 3.5 mm, and Solar et al. (1994) found a mean width of 5 mm. In a Turkish population smaller than that in our study, Oguz and Bozkir (2002) found the horizontal dimension of the MF to be 2.93 mm on the right side and 3.14 mm on the left side; the vertical dimension was 2.38 mm on the right side and 2.64 mm on the left side.

Our results showed that MF dimensions did not differ between sides but were significantly greater in males than in females ($P < 0.05$). Female mandibles thus appear to have been smaller than male mandibles in this study population, in accordance with some previous studies (Williams et al., 1989; Apinhasmit et al., 2006). However, no attempt was made to measure the complete mandible in this study.

Individuals typically have one MF on each side. Chinami et al. (2004) mentioned that Simonton presented a detailed report of the incidence of a variety of multiple MFs in 1923. He also reported that non-Caucasian populations have a higher incidence of this condition than do Caucasian populations. Subsequent studies (Sawyer et al., 1998; Kieser et al., 2002) have found similar results. Sawyer et al. (1998) assessed the frequency of AMFs in the skulls of American Whites (1.4%), Asian Indians (1.5%), African Americans (5.7%), and Columbian Nazca Indians (9.0%). In other studies, two MFs were noted in 1.8% of examined Asian skulls (Agthong et al., 2005) and in 10% of examined cadavers (Mraiwa et al., 2003). In contrast, de Freitas et al. (1979) found that MFs were absent in a small proportion (right: $n = 2$, 0.06%; left: $n = 1$, 0.03%) of 1,435 dry human mandibles. A variety of patterns thus occurs, and clinicians should not assume that a patient has only one MF on each side.

No previous study has assessed the incidence of AMFs in a Turkish population. In our study, AMFs were seen in 6.5% of examined patients; this incidence is similar to those in some other populations (Sawyer et al., 1998; Berge and Bergman, 2001; Hanihara and Ishida, 2001; Agthong et al., 2005). Some studies have found a higher incidence of AMFs in women, whereas other studies have reported the opposite (Hanihara and Ishida, 2001; Kieser et al., 2002). In our study, AMF incidence did not differ significantly by sex ($P > 0.05$).

Osteological investigations have reported AMF diameters ranging from 0.74 mm to 0.89 mm (Toh et al., 1992). AMFs may be as small as 0.1 mm or reach a width exceeding 1.5 mm, and they often resemble the size of the MF (Shiller and Wiswell, 1954; Liang et al., 2007). Our results indicated that the mean vertical and horizontal dimensions of the AMF were 1.4 mm (range: 0.8–2.4 mm) and 1.6 mm (range: 0.8–3 mm), respectively, which were obviously smaller than those of the MF.

These differences in size and number may be explained by different inclusion criteria for size and different methods of evaluation (Kaufman et al., 2000). Although researchers have stated that the dissection and examination of dry mandibles allows the identification of a greater and more accurate number of foramina than do studies based solely on radiographic evaluation because many foramina are not visible on conventional radiographs, CT evaluations of the AMF have demonstrated greater reliability and accuracy than those using conventional radiography (Klinge et al., 1989; Quirynen et al., 1990).

The location of the AMF is influenced by the branching site and the length of the accessory branch. Longer branched nerves result in increased distances between the AMF and the MF. The location of the AMF relative to the MF shows more horizontal than vertical variation (Katakami et al., 2008). Although Naitoh et al. (2009a) found that the AMF was located posteroinferior to the MF in a Japanese population; our study found that the AMF was most commonly located anteroinferior to the MF. The distance between the MF and the AMF found in this study (mean: 5.2 mm, range: 1.3–15.4 mm) was similar to the results of other studies (Toh et al., 1992; Naitoh et al., 2009b).

A previous study (Apinhasmit et al., 2006) indicated that the vertical position of the MF can be determined by calculating the ratio of the distance between the center of the MF and the lower border of the mandible to the distance between the alveolar crest across the MF and the lower border of the mandible. Apinhasmit et al. (2006) also stated that the ratio determining the horizontal position of the MF is a more reliable parameter for clinical use than is the vertical ratio because the alveolar bone crest readily changes depending on periodontal status. In this study, no measurement was made from the alveolar crest due to this potential variation. We instead measured the distance between the MF or AMF and the lower border of mandible because this area is free from bony changes and resorptions. We found that the MF was located closer to the alveolar area than the AMF was. Additionally, these distances were greater in males than in females, likely because females' mandibles were smaller than those of males (Williams et al., 1989; Apinhasmit et al., 2006; Chrcanovic et al., 2011).

The distance from the MF to the closest tooth ranged from 2.1 to 12.5 mm (mean: 4.2 mm, SD: 2.4 mm), and that between the AMF and the closest tooth ranged from 3.5 to 11 mm (mean: 6.5 mm, SD: 2.3 mm). In our opinion, the addition of these measurements to similar studies is important because these distances should be taken into consideration to avoid nerve damage during periapical surgery.

Because the literature has indicated the influence of dental status on some anatomical parameters (Prado et al., 2010; Chrcanovic et al., 2011), we compared our parameters among dentate, partially edentulous, and edentulous patients (Table 4). The distance between the MF and the AMF was significantly greater in dentate patients than in partially edentulous or edentulous patients. This result can be interpreted as indicating individual or related changes in the locations of the MF and the AMF with age, tooth loss, and alveoler bone resorption (Prado et al., 2010; Chrcanovic et al., 2011). Previous studies (Carlsson, 2004; Pietrokovski et al., 2007; Prado et al., 2010) have indicated that sex, genetics, systemic conditions, tooth loss sequence, length of edentulous time, and other unknown factors influence the chronic remodeling/resorption process of edentulous jaws. Hence, one of these factors may be responsible for the smaller distances between the AMF and MF in partially edentulous and edentulous patients. We also found a greater distance between the AMF and the closet tooth in partially edentulous patients than in dentate patients ($P < 0.05$). In our opinion, this was due to the absence of teeth close to the AMF, which increased this distance in comparison with dentate patients. However, as stated above, our partially edentulous patients were classified as Kennedy Class I–III. To determine the exact relationship between dental status and foramina, stricter and more standardized (e.g., divided by Kennedy class) studies with larger sample sizes are necessary.

In this study, CBCT imaging was used to evaluate the MF and AMF. Naitoh et al. (2009b) stated that the detection of buccal foramina is difficult when 3D anatomical structures are projected onto two-dimensional film, and it is also complicated by overlap between these foramina and the trabecular and lingual cortical bones, the opposite mandibular body, and the cervical vertebrae in dental panoramic radiographs. To overcome these obstacles, 3D imaging is essential, especially for patients who will undergo oral surgical procedures. Moreover, such anatomical variations may cause pain and discomfort in prosthesis usage and paresthesia during anesthetic, surgical, and endodontic applications (Orhan et al., 2010).

Dental CBCT has been recommended as a dose-sparing technique, compared with standard medical CT scans, for the imaging of anatomical landmarks before surgical procedures. The effective dose (ICRP 2007) from a standard dental protocol scan using a traditional CT was 1.5 to 12.3 times greater than comparable medium-FOV dental CBCT scans (Ludlow and Ivanovic, 2008). CBCT image quality has also been found to be equivalent to that of traditional CT for visualizing the maxillofacial structures (Ludlow and Ivanovic, 2008; Periago et al., 2008; Loubele et al., 2009; Ludlow et al., 2009; Liang et al., 2010).

In conclusion, clinicians must be aware of the variability in MF and AMF positions when radiographically examining periapical areas and performing periodontal or endodontic surgical treatments in the area between the first premolar and the mesial root of the first molar. Knowledge of the presence of the AMF, which shows continuity with the mandibular canal, may avoid injury to the neurovascular bundles and facilitate surgical, local anesthetic, and other invasive procedures. CBCT examinations may be used instead of CT scans to evaluate these anatomical variations. When 3D imaging is required to visualize the anatomical structures, CBCT should be preferred over CT.

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