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Detection and characterization of the accessory mental foramen using cone-beam computed tomography

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ABSTRACT

Objective: This study aimed to investigate the frequency and characteristics of accessory mental foramina (AMFs) and their bony canals in a selected Chinese population using cone-beam computed tomography (CBCT).

Materials and methods: Reconstructed CBCT images of the mandible in 784 Chinese patients (305 males and 479 females) were retrospectively analysed to identify the AMF. The presence, dimension and location of the AMF as well as the origin and course of the associated bony canal were evaluated and classified. Variations in these characteristics were analysed according to gender, side and age.

Results: A total of 66 AMFs were found in 57 (7.3%) of the 784 patients. The frequency of AMFs was significantly influenced by gender and side of the mandible ($p < .05$). Most AMFs were located apically between apices of the first and second premolars. The high-position AMFs (above the mental foramen) accounted for 54.5% of the total. The mean horizontal and vertical diameters of the AMF were 1.38 ± 0.47 and 1.23 ± 0.37 mm, respectively. Two typical types of the bony canal leading to the AMF were identified according to their bifurcation site from the mandibular canal. Most bony canals originated from the anterior loop of the mental canal (56.1%) and coursed posterosuperiorly (36.3%). The mean length of the bony canals was 5.78 ± 2.31 mm.

Conclusions: This study presents a considerable frequency of AMFs in a Chinese population. The high-position AMF and the associated bony canal coursing in the oblique upward direction appear frequently. Thus, clinicians should be alert to the presence of the AMF to avoid neurovascular complications especially when dental procedures require periosteum detachment and implant insertion in the mental region.

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Accessory mental foramen; anatomical variation; cone-beam computed tomography; mental foramen; dental implant

Introduction

The mental foramen (MF) is a single opening on each side of the mandible through which the mental nerve and vessels emerge to provide sensory innervation and blood supply. However, human mandibles presenting additional foramina are not a rare finding and reported to complicate certain dental procedures [1,2]. Especially, the additional buccal foramen showing continuity with the mandibular canal is referred to as the accessory mental foramen (AMF) and deserves the full attention of clinicians and surgeons for its neurovascular contents [3–7].

The presence of AMF makes neurovascular structures that the MF transmits follow alternative courses. According to Toh et al., the AMF supplied passage for accessory branches of the mental nerve to innervate the mucous membrane and skin extending from the corner of the mouth to the median labial region [3]. Iwanaga et al.'s cadaver study [5] revealed the variable composition of arteries and nerves passing through the AMF and noticed that an AMF with comparatively large size and distant location trended to include an artery. Thus, the ignorance of the AMF might explain inadequate levels of local anaesthesia or result in postoperative complications, such as haemorrhages and neurosensory disturbances by injuring these neurovascular contents [1,5,8]. Jha et al. [7] also reported that failure to excise an accessory mental nerve during the neurectomy of the mental nerve in case of trigeminal neuralgia would cause the duration of neuralgic pain. These findings indicated that the preoperative recognition of the AMF was crucial to promote favourable therapeutic results that involved local anaesthesia, endodontic and periodontal treatments and surgical procedures, such as neurectomy, dental implant insertion, orthognathic operation, etc.

Numerous methods have been adopted to examine the AMF, including gross anatomical dissection [5,6,9],

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radiological techniques [10,11] and observation of the dry mandibles [12]. Although anatomical methods showed high precision in confirming the existence of AMF and conducting measurements, the findings often had limited reliability due to a small sample size [13]. Visualization of the AMF through panoramic radiographs might be difficult because of the small size of the AMF and geometric distortion of the images [10,11]. Cone-beam computed tomography (CBCT) has been recommended as a non-invasive imaging tool capable of offering in-depth information about the maxillofacial structures through sufficient resolution of multiplanar reconstruction images [14]. Imada et al. [11] agreed that CBCT was more effective than panoramic radiographs for presurgical assessment of the AMF.

Published research pointed out the ethnic differences of AMFs with respect to the frequency and morphological characteristics [3,9,12]. For example, higher frequencies of AMF have been found in Central Asian and sub-Saharan African samples [15]. However, research on AMF in Chinese populations, which occupy one-fifth of the world's population with increasing demand for dental treatment, is absent. Additionally, few studies have described the bony canals connecting to accessory foramina, while the course of these neurovascular canals is an important consideration for implant-related surgeries [10,16]. Therefore, this study sought to characterize the AMF in a selected Chinese population by describing its frequency, dimension and location as well as the course of the associated bony canal using CBCT.

Materials and methods

Subjects

The initial sample consisted of 900 consecutive patients who underwent dental CBCT examinations from January 2012 to July 2013. Their CBCT images were retrieved from the radiology database at the Department of Stomatology Special Consultation Clinic, Ninth People's Hospital (Shanghai, PR China). This study was exempt from approval by an institutional review board because of its retrospective nature. The inclusion criteria were high-resolution images and mandibles without malocclusion, fractures, partially erupted or unerupted teeth, pathological disease or surgeries in the mental region.

Data acquisition and image reconstruction

A CBCT device (NewTom VG, QR srl Corp, Verona, Italy) was used to obtain scanned data of patients' mandibular structures. The scan parameters followed the manufacturer's recommended setting of 110 kVp, 10 mA and an exposure time of 18 s. The fixed field of view was $16 \times 14\,cm^2$ with voxel size 0.16 mm. Three-dimensional (3D) images were reconstructed from CBCT data using NewTom VG software NNT version 2.21 (ImageWorks, Elmsford, NY). The consecutive slice images on the axial, coronal and sagittal planes were subsequently set at 0.25 mm thickness.

Radiographic evaluation

Two experienced prosthodontists jointly determined the presence of AMFs and completed the relevant measurements. A senior oral radiologist participated in decision making when a consensus could not be reached.

The presence of the AMF was evaluated according to the following criteria:

1. At least one additional buccal foramen, which was smaller than the ipsilateral MF in size, appeared on three-dimensionally reconstructed images of the mandible regardless of its location (Figure 1(a)).
2. A bony canal, connecting the additional buccal foramen with the mandibular canal, was observed on axial images (Figure 1(b,c)) and coronal images (Figure 1(d)).

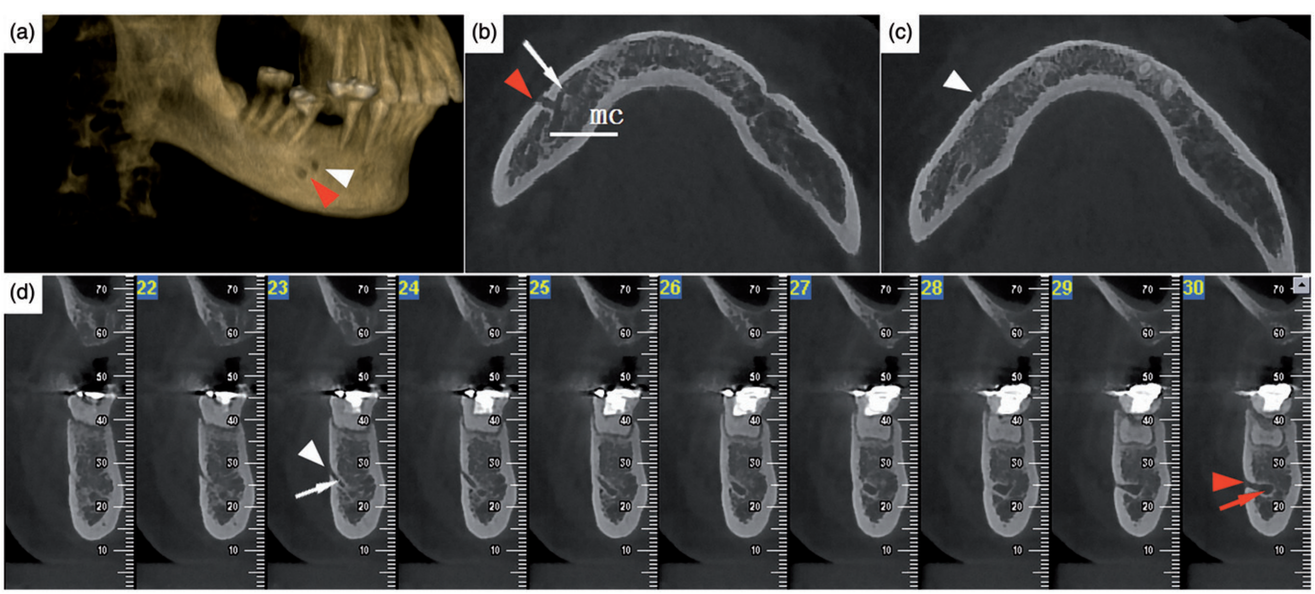

Figure 1. (a) One AMF (upper arrowhead) on the right side of the mandible is presented in a 3D reconstruction image of a 45-year-old Chinese male. Lower arrowhead refers to the MF. (b) Axial image at the level of the MF (arrowhead). The arrow indicates the part of an intraosseous canal connecting the mandibular canal (mc) to the AMF. (c) Axial image at the level of the AMF (arrowhead). (d) Cross-sectional sequential images from 21 to 30 showing the mental canal (image 30, arrow), the bony canal of the AMF (image 23, arrow), the AMF (image 23, arrowhead) and the MF (image 30, arrowhead).

3. Any additional buccal openings showing discontinuity with the mandibular canal were considered as nutrient foramina and excluded from the analysis.

The location of the AMF and the MF was determined by the long axis of the adjacent tooth and classified as being below or between apices of adjacent teeth. The relative position of the AMF with respect to the MF was recorded on 3D images of mandibles (Figure 2(a)). The linear distance from the AMF to the MF and maximum diameters of the AMF and the ipsilateral MF in width (a) and height (b) were measured. The area of the AMF and the MF was further calculated using the formula of the elliptic area: $S = (a \times b \times \pi)/4$. The shortest distance from the AMF to the adjacent root was recorded in the sagittal images (Figure 2(b)). The vertical distance between the lower border of the mandible (MIB) and the centre of the AMF (L1) and the vertical distance between the MIB and the centre of the MF (L2) were recorded in the coronal images (Figure 2(d)) .

The bony canal leading to the AMF was observed for its origin and course. According to the point of bifurcation from the mandibular canal, bony canals were divided into two main types (Figure 3): Type I, originating from the mental canal of the mandibular canal; Type II, originating from the main trunk of the mandibular canal. It was worth noting that the origin of the bony canal at the anterior loop (AL) belonged to Type I as well because the AL was part of the mental canal in the situation that the mandibular canal extended beyond the MF in an anterior direction and turned back to the MF, forming a loop structure [17]. To describe the intraosseous course of the bony canal, the opening angulation between the canal and the buccal cortical bone surface was measured on axial and coronal slices (Figure 2(c,d)). The length of the bony canals was also measured on multiplanar reconstruction images along their direction.

Statistical analysis

Statistical software SPSS version 19 (SPSS, Chicago, IL) was applied to statistical analysis. Pearson's chi-square test was used to determine potential differences in the frequency of AMF across gender, side and age. Differences in the morphologic characteristics of the foramina regarding gender and side were analysed using Student's t test, while one-way analysis of variance (ANOVA) with post-hoc test (Fisher's least significant difference or Tamhane's T2 test) was performed to clarify the difference in these values among different age stages. The characteristics of bony canals from different types were compared using ANOVA. The significance level determined for all tests was set at 5%.

Results

A total of 784 Chinese patients' CBCT scans from the initial sample met the inclusion criteria with 305 males and 479 females (mean age: 34.0 years, range: 13–81 years, SD: 15.1 years).

Frequency

Overall, 66 AMFs were identified in 57 (7.3%) patients. Four bilateral cases were presented in this study, with one case possessing two AMFs respectively in each side (Table 1). The presence of AMF based on different groups is described in Table 2. No statistically significant difference was found with respect to age ($p > .05$). However, gender ($p = .003$) and side ($p = .000$) of the mandible were considered as significant factors influencing the presence of AMF. The frequency of AMF was 10.8% in males and 5.0% in females, while the frequency of right-side and left-side AMF was 5.7 and 2.0%, respectively.

Location

The AMF and the MF were commonly located apically between the apices of the first and second premolars, followed by below the apex of the second premolar (Figure 4). The distribution of the AMF in relation to the MF is illustrated in Figure 5. The AMFs were most frequently positioned in the posteroinferior (30.3%), posterosuperior (27.3%) and anterosuperior (22.7%) areas of the MF. The high-position AMFs (above the MF) accounted for 54.5% of the total. The mean

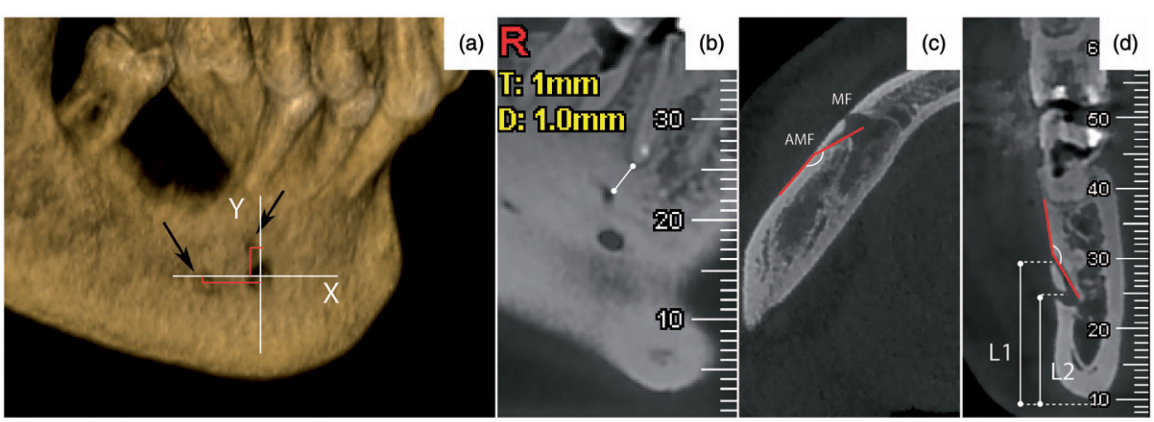

Figure 2. (a) The position of two AMFs in relation to the MF. The origin of rectangular coordinate was the centre point of the MF. Black arrows indicated AMFs. (b)The proximity of the AMF to the nearest adjacent root apex. (c) Measurement of the opening angle of the associated bony canal leading to the AMF at the axial plane. (d) Measurement of the opening angle of the associated bony canal leading to the AMF at the coronal plane. L1 (L2), the vertical distance from the lower border of the mandible to the AMF (MF).

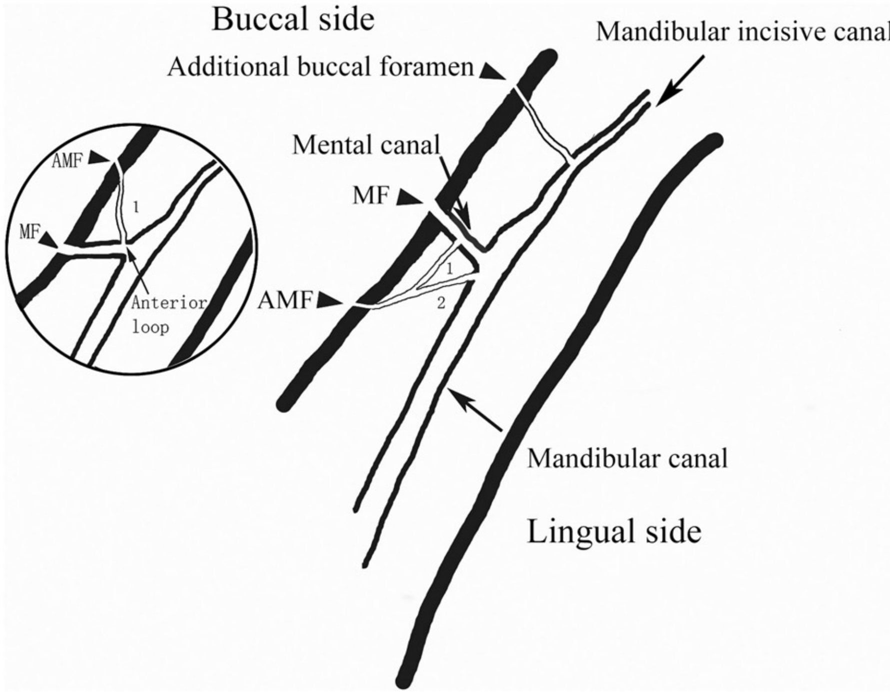

Figure 3. Schematic drawing showing two types of bony canals bifurcating from the mandibular canal to the AMF. (1) Type 1 starting from the mental canal or anterior loop to the AMF. (2) Type 2 starting from the main trunk of the mandibular canal to the AMF.

Table 1. Number of AMFs on each mandibular side in the assessed individuals.

Owning the number of AMFs	Specific number of AMFs on each mandibular side: Left	Right	Number of patients meeting the condition, *n* (%)
Absent	0	0	727 (92.7)
One AMF	0	1	40 (5.1)
	1	0	12 (1.5)
Two AMFs	0	2	1 (0.1)
	1	1	1 (0.1)
Three AMFs	1	2	1 (0.1)
	2	1	1 (0.1)
Four AMFs	2	2	1 (0.1)
Total			784 (100)

Table 2. Occurrence of the AMF in different gender, side and age groups.

Variables (AMF)		Presence, *n* (%)	Absence, *n* (%)	*p* Value
Gender	Male	33 (57.9)	272 (37.4)	.003*
	Female	24 (42.1)	455 (62.6)	
Side	Left	16 (26.2)	768 (51.0)	.000*
	Right	45 (73.8)	739 (49.0)	
Age (y)	0–20	9 (15.8)	161 (22.1)	.379
	21–40	26 (45.6)	340 (46.8)	
	41–81	22 (38.6)	226 (33.1)	

*Denotes statistical significance.

linear distance between the AMF and the MF was 5.32 ± 1.55 mm (range, 1.58–10.41 mm). The mean linear distance from the AMF to the nearest adjacent root was 4.74 ± 3.07 mm (range, 0.6–13.2 mm). In 11 cases (21.2%), the AMFs were located within 2 mm of the nearest root, whereas 21 AMFs (40.4%) were located >5 mm. The L1 distance was 14.20 ± 3.97 mm (range, 7.80–21.50 mm), and the L2 distance was 13.36 ± 1.77 mm (range, 10.30–16.50 mm). Only the L2 distance was significantly influenced by gender ($p = .046$) and age ($p = .030$) (Tables 3 and 4). The values of the L2 distance in the ≤20, 21–40 and ≥41 years age groups were 11.91 ± 0.86, 13.46 ± 1.87 and 13.81 ± 1.68 mm, respectively, showing an increase with age.

Morphological measurement of AMF

The mean horizontal and vertical diameter of the AMF was 1.38 ± 0.47 (range, 0.6–2.8 mm) and 1.23 ± 0.37 mm (range, 0.6–2.1 mm), respectively. The ipsilateral MF possessed a mean horizontal and vertical diameter of 3.10 ± 0.55 (range, 2.2–5.3 mm) and 2.91 ± 0.47 mm (range, 2.0–4.7 mm), respectively. The AMF/MF area ratio ranged from 0.02 to 0.69 (mean: 0.22, SD: 0.15). No significant differences regarding the measurements of the AMF to the gender or side were found ($p > .05$) (Table 3). In contrast, the diameter of the ipsilateral MF was significantly greater in males than in females ($p < .05$) (Table 3). Regarding age, no significant difference was found in the AMF and MF morphological characteristics (Table 4).

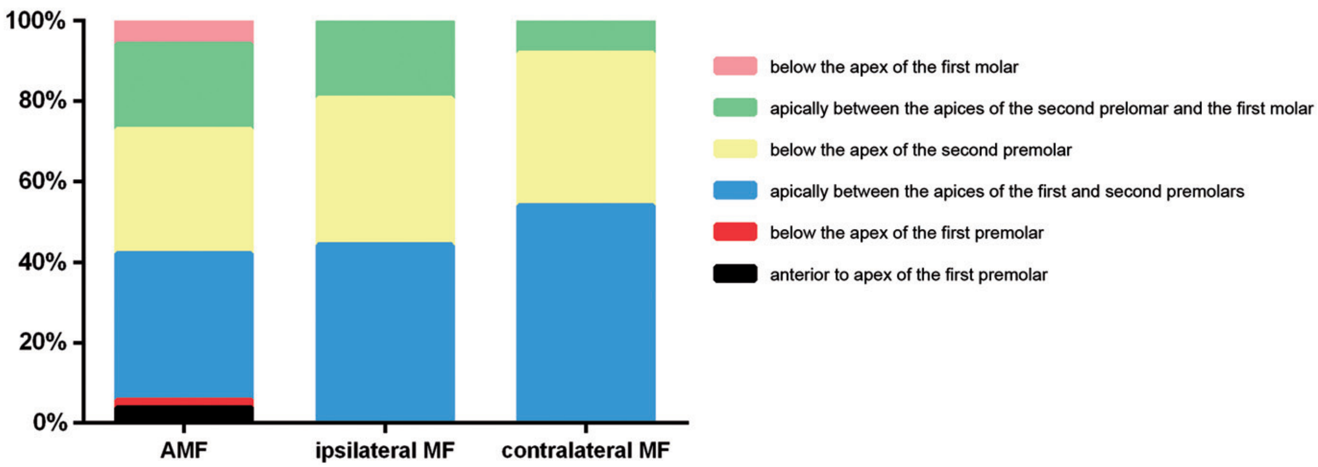

Figure 4. The location of the AMF and the MF in relation to the adjacent teeth.

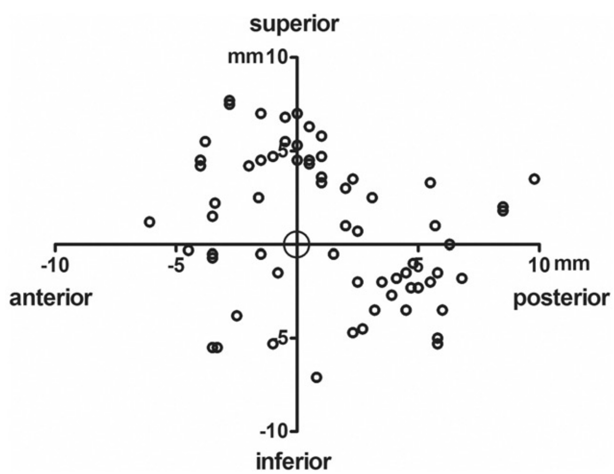

Figure 5. Schematic diagram showing the distribution of the AMF in relation to the MF. The centre of the figure was set as the centre of the MF. The horizontal axis is parallel to the occlusal plane.

Characteristics of the associated bony canal

Of the 66 bony canals connecting to their corresponding AMFs, 52 (78.8%) belonged to Type I and 14 (21.2%) belonged to Type II. Among the cases of Type I, 71.2% (37/52) of the canals were observed to set out from the AL of the mental canal. The mean length of the bony canals was 5.78 ± 2.31 mm (range, 1.6–11.9 mm). With regard to the opening angulation of the bony canal exiting to the AMF, the mean angle in the axial and coronal image was 116.37 ± 36.09°(range, 38.50–165.40°) and 114.89 ± 37.99° (range, 24.20–164.30°), respectively.

The variable courses of the bony canals are depicted in Table 5. Overall, 62.1% (41/66) of the bony canals had an upward intraosseous pathway due to their opening angulation in the coronal plane exceeding 90°. Among them, 58.5% (24/41) of the canals formed an angle over 90° with the buccal bone surface in the axial plane simultaneously, meaning that the bony canals of the AMFs commonly coursed posterosuperiorly. There was no bony canal coursing in the inferior direction. The bony canal of Type II trended to extend posteroinferiorly. The mean coronal opening angulation in Type II canals was significantly lower than that in Type I canals, regardless of whether there was a loop structure in Type I canals ($p = .022$).

Discussion

The presence of the AMF has important clinical implications for dental procedures involving the mandible. Toh et al. [3] considered that the formation of the AMF was attributed to the ramification of the mental nerve prior to the formation of the MF. Accurate identification of AMFs is central to perform sufficient anaesthesia of the mental nerve or to avoid neurovascular complications during treatment in the vicinity of the MF.

The frequency of the AMF in literature ranges widely from 1.4 to more than 20% [10,12,15,18,19]. In addition to ethnic variations, the wide range of the frequency might result from differences in methodology and definition of AMF. In this study, CBCT was used to evaluate the AMF in a selected Chinese population due to its accuracy, non-invasive nature and convenience for a large-sample research. The AMF was defined as an additional buccal foramen with its bony canal bifurcating from the mandibular canal. It was also essential to distinguish AMFs from nutrient foramina showing no continuity with the mandibular canal [9,20]. The additional buccal foramina originating from the mandibular incisive canal were not qualified as AMFs [6,21].

In this study, 7.3% of the patients displayed the AMF in 784 CBCT images. Bilateral AMFs were observed in four cases (7.0%, 4/57), which were rare. The frequency of AMFs was reported from 3 to 13% in the CBCT-based studies with the similar definition of AMF and bilateral AMF occurred in 8.3–33.3% of AMF cases [10,11,19,22]. Our results were close to the findings of Han et al. who reported the AMF in 8.1% of a Korean population [22]. In fact, population and geographic variations played an important role in the frequency of the AMF according to a Hanihara et al.'s study on worldwide frequency distributions of AMFs [15]

Regarding gender and side, there was a debate over their influence on the presence of AMFs [5,10,15,19,22,23]. This study noted a significant gender difference in the frequency of AMF; further, the Chinese population seems to possess more right-sided AMFs. No significant difference in age

Table 3. Comparison of measurements of the AMF and the ipsilateral MF taken in males and females on both sides of mandible.

	Left side				Right side				Male + female sides
Characteristic	Total ($n = 12$)	Male ($n = 7$)	Female ($n = 5$)	p Value[a]	Total ($n = 40$)	Male ($n = 22$)	Female ($n = 18$)	p Value[a]	p Value[b]
Horizontal dimension of AMF	1.45 ± 0.59	1.38 ± 0.70	1.54 ± 0.45	.677	1.35 ± 0.42	1.35 ± 0.48	1.34 ± 0.39	.967	.587
Vertical dimension of AMF	1.26 ± 0.38	1.28 ± 0.44	1.22 ± 0.31	.782	1.23 ± 0.52	1.23 ± 0.38	1.21 ± 0.37	.836	.790
Horizontal dimension of ipsilateral MF	3.04 ± 0.41	3.24 ± 0.37	2.76 ± 0.29	.035*	3.12 ± 0.59	3.37 ± 0.59	2.82 ± 0.42	.022*	.657
Vertical dimension of ipsilateral MF	2.83 ± 0.40	3.03 ± 0.37	2.56 ± 0.27	.038*	2.94 ± 0.49	3.14 ± 0.45	2.69 ± 0.41	.002*	.503
Linear distance between AMF and MF	5.03 ± 1.26	5.17 ± 1.10	4.82 ± 1.57	.653	5.40 ± 1.63	5.34 ± 1.88	5.50 ± 1.31	.778	.455
S_{AMF}/S_{MF}	0.24 ± 0.17	0.20 ± 0.18	0.28 ± 0.15	.438	0.26 ± 0.09	0.17 ± 0.10	0.27 ± 0.19	.061	.706
Distance from AMF to the nearest adjacent tooth	4.13 ± 2.72	3.54 ± 2.31	4.96 ± 3.28	.435	4.93 ± 3.18	4.80 ± 3.60	5.08 ± 2.67	.791	.437
Distance between AMF and mandibular inferior border (L1 distance)	14.98 ± 3.40	15.20 ± 2.54	14.66 ± 4.68	.801	13.48 ± 4.15	13.99 ± 4.22	12.84 ± 4.10	.392	.206
Distance between MF and mandibular inferior border (L2 distance)	13.31 ± 1.74	13.40 ± 1.72	13.18 ± 1.98	.841	13.38 ± 1.80	13.89 ± 1.84	12.76 ± 1.61	.046*	.960

*Denotes statistical significance.
[a]Comparison between mean values of male and female, same side.
[b]Comparison between mean values of all right and left sides.
Values are expressed as mean ± SD.

Table 4. Comparison of measurements of the AMF and the ipsilateral MF taken in different age groups.

	Age group (y)			p Value			
Characteristic	≤20 ($n = 8$)	21–40 ($n = 23$)	≥41 ($n = 21$)	One-Way ANOVA	≤20 vs. 21–40 y	≤20 y vs.≥41 y	21–40 vs.≥41 y
Horizontal dimension of AMF	1.48 ± 0.31	1.47 ± 0.46	1.26 ± 0.51	.278	.977	.267	.138
Vertical dimension of AMF	1.39 ± 0.20	1.26 ± 0.33	1.14 ± 0.45	.262	.410	.119	.297
Horizontal dimension of ipsilateral MF	2.96 ± 0.45	3.04 ± 0.51	3.22 ± 0.61	.408	.720	.255	.280
Vertical dimension of ipsilateral MF	2.83 ± 0.45	2.83 ± 0.44	3.03 ± 0.49	.318	.959	.286	.163
Linear distance between AMF and MF	5.65 ± 1.38	5.58 ± 1.81	4.91 ± 1.25	.295	.916	.255	.156
S_{AMF}/S_{MF}	0.23 ± 0.10	0.29 ± 0.20	0.16 ± 0.15	.058	.365	.384	.018*
Distance from AMF to the nearest adjacent tooth	3.93 ± 2.93	5.27 ± 3.50	4.50 ± 2.74	.296	.695	.413	.513
Distance between AMF and mandibular inferior border (L1 distance)	15.90 ± 4.14	13.30 ± 4.30	13.60 ± 3.55	.277	.119	.171	.804
Distance between MF and mandibular inferior border (L2 distance)	11.91 ± 0.86	13.46 ± 1.87	13.81 ± 1.68	.030*	.013*	.002*	.888

*Denotes statistical significance.
Values are expressed as mean ± SD.

Table 5. The characteristics of different bony canals according to their branching position from the mandibular canal.

Type	Course								Total, *n* (%)	Length (mm)	Exiting angulation (degree, axial view)	Exiting angulation (degree, coronal view)
	Postero-superior, *n* (%)	Posterior, *n* (%)	Postero-inferior, *n* (%)	Inferior, *n* (%)	Antero-Inferior, *n* (%)	Anterior, *n* (%)	Antero-superior, *n* (%)	Superior, *n* (%)				
Type I												
At the mental canal (without a loop structure)	8 (12.1)	1 (1.5)	0 (0.0)	0 (0.0)	1 (1.5)	1 (1.5)	3 (4.5)	1 (1.5)	15 (22.7)	5.98 ± 2.18	105.26 ± 37.38	123.24 ± 32.21
At the anterior loop of mental canal (with a loop structure)	14 (21.2)	4 (6.1)	6 (9.1)	0 (0.0)	2 (3.0)	1 (1.5)	4 (6.1)	6 (9.1)	37 (56.1)	5.84 ± 2.58	116.95 ± 33.70	120.76 ± 37.33
Type II	2 (3.0)	1 (1.5)	7 (10.6)	0 (0.0)	1 (1.5)	0 (0.0)	3 (4.5)	0 (0.0)	14 (21.2)	5.42 ± 1.78	126.75 ± 40.04	90.39 ± 37.58
Total, *n* (%)	24 (36.3)	6 (9.1)	13 (19.7)	0 (0.0)	4 (6.0)	2 (3.0)	10 (15.1)	7 (10.6)	66 (100)	$p = .793$	$p = .278$	$p = .022$*

*Denotes statistical significance.
Values are expressed as mean ± SD.

groups was found in this and previous studies [19,24,25]. In the viewpoint of embryology, the AMF appeared with the development of the mandibular bone and its number remained constant after the mandible had matured [13]. Therefore, further effort is needed to pertinently investigate AMFs in the young, because our sample only included very few children as was the same in other studies [5,19,25].

Precise knowledge of the location of the AMFs is of prime importance, since their location influences innervation patterns of accessory mental nerves after exit from the AMF and treatment planning [3,5]. Katakami et al. [26] reported that the majority of AMFs were concentrated in the apex of the first molar, while Han et al. [22] noticed that the typical AMF site was between the apices of the premolars. This study observed that both AMFs and MFs were predominantly located apically between the apices of the first and second premolars, followed by below the apex of the second premolar. Regarding the positional relationship of the AMF with the MF, previous studies claimed that the position of the AMF was usually inferior or posteroinferior to the MF [20,26]. In this case, the adverse interference caused by the AMF would be lower since the location of the MF and the mandibular canal must be well assessed in the process of treatment planning. However, up to 54.5% of the AMFs in this study were in a position above the MF. Among them, 11 AMFs (21.2%) were located critically close, within 2 mm of the nearest root. These high-position AMFs were susceptible to encounter and injury when periosteum detachment was required in certain dental treatments, such as dental implant and periodontal and periapical microsurgeries [1,5,9,26].

The past literature well illustrated the discernible gender effect in the dimension of the MF [27–29]. The same conclusion was achieved in this study. However, no significant difference regarding morphologic measurements of the AMF with regard to the gender or side was found, consistent with radiographic studies [19,20,27]. In fact, the thickness and component of neurovascular contents might influence AMF size [6,13]. The mean horizontal diameter and vertical diameter of the AMF was 1.38 ± 0.47 and 1.23 ± 0.37 mm, respectively, which was smaller than previous findings [19,27]. The small dimension of AMFs in Chinese populations might be attributed to the smaller mandible of the Asian ethnic group, compared to European and North American ethnic groups. Regarding the age effect to the morphology of the foramina, differences in the division of the age group could lead to different conclusions [19,23,30]. Only one study pointed out the age-related difference of AMF size between paediatric and adult populations due to the growth process of the mandible [23]. In contrast, our study failed to confirm such age difference due to a lack of children samples.

The bony canal leading to the AMF is functionally important in transferring internal branches of neurovascular bundles to the surface of the mandible. This study was the first to examine the angle of the associated bony canals to specifically classify their courses. Although the intraosseous path of the canals was diversified, the bony canal of Type I commonly coursed in the posterosuperior direction, whereas the canal of Type II trended to course posteroinferiorly. The mean length of the bony canals was 5.78 ± 2.31 mm (range, 1.6–11.9 mm), similar to the value found in a previous study [26]. Therefore, this study underscored that the position of the AMF was determined by orientation, length and the branching site of the bony canal. Generally, a high-position AMF was associated with a bony canal coursing oblique upward in a steep angle.

The course of the bony canal is clinically important to the treatment planning of implant surgeries. In order to achieve a safety margin between the implant and neurovascular canal, the length, diameter, insertion angle and site of the dental implant are strictly limited. Pancer et al. [1] reported that they encountered an unexpected AMF through full-thickness flap reflection and had to place the implant 4 mm anterior to the planned implantation site to avoid potential neurovascular structures. However, the variable course of the bony canal leading to the AMF found in this study implied that such experience-based prejudgment on the trajectory of bony canal might be at risk, since neurovascular contents could be impaired in individuals having a bony canal with long length and steep upward angle as a result of surgical invasion. Nowadays, the flapless installation of osseointegrated implants in implant dentistry becomes popular due to its advantages of lesser trauma and haemorrhage, slight pain and rapid recovery. Conversely, there is almost no chance for surgeons to be aware of the existence of the AMF and its neurovascularization, without the flap reflection during the operation. Therefore, preoperative imaging examination to detect the AMF is important prior to the implant-related surgeries in the mental region to avoid possible complications like sensory disturbances or haemorrhages.

To our knowledge, this is the first study to investigate the AMF in a Chinese population. This study does not reveal all aspects of the AMF, such as components of neurovascular contents, distribution patterns of accessory nerves and AMF characteristics in paediatric populations, but could serve as a starting point to promote safer dental procedures in China and add information to the literature concerning AMFs in the East Asian population.

In conclusion, this study indicated a considerable frequency of AMF in a Chinese population. The high frequency of high-position AMFs and associated bony canals coursing in the oblique upward direction greatly increased the risk of complications in contain dental procedures. Thus, before operation, the detection of AMFs by advanced imaging equipments should be seriously taken into account in treatment plan of procedures performed in the mandible (i.e. placement of dental implant, periodontal and periapical microsurgeries, osteotomy). During the operation, clinicians should be alert to the presence of the unexpected AMF especially when dental procedures require periosteal detachment and implant insertion in the mental region.

Disclosure statement

The authors report no conflicts of interest.

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References

[1] Pancer B, Garaicoa-Pazmino C, Bashutski JD. Accessory mandibular foramen during dental implant placement: case report and review of literature. Implant Dent. 2014;23:116–124.
[2] ten Bruggenkate CM, Krekeler G, Kraaijenhagen HA, et al. Hemorrhage of the floor of the mouth resulting from lingual perforation during implant placement: a clinical report. Int J Oral Maxillofac Implants. 1993;8:329–334.
[3] Toh H, Kodama J, Yanagisako M, et al. Anatomical study of the accessory mental foramen and the distribution of its nerve. Okajimas Folia Anat Jpn. 1992;69:85–88.
[4] Concepcion M, Rankow HJ. Accessory branch of the mental nerve. J Endod. 2000;26:619–620.
[5] Iwanaga J, Watanabe K, Saga T, et al. Accessory mental foramina and nerves: application to periodontal, periapical, and implant surgery. Clin Anat. 2016;29:493–501.
[6] von Arx T, Lozanoff S, Bosshardt D. Accessory mental foramina: anatomy and histology of neurovascularisation in four cases with apical surgery. Oral Surg. 2014;7:216–227.
[7] Jha AK, Kumar NG. Accessory mental nerve: case report, review and its role in trigeminal neuralgia. Surg Radiol Anat. 2012;34:469–473.
[8] Boronat Lopez A, Penarrocha Diago M. Failure of locoregional anesthesia in dental practice. Review of the literature. Med Oral Patol Oral Cir Bucal. 2006;11:E510–E513.
[9] Fuakami K, Shiozaki K, Mishima A, et al. Detection of buccal perimandibular neurovascularisation associated with accessory foramina using limited cone-beam computed tomography and gross anatomy. Surg Radiol Anat. 2011;33:141–146.
[10] Naitoh M, Yoshida K, Nakahara K, et al. Demonstration of the accessory mental foramen using rotational panoramic radiography compared with cone-beam computed tomography. Clin Oral Implants Res. 2011;22:1415–1419.
[11] Imada TS, Fernandes LM, Centurion BS, et al. Accessory mental foramina: prevalence, position and diameter assessed by cone-beam computed tomography and digital panoramic radiographs. Clin Oral Impl Res. 2014;25:e94–e99.
[12] Paraskevas G, Mavrodi A, Natsis K. Accessory mental foramen: an anatomical study on dry mandibles and review of the literature. Oral Maxillofac Surg. 2015;19:177–181.
[13] Iwanaga J, Saga T, Tabira Y, et al. The clinical anatomy of accessory mental nerves and foramina. Clin Anat. 2015;28:848–856.
[14] Price JB, Thaw KL, Tyndall DA, et al. Incidental findings from cone beam computed tomography of the maxillofacial region: a descriptive retrospective study. Clin Oral Impl Res. 2012;23:1261–1268.
[15] Hanihara T, Ishida H. Frequency variations of discrete cranial traits in major human populations. IV. Vessel and nerve related variations. J Anat. 2001;199:273–287.
[16] Babiuc I, Tarlungeanu I, Pauna M. Cone beam computed tomography observations of the lingual foramina and their bony canals in the median region of the mandible. Rom J Morphol Embryol. 2011;52:827–829.
[17] Mardinger O, Chaushu G, Arensburg B, et al. Anterior loop of the mental canal: an anatomical-radiologic study. Implant Dent. 2000;9:120–125.
[18] Sawyer DR, Kiely ML, Pyle MA. The frequency of accessory mental foramina in four ethnic groups. Arch Oral Biol. 1998;43:417–420.
[19] Muinelo-Lorenzo J, Suarez-Quintanilla JA, Fernandez-Alonso A, et al. Anatomical characteristics and visibility of mental foramen and accessory mental foramen: panoramic radiography vs. cone beam CT. Med Oral Patol Oral Cir Bucal. 2015;20:e707–e714.
[20] Naitoh M, Hiraiwa Y, Aimiya H, et al. Accessory mental foramen assessment using cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107:289–294.
[21] Ogawa A, Fukuta Y, Nakasato H, et al. Cone beam computed tomographic evaluation of nutrient canals and foramina in the anterior region of the mandible. Surg Radiol Anat. 2016;38:1029–1032.

[22] Han SS, Hwang JJ, Jeong HG. Accessory mental foramina associated with neurovascular bundle in Korean population. Surg Radiol Anat. 2016;38:1169–1174.

[23] Cantekin K, Sekerci A. Evaluation of the accessory mental foramen in a pediatric population using cone-beam computed tomography. J Clin Pediatr Dent. 2014;39:85–89.

[24] Oliveira-Santos C, Souza PH, De Azambuja Berti-Couto S, et al. Characterisation of additional mental foramina through cone beam computed tomography. J Oral Rehabil. 2011;38:595–600.

[25] Khojastepour L, Mirbeigi S, Mirhadi S, et al. Location of mental foramen in a selected Iranian population: a CBCT assessment. Iran Endod J. 2015;10:117–121.

[26] Katakami K, Mishima A, Shiozaki K, et al. Characteristics of accessory mental foramina observed on limited cone-beam computed tomography images. J Endod. 2008;34:1441–1445.

[27] Kalender A, Orhan K, Aksoy U. Evaluation of the mental foramen and accessory mental foramen in Turkish patients using cone-beam computed tomography images reconstructed from a volumetric rendering program. Clin Anat. 2012;25:584–592.

[28] Chu RA, Nahas FX, Di Martino M, et al. The enigma of the mental foramen as it relates to plastic surgery. J Craniofac Surg. 2014;25:238–242.

[29] von Arx T, Friedli M, Sendi P, et al. Location and dimensions of the mental foramen: a radiographic analysis by using cone-beam computed tomography. J Endod. 2013;39:1522–1528.

[30] Orhan AI, Orhan K, Aksoy S, et al. Evaluation of perimandibular neurovascularization with accessory mental foramina using cone-beam computed tomography in children. J Craniofac Surg. 2013;24:e365–e369.