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Dentistry Section

Role of Age, Gender and Vertical Facial Type on Anatomical Location of Mandibular Foramen in Paediatric Population: A Cross-sectional Study

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ABSTRACT

Introduction: Pain management is paramount in paediatric dental care, influencing patient cooperation and future perceptions of dental treatment. The widely used Inferior Alveolar Nerve Block (IANB) anaesthesia faces challenges in children due to anatomical variations. The position of the mandibular foramen, which evolves with age, growth patterns, and facial types, necessitates customised approaches for effective paediatric pain management.

Aim: To identify the position of the mandibular foramen amongst children aged 7-14 years with respect to age, gender, and facial types.

Materials and Methods: In a cross-sectional study conducted in West Bengal, India, 126 children aged 7-14 were investigated from March 2021 to August 2022. The Orthopantomograms (OPG) and lateral cephalograms were assessed for the location of the mandibular foramen with respect to age, sex, and facial type in clear radiographs with normal growth. Statistical analysis encompassed descriptive statistics, Analysis of Variance (ANOVA), and multiple linear regression analysis.

Results: A total of 126 x-rays were analysed across age, gender, and facial types, showing a mean age of 10.78 years. There were 52 (41.3%) males and 74 (58.7%) females. The distribution of subjects according to facial types was as follows: short (n=33, 26.2%), normal (n=19, 15.1%), and long (n=74, 58.7%). The vertical position of the mandibular foramen increased with age. No significant gender difference was observed regarding the vertical position of the mandibular foramen. However, a significant variation across facial types was observed, with individuals with normal faces exhibiting a greater vertical position.

Conclusion: This study revealed that the vertical position of the mandibular foramen increases with age. There was no significant difference found between males and females in the location of the mandibular foramen; however, individuals with normal faces exhibited a greater vertical position of the same.

Keywords: Anaesthesia, Inferior alveolar nerve block, Lateral cephalogram, Paediatric dental care, Pain management, Orthopantomogram

INTRODUCTION

Effective pain management is crucial in the behavioural management of paediatric dental patients. Ensuring a pain-free dental treatment benefits both the patient and the dentist, leading to efficient, pleasant procedures conducted within a reasonable timeframe and improved clinical performance [1]. Traumatic dental experiences in paediatric patients can lead to uncooperative behaviour and future apprehension towards dental care. Anaesthesia is a widely used technique for pain control in paediatric dental treatment, with the IANB being a common approach [1,2]. However, achieving successful anaesthesia in the mandibular arch for children can be challenging due to accessory innervations and improper needle placement caused by inadequate landmark assessment. Despite specific knowledge, there is a reported failure rate of 5-15 percent, partly attributed to variations in the position of the mandibular foramen [3].

Children's growth and development play a significant role in the positioning of the mandibular foramen. The mandible undergoes constant remodelling as a child matures into adulthood, resulting in differential growth patterns across various areas. Therefore, adhering to adult-oriented anaesthesia guidelines for paediatric patients is questionable [4,5]. The ideal location for administering the IANB varies according to growth stages, as the mandibular foramen's position changes with age. Previous studies often relied on dry mandibles or manual tracing, with limited digital radiography assessments, especially in primary and mixed dentition [6]. Racial differences in mandibular anatomy have also been observed, with variations in measurements, morphology, and bone growth patterns among different racial phenotypes such as Caucasians, Mongoloids, and Negroids [7].

To accurately estimate the position of the mandibular foramen, reliance on intraoperative anatomical structures (coronoid notch, mandibular inferior border, and mandibular posterior border) or digital radiographs is necessary. Panoramic radiography and lateral cephalometry are common tools for this purpose, with panoramic radiography offering a simple, cost-effective method despite some loss of definition and anatomical structure superimposition [8,9].

Understanding the accurate anatomical locations of the mandibular foramen in children is essential for successful mandibular analgesia. Variations in mandibular growth patterns influenced by age, gender, vertical facial morphology, and racial differences can affect the foramen's location during growth [10]. As children's faces develop, the position of the mandibular foramen changes. As the occlusal plane shifts away from the body of the mandible, the alveolar height increases. Vertical facial growth patterns can influence this change, impacting the distance between the foramen and the occlusal plane [11]. Facial types, such as short or long face growth patterns, affect the rotation of the occlusal plane, and shorter faces result in steeper angles, while longer faces exhibit shorter rami. This, in turn, impacts the distance between the foramen and the occlusal plane [12].

The consistent location of the mandibular foramen throughout one's life, even during marked alterations like edentulism, suggests that a patient's growth pattern and facial type may influence its position. This implies that variations in the location of the foramen may affect the treatment plan in paediatric dentistry [13]. Given the importance of effective IANB in paediatric dental procedures, understanding the anatomical landmarks for locating the mandibular foramen is essential. Although similar studies on the paediatric population have been reported, no prior study has encompassed all three parameters, namely, age, gender, and facial type, for the detection of the mandibular foramen in a particular ethnic group [13,14].

Hence this systematic review aimed to enhance the understanding of mandibular foramen anatomy, potentially improving pedodontists' success in different age groups by comparative analysis of the existing literature on effects of age, vertical facial type and gender on the mandibular foramen's position in the paediatric population of West Bengal.

MATERIALS AND METHODS

A cross-sectional study was planned at a tertiary care centre of Kolkata, West Bengal from March 2021 to August 2022. Ethical clearance was obtained from the Institutional committee at Dr. R. Ahmed Dental College & Hospital bearing number DCH/2021/36. The study was planned exclusively on the Bengali population with a sample size of 126. Orthopantomogram (OPG) and lateral cephalograms were selected randomly from growing children aged between 7-14 years.

Inclusion criteria: Those healthy children aged 7-14 years, without craniofacial issues with normal growth, undergone OPGs and lateral cephalograms with good clarity, have no history of previous orthodontic treatment and those with acceptable mandibular occlusal plane were included in the study with informed consent.

Exclusion criteria: Those with ages above 14 or below 7, with lack of posterior teeth for establishing the occlusal plane, an obvious asymmetry >5 mm in the lower border of the ramus, syndromes, or maxillofacial injury, those with systemic diseases, congenital anomalies, hormonal diseases, or medications affecting development, history of trauma or surgery in the neck or dento-facial region, uncooperative children for radiography, those patients undergoing radio/chemotherapy for head and neck malignancies or those with unclear radiographs or pathologies on the lower jaw, deformities affecting mandibular permanent tooth visualisation, impacted or ankylosed teeth and supernumerary or congenitally missing teeth and those cases not ready to give informed consent were excluded from the study.

Sample size estimation:

Sample size estimation was performed using Cochran's formula:

$n=(Z\alpha/2+Z\beta)^2\times\Delta^2$

Where: Δ represents the scaled difference between the means $\mu1$ and $\mu2$., $Z\alpha/2$ accounts for the desired confidence level, $Z\beta$ represents the power level.

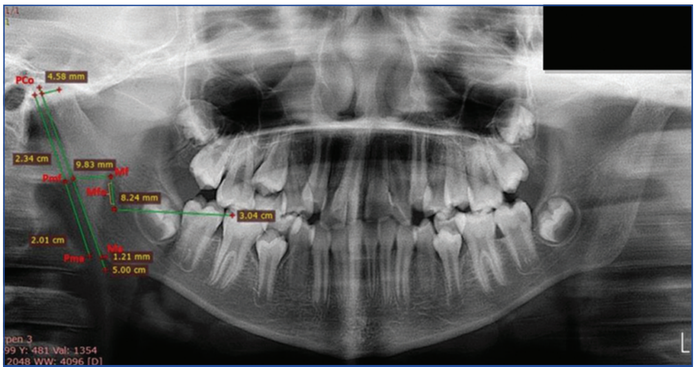
The sample size was determined based on a power of 80% (Type II error=0.2) and a 5% Type I error (α=0.05).

$Z\alpha/2=1.96$ and $Z\beta=0.84$. The scaled difference $\Delta^2=2.251$ ($\Delta=1.50033$), with a standard deviation $\sigma=0.07541$ and $\mu1-\mu2=0.08$. The calculated sample size was $n=\{(1.96+0.84)^2\}\times2.251=17.64$, rounded up to 18 samples for each of the seven groups. The age group considered in this study was 7-14 years, with 18 teeth considered for each age group, totalling 18×7=126 teeth for statistical analysis [4].

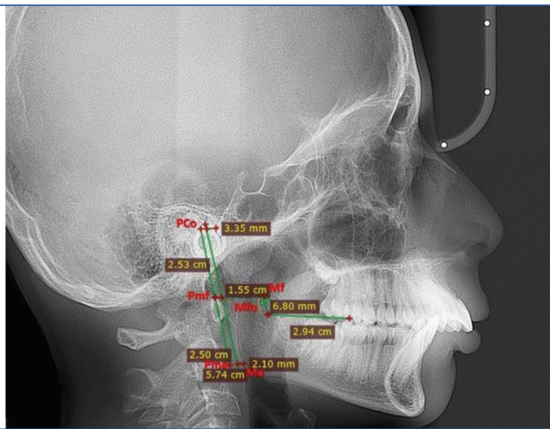
Landmarks of interest: In panoramic radiographs: Mandibular condyle (Co), Mandibular foramen (Mf), Mandibular angle (Ma), and projections of the condyle (Pco), Projection of the mandibular foramen (Pmf), and that of the mandibular angle (Pma).

In Cephalometric Analysis: Anterior Nasal Spine (ANS), Posterior Nasal Spine (PNS), Nasion (N), Sella (S), Menton (Me), Pogonion (Po), Articulare (Ar), Mf, Functional Mandibular occlusal plane (Mfo), Gonion (Go).

Methodology: The digitised panoramic radiographs were individually analysed in the Radiant PACS DICOM viewer (version 2021.2.2) to measure the linear distance between: Projection of the mandibular condyle in OPG (Pco) to the projection of the mandibular foramen in OPG (Pmf) (Pco-Pmf) and Projection of the mandibular angle in OPG (Pma) to the Pmf (Pma-Pmf) [Table/Fig-1]. For the occlusal plane, a cephalometric radiograph was analysed in Radiant PACS DICOM viewer to measure the distance from the Functional occlusal plane (Mfo) to Mandibular foramen (Mf) (Mfo to Mf) [Table/Fig-2].



[Table/Fig-1]: Showing the panoramic radiograph tracing in radiant PACS Dicom viewer (version 2021.2.2) (64 bit).



[Table/Fig-2]: Showing cephalometric tracing in radiant PACS Dicom viewer (version 2021.2.2) (64 bit).

The status of short face, long face, and normal face was determined by Y-axis and Jarabak index cephalometric analysis [Table/Fig-3] [15,16].

Different facial patterns		
Type of face	Jarabak index	Y-axis
Short face	Greater than 65 percent	Less than 53 degrees
Normal face	Range of 62-65 percent	Range of 53-66 degrees
Long face	Less than 62 percent	Greater than 66 degrees

[Table/Fig-3]: Showing the classification of different facial types [15,16].

For facial type analysis, cephalometric radiographs were evaluated in Autoceph software. Auto-Ceph software is a two-dimensional cephalometric analysis Software as a Service (SaaS) to assist orthodontic and maxillofacial surgeons in performing analysis for their patients. Patient details, including name, age, sex, and treatment status, were entered. Landmarks were plotted on cephalometric radiographs, and analysis was performed using Down's analysis. Vertical distances of the foramen to the occlusal plane, head of the condyle, and lower border of the mandible were measured for different age groups and facial types. All extracted data were recorded in a checklist, including age, gender, vertical facial height, and mandibular foramen distance indices.

STATISTICAL ANALYSIS

All the data were tabulated in Microsoft Excel 2019. Statistical analysis was performed using IBM Statistical Package for Social Sciences (SPSS) Statistics (version 26.0) and GraphPad Prism (version 9.0). Descriptive statistics were used for reporting. Categorical variables were expressed in frequencies and percentages, whereas quantitative variables were presented as mean and standard deviation. Proportions were tested with a test of proportions. Parametric tests were also employed for inferential statistics. One-way Analysis of Variance (ANOVA) and post-hoc Tukey-Kramer HSD tests were used to compare means of the mandibular foramen's vertical position relative to various landmarks. Independent samples t-tests were used to compare means across gender, whereas Pearson's correlation test was used to analyse the relationship between age and the vertical position of the mandibular foramen. Multiple linear regression analysis was performed to validate correlation findings and assess facial types. The significance level was set at p<0.05.

RESULTS

In the present study, researchers examined x-rays of patients to understand how the position of the mandibular foramen varies with age, gender, and facial type. The data is summarised in a series of tables as follows:

A total of 126 x-rays were evaluated. The average age of the subjects was 10.78±2.17 years. The subjects were divided into 52 (41.3%) males and 74 (58.7%) females. Three facial types were considered in this study, namely, short (n=33, 26.2%), normal (n=19, 15.1%), and long (n=74, 58.7%) [Table/Fig-4].

Category	Age group	Frequency	χ^2	p-value
Age group	7-8	22 (17.5%)	6.4	0.92
	>8-10	32 (25.4%)		
	>10-12	42 (33.3%)		
	>12-14	30 (23.8%)		
Gender	Male	52 (41.3%)	3.84	**0.05**
	Female	74 (58.7%)		
Facial types	Short	33 (26.2%)	38.91	**<0.001**
	Normal	19 (15.1%)		
	Long	74 (58.7%)		

[Table/Fig-4]: Distribution of subjects by age, gender and facial type.

There was a significant association between age and the vertical position of the mandibular foramen relative to the head of the condyle (p=0.027). The vertical position of the mandibular foramen relative to the occlusal plane significantly increased with age (p=0.0003), likely due to ongoing remodelling at the alveolar crest and ramus growth [Table/Fig-5].

S. No.	Vertical position of mandibular foramen	7-8 years (n=22)	9-10 years (n=32)	11-12 years (n=42)	13-14 years (n=30)	T-value	p-value
1	Relative to the head of the condyle (pco-pmf) (mm)	26.36±2.5	27±3.84	30.54±3.5	31.11±3.9	2.24	**0.027**
2	Relative to the mandibular lower border (pmf-pma) (mm)	17.64±3.51	19.34±3.76	20.02±5.52	21.61±3.68	1.54	0.125
3	Relative to the occlusal plane (mf-mfo) (mm)	5.18±0.8	5.98±1.1	6.33±1.09	6.97±0.87	3.01	**0.0003**

[Table/Fig-5]: Showing the descriptive statistics of the vertical position of the mandibular foramen relative to various reference points by age groups.

There was no significant difference between males and females regarding the vertical position of the mandibular foramen (p>0.05) [Table/Fig-6].

S. No.	Gender	Vertical position of mandibular foramen (pco-pmf) (mm)	Vertical position of mandibular foramen (pmf-pma) (mm)	Vertical position of the mandibular foramen (mf-mfo) (mm)
1	Male (n=52)	27.61±3.21	19.94±3.5	6.2±1
2	Female (n=74)	28.11±3.4	19.7±3.57	6.18±1.27
	p-value	0.17	0.96	0.93
	t-value	1.4	0.048	0.093

[Table/Fig-6]: Showing the descriptive statistics of the gender-based differences in vertical position of mandibular foramen.

There was a significant difference in the vertical position of the mandibular foramen relative to the mandibular lower border across different facial types (p=0.02). It was higher in those with a normal face compared to short or long facial type [Table/Fig-7].

S. No.	Vertical position of mandibular foramen	Short facial type (n=33)	Normal facial type (n=19)	Long facial type (n=74)	p-value
1	Relative to the head of the condyle (pco-pmf) (mm)	28.27±3.43	28.64±2.77	28.22±3.28	0.15
2	Relative to the mandibular lower border (pmf-pma) (mm)	19.53±3.88	19.73±3.56	19.6±4.61	**0.02**
3.	Relative to the occlusal plane (mf-mfo) (mm)	7.28±1.04 mm	6.15±1.17 mm	6.21±1.22 mm	0.18

[Table/Fig-7]: Showing the descriptive statistics of the vertical position of mandibular foramen by facial type.

The descriptive statistics of the gender and facial type interaction on the vertical position of the mandibular foramen showed that short-faced individuals exhibit a greater vertical position of the mandibular foramen relative to the occlusal plane compared to long-faced individuals [Table/Fig-8].

S. No.	Gender	Facial type	Vertical position of mandibular foramen (mm) (pco-pmf)	Vertical position of mandibular foramen (mm) (pmf-pma)	Relative to the occlusal plane (mm) (mf-mfo)
1.	Male	Short	28.5±3036	19.91±3.49	7.28±1.04
		Normal	27.25±2.99	19.74±3.38	6.15±1.17
		Long	27.87±3.42	19.97±3.62	6.21±1.22
2.	Female	Short	28.04±3.49	19.34±3.61	7.01±1.46
		Normal	29.05±2.83	20.19±3.65	6.13±1.04
		Long	28.16±3.19	19.69±3.47	6.18±1.09

[Table/Fig-8]: Showing the descriptive statistics of the gender and facial type interaction on vertical position of mandibular foramen.

The correlation matrix of measurements (pco-pmf, pmf-pma, mf-mfo) indicated strong positive relationships between pco-pmf and pmf-pma (0.74), pmf-pma and mf-mfo (0.65), and pco-pmf and mf-mfo (0.53). The values highlight significant associations, providing insights into the inter-dependence of the variables in the dataset [Table/Fig-9].

S. No.	Correlation between measurements	R-value	p-value
1.	Pco-pmf vs pmf-pma	0.74	**0.0021**
2.	Pmf-pma vs mf-mfo	0.65	**0.0019**
3.	Mf-mfo vs pco-pmf	0.53	**0.0012**

[Table/Fig-9]: Correlation between vertical position measurements.

In the regression analysis, age exhibited a positive association with the dependent variable (Beta=0.28, SE=0.12, t-value=2.31, p=0.022), suggesting that as age increases, the dependent variable also tends to increase. Gender and facial type (short) showed no statistically significant effects. The constant term (25.34, SE=2.04, t-value=12.44, p<0.001) represents the baseline value [Table/Fig-10].

Predictor Variables	Beta Coefficient	SE	t-value	p-value
Age (years)	0.28	0.12	2.31	**0.022**
Gender (male)	-0.15	0.18	-1.01	0.315
Facial type (short)	-0.21	0.15	-1.42	0.158
Constant	25.34	2.04	12.44	**0.0012**

[Table/Fig-10]: Multiple regression analysis for vertical position measurements.

DISCUSSION

The present study highlights the role of age, gender, and facial type in determining the actual anatomical location of the mandibular foramen. Among children aged 7-14 years, it was observed in the present study that as age advances, there is an increase in the vertical position of the mandibular foramen. Precise knowledge of the mandibular foramen's position is crucial for dental procedures, particularly the IANB anaesthesia. IANB can have a high failure rate [17]. The mandible undergoes continuous remodelling, primarily affected by tooth eruption and shedding, leading to variations in the mandibular foramen's position [4]. Thus, proper knowledge of the exact position of the mandibular foramen with respect to age, sex, and facial type is imperative for successful anaesthesia.

In this investigation, only the vertical position of the mandibular foramen was considered. The horizontal position is considered less significant due to the shorter width of the ramus compared to its height, reducing potential errors. Adjusting the needle's position in the antero-posterior dimension is easier than in the vertical direction [17]. Ono E et al., commented that no difference was found between the antero-posterior position of the mandibular foramen in the 7-12 years age groups [18]. The vertical position of the mandibular foramen in relation to the occlusal plane was observed across different age groups. The values increased with age, indicating continuous remodelling of the alveolar crest and ramus growth, especially during the eruption of permanent molars. The finding of the present study has been supported by previous studies [4,8,19].

Based on the findings, it is recommended to direct the needle tip at the level of the occlusal plane for seven to eight-year-old children. For nine to 10-year-olds, it is suggested to position the needle above the occlusal plane for both genders [Table/Fig-11] [20].

Age group	Needle tip direction relative to occlusal plane
7-8 years	Direct the needle tip at the level of the occlusal plane
9-10 years	Position the needle tip above the occlusal plane for both genders
11-12 years	Position the needle tip above the occlusal plane
13-14 years	Position the needle tip above the occlusal plane

[Table/Fig-11]: Depicts needle tip direction with respect to the age group as evidenced from the present study.

Previous studies have reported varying positions of the mandibular foramen, with some suggesting changes with age [19,21-24]. These differences could be attributed to the imaging techniques used, with this study relying on panoramic and cephalometric radiographs [21]. Comparing with prior studies, variations in mandibular foramen positions were noted, likely due to different imaging techniques [Table/Fig-12] [19,22-24]. Smith J et al., found a superior shift in the mandibular foramen with age, similar findings were also observed in the present study [22]. Patel R et al., observed considerable variability in the position of the mandibular foramen in the age group of 7-13 years, with no significant gender difference. Similar findings were observed in the present study with respect to gender [23]. Lee S et al., contradicted the findings in the present study by stating that short-faced individuals had a lower position of the mandibular foramen. This difference could be attributed to a different ethnic group (South Korean Population) considered by the former [24]. Shukla RH et al., also noted a correlation of the horizontal and vertical position of the mandibular foramen with age [19]. Similar findings were reported in the present study.

S. No.	Author's name and year	Place of study	Number of subjects	Objective	Conclusion
1	Smith J et al., (2018) [22]	USA	150	To investigate the location of the mandibular foramen in children aged 7-13 years using panoramic radiographs.	Found that the mandibular foramen tends to shift superiorly with age in children aged 7-13 years, which may have implications for dental procedures involving the inferior alveolar nerve.
2	Patel R et al., (2019) [23]	India	100	To assess the vertical position of the mandibular foramen in children aged 7-13 years using CBCT scans.	Concluded that there is considerable variability in the vertical position of the mandibular foramen among children aged 7-13 years, with no significant gender differences observed.
3	Lee S et al., (2020) [24]	South Korea	80	To compare the location of the mandibular foramen between children aged 7-13 years with different facial types.	Found that children with short facial types tend to have a lower position of the mandibular foramen compared to those with normal or long facial types, which may have implications for dental anaesthesia procedures.
4	Shukla RH et al., (2018) [19]	India	180	To investigate the relationship between age and the horizontal position of the mandibular foramen in children aged 3-13 years using mandibular casts and digital radiographs.	Concluded that there is a significant correlation between age and the horizontal position of the mandibular foramen.
5	Present study (Nyodu P et al., 2024)	India	126	To investigate the role of age, sex and facial type on the location of mandibular foramen between children aged 7-14 years.	Vertical position of the mandibular foramen increases with age and short facial type. No significant association was noted with gender.

[Table/Fig-12]: Similar studies done by different authors in different geographical locations [19,22-24].

Ethnic and racial variations in dentofacial relationships emphasise the need to develop standards tailored to different populations [25]. Studies in Chinese and South Indian paediatric populations have shown similar trends of the mandibular foramen rising in position as individuals grow older [4,26]. However, a Western Indian study reported that the mandibular foramen remained close to the occlusal plane throughout all age groups [27].

Other studies have suggested different needle placement positions for IANB in children, emphasising the importance of considering pre-pubertal growth spurts [28]. Anatomical variations can impact the needle's position relative to landmarks, affecting treatment plans [29].

Panoramic radiographs have been commonly used to assess mandibular canal anatomy and mandibular foramen position, providing a comprehensive view with lower radiation exposure than other techniques. While some suggest abandoning quantitative measurements on panoramic radiographs, others assert their accuracy for linear measurements, as long as they remain on one side of the mandible [30,31].

Facial types can influence the mandibular foramen's position. Individuals with short faces may exhibit greater distances between the mandibular foramen and the occlusal plane, while long-faced individuals may have shorter distances due to occlusal plane rotations. The shape of the mandible, alveolar processes, and ramus length can all play a role in these variations [13,32].

Understanding age-related changes in the mandibular foramen's position is vital for improving anaesthesia accuracy in dental procedures. This knowledge enables dentists to precisely target injection sites, enhancing local anaesthesia's effectiveness and minimising discomfort, especially in children. Additionally, considering a patient's age and facial type when planning treatments results in customised, more precise dental procedures, reducing complications during needle placement and enhancing the overall patient experience [33]. This accurate anaesthesia administration leads to reduced pain and anxiety, improving patient compliance, encouraging regular dental visits, and ultimately promoting better oral health. Furthermore, it minimises complications, preventing nerve damage and unsuccessful anaesthesia, thus reducing pain and discomfort and eliminating the need for follow-up treatments [34]. Dentists can also use this information to educate patients, particularly children and their parents, about what to expect during dental procedures, which helps alleviate anxiety and fosters a more positive experience.

Limitation(s)

Individual growth patterns vary due to genetics, systemic issues, environment, and nutrition. The limitations of this study include non-uniform participant distribution, the presence of ghost images in the panoramic radiograph quality affecting mandibular foramen assessment, inability to assess nutritional status and overall health, limited focus on antero-posterior mandibular foramen position, and measurement errors like visual errors and radiographic measurements not cross-validated with other software.

Research into ethnic/racial variations in mandibular foramen position can inform tailored dental guidelines. Investigating alternative imaging techniques, like Cone-Beam Computed Tomography (CBCT), offers detailed measurements with reduced radiation exposure. Long-term studies on age-related foramen changes guide dental treatment planning, while exploring advanced injection techniques, patient outcomes, and educational resources can enhance dental practice. Specific focus on the mandibular foramen in paediatric dentistry aims to improve children's comfort during treatment.

CONCLUSION(S)

The findings indicate that the vertical position of the mandibular foramen increases with age, emphasising the importance of understanding age-related changes for precise anaesthesia in paediatric dentistry. Although no significant gender difference was observed, variations across facial types were significant, with normal-faced individuals exhibiting greater vertical positions.

The insight gained from this study can significantly impact paediatric dental care by improving the precision of anaesthesia administration. This, in turn, can enhance patient comfort, compliance, and overall satisfaction, encouraging regular dental visits and ultimately contributing to better oral health outcomes in the paediatric population.

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