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Evaluation of Perimandibular Neurovascularization With Accessory Mental Foramina Using Cone-Beam Computed Tomography in Children

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Objectives: The purpose of this study was to clarify the perimandibular neurovascularization with mandibular accessory mental foramina in a children population using cone-beam computed tomography (CBCT) to avoid complications during anesthetic and surgical procedures.

Methods: This retrospective study evaluated cone-beam CT images for bifid mandibular canals in the mandibles of 63 children (35 girls, 28 boys; age range, 7–16 years; mean age, 12.3 years). Both right and left sides were examined from CT images (n = 126), including axial, sagittal, cross-sectional, and panoramic views as well as reconstructed three-dimensional images, as necessary. The course, length, and superior and inferior angles between canals were classified and measured.

Results: Bifid mandibular canals were observed in 34 (27%) of the 126 sides examined. The most frequently encountered type of bifid canal was the retromolar canal (11.1%), followed by the forward (7.14%), buccolingual (6.35%), and dental canal (2.4%). Mean lengths of bifid canals were 10.2 mm on the right side and 10.6 mm on the left side. Mean superior angles were 131 degrees on the right side and 147 degrees on the left side, whereas mean inferior angles were 47 degrees on the right side and 34 degrees on the left side. No statistically significant differences were found in the lengths or angles between the right and left sides or between boys and girls ($P < 0.05$). The most common position for the mental foramen was between the first and second premolars, and an accessory mental foramen was observed in 4 children (6.34%).

Conclusions: This study utilized CBCT images to identify bifid mandibular canals and accessory mental foramina in children. Cone-beam CT was found to be a useful technique for detecting secondary canals. However, despite the fact that CBCT uses less ionizing radiation than other types of three-dimensional imaging, unless the diagnostic information provided through CBCT improves treatment results, CBCT should not be recommended for use in children or adolescents.

Key Words: Mandible, mental, canal, anatomy, bifid

The mandibular canal transmits the inferior alveolar nerve and vessels supplying the mandibular teeth and adjacent structures. This hollow space surrounded by bony tissue extends from the mandibular foramen posteriorly toward the mental foramen anteriorly.[1] In conventional radiographs, the mandibular canal appears as a dark, linear shadow with thin, radiopaque superior and inferior borders cast by the lamella of bone that bounds the canal.[2]

The location and the configuration of the mandibular canal and the mental foramen are important for surgical procedures that involve the mandible[3] and must be identified preoperatively to prevent confusion with bony pathosis defects. Although the canal is generally composed of a single structure, variations such as bifid and trifid canals have been reported.[4–7]

The term *bifid* is derived from the Latin word meaning “cleft into 2 parts or branches.”[8] Chavez-Lomeli et al[9] suggested that 3 distinct inferior dental nerves innervating 3 groups of mandibular teeth—incisors, primary molars, and permanent molars—are fused together during embryonic development to form a single nerve, with bifid and trifid mandibular canals occurring as a result of incomplete fusion of these 3 nerves.

The prevalence of bifid mandibular canals can be determined using dental panoramic radiography, computed tomography (CT), or cone-beam CT (CBCT). Studies[5,6,8,10] in which dental panoramic radiographs have been used to identify bifid mandibular canals have reported incidences rates of less than 1.0%. However, conventional radiographs have several drawbacks, including errors of projection and errors of identification. Ghost shadows produced by the opposing side of the mandible, the pharyngeal airway, the soft palate, and the uvula may hamper the localization of the mandibular canal.[2] Panoramic radiography has also been reported to be unable to identify buccally and lingually bifurcated canals.[11] In 1 study, dental panoramic radiographs failed to identify 3 of 5 bifid canals that were identified using multislice CT images.[12] Studies in which CT imaging[13,14] and low-dose CBCT imaging[12,15,16] were used to identify bifid mandibular canals found much higher prevalence rates than those reported using panoramic radiography.

Location of the mandibular canal and mental foramen in children is important for mandibular surgical interventions such as sagittal split osteotomies and molar tooth extractions as well as for successful inferior alveolar nerve blocking. To the best of our knowledge, the literature has not reported on the prevalence of

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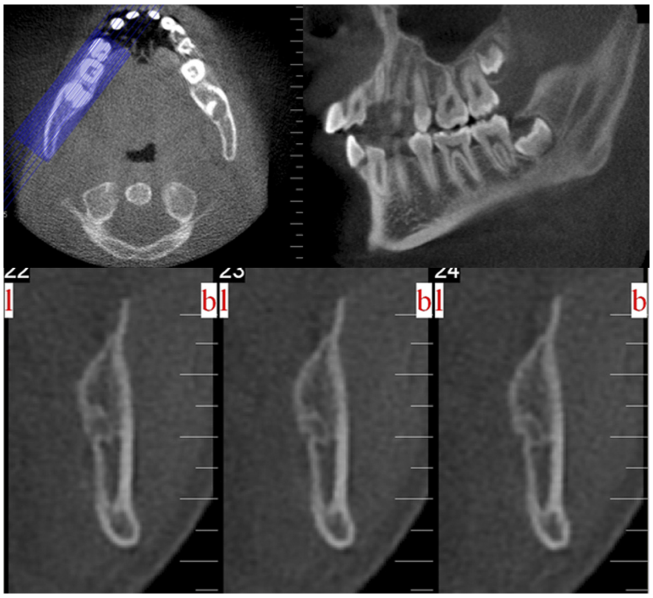

FIGURE 1. Reconstructed axial, cross-sectional, sagittal CBCT images used for detection and measurement of the bifid mandibular canals.

variations of mandibular canals in children. Therefore, this study aimed to identify the incidence and location of bifid mandibular canals in a study population comprised of children and adolescents using CBCT.

MATERIALS AND METHODS

The study population was composed of 63 children (35 girls [55%], 28 boys [45%]; mean age, 12.3 years; age range, 7–16] years) who had undergone CBCT imaging for impacted third-molar surgery, management of impacted canine/premolar teeth, cyst imaging, or orthodontic treatment. All images were taken in a private dental imaging center (Teknogem, Istanbul, Turkey). Before imaging, informed consent was obtained from patients or their legal guardians. Low-quality images that showed scattering or failed to provide accurate representations of bony borders were excluded from the study.

CBCT Imaging

Cone-beam CT scans were obtained using a NewTom 3G (Quantitative Radiology, Verona, Italy). Despite recent studies indicating that small variations in head position do not influence the accuracy of three-dimensional CBCT measurements,[17] every CBCT scan was standardized according to the imaging center's strict scanning protocol. Children were placed in a horizontal position, stabilized with custom-made headbands and chin supports, and monitored to ensure that they remained motionless throughout the duration of the scan (36 seconds). All images were recorded at 120 kVP and 3 to 5 mA using a 9-in field of view, an axial slice thickness of 0.3 mm, and isotropic voxels. The NewTom 3G automatically defines kV and mA parameters from previews and permits variations in exposure of up to 40%, depending on the size of the patient and the extent of beam attenuation. Images were transferred to a database and downloaded to a workstation for reconstruction and measurement. All procedures were performed using a Windows XP–based, 64-bit PC with 2 quad-core 2.83-GHz Xenon processors and a 21.3-in flat-panel, active-matrix color TFT medical display (Nio Color 3MP, Barco, Belgium) with 2048 × 1536 resolution at 76 Hz and 0.2115-mm dot pitch operated at 10 bit.

Image Evaluation

All CBCT images were evaluated retrospectively by an oral and maxillofacial radiologist and a pediatric dental consultant who were blinded to all patient data. Examiners were calibrated to recognize and agree on parameters for identifying mandibular canals, bifid mandibular canals, and surrounding structures using 50 CBCT images obtained from the same imaging center as those used in the study. During calibration, the examiners also received detailed explanations about the CBCT imaging process. Identification of the radiographic course of the canals from the CBCT images used in this study was recorded based on consensus between the 2 examiners.

Axial, sagittal, cross-sectional, and panoramic images were reconstructed for all semimandibles, with three-dimensional reconstructions used as necessary (Fig. 1). Bifid mandibular canal course and length were measured from either sagittal or panoramic CBCT images reconstructed using the CBCT system's own software, which allows the observer to measure both straight and curved structures. Bifid mandibular canal length was measured from the point of separation from the main canal to the termination of the bifid canal in the mandible. The superior and inferior angles between canals were also measured using the CBCT system software from reconstructed sagittal or panoramic images. The superior angle was defined as the angle between the main canal and the superior wall of the bifid canal, and the inferior angle was defined as the angle between the main canal and the inferior wall of the bifid canal (Fig. 2).

Bifid mandibular canals were classified by location into 1 of 4 main groups, namely, forward, retromolar, buccolingual, or dental canals. Forward canals were further subdivided into those with and without confluence, whereas the other groups were named as dental canals and buccolingual canals (which were subdivided into either buccal or lingual canals separately) following the classification of Naitoh et al[16] for bifid mandibular canals.

The position of the mental foramen was recorded as follows[18]: (1) in line with the first permanent molar, (2) between second premolar and first permanent molars, (3) in line with second premolar, (4) between first and second premolars, (5) in line with first premolar, (6) anterior to first premolar, (7) anterior to first primary molar, (8) in line with first primary molar, (9) between first and second primary molars, and (10) in line with second primary molar.

The position of any accessory mental foramen was recorded as follows: (1) posterosuperior, (2) posterior, (3) posteroinferior,

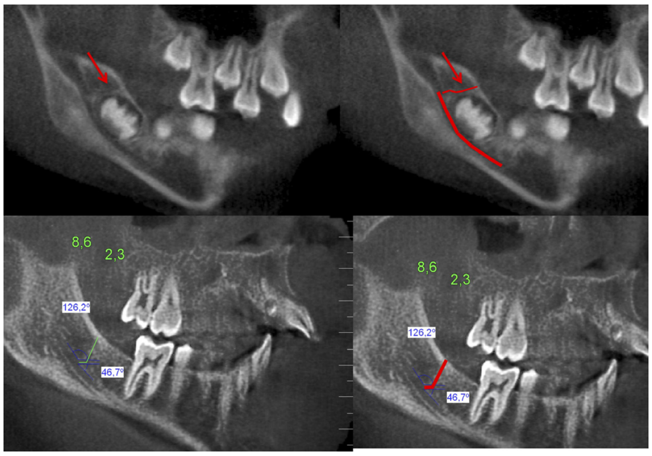

FIGURE 2. Sagittal images showing the bifid mandibular canal with and without length measurement of the canal in the same patient (Fig. 1), sagittal image also showing the measurement of superior and inferior angle of the bifid mandibular canal. Note that the superior angle is the angle between the main canal and superior wall, whereas the inferior angle was the angle between the main canal and inferior wall of bifid mandibular canal (below).

TABLE 1. Prevalence and Rate of Bifid Mandibular Canal According to Sex, Type, and Localization

Classification	Of All Patients, % (n = 63)	Of All Sides, % (n = 126)	Left Side			Right Side		
			Male, n (%)	Female, n (%)	Total, n (%)	Male, n (%)	Female, n (%)	Total, n (%)
Type 1: retromolar canal	22.20%	11.10%	3 (11.1)	2 (7.40)	5 (18.5)	6 (22.2)	3 (11.1)	9 (33.3)
Type 2: dental canal type	4.76%	2.40%	1 (3.70)	0 (0)	1 (3.70)	2 (7.40)	0 (0)	2 (7.40)
Type 3: forward canal	14.28%	7.14%	3 (11.1)	0 (0)	3 (11.1)	5 (18.5)	1 (3.70)	6 (22.2)
a. With confluence	4.76%	2.38%	1 (3.70)	0 (0)	1 (3.70)	2 (7.40)	0 (0)	2 (7.40)
b. Without confluence	9.52%	4.76%	2 (7.40)	0 (0)	2 (7.40)	3 (11.1)	1 (3.70)	4 (14.81)
Type 4: buccolingual canal	12.80%	6.35%	2 (7.40)	3 (11.1)	5 (18.5)	1 (3.70)	2 (7.40)	3 (11.1)
a. Buccal canal	4.76%	2.38%	1 (3.70)	1 (3.70)	2 (7.40)	0 (0)	1 (3.70)	1 (3.70)
b. Lingual canal	7.92%	3.96%	2 (7.40)	1 (3.70)	3 (11.1)	1 (3.70)	1 (3.70)	2 (7.40)

(4) superior, (5) inferior, (6) anterosuperior, (7) anterior, and (8) anteroinferior.

Sex differences among the groups were also assessed using Mann-Whitney *U* statistical test ($P < 0.05$). Each observer obtained 3 measurements, and the mean of these measurements was recorded for analysis. Intraobserver variability was examined by having the observers reevaluate the images after an interval of 2 weeks.

Statistical Analysis

Statistical analysis was performed using the software program SPSS 12.0.1 (SPSS, Chicago, IL). Interobserver and intraobserver reliability was assessed using Wilcoxon matched-pairs signed rank tests. Differences in localization and measurements between male and female subjects were identified using Pearson χ^2 and Student *t* tests ($P < 0.05$).

RESULTS

No significant intraobserver or interobserver differences were observed ($P > 0.05$). Intraobserver consistency was 93.8%, and interobserver agreement was 91.9%. Bifid mandibular canals were identified in 34 (26.9%) of 126 sides and in 27 (42.8%) of 63 patients. Bifid mandibular canals were observed in 11 females (17.4%) and 17 males (26.9%). The incidences of different types of bifid mandibular canals are given in Table 1.

The most frequently observed type of bifid canal was the retromolar canal (n = 14; 9 right side [7.14%], 5 left side [3.96%]; Fig. 3]), followed by the forward canal (n = 9; 6 right side [4.76%], 3 left side [2.38%]; Fig. 4A]), the buccolingual canal (n = 8; 3 right side [2.38%] and 5 left side [3.96%]; Figs. 4B, C]), and the dental canal (n = 3; 2 right side [1.58%] and 1 left side [0.79%]; Fig. 4D]). Of the 9 forward canals identified, 3 (2.38%) occurred with confluence, and 6 (4.76%) without confluence. All (100%) of the 3 dental canals identified extended to the root apex of the third molar. Of the 8 buccolingual canals identified, 3 (2.38%) were buccal, and 5 (3.96%) were lingual canal (Table 1).

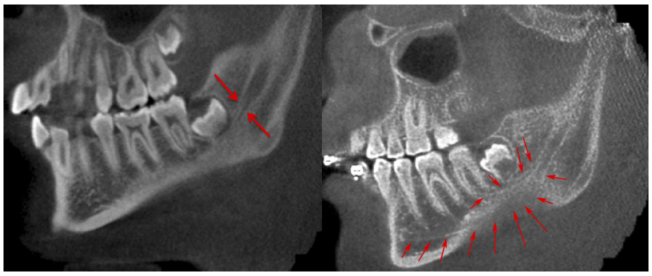

FIGURE 3. Forward canals without confluence (arrows), which bifurcated from the mandibular.

All dental canals entered the teeth from the apex of the root. Forward canals with confluence reentered the main canal, whereas forward canals without confluence extended to the premolar/primary molar region and located in buccal plate of the mandible (Fig. 3). All buccal and lingual canals were located in the mandibular ramus (Figs. 4 and 5).

The mean length of bifid canals located in right semimandibles was 10.2 mm, compared with 10.6 mm for those in left semimandibles. When looked at by type, the mean length of bifid retromolar canals was 11.37 mm (right side, 11.34 mm; left side, 11.42 mm), compared with 8.36 mm for dental canals (right side, 8.1 mm; left side, 8.4 mm), 16.31 mm for forward canals (right side, 15.68 mm; left side, 16.94 mm), and 2.62 mm for buccolingual canals (right side, 2.73 mm; left side, 2.56 mm).

The mean superior and inferior angles of bifid canals located in right semimandibles were 131 and 47 degrees, respectively, compared with 147 and 34 degrees, respectively, on the left side. When differentiated by type as well as side, the mean superior angles of bifid retromolar, dental, and forward canals located in right semimandibles were 113, 169.1, and 144.9 degrees, respectively, compared with 126.2, 152.9, and 173.4 degrees, respectively, for retromolar, dental, and forward canals located in left semimandibles, whereas the mean inferior angles of bifid retromolar, dental, and forward canals located in right semimandibles were 63.84, 28.32, and 33.58 degrees, respectively, compared with 53.98, 29.22, and 31.66 degrees, respectively, for bifid retromolar, dental, and forward canals located in left semimandibles. Neither the length nor the angle of the bifid canal varied significantly by the side of the mandible or by the sex of the patient ($P < 0.05$). Figure 6 shows a photographic view of the surgical extraction of a third molar in a 16-year-old male patient with a bifid mandibular canal.

The mental foramen was most commonly located in position 3 (in line with the second premolar) or position 4 (between the first and second premolars). No incidences were found of a mental

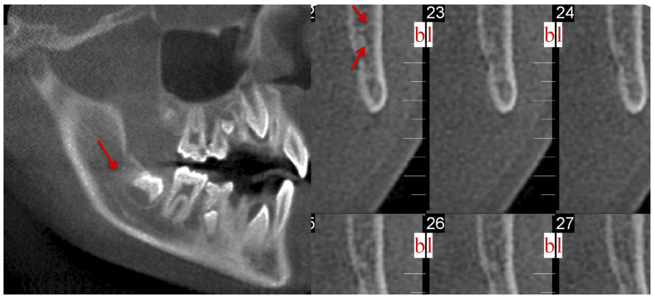

FIGURE 4. Sagittal reconstructed image showing retromolar canal type, which bifurcated from the main canal to retromolar region, cross-sectional images also showing buccal canals bifurcated from the main canal to lingual and buccal side of the mandible.

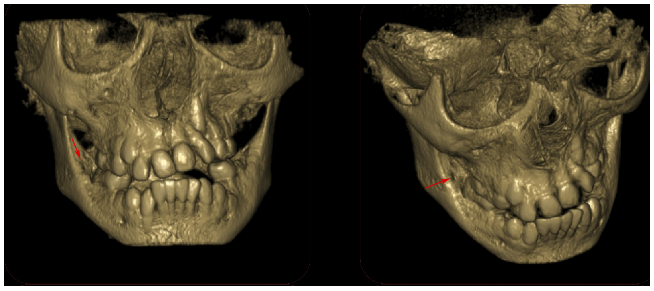

FIGURE 5. Three-dimensional representations of bifid mandibular canal openings.

foramen in position 1, 2, 6, 7, or 10. The mental foramen was found to have a mean height of 3.3 mm (range, 1.5–5.8 mm) and a mean width of 3.1 mm (range, 1.5–6 mm). Both the height and width of the mental foramen varied significantly ($P < 0.05$) between age groups.

An accessory mental foramen was observed in 4 children (6.34%)—3 girls and 1 boy. Of these, 2 were aged 10 years and 1 each was aged 14 and 16 years. In terms of localization, 2 were located posteroinferiorly to the mental foramen, 1 posteriorly and 1 posterosuperiorly. The mean height and width of the accessory mental foramen were 1.3 and 1.2 mm, respectively.

The mean distance between the mental and accessory mental foramen was 6.7 mm. Significant difference was found for the distance between the mental foramen and the alveolar ridge, which varied significantly by age group, with the greatest mean distance found in the 16- to 18-year age group (13.2 mm), followed by the 13- to 15-year age group (12.1 mm) and the 6- to 12-year age group (11.7 mm). The mean distance between the mental foramen and the nearest tooth was 3.3 mm.

DISCUSSION

An understanding of perimandibular neurovascularization is important in terms of avoiding complications during anesthetic and surgical procedures. This study used CBCT to identify the incidence of bifid mandibular canals and accessory mental foramina in the semimandibles of a child population. Of a study population of 63 children, 27 (42.8%) were found to have bifid mandibular canals, and 4 (6.34%) were found to have accessory mental foramina.

Previous studies using panoramic radiography have reported bifid mandibular canals at rates ranging from 0.08% to 0.95%[5,6,8,10]; however, identification of bifid canals using panoramic radiography is complicated by ghost shadows created by the opposing semimandible, pharyngeal airway, soft palate, and uvula.[2] Moreover, the two-dimensional nature of panoramic radiography may result in the appearance of thin, cortical outlines in images of the mandible that may simulate the presence of a bifid canal. False images may also be produced by radiological osteocondensation caused by the insertion of the mylohyoid muscle into the internal mandibular surface.[19] Because of these limitations, three-dimensional imaging is required to reveal the anatomical truth, and CBCT examination has been recommended as a low-cost method with an effective radiation dose less than that of medical CT imaging and only slightly higher than that of panoramic radiography.[14] Not only does CBCT impart less radiation than CT imaging, it has also been reported to provide better image quality than CT imaging.[3,12,13,16,20] For example, multislice CT images in the retromolar region have been found to be negatively affected by artifacts from metal restorations and crowns.[12]

Different classifications have been used to describe bifid mandibular canals.[5,6,16] In line with a CBCT study conducted by Naitoh et al,[16] the present study classified bifid mandibular canals into 4 main types. This study found bifid mandibular canals to be present in 42.8% of children and 26.9% of unilateral mandibles, which is lower than the findings of Naitoh et al (65% and 43%, respectively). Both of these studies, as well as a study by Bilecenoğlu and Tuncer,[21] were conducted with dry mandibles. Different studies reported different prevalence rates for different types of bifid mandibular canals. For example, the present study found retromolar bifid canals to be present in 41% of sides in the present study, compared with 13.5% in Naitoh et al[16] and 15%, in Bilecenoğlu and Tuncer,[21] respectively. Moreover, in the present study, the retromolar canal was found to be the most commonly occurring type of bifid mandibular canal (41%), whereas the least common type was found to be the dental canal (8%), whereas Naitoh et al[16] found the forward canal to be the most common type of bifid mandibular canal (44.3%) and the buccolingual canal to be the least common type (1.6%). Although some authors[6,8,17,20] have reported a slightly higher incidence of bifid mandibular canals among females, our study found no significant difference between males and females in the incidence of bifid mandibular canals.

Effective pain control is critical in dentistry. Painful treatment has been shown to be an important factor in the etiology of dental fear, with individuals who experience pain while receiving dental care as children more likely to avoid dental care as adults.[22] Common procedures such as root canal treatment, extractions, and surgical procedures performed in the posterior mandible require administration of an inferior alveolar nerve block. Although sufficient anesthesia is easily obtained when no anatomic variations exist, bifid canals may be associated with increased difficulty in obtaining inferior alveolar nerve block, especially in cases where there are 2 mental foramina, and patients may often experience dysthesia under mandibular anesthesia.[23] Whereas anesthesia of the soft tissue around the injection site, but not of the ipsilateral lip and chin, may be an indication of local anesthesia failure, anesthesia of the lips and chin, but not the teeth, may indicate the presence of a bifid mandibular canal or other anatomical variations.[24,25] When bifid or trifid mandibular canals are present, the use of the Gow-Gates or other alternative to the inferior alveolar technique is needed to block the inferior alveolar nerve.[26]

The presence of a bifid mandibular canal has important clinical implications for surgical procedures involving the mandible, such as impacted third-molar extraction and sagittal split ramus osteotomy. Failure to accurately localize a bifid mandibular canal may result in damage to the canal and other complications such as traumatic neuroma, paresthesia, anesthesia, and bleeding during surgery.[24,25] A retromolar canal may be particularly at risk of damage during surgical treatment of an impacted third molar because of its proximal location, whereas a bifid dental canal has implications for root canal treatment as well as extraction[16]; therefore, to perform safe, painless surgery in the posterior mandible in children, preoperative CBCT imaging may be required.

The positions of the mental foramen and accessory mental foramen are also important with regard to surgical procedures involving the mandible. In line with previous studies with Turkish populations,[27,28] the present study found the mental foramen to be the most commonly positioned between the first and second

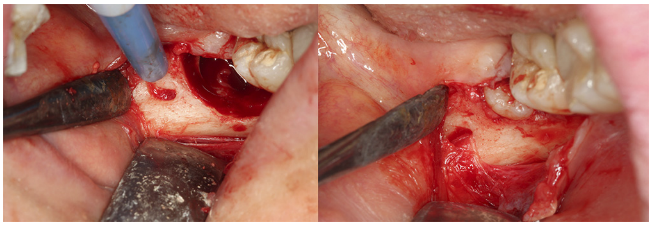

FIGURE 6. Photos showing third-molar extraction of 16 year old female with bifid mandibular canal. The image showing the nerve bundle.

premolars. In contrast, other studies with Turkish populations found the most common position of the mental foramen to be in line with the second premolar.[29,30]

There are many cadaveric and radiographic studies on the occurrence of accessory mental foramen, but no study has been reported in Turkish children population with CBCT. In our study, accessory mental foramina were seen in 4.25% of children.

The present study found the length and width of the mental foramen to be significantly smaller in children aged 6 to 12 years when compared with children in older age groups. This may be related to the growing process. The distance between the mental foramen and the alveolar ridge was also found to vary significantly among age groups (11.7 mm among children aged 6–12 years, 12.1 mm among children aged 13–15 years, 13.2 mm among children aged 16–18 years). In children whose permanent teeth have yet to erupt, the mental foramen is somewhat closer to the alveolar margin; during the eruption period, the mental foramen descends to half-way between the basis of the mandible.

The success of pediatric dental surgery may be affected by variations in the position of the mental foramen and the presence of an accessory mental foramen. In particular, an accessory mental foramen may result in local anesthetic failure.[31] Surgical extraction of a supernumerary tooth or removal of an odontoma near the mental foramen may also have a negative affect on neurovascularization if special care is not given to the exact location of the mental foramen.

Although most surgeons take a more conservative approach to mandibular fractures in children than in adults, management of severe injuries follows the same protocols in both cases. Osteosynthesis may be indicated in cases of simple or multiple fractures with displacement, especially when possibilities of conservative fixation are limited. A miniplate may be positioned at the lower border of the buccal side of the mandible, taking into consideration the position of the mental foramen and tooth germs.[32] In cases of trauma, all mandibular fractures should be handled with care to ensure precise alignment of the neurovascular bundle and avoid impingement when the fracture is healed; in cases where a second neurovascular bundle is located in a different plane, alignment of the fragments becomes much more difficult.[24]

CONCLUSIONS

The findings of this study indicate that the size of the mental foramen increases with age. Awareness of the possible presence of an accessory mental foramen is an important aspect to the application of anesthetics in children. Moreover, the higher rate of bifid mandibular canals and accessory mental foramina found in this study compared with earlier studies using panoramic radiography reinforces the conclusion that CBCT is better able to identify such anomalies than panoramic radiography.

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