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MORPHOMETRIC ANALYSIS OF THE INFERIOR ALVEOLAR CANAL AND ITS FORAMINA IN EGYPTIAN CHILDREN UTILIZING CONE BEAM COMPUTED TOMOGRAPHY: AN OBSERVATIONAL RETROSPECTIVE STUDY

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ABSTRACT

Aim: This study assessed the effect of age, gender, and arch side on the location, length, and diameter of the inferior alveolar canal and its foramina in a group of Egyptian children using cone beam computed tomography.

Material and Methods: Fifty scans of 10-15-year-old children of both genders were evaluated for the location, length, and diameter of the inferior alveolar canal, and the location and diameter of the mandibular and mental foramina on both sides of the jaw. Data was collected and analyzed using independent t test for comparing gender and age categories, and Paired t test for comparing arch sides.

Results: Age significantly affected the position of the inferior alveolar canal to the superior, P= 0.029 and inferior, P=0.034 mandibular borders, position of the mandibular foramen to the sigmoid, P=0.008, and the size of the inferior alveolar canal, P=0.012. Gender only significantly affected the position of the mandibular foramen to the anterior, P=0.035, and posterior, P=0.013 mandibular borders. The arch side significantly affected the position of the inferior alveolar canal to the superior border, P=0.025, and position of the mandibular foramen to the gonion, P=0.006.

Conclusions: Cone-beam computed tomography offers valuable insights into the dimensions and location of the inferior alveolar canal and its foramina for clinicians. Such information is crucial for procedures like mandibular block anesthesia, surgical extraction of supernumerary teeth, odontome removal, and managing severe mandibular fractures resulting from traumatic injuries.

KEYWORDS: Cone-beam CT, inferior alveolar canal, mandibular foramen, mental foramen, Pediatric dentistry

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INTRODUCTION

The inferior alveolar canal (IAC), alternatively referred to as the mandibular canal, is situated inside the mandible's internal aspect. Within this canal, one can find the inferior alveolar artery, vein, and nerve. Its course commences at the mandibular foramen (MF) and extends to the mental foramen (MnF). Variations in canal height and other anatomical characteristics could hold significant importance in safeguarding the inferior alveolar nerve (IAN) during surgical procedures involving the mandible [1]. The mandibular foramen (MF) serves as an aperture located on the mandible's inner side, allowing the IAN to traverse into the mandibular canal. This nerve pathway travels downward and forward within the mandible before eventually emerging through the mental foramen onto the chin. The precise position of this foramen is a paramount land mark in the IAN Block anesthetic procedure, and discrepancies in its placement are associated with a decreased success rate [2].

In children, the MF is situated below the occlusal plane of the primary teeth, specifically positioned between the first and second primary molars. Before the teeth emerge, the MF is closer to the alveolar ridge. As the teeth begin to erupt, it gradually moves downward, reaching a midpoint between the margins. Hence, it was recommended administering injections in children at a lower and more posterior site compared to adults [3], while others suggested delivering the local anesthetic agent near the MF, either directly at or slightly above the level of the occlusal plane in the primary dentition [4].

The MnF is a paired aperture located in the vestibular region of the mandible, from which the mental nerve, along with corresponding arteries and veins, emerge [5]. For simple restorative procedures, opting for a mental block instead of an IAN block is viable, as the latter may result in prolonged numbing in children and pose risks such as lip biting [6]. Akman and Surme [7] noted a posterior and upward shift in the position of the MF on the ramus with aging in panoramic radiographs, while Shaaban and El-Shall [8] observed gender-related variations in its location, even within individuals bilaterally. Plain radiographs like cephalometric ones often produce distorted images, limiting their validity, whereas panoramic radiographs offer various magnifications of the maxilla and mandible. Consequently, studies relying solely on such imaging may lack credibility [9]. Conversely, CBCT, an advanced technology, allows for precise identification of anatomical structures, thereby enhancing the validity of research in this domain [10].

Considerable studies have been held to analyze the location of the inferior alveolar canal [11,12,13] and its foramina [9,14,15,16] in adult population; however, studies aiming children population are scarce. Furthermore, to our knowledge, no studies have been conducted to examine the anatomical location, length, and dimensions of the inferior alveolar canal and its foramina in relation to different age categories, gender distinctions, and sides of the dental arch using CBCT scans. Hence, the objective of this study was to assess the effect of age, gender, and arch side on the anatomical location, length, and diameter of the inferior alveolar canal and its foramina in children employing CBCT imaging. The proposed hypothesis was that there is no effect of age, gender, and side of the arch on the anatomic location, length, and diameter of the inferior alveolar canal and its foramina.

MATERIAL AND METHODS

Study design and setting

This retrospective observational study was conducted on a convenience sample of 50 high quality CBCT images (both sides= 100 images) collected from the database of the Radiology Imaging Department, Pharos University in Alexandria, Egypt.

Ethics Approval

This retrospective study, which utilized data from human participants, adhered to the ethical guidelines established by the institutional and national research committee. It also conformed to the principles outlined in the 1964 Helsinki Declaration and its later amendments, or similar ethical standards. Prior to conduction of the study, approval was obtained from the Unit of Research Ethics Approval Committee (UREAC), Faculty of Pharmacy, Pharos University in Alexandria, Egypt, (PUA0220233263061). This study was conducted in an Educational Institute where all the legal guardians/care givers of children less than 16-year-old are requested to sign an informed consent granting an explicit permission for their records to be utilized for research purposes, with a steadfast commitment to honoring the confidentiality principles.

Eligibility criteria

In this exploratory study, we screened all the already available CBCT scans. Seventy-four scans of 10-15-year-old children who had undergone imaging for diagnosis of impacted canines or premolars, supernumerary teeth, or orthodontic treatment were selected from the recent database records presented from July 2021 till August 2023. Images included displayed acceptable occlusal mandibular plane, with no submerged or super erupted teeth, and exhibited satisfactory qualities with accurate depiction of the bony borders. Fifteen images of cases depicting pathology, bone fracture, or gross anatomical abnormality were excluded from the selection. Nine images were further excluded from the measurements because they were not well observed due to movement artifacts, (Fig.1). This study was reported following the STROBE guidelines for observational studies, (Supplementary file 1).

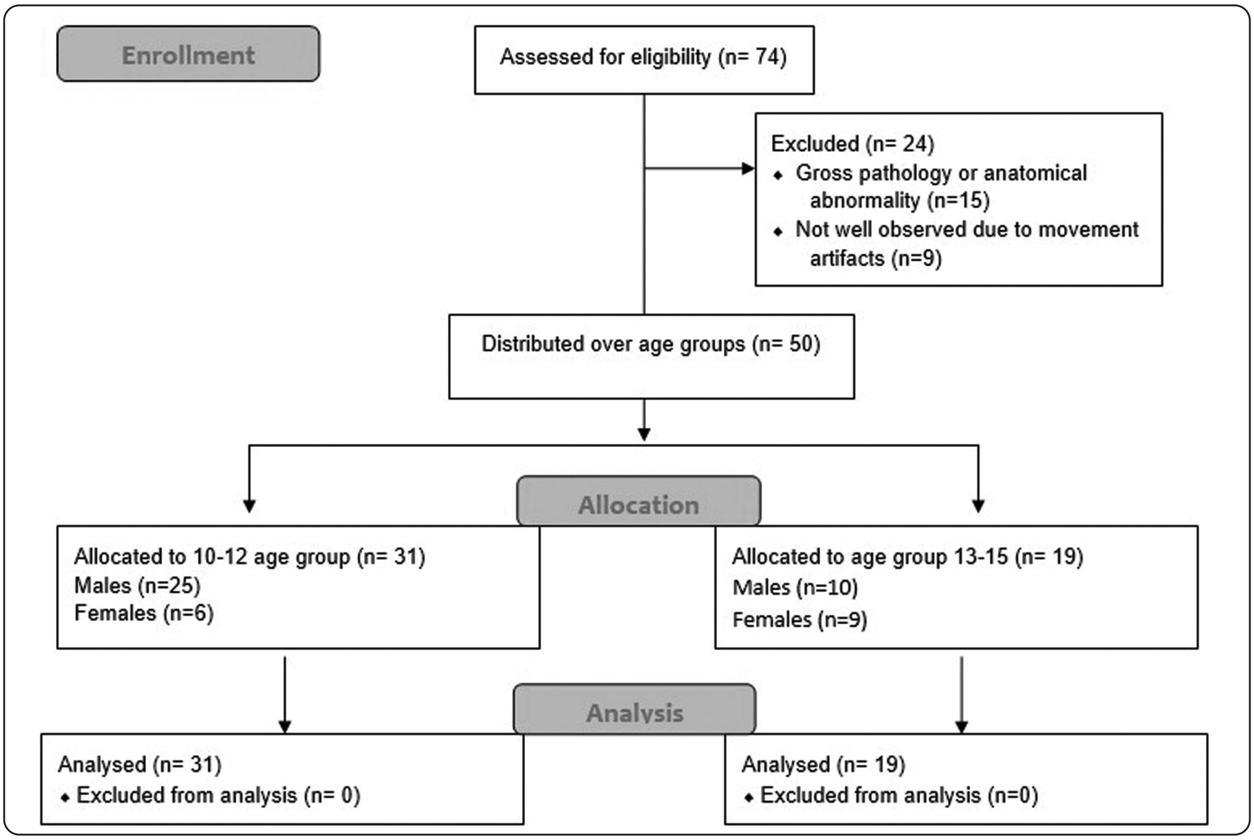

Fig. (1) Flow diagram of the study design.

Data selection

Two expert independent dental radiologists selected the CBCT images, and the mean measurements were recorded. The reliability of the obtained data was confirmed through the Intra-class Correlation Coefficient (ICC) test. The intra-rater agreement yielded a value of 0.905, while the inter-rater agreement was 0.788 [17]. The age groups were categorized into (10- >13) and 13-15-year-old categories.

For standardization purposes, it was ensured that all images were recorded by a single machine (Sordex Scanora Cone Beam CT 3Dx system, Germany) with parameters 90 KVp, 10mA, 4 secs, with field of view 14 x 16.5 cm, and single personnel was in charge of taking all the included images. All patients were positioned vertically with the aid of a chin rest and head strap to ensure stability throughout the procedure. The slice thickness was set at 2mm. Measurements were effectuated on a computer monitor using the official On Demand 3D software associated with the machine (On Demand), achieving a precision of 0.1 mm.

Measurements

1. Length of inferior alveolar canal: measured on a panoramic view from the mandibular foramen to the mental foramen [12], (Fig. 2 a, b).
2. Diameter of the inferior alveolar canal: measured on a cross section view at 3 points; point A is 1cm from the beginning of mandibular foramen, point B is opposite to the furcation of the second primary molar/premolar if present or imagine its position, and point C is 1cm from the beginning of the mental foramen [12], (Fig 3 a, b, c).
3. Position of the inferior alveolar canal: measured on a cross section view at the same previous 3 points; (A, B, C) to the superior and inferior borders of the alveolar ridge [12], (Fig. 3 d, e, f).
4. Position of the mandibular foramen: measured on a sagittal view relative to 5 points; anterior and posterior borders of the mandible, deepest point of the sigmoid notch, gonion, and occlusal plane (positive value indicated position above the occlusal plane and negative value indicated position below the occlusal plane) [15], (Fig. 4a,b).
5. Diameter of the mandibular foramen: measured vertically on a cross sectional view, (Fig. 4c).
6. Position of the mental foramen: measured on a cross sectional view from the beginning of the mental foramen to the superior and inferior border of the mandible [14], (Fig. 4d).
7. Diameter of the mental foramen: measured vertically on a cross sectional view[14], (Fig. 4e).

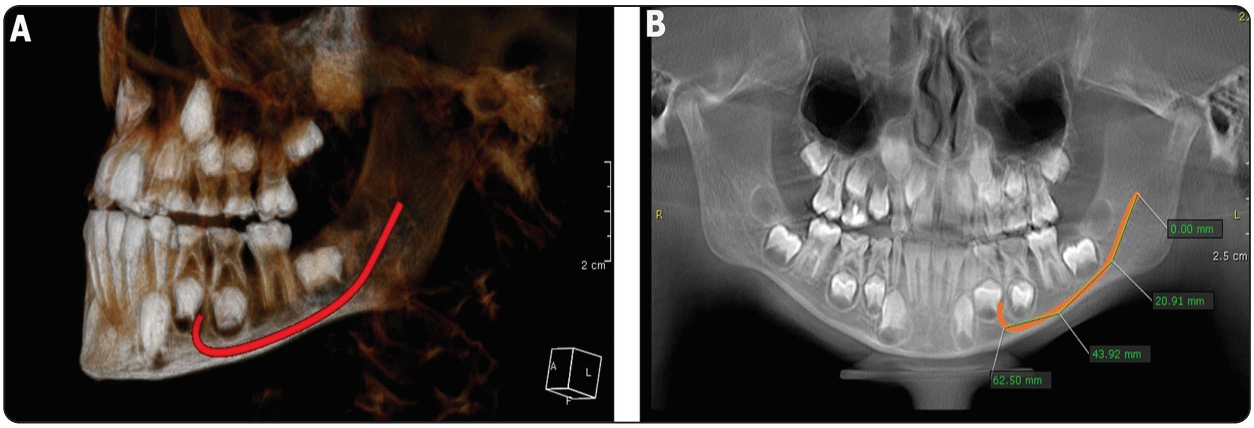

Fig. (2) a 3D view showing course of inferior alveolar canal, b Dental Volume Reformat (DVR) Panoramic view showing length of the inferior alveolar canal.

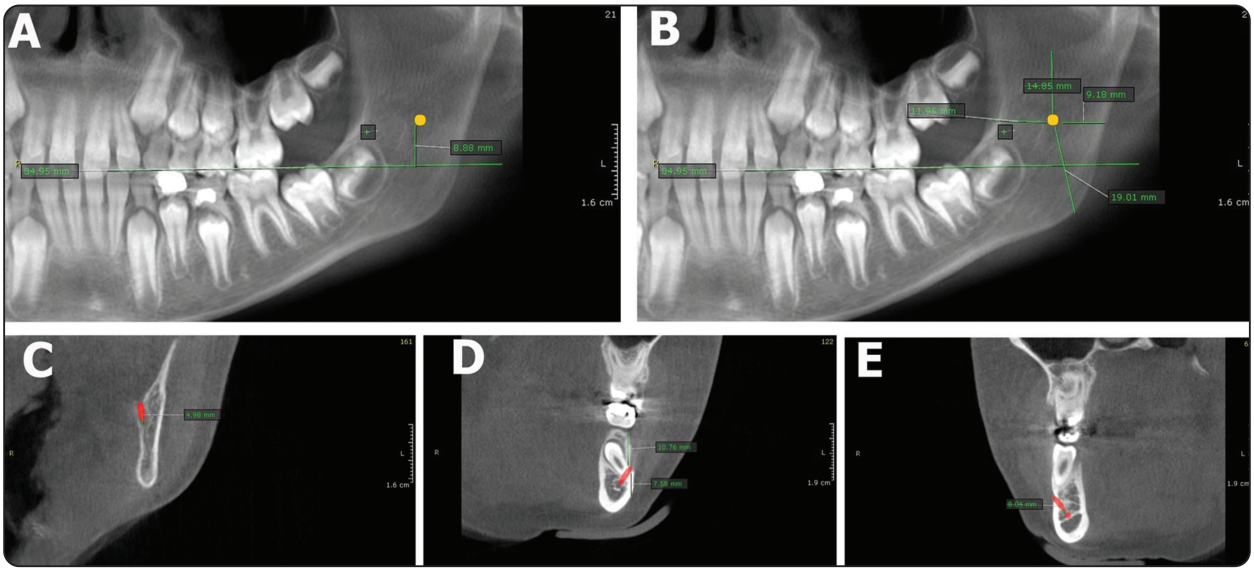

Fig. (3) Cross section view showing: a, b, c diameter of the inferior alveolar canal measured at 3 points, d, e, f: position of the inferior alveolar canal measured at the same points.

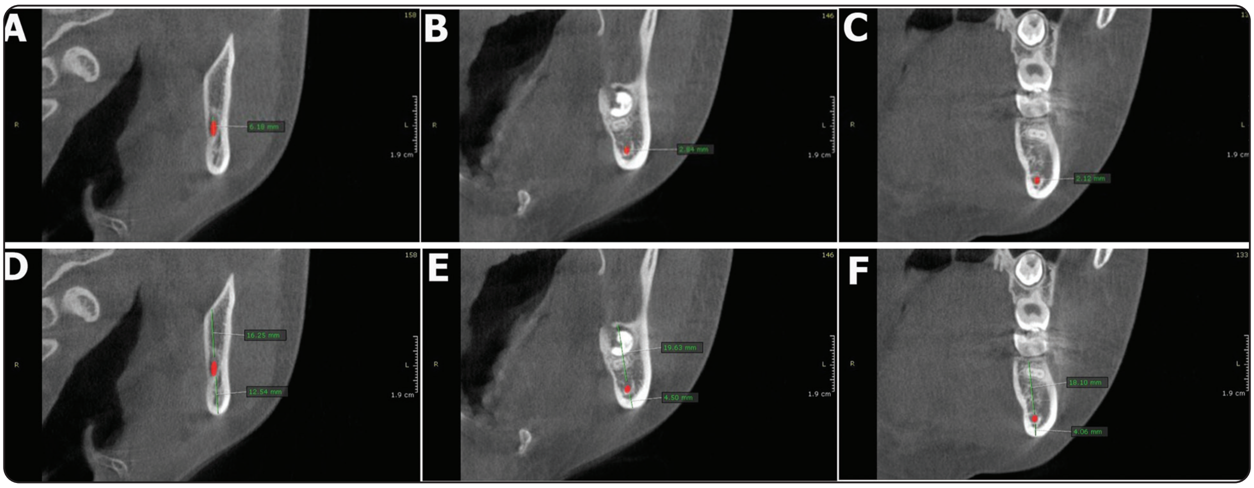

Fig. (4) a, b DVR panoramic view showing the relative position of the mandibular foramen to the anterior and posterior border of the mandible, sigmoid notch, gonion, and the occlusal plane. c Cross section view showing Diameter of the mandibular foramen, d position of the mental foramen from the superior and inferior alveolar ridge, e Diameter of the mental foramen.

Data analysis

The information was recorded on a Microsoft Office Excel secure sheet with strict respect for anonymity. Data was presented using mean and standard deviation. All variables were normally distributed and compared between gender group and age categories using intendent t test while Paired t test was performed to compare between right and left sides. The significance level was set at P value of 0.05. All tests were two tailed. Data were analyzed using SPSS for windows version 23.

RESULTS

Fifty CBCT scans (100 images from right and left sides) of 36 males (72 %) and 14 females (28 %), with age range of 10-15 years and a mean age of 12.14±1.47 years were included for statistical analysis. Distribution of the measurements of the IAC and its foramina according to gender are displayed in table 1. There was no statistically significant difference in the measured parameters between both genders except for the position of the mandibular foramen from the anterior and posterior borders of the mandible. The males showed closer position of the foramen to the anterior border of the mandible than the females with mean values, 12.7±2.0, 14.1±1.8, P=0.035 in males and females, respectively. Consequently, the males showed farther position from the posterior border of the mandible than the females with mean values 10.9±1.6, 9.7±1.3, P=0.013 in males and females, respectively.

Distribution of the measurements of the IAC and its foramina according to age categories is displayed in table 2. The IAC showed a narrower diameter 2.5 ±0.2 in the age group 10->13- year-old than in the 13-15-year-old group 2.8±0.4, with statistically significant difference between both age groups, P = 0.012. The position of IAC to the superior alveolar border was closer in the 10->13-year-old group 18.4±3.9 than in the 13-15-year-old group 21.0±4.0 with statistically significant difference between both age groups, P = 0.029. Similarly, the position of the IAC to the inferior mandibular border was closer in the 10->13-year-old age group than in the 13-15-year-old group with mean values 5.5±1.9 and 6.7±1.7, respectively, and with statistically significant difference between both age groups, P =0.034. The mandibular foramen was closer to the sigmoid notch in the age group 10->13- year-old than in the 13-15-year-old group with mean values 12.2 ±2.5 and 14.1±2.1, respectively and with statistically significant difference between both age groups, P =0.008.The position of the MnF was closer to inferior border in the 10->13-year-old age group than in the 13-15-year-old group with mean values of 8.1±2.0 and 9.5±2.6, respectively, and with statistically significant difference between both age groups, P =0.039.The MnF showed narrower diameter in the 10->13-year-old age group than in the 13-15-year-old group with mean values of 4.2±1.8 and 5.4±2.0, respectively, and with statistically significant difference between both age groups, P =0.037. However, there was no statistically significant difference in the length of the IAC, diameter of the MF, position of MF to the occlusal plane, anterior and posterior borders, and gonion, and position of the MnF to the superior border between both age groups.

The measurements of the IAC and its foramina according to arch side are presented in table 3. The position of the IAC was farther to the superior alveolar border on the right side than to the left side, with mean values of 20.1±5.0 and 18.7±4.1, respectively, and with statistically significant differences between both sides. Likely, the position of MnF was farther to the superior border in the right side than in the left side with mean values of 14.2±3.3 and 13.6±2.7, respectively and with statistically significant difference between both sides, P =0.017. The MF, as well, was positioned farther to the gonion point on the right side than in the left side with mean values of 19.8±3.1 and 18.8±2.6, respectively, and with statistically significant difference between both arch sides.

TABLE (1) Measurements of inferior alveolar canal and its foramina according to age categories

		10 – 12 years (n=31)	13 – 15 years (n=19)	P value
		Mean (SD)	Mean (SD)	
Length of inferior alveolar canal		69.0 (5.8)	71.8 (5.8)	0.101
Diameter of inferior alveolar canal		2.5 (0.2)	2.8 (0.4)	**0.012***
Position of inferior alveolar canal to	Superior alveolar border	18.4 (3.9)	21.0 (4.0)	**0.029***
	Inferior mandibular border	5.5 (1.9)	6.7 (1.7)	**0.034***
Position of mandibular foramen	Occlusal Plane	12.2 (4.1)	14.5 (5.0)	0.086
	Anterior Border	13.2 (2.1)	12.9 (2.0)	0.601
	Posterior Border	10.7 (1.6)	10.3 (1.6)	0.395
	Sigmoid	12.2 (2.5)	14.1 (2.1)	**0.008***
	Gonion	19.4 (2.8)	19.2 (2.5)	0.767
Diameter of mandibular foramen		6.9 (1.8)	7.5 (2.1)	0.269
Position of mental foramen	Superior border	13.9 (2.7)	13.9 (3.3)	0.939
	Inferior border	8.1 (2.0)	9.5 (2.6)	**0.039***
Diameter of mental foramen		4.2 (1.8)	5.4 (2.0)	**0.037***

Statistically significant at p value<0.05

TABLE (2) Measurements of inferior alveolar canal and its foramina according to gender

		Male (n=36)	Females (n=14)	P value
		Mean (SD)	Mean (SD)	
Length of inferior alveolar canal		70.8 (5.8)	67.9 (5.7)	0.118
Diameter of inferior alveolar canal		2.6 (0.2)	2.7 (0.4)	0.253
Position of inferior alveolar canal to	Superior alveolar border	19.7 (4.2)	18.5 (3.8)	0.353
	Inferior mandibular border	5.9 (2.0)	6.2 (1.6)	0.580
Position of mandibular foramen	Occlusal Plane	13.2 (4.7)	12.7 (4.4)	0.724
	Anterior Border	12.7 (2.0)	14.1 (1.8)	**0.035***
	Posterior Border	10.9 (1.6)	9.7 (1.3)	**0.013***
	Sigmoid	13.1 (2.5)	12.6 (2.8)	0.521
	Gonion	19.5 (2.7)	18.9 (2.5)	0.471
Diameter of mandibular foramen		7.2 (2.0)	7.1 (1.7)	0.852
Position of mental foramen	Superior border	13.7 (2.8)	14.3 (3.1)	0.542
	Inferior border	9.0 (2.3)	7.9 (2.4)	0.164
Diameter of mental foramen		4.8 (2.0)	4.4 (2.0)	0.524

Statistically significant at p value<0.05

TABLE (3) Measurements of inferior alveolar canal and its foramina according to arch side

		Right (n=50)	**Left (n=50)**	**P value**
		Mean (SD)	Mean (SD)	
Length of inferior alveolar canal		70.5 (6.6)	69.5 (6.2)	0.170
Diameter of inferior alveolar canal		2.6 (0.4)	2.6 (0.4)	0.571
Position of inferior alveolar canal to	Superior alveolar border	20.1 (5.0)	18.7 (4.1)	**0.025***
	Inferior mandibular border	6.1 (2.5)	5.9 (1.8)	0.377
Position of mandibular foramen	Occlusal Plane	13.3 (5.3)	12.8 (4.3)	0.277
	Anterior Border	13.0 (2.4)	13.2 (2.2)	0.451
	Posterior Border	10.8 (1.9)	10.3 (2.1)	0.152
	Sigmoid	13.0 (3.0)	12.9 (2.4)	0.763
	Gonion	19.8 (3.1)	18.8 (2.6)	**0.006***
Diameter of mandibular foramen		7.1 (2.0)	7.2 (2.1)	0.762
Position of mental foramen	Superior border	14.2 (3.3)	13.6 (2.7)	**0.017***
	Inferior border	8.7 (2.3)	8.6 (2.6)	0.475
Diameter of mental foramen		4.6 (2.1)	4.7 (2.2)	0.848

Statistically significant at p value<0.05

DISCUSSION

Accurately identifying the location of the IAC and its foramina is essential when devising restorative or surgical procedures, as inadvertent damage to the vasculo-nervous components passing through these areas could occur [18]. These structures have been examined using different radiographic methods such as panoramic X-rays and CT scans [19]. With the progression of digital imaging, assessing their location and dimensions in a three-dimensional context and measuring specific points has become more convenient [20]. In the present study, the location, diameter, and length of the inferior alveolar canal and its foramina were measured relative to the anatomical landmarks on a sample of Egyptian individuals using CBCT scans. The anatomic position of the MF was significantly associated with gender, age, and arch side while the anatomic location of the IAC, diameter, and position of the MnF were significantly correlated with age and arch side and not correlated to gender. Thus, the null hypothesis was partially rejected.

Administering successful inferior alveolar nerve block anesthesia in children poses a considerable challenge. The primary reasons for failure include the involvement of accessory innervations in the mandibular teeth and inaccuracies in needle placement due to improper identification and assessment of anatomical landmarks. The location of the MF in children is greatly influenced by their growth and development, as the mandible undergoes continuous remodeling during tooth shedding and eruption, especially at the anterior border of the ramus and the crest of the alveolar bone. This remodeling indirectly impacts the position of the foramen and consequently affects the efficacy of IAN blocks in children [21]. This corresponds to the findings of our study and other studies [7,9,22,23].

In this study, the position of the MF varied significantly with age as it got farther from the sigmoid notch in the 13-15-year-old group (14.1±2.1) than in the 10->13- year-old group (12.2±2.5). The position of the MF did not exhibit bilateral symmetry in our study which corresponds to the findings of Krishnamurthy et al. [9]. However, it disagrees with Setyawan et al. [16] who reported that there was no difference in the MF position based on age.

The position and diameter of the MnF were also significantly related to age, where the diameter increased by age from 4.2±1.8 to 5.4±2.0 mm, and the position was farther from the inferior mandibular border in the 13-15-year-old group (9.5±2.6 mm) than the 10->13- year-old group (8.1±2.0 mm). This was in accordance with the study by Orhan et al [24] who found that width of the MnF was significantly smaller in children aged 6 to 12 years when compared to children in older age groups The distance between the MnF and the alveolar ridge was also found to vary significantly among age groups; 11.7 mm among children aged 6-12 years and 12.1 mm among children aged 13-15 years. This was elucidated by the postulation that in children with primary teeth, the MnF tends to be closer to the alveolar ridge. As the eruption of permanent teeth progresses, the MnF descends to approximately halfway between the superior and inferior borders of the mandible. Furthermore, agrees with Lim et al. [25] who reported that as the mandible grew, there was a progressive shift of the mental foramen towards the apex of the second primary molar.

A significant difference was noted as well in the diameter and position of IAC to the superior and inferior mandibular borders also in reference to age. Dos Santos Oliveira et al. [26] reported that 75% of patients had canal diameter between 2.1 and 4 mm which correlates to the findings of our study in which the diameter of the IAC increased with age with mean values of 2.5 and 2.8 mm in the 10->13 and 13-15 age groups, respectively. This was also in accordance with Obradovic et al. [27] who had reported 2.7 mm diameter, and Aghdasi et al. [12] who had reported 2.95 mm. The slight variance in the findings could be attributed to differences in race and age demographics between the participants in the two studies. In our investigation, the individuals were still in the process of growth, whereas in the other studies, the cases were selected from diverse age brackets, potentially including individuals who had already completed their growth phase, resulting in no observed changes in bone growth. On the other hand, Rashid et al. [28] showed no significant difference in the canal's diameter in reference to age. This disparity could also be related to the variation in the measurement tool utilized in this study, given that panoramic radiographs may not offer the same level of precision as CBCT scans. The age related change in the position of the IAC also agrees with the study by Levine et al. [29] and Aghdasi et al. [12].

The utilization of mandibles for gender determination constitutes a fundamental aspect of forensic anthropology and medical-legal research, primarily due to their compactness and resilience to destruction. There are notable disparities in the size and shape between male and female mandibles [30]. Various measurements, particularly those concerning the ramus, can effectively show significant gender distinctions. Notably, the mandible persists within the human body even after other bony regions have decomposed, rendering it valuable in age and gender determination [31]. In our study, the MF was not located at the center in the anteroposterior dimension of the ramus; however, it was more anteriorly positioned in males (12.7±2.0 mm) than females (14.1±1.8 mm). Our findings are similar to those by Ahn et al. [15] who reported that the MF was slightly anterior to the center of the ramus in males than females. However, according to Ebogo et al. [32] and Altunsoy et al. [33], the MF was situated farther posteriorly from the anterior edge of the mandible in males compared to females with 19.4, 24.4 mm and 19.2, 23.2 mm, respectively. This variation may be attributed to differences in age groups between children and adults, as well as discrepancies in the ethnic backgrounds among the subjects included in the studies.

Regional anesthesia targeting the mental nerve is frequently achieved via the MnF. Osteotomies are frequently necessary for various maxillofacial or orthognathic procedures. Given the susceptibility of the neurovascular bundle to injury during such procedures, precise and reliable prediction of its position is imperative to prevent inadvertent damage to the structures traversing the foramen [14]. In this study, the position of the MnF to the superior mandibular border was significantly different between the right (14.2±3.3 mm) and left (13.6±2.7 mm) sides of the arch. The results are also in line with study that analyzed six dry mandibles to ascertain the size, and position in relation to anatomical landmarks in an adult Sri Lankan population [14] where the vertical diameter was in the range of 2.38±0.41mm to 2.41±0.46mm on the right and left side, respectively. The mental foramina were located at a mean distance of 13.34±1.79mm and 12.89±1.56mm, vertically above the lower border of the mandible on the right and left side, respectively. However, the variance in the average values may stem from the age discrepancies and the ethnic composition between the adult Sri Lankan and the pediatric Egyptian populations, alongside the variations in the measurement techniques involving CBCT and dry mandibles.

One of the study's limitations was not including younger age groups, who are of significant concern and variations, given the challenges in obtaining CBCT scans for this age groups. Furthermore, it is of utmost importance to acknowledge that the scans retrieved for this study were from a single center, which is considered a constraint, as it could not represent the whole Egyptian population. Therefore, it is crucial to exercise caution while interpreting the findings of this relatively small sample size. Additionally, it is highly recommended to conduct further studies involving multicenter in order to be able to generalize the results.

CONCLUSIONS

This study yielded valuable insights into the site and size of the inferior alveolar canal and its foramina in children. The anatomic position of the mandibular foramen was significantly associated with gender, age, and arch side while the anatomic location of the inferior alveolar canal, diameter, and position of the mental foramen were significantly correlated only with age and arch side. These findings provide essential guidance for effectively administering inferior alveolar nerve blocks in children with these age categories. Additionally, they contribute to precise identification of the mental neurovasculature when planning mental nerve blocks, performing surgical extractions of supernumerary teeth, removing odontomes, or managing severe traumatic injuries involving mandibular fractures.

Competing interests

The authors have no competing interests to declare.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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