Accessory Mental Foramina and Nerves: Application to Periodontal, Periapical and Implant Surgery

ABSTRACT

Introduction: Recent studies investigating accessory mental foramina using imaging diagnostic developments have primarily defined foramina morphology; however, there have been few studies that have described the structures passing through the foramina. Thus, additional clinical knowledge of the foramina is required for preoperative diagnosis prior to surgery, including implant surgery, periodontal surgery and periapical surgery.

Materials and Methods: In this study, we investigated the accessory mental foramina and the associated nerves and arteries in donated cadaveric mandibles using anatomical and radiological observation methods. We examined 63 mandibles with overlying soft tissue by cone-beam computed tomography and observed the existence of the accessory mental foramina. Mandibles with accessory mental foramina were subsequently analyzed. Additionally, the neurovascular bundles passing through the foramina were dissected using anatomical methods.

Results: The accessory mental foramina incidence was 14.3%. The larger foramina tended to be located anteriorly or superiorly and proximal to the mental foramen, while the smaller foramina tended to be located postero-superiorly and distal to the mental foramen. The mental foramen ipsilateral to the accessory mental foramen was smaller than the mental foramen contralateral to the accessory mental foramen. The comparatively distant and large accessory mental foramen included an artery.

Conclusions: This study elucidated the relationship between accessory mental foramina and the associated nerves and arteries. We believe that the results of this study will contribute to the clinical dentistry field.

Key words: Periodontal Diseases; Periapical Diseases; Dental Implants; Cone-Beam CT; Mandible

INTRODUCTION

The development of cone-beam computed tomography (CBCT) has advanced preoperative imaging diagnosis of the mandibular bone. The high resolution and thin slice thickness provides a clear view of the mandibular bone accessory foramina, including the retromolar foramina, the lingual foramina and the accessory mental foramina (AMF). The AMF, in particular, have been widely studied, because many dentists encounter these foramina during routine clinical examinations, such as implant surgery, periodontal surgery and periapical surgery. Thus, not only oral and maxillofacial surgeons but also general dentists encounter these structures, which were not taught in dental school and are not well reflected in panoramic images. Pancer et al. (2014) reported that the existence of the AMF during implant surgery prompted them to change the osteotomy site to prevent complications. Concepcion et al. (2000) identified the AMF close to the operative field during periapical surgery. These studies have gradually made dentists more aware of AMF. However, AMF are recognized only as structures that require extreme care during surgery. It is unknown how AMF should be managed, what structures run through AMF or what would happen in case of injury, paresthesia and/or hemorrhage. This is because most AMF research has been performed using only CBCT images or dry human skulls. Thus, we need to dissect the neurovascular bundles within the overlying soft tissue of the mandibular bone and reveal the accessory mental nerve (AMN) and accessory mental artery (AMA) distributions. To date, only two reports have investigated the detailed AMN running route in anatomical studies (Toh et al., 1992; Iwanaga et al., 2015), and only one report described the arteries passing through the accessory foramina (Fuakami et al., 2011). The purpose of this study is to clarify the relationship among the AMF, AMNs and AMAs using anatomical and radiologic methods to promote safer clinical surgeries.

MATERIALS AND METHODS

CBCT analysis

Using a CBCT unit (Galileos, Sirona, Germany), we examined 63 (31 male and 32 female) mandibles from Japanese cadavers donated to our department between 2014 and 2015 with the overlying soft tissue of the mental region resected. The mean age was 79.4 years ± 11.9 years (range: 39–97 years). The exposure volume was set at 150 mm in diameter and 150 mm in height. The scan was set at 85 kV and 6 μA. The axial images were transmitted in the digital imaging and communication in medicine (DICOM) format, and 2D images in the mandibular body region were then reconstructed using the DICOM viewer (OsiriX, Rosset et al., 2004). In this study, we defined the AMF as the foramen that was located around but smaller than the mental foramen (MF) and displayed continuity with the mandibular canal by CBCT, as proposed by Naitoh et al. (2011). Furthermore, nerves and/or arteries travelled through the AMF (Iwanaga et al., 2015). The other foramina, which displayed discontinuity with the mandibular canal, were excluded. We analyzed the following components in mandibles with AMF: incidence, sex and age, position of the AMF as observed from the MF, area of the AMF and MF, AMF/MF ratio (area of AMF/area of MF ipsilateral to the AMF × 100%), MF/MF ratio (area of MF ipsilateral to the AMF/area of MF contralateral to the AMF × 100%), distance from MF to AMF (measured between the closest edges), distance between the lower border of the mandible and MF and distance between the lower border of the mandible and AMF. The following components were also analyzed in the same number of mandibles without AMF (the normal MF group): sex, age, MF area and distance between the lower border of the mandible and MF. The area of each foramen was calculated using the following formula: elliptical area = $\pi \times$ (long axis)/2 $\times$ (short axis)/2.

Anatomical dissection

Following CBCT analysis, the periosteum was carefully detached from the mandibular bone and confirmed neurovascular bundles set off from the mandibular bone comparing with CBCT images (Fig. 1A and B). To investigate the distribution of the nerves and arteries travelling through the MF and the AMF, the neurovascular bundles were dissected from the mandibular bone, and the periosteum was removed with a stereomicroscope from the medial side of the soft tissue (Fig. 1C). Nerve running routes were observed, and artery external diameter was measured using caliper just after setting off the MF, and investigated the distribution. Nerve branch distributions were divided into four groups based on studies by Hu et al. (2007) and Won et al. (2014): the mental branch (MB), the medial inferior labial branch (*m*-ILB), the lateral inferior labial branch (ℓ-ILB) and the angular branch (AB). Based on CBCT imaging and gross anatomical observation results, the relationship between AMF location and area and neurovascular bundle components were analyzed. The protocol for the present study did not include any specific issue that needed to be approved by the ethics committees of our institutions, and was performed in accordance with the requirements of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013).

RESULTS

CBCT findings

Accessory mental foramina incidence and number

We analyzed 126 sides of 63 mandibles. Of these, 14 sides in nine (6 men and 3 women) mandibles (14.3%) displayed a total of 20 AMF. Four mandibles had a unilateral AMF (right: 1, left: 3), while five mandibles had bilateral AMF. Three sides in two mandibles had three AMF on each side. The number of AMF ranged from one to six in each mandible.

Age

The mean ages were 85.9 years ± 7.8 years (range: 71–97 years), 78.1 years ± 12.1 years (range: 39-96 years) and 81.0 years ± 9.2 years (range: 61–93 years) in the AMF group, the group without AMF and the normal MF group, respectively.

Accessory mental foramina position relative to the MF

The MF position ranged from the distal part of the first premolar tooth to the mesial part of the first molar tooth in all cases. Thus, AMF position was divided into eight areas relative to the position of the MF centrally. Two horizontal lines were defined as parallel to the occlusal plane passing by the superior and inferior edge of the MF, and two vertical lines were defined as perpendicular to the occlusal plane passing by the anterior and posterior edge of the MF. One AMF was located superior to the MF, three were anterosuperior, one was anterior, four were anteroinferior, one was inferior, two were posteroinferior, one was posterior and seven were posterosuperior (Fig. 2).

Mental foramina and AMF size

The mean area of the 20 AMF in nine mandibles was 1.8 mm^2 ± 1.4 mm^2 (range: 0.2–5.1 mm^2). The mean areas of the MF ipsilateral and contralateral to the AMF were 12.9 mm^2 ± 8.0 mm^2 (range: 3.8–36.2 mm^2) and 14.3 mm^2 ± 7.2 mm^2 (range: 5.6–36.2 mm^2), respectively. The mean area of the other MF in 9 mandibles without AMF, was 13.1 mm^2 ± 7.0 mm^2 (range: 6.0–33.3 mm^2).

Accessory mental foramina to mental foramina ratio

The mean AMF/MF ratio was calculated as follows: AMF area/area of MF ipsilateral to the AMF × 100%. The mean ratio was 20.9% ± 27.2% (range: 2.4–98.7%). The AMF/MF ratio of the large AMF, named the double MF, was greater than 90% (Fig. 3). Two double mental foramina were present in this study.

Distance between the MF and the AMF

The mean distance from the MF to the AMF was 8.7 mm ± 4.3 mm (range: 1.5–16.2 mm). The distance was measured between the closest edges.

Distance between the lower border of the mandible and the MF or the AMF

The mean distance between the lower mandible border and the MF ipsilateral to the AMF was 14.5 mm ± 1.9 mm (range: 10.2–17.4 mm). The mean distance between the lower mandible border and the AMF was 17.9 mm ± 5.7 mm (range: 9.3–25.9 mm). The mean distance in the normal MF group was 14.4 mm ± 1.5 mm (range: 12.2–16.3 mm).

Gross anatomical observations by stereomicroscope

Number of AMF through which an artery only, a nerve only or an artery with a nerve pass

We observed only nerves in 15 of 20 AMF. Four AMF displayed only arteries, which communicate to inferior labial arteries not including nerves. Only one AMF had both a nerve and an artery passing through (Fig. 2).

Mental nerve and AMN distribution

We observed that AMNs travel through 16 of 20 AMF. The ILB or communicating branches to the ILB primarily coursed through the AMF located superior to the MF. The ℓ-ILB and AB, or communicating branches to the ℓ-ILB and AB, primarily travelled through the AMF located posterior to the MF. The nerve bundles from the AMF located anterior or inferior to the MF primarily traveled through the mental region or communicated with the *m*-ILB and MB. The four mental nerves (MNs) derived from the MF without AMF ipsilateral to the MF branched off the AB, ℓ-ILB, *m*-ILB and MB (Fig. 4).

Arterial mental arteries and mental arteries

Mental arteries (MAs) and AMAs could be observed in 77 sides in 43 mandibles (79 arteries) of 126 sides in 63 mandibles. There were 74 and five MAs and AMAs, respectively. Three of five AMAs were identified in mandibles without MAs. The mean MA and AMA external diameters were 0.5 mm ± 0.2 mm (range: 0.1–1.0 mm) and 0.6 mm ± 0.1 mm (range: 0.5–0.8 mm), respectively. All arteries anastomosed with inferior labial arteries.

Relationship among AMF area, distance between the MF and the AMF, and the neurovascular system

The five AMF located anterior, superior and anterosuperior to the MF tended to be large compared with the MF (mean AMF/MF ratio: 55.6%), and the distance between the MF and the AMF was small (mean: 3.7 mm ± 1.1 mm). In contrast, eight AMF located posterior or posterosuperior to the MF tended to be small compared with the MF (mean AMF/MF ratio: 6.6%), and the distance between the MF and the AMF was large (mean: 10.0 mm ± 3.6 mm). The large ILBs traveled through two AMF that were a similar size to the MF ipsilateral to the AMF and opened proximally to the MF (1.5 mm and 4.5 mm). We observed 65% (13/20) of AMF in the same or higher position (Fig. 3). In addition, three AMF of seven that were located in a lower region than the MF had only arteries (Fig. 5).

The results of CBCT examination and the gross anatomical dissection are displayed in Table 1.

DISCUSSION

The present study demonstrated that AMF incidence is 14.3%, as determined by CBCT. Previous studies have reported AMF incidences between 5.5% and 13.0% by observation of the dry skull (Singh et al., 2010; Udhaya et al., 2014) and between 2.0% and 11.9% by CT studies (Kalender et al., 2012; Sisman et al., 2012). Bilateral AMF are rare and have been described in only 6–8% of AMF cases, corresponding to approximately 0.53% of the total population (Oliveira-Santos et al., 2011; Kalender et al., 2012; Sekerci and Sisman, 2014). Unilateral AMF occur in single, double or triple forms. Mandibles with triple AMF unilaterally are very rare and have only been reported by Kalender et al. (2012) and Sisman et al. (2012). In this study, we identified five mandibles with bilateral AMF and two with multiple foramina unilaterally. Although definition of the AMF have been proposed by many researchers including us, it is very difficult to set a boundary between small AMF and just foramina because the resolution differs depending on the model of CBCT and there are some large AMF which has unclear continuity with the mandibular canal. We thought that is the reason why AMF incidence varies widely depending on the reports. Patil et al. (2013) examined different age groups and found no significant differences in the groups analyzed. The present study used donated cadavers and, thus, most individuals were elderly, where the mean ages in the groups with and without AMF were 85.9 years ± 7.8 years and 78.1 years ±

12.1 years, respectively.

Accessory mental foramina sites, size and distance from MF and AMN innervation

Many literature reviews have demonstrated that the majority of MF are positioned in the longitudinal axis of the second premolar or in the longitudinal axis passing between the first and second premolar (Udhaya et al., 2013). We observed that in all 54 mandibles without AMF, the MF was located in the same position. Thus, AMF position was divided into eight areas relative to the position of the MF centrally and based on the assumption that MF position does not differ significantly between individuals. Although some studies have described the typical AMF sites, there is still no consensus. Iwanaga et al. (2015) suggested that AMF appear to be located posterior to the MF rather than anterior. In the present study, we investigated not only the common AMF positions but also the relationship between position, area and the neurovascular bundles that travel through the AMF. The results indicated that the mean AMF area tended to vary by position, and neurovascular bundle thickness and components may depend on AMF location. Thus, at the same level or in a higher position than the MF, the large AMF tended to be located anterosuperior and close to the MF. The small AMF tended to be located posterosuperior to the MF and may have a higher incidence and increased distance than those anterosuperior to the MF. In addition, the larger AMF had more nerve bundles, except in the presence of arteries. Iwanaga et al. (2015) indicated that the mean area of the MF contralateral to the AMF may be smaller than that of the MF contralateral to the AMF. In the present study, four mandibles had unilateral AMF, and all four had the smaller MF ipsilateral to the AMF rather than the MF contralateral to the MF. The result also showed the closer area of the AMF to the MF ipsilateral to the AMF, the larger difference between the size of right and left MF (Table 1). It is thought that, in the presence of the AMF, some parts of the neurovascular bundles that pass through the MF are transferred to the AMF.

Embryologically, the mandible bone and the MF are induced following formation of the inferior alveolar nerve during the 12th week of gestation (Balcioglu et al., 2011). Thus, normal MF is formed by bone addition around the nerve bundles before branching. Iwanaga et al. (2015) described that the AMF is formed by bone addition after branching. AMF size may be affected by nerve bundle thickness. The thin bundles induced the small AMF, while the thick bundles induced the large AMF.

The MN distribution pattern has been previously described. One study indicated that the MN was divided into multiple branches to supply the skin and mucous membrane of the lower lip and the skin of the chin (Drake et al., 2005). Another study indicated that the MN was divided into three branches, the MB, the ILB and the AB (Kamijo, 1967). Hu et al. (2007) and Won et al. (2014) determined that the ILB innervated a wide range and was divided into two groups, the *m*-ILB and the ℓ-ILB. Our previous study revealed that two large trunks were primarily located towards the inferior labial region, consistent with the work of Hu et al. (2007) and Won et al. (2014) (Fig. 4). The distribution pattern of the AMN, which is the nerve bundle associated with the mandibular bone after branching from the MN, is thought to depend on AMF position, consistent with the results of this study. In particular, the AMF near the mental region conveyed the MBs, while the AMF near the inferior labial and angular regions conveyed the ILBs and ABs, respectively (Fig. 6). In the present study, two mandibles had a large AMF, approximately the same area as the MF, and both conveyed the ILB. Thus, we presumed that these two AMF had been formed as a result of addition of the bone around the nerve bundles soon after the ILB divided into two branches. In two present cases, the AMF were very close (1.5 mm and 4.5 mm) to the MF. Thus, we hypothesized that AMF located close to and with a similar size as the MF tend to have thick ILB bundles, and we defined these as double MF (Fig. 3). In contrast, AMF located 10 mm or more from the MF had small areas, and the AMF/MF ratio was a maximum of 21.2%. AMF located far from the MF may not have a thick ILB. If there are large AMF located far from the MF, it may be because of the passage of an artery.

Arteries passing through the AMF

We defined the artery passing through the AMF as the AMA. The MA feeds the inferior labial region as well as the inferior labial artery, which is a branch of the facial artery (Crouzet et al., 1998; Norton et al., 2011). However, there are few reports describing the MA (Crouzet et al., 1998). In the present study, 79 arteries, including the MA and the AMA, could be observed in 126 sites in 63 mandibles. There are a few explanations as to why MAs could not be identified in all 126 sites. First, the arteries are very thin (range: 0.1–1.0 mm). Though there are no previous reports investigating the diameter of the MA, Kilic et al. (2010) analyzed the diameter of the mandibular canal and the neurovascular bundles. They determined that the mean diameters of the mandibular canal and the inferior alveolar artery were approximately 2.5 mm and 0.4 mm, respectively. Thus, the MA diameter is thought to be similar, consistent with our findings. Second, it is possible that the MA is not present in all sites. Additional investigations, such as contrast imaging with μCT, are warranted. To our knowledge, there are no studies describing the AMA. Kamijo (1967) determined that the branches of the submental artery entered into the mandibular bone through the small foramen of the mandibular fossa. Fuakami et al. (2011) observed that the branches of the facial artery, submental artery, buccal artery and MN entered the mandible through the accessory buccal foramina. Smartt et al. (2005) determined that the blood supply to the majority of the postnatal developing mandible is via the inferior dental artery and the periosteal plexus provided by the terminal branches of the lingual and facial arteries. Thus, the mandibular bone is supplied by many arteries, and those arteries may form a complicated plexus. The MF and the AMF may be the path of anastomosis of those arteries, from the point of arterial system. Further investigation of the arteries around the mandible, including embryological studies, is in progress.

Clinical Significance

In general dental surgery, such as periodontal surgery, the region below the MF is often not affected, and thus, the AMF inferior to the MF may not be disturbed. However, in this study, the AMF were often positioned at the same level or higher than the MF. We observed 11 AMF superior and seven AMF inferior to the MF. Our findings indicate that, in the clinical setting, when the periosteal is detached from coronal to apical, the AMF may be injured before reaching the MF. Ramadhan et al. (2010) reported that during trauma surgery, the AMF were revealed when an intraoral approach for mandible repositioning and fixation was attempted. A submandibular approach was subsequently undertaken, resulting in an uneventful recovery. Recently, many general dentists have performed implant surgery, periapical surgery and periodontal surgery, resulting in opportunities to encounter the AMF and subsequent clinical case reports. Since CBCT become a popular technique, AMF research has drastically increased, and foramen morphology has been extensively investigated. Although three-dimensional CBCT images could facilitate AMF detection, they sometimes produce false-positive results. We have misdiagnosed a fistula as an AMF using a three-dimensional CBCT image. We have also confirmed that the undetectable small AMF depends on the viewer. Information regarding AMF is limited for clinicians, because relationships such as those between neurovascular bundles and foramen morphology have not been investigated. This study indicated that, like the MF, we should avoid injuring the AMF, and in particular large AMF, during oral surgery. Additionally, panoramic AMF examination yields a lower detection rate than that by CBCT (Naitoh et al., 2011). Thus, it is preferable to perform CBCT scans as a preoperative diagnosis when disruption to the region around the MF, particularly anterior and superior to the MF, may occur during implant, periodontal and periapical surgery with periosteal detachment.

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FIGURE LEGENDS

Figure 1. Observation process of the mental foramen (MF) and nerve (MN) and the accessory mental foramen (AMF) and nerve (AMN).

All three images depict the left side of the mandible. CBCT analysis was first performed by three-dimensional reconstruction of the image (A). The neurovascular bundles that arose from the MF and the AMF were observed by gross anatomical dissection (B). The base of the neurovascular bundles was removed, followed by the periosteum. Neurovascular bundle distribution was investigated from the medial side of the overlying soft tissue (C). The MN arose from the MF, and the AMN arose from the AMF, as indicated by the dotted line.

Black arrowhead: MF, White arrowhead: AMF, Scale bar: 1mm

Figure 2. Accessory mental foramen position, distance from the mental foramen, accessory mental foramen to mental foramen ratio and neurovascular bundle components.

Accessory mental foramen (AMF) position was divided into eight areas. The distance from the mental foramen (MF) to the AMF was plotted by relative distance. The AMF/MF ratio is expressed by varying circle size. The type of circle indicates the neurovascular bundle component.

Figure 3. Double mental foramen.

(A) Three-dimensional reconstructed image of the mandible. (B) Coronal image of the mandibular bone including the mental foramen (MF) and the accessory mental foramen (AMF). (C) Gross anatomical dissection of the MF and the AMF.

Black arrowhead: MF, White arrowhead: AMF, Scale bar: 10mm

Figure 4. Branching pattern of the right mental nerve displayed from the medial view.

The region surrounded by black dotted lines indicates the angular branch (AB), the lateral inferior labial branch (ℓ-ILB), the medial inferior labial branch (*m*-ILB) and the mental branch (MB).

Scale bar: 1mm

Figure 5. Left side of the mandible with only an artery through the accessory mental foramen.

The three-dimensional reconstructed image displays the small accessory mental foramen (AMF) posteroinferior to the mental foramen (MF) (A), and the axial image displays the continuity between the AMF and the mandibular canal (B). After periosteum detachment, the neurovascular bundles that arise from the MF and AMF were observed (C). Anatomical dissection revealed that the bundles arising from the AMF include only an artery. Medial view of the overlying soft tissue following removal of the periosteum. Black dotted lines indicate branches of the facial artery (D).

White arrowhead: AMF with only an artery passing through, Black arrowhead: MF, White arrow: accessory mental artery (AMA), Black arrow: inferior labial artery

Scale bar: 1mm

Figure 6. Accessory mental nerve distribution depends on the position of the accessory mental foramen.

Area a: angular region, Area b: lateral inferior labial region, Area c: medial inferior labial region, Area d: mental region

AB: angular branch, m-ILB: medial inferior labial branch, l-ILB: lateral inferior labial branch, MB: mental branch