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Assessment of changes in mandibular foramen position in different age groups by panoramic radiograph in children: a cross-sectional study

Abstract. Children's dental treatment processes require attaining deep and efficient local anesthesia. The knowledge of the mandibular foramen location and its changes along with age increases the probability of successful block injection. **The aim of this study** was to evaluate the changes in mandibular foramen position in different age groups by panoramic radiographs in children. **Materials and methods.** The present study was performed by panoramic radiographs of 135 patients aged 3—13 years. In this study, the relative location of the mandibular foramen was compared in different age groups after removing the magnification of the radiographic device using 6 points and 5 lines, and the changes of this anatomical landmark were surveyed along with age. **Results.** The average age of the children in the study was 7.8±2.7 years. It has been shown that the average horizontal distance of the mandibular foramen with the line perpendicular to the orbital plane and the average vertical distance of the lingula to the occlusal plane have a significant difference from each other in various age groups of patients ($p<0.001$). There was no significant difference in the average horizontal distance between the age group of 9—11 years and 7—9 years. The most obvious changes were seen in the age group of 11—13 years, that is at the end of the mixed dentition. The result showed a noteworthy variation in the mean vertical distance of the lingula to the occlusal plane among all age categories. As patients' age increases, the vertical distance of the lingula to the occlusal plane also increases significantly ($p<0.001$). **Conclusion.** The mandibular foramen is significantly shifted in the horizontal dimension and tilts backward with increasing age. Moreover, the mandibular foramen is significantly shifted in the vertical dimension and tilts to the top of the occlusal plane.

Key words: mandibular foramen, local anesthesia, panoramic radiography, pediatric dentistry

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Оценка изменений положения нижнечелюстного отверстия в разных возрастных группах с помощью панорамной рентгенографии у детей: перекрестное исследование

Реферат. Лечение зубов у детей требует глубокой и эффективной местной анестезии. Знание расположения нижнечелюстного отверстия и его изменений с возрастом увеличивает вероятность успешной блоковой инъекции. **Цель исследования** — оценить изменения положения нижнечелюстного отверстия в разных возрастных группах с помощью панорамных рентгенограмм у детей. **Материалы и методы.** Были изучены панорамные рентгенограммы 135 пациентов от 3 до 13 лет. По 6 точкам и 5 линиям сравнивали относительное расположение нижнечелюстного отверстия в разных возрастных группах, а также изучали изменения этого анатомического ориентира с возрастом. **Результаты.** Средний возраст детей, участвовавших в исследовании, составил 7,8±2,7 года. Было показано, что среднее горизонтальное расстояние от нижнечелюстного отверстия до линии, перпендикулярной орбитальной плоскости, и среднее вертикальное расстояние от лингвальной кости до окклюзионной плоскости значимо различаются между различными возрастными группами пациентов ($p<0{,}001$). Не отмечено значимой разницы в среднем горизонтальном расстоянии между возрастной группой 9—11 лет и 7—9 лет. Наиболее заметные изменения наблюдались в возрастной группе 11—13 лет, то есть в конце периода смешанного прикуса. Результаты показали заметные различия в среднем вертикальном расстоянии от лингвальной кости до окклюзионной плоскости во всех возрастных категориях. С увеличением возраста пациентов вертикальное расстояние от лингвальной кости до окклюзионной плоскости также значительно увеличивается (p<0,001). **Заключение.** С увеличением возраста нижнечелюстное отверстие значительно смещается в горизонтальном направлении и наклоняется назад. Кроме того, нижнечелюстное отверстие значительно смещается в вертикальном направлении и наклоняется к верхней части окклюзионной плоскости.

Ключевые слова: нижнечелюстное отверстие, местная анестезия, панорамная рентгенография, детская стоматология

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INTRODUCTION

Pain control plays a crucial role in the behavioral management of pediatric dental patients. The inferior alveolar nerve block (IANB) is the most commonly employed technique in dentistry for local anesthesia of mandibular molars [1]. Local anesthesia is vital for managing pain in pediatric dental and surgical procedures. However, age restrictions and the physiological characteristics of the maxillofacial region in children necessitate a careful and tailored approach [2]. By understanding these factors, clinicians can ensure safer and more effective anesthesia practices, ultimately leading to better outcomes for young patients.

The mandibular foramen (MF) is an irregularly shaped foramen located on the medial surface of the upper center of the mandibular ramus [3]. This particular structure serves as the entry point for the inferior alveolar nerve in children, which is the primary target during the administration of the mandibular block anesthetic technique [4]. The varying position of the MF is a significant factor contributing to the increased failure rate of this method [5]. Postoperative pain management, chronic pain conditions, procedural sedation, procedural sedation, trauma management, palliative care and specific conditions (sickle cell disease and burns) are some indications for nerve block in children [6].

The mandibular foramen is positioned above the midpoint of the medial surface of the mandibular ramus and allows the passage of the inferior alveolar nerve, artery, and vein, with its terminal branch exiting through the mental foramen. It connects to the other mandibular foramen via the mandibular canal [7, 8]. Knowing its location is vital for safely performing inferior alveolar nerve blocks, helping to prevent aspiration and nerve damage. The anatomical position of the mandibular foramen varies, typically found 10—25 mm from the anterior edge, 9—20 mm from the posterior edge, 17—29 mm from the mandibular notch, and 15—35 mm from the mandibular angle [9].The position of the mandibular foramen is influenced by the mandible growth, which can occur with age [10]. Numerous research studies have been conducted to analyze the location of the mandibular foramen in adults, but there is a lack of studies focusing on the pediatric population [11]. Administering a successful IANB in pediatric patients can be challenging due to the nerve's additional branching and the frequent occurrence of inappropriate needle insertion positions [12]. Furthermore, the location of the mandibular foramen can vary as a child's mandible grows and their teeth erupt, resulting in differences in dentofacial characteristics among patients of different age groups. Therefore, taking into account the changes in the mandibular foramen's position during the growth period can help reduce the risk of a failed injection [13, 14].

The mandibular foramen position in children is typically situated below the occlusal plane, whereas in adolescents, it is commonly parallel to the occlusal plane [15]. As a result, panoramic radiographs can be a useful tool for dentists to determine the relationship between the lower occlusal plane and MF, aiding in the administration of IANB [16]. Panoramic radiography reveals the mandibular canal as a radiolucent, curved plane that stretches from the MF to the mental foramen. Additionally, clinicians rely on panoramic radiography due to its cost-effectiveness and ability to identify anatomical landmarks [13, 17].

Hence **the aim of this study** was to evaluate the changes in mandibular foramen position in different age group by panoramic radiograph in children in Iran.

MATERIALS AND METHODS

This study employed a descriptive observational approach with a cross-sectional design and a semi-blinding method to minimize biases. The data for the study were obtained from panoramic radiographs of patients at Jundishapur Dental School of Ahvaz between 2021 and 2022. The research sample was selected using the Willems et al. (2006) sampling method.

Inclusion criteria: aged 3 to 13 years, normal facial morphology, no history of fracture or trauma to the jaw. Exclusion criteria: poor radiograph quality, undergoing orthodontic treatment.

A total of 135 panoramic radiographs from children aged 3 to 13 years (63 girls and 72 boys) the study classified in 5 groups (27 patients each) according by age and condition of the teeth:

- **I — 3—5 years old children in wich all deciduous teeth have erupted;**
- **II — 5—7 years old children with an early mixed dentition — eruption phase of the first molar;**
- **III — 7—9 years old children with a mixed dentition — completion of the eruption phase of the first molar;**
- **IV — 9—11 years old children with a late mixed dentition — eruption exchange phase of lateral incisor teeth;**
- **V — 11—13 years old children at the early period of permanent teeth — The beginning of the eruption phase of the second molar and its completion.**

The 3 to 13 years range encompasses critical periods of dental and craniofacial development. Understanding the position and morphology of the mental foramen during these years provides insights into normal anatomical changes that occur as children grow. The radiographs were part of routine dental examinations and no additional radiographs were taken specifically for this study. All radiographs were taken by the same radiology technician, and the subjects were positioned according to the Frankfurt horizontal plane. The subjects' lips were in a resting position and the midline was properly aligned. The radiographs were captured using Cranex D (Soredex, Finland).

The Digora software (Finland) was utilized to extract the images in DICOM format after adjusting the contrast and transparency. Only the left sides of the patients were measured as previous studies showed no significantly difference between measurements in the right and left regions. The location of MF was determined through panoramic images and precise linear measurements were recorded using anatomic sites as reference points. To eliminate magnification discrepancies, the mesiodistal width of the posteriormost erupted deciduous and permanent tooth on the left side of the patient was measured with a caliper in the mouth. The cranial index (CI) and Izard's facial index (FI) were calculated, the linear anatomic parameters of the skull and mandible were measured, the location of the mandibular foramen was identified, and the shapes of the skulls and mandibles were determined.

All measurements, including points, planes, and lines, were drawn with 100th millimeters of accuracy using Radiant DICOM viewer software and registered by a single calibrated examiner. The L2 line was used to measure the horizontal position of the MF, while the L1 line was used to measure the vertical position of the MF relative to the occlusal plane. The distance of 5 points to P1 and P2 planes was measured after drawing lines and points in the software (fig. 1).

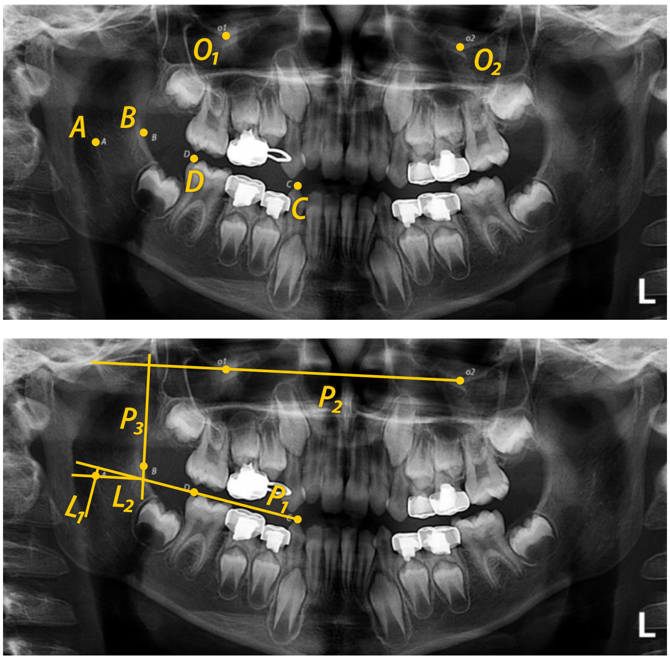

Fig. 1. Hypothetical points and lines for measurements: point A — the most anterior part of the mandibular canal; point B — the deepest point in the anterior ramus; point C — cusp tip of tooth 3 if erupted; point D — the most posterior cusp of the most distal molar tooth has been developed; points O_1 and O_2 — the lowest points of the infraorbital margins; P_1 — occlusal plane (connecting points C and D); P_2— orbital plane (connecting points O_1 and O_2); P_3 — the perpendicular line from point B to the orbital plane; L_1 — a perpendicular line from point A to the P_1 plane; L_2 — a perpendicular line from point A to the P_3 plane

In statistical analysis Shapiro—Wilk test was employed to assess the normality of distribution. For normally distributed data, a one-way analysis of variance (ANOVA) was conducted, followed by Tukey's multiple comparison tests to compare the locations of the MF by age. Additionally, a Bonferroni post-test (correction) was employed to compare the results of the analysis of variance. Correlation analysis was performed on repeated within-observation measurements. In all the analyses, p-value<0.05 was considered statistically significant.

RESULTS

In the present study, the average age of the children in the study was 7.8±2.7 years.

Table 1 compares the average changes of the mandibular foramen in the horizontal dimension in different age groups. For this purpose, average horizontal distance of the mandibular foramen with the line perpendicular to the orbital plane was examined in patients of different age groups. The results showed that the average of this distance in different age groups is significantly different from each other (p<0.001).

Table. 1. Comparison of the average horizontal distance of the mandibular foramen with the line perpendicular to the orbital plane in different age groups (in mm)

Group and age	Mean±SD	Min—Max
I (3—5 yo)	7.89±0.58	6.78—8.83
II (5—7 yo)	9.57±0.64	8.52—10.85
III (7—9 yo)	10.53±0.55	9.45—1.41
IV (9—11 yo)	11.06±0.51	9.82—12.18
V (11—13 yo)	12.92±1.06	10.97—14.97

Then, Benferroni's post-test was used to investigate the origin of differences between groups. The results showed that there is a significant difference in the average horizontal distance of the mandibular foramen with the line perpendicular to the orbital plane between most age groups. Accordingly, there was no significant difference in the average horizontal distance between the Group III and IV in the average distance. It has been demonstrated that as the patient's age increases up to 7 years, there is a notable increase in the distance from the lingula to the perpendicular to the orbital plane. Subsequently, this distance remains consistent until the age of 11. Additionally, after the age of 11, the vertical growth of the mandibular ramus leads to the posterior displacement of the mandibular foramen in the horizontal dimension. In other words, as age increases, the mandibular foramen undergoes significant horizontal movement (fig. 2).

To achieve average distance of the mandibular foramen in the vertical dimension, the average vertical distance of the lingula to the occlusal plane was examined in patients of different age groups. The negative values indicate the location of the mandibular foramen at the bottom of the occlusal plane and the positive values indicate its location at the top of the occlusal plane. The results of this study showed that the average vertical distance of the lingula to the occlusal plane is significantly different in groups of patients (p<0.001; table 2).

The study findings indicate a noteworthy variation in the mean vertical distance of the lingula to the occlusal plane among all age categories. As patients' age increases, the vertical distance of the lingula to the occlusal plane also increases significantly (p<0.001; fig. 3).

In this study, we conducted a comparison of the average displacement of the mandibular foramen in the horizontal and vertical dimensions across various age groups. This ratio was determined by dividing vertical distance of the lingula to the orbital plane by vertical distance of the lingula to the occlusal plane. The findings revealed a significant variation in the average displacement among different age groups of patients (p<0.001; table 3).

Furthermore, our findings indicate a notable distinction in the displacement ratio of the mandibular foramen between the age groups of 3 to 5 years and 7 to 9 years, as well as 9 to 11 years. Moreover, a significant variation was observed among the age groups of 5 to 7 years, 9 to 11 years, and 11 to 13 years (p<0.05; fig. 4).

Table. 2. Vertical distance of the lingula to the occlusal plane in patients of different age groups (in mm)

Group and age	Mean±SD	Min	Max	*p*
I (3—5 yo)	−2.79±0.70	−4.09	−1.72	
II (5—7 yo)	−1.60±0.53	−2.69	−0.84	
III (7—9 yo)	0.11±0.82	−1.58	1.72	<0.001
IV (9—11 yo)	1.15±0.31	0.68	1.73	
V (11—13 yo)	4.11±1.30	1.25	6.63	

Table. 3. Comparison of the average displacement of the mandibular foramen in the horizontal and vertical dimensions in all age groups (in mm)

Group and age	Mean±SD	Min—Max	*p*
I (3—5 yo)	3.02±0.87	1.79—4.87	
II (5—7 yo)	6.59±1.99	3.55—10.77	
III (7—9 yo)	24.21±12.50	5.96—97.08	<0.001
IV (9—11 yo)	10.27±2.73	6.41—17.86	
V (11—13 yo)	1.93±3.62	2.09—10.61	

DISCUSSION

The mandibular foramen situated on the inner surface of the ramus bone is the entry point for the inferior alveolar nerve, which is responsible for providing sensation to the teeth, lower jaw gums, part of the lip, tongue, and chin on the same side. Administering a successful IANB in pediatric patients is a challenging task. The primary reasons for the failure of this block in children are accessory innervations of the mandibular dentition and improper recognition and evaluation of anatomic landmarks, which is the most common cause of needle placement error [4, 18]. Many studies have investigated the position of the mandibular foramen in adults, but less attention has been paid to this issue in children [1, 19]. Therefore, the purpose of this study was to evaluation of changes in mandibular foramen position in different age group by panoramic radiograph.

Studies have shown that there is no difference in the location of the mandibular foramen between male and female, and there is no significant difference in determining the position of the mandibular foramen between the right and left ramus [20, 21]. Therefore, the samples of the present study were collected from the left side of the patients without considering the gender.

The findings of the current study indicate that there is a significant difference in the average distance between the lingula and the occlusal plane among different age groups of patients. Specifically, in terms of vertical dimension, the distance between the mandibular foramen

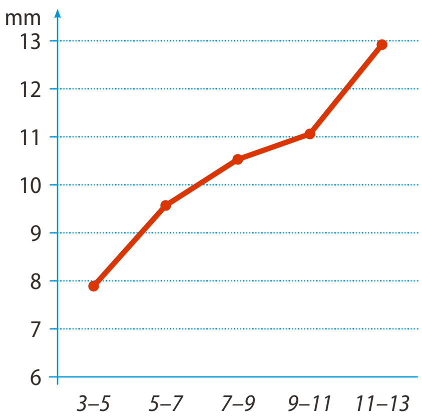

Fig. 2. Investigating the trend of mandibular foramen changes in the horizontal dimension with age. The average horizontal distance has shown an upward trend across various age groups. Specifically, it increased from 7.9 mm in the 3 to 5-year-old age group to 9.6 mm in the 5 to 7-year-old age group, and then to 10.5 mm in the 7 to 9-year-old age group. This trend has persisted in the age groups of 9 to 11 years and 11 to 13 years

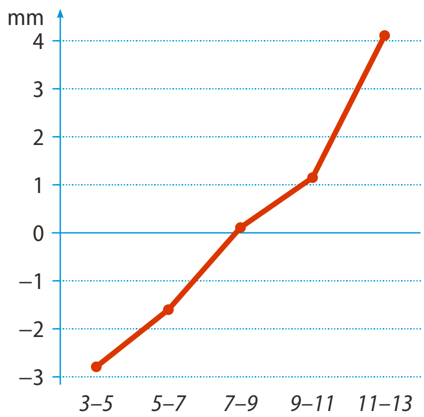

Fig. 3. Investigating the trend of mandibular foramen changes in the vertical dimension with age. The highest amount of changes related to the displacement of the mandibular foramen was between the 9 to 11 years and 11 to 13 years age groups. Also, the lowest amount of changes related to displacement in the vertical dimension was between the 7—9 years and 9—11 years age groups

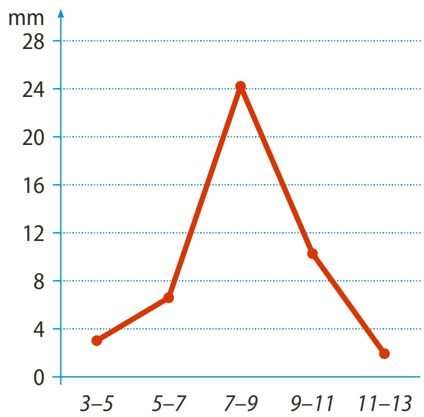

Fig. 4. Investigating the trend of mandibular foramen changes in the horizontal to vertical dimension with age. The age groups of 7 to 9 years showed the highest displacement ratio compared to other groups. In addition, the results showed that in all age groups, the displacement of the mandibular foramen in the horizontal dimension is more than the vertical dimension

and the occlusal plane increases as children age. Additionally, the results reveal that the mandibular hole is positioned below the occlusal plane in the age groups of 3 to 5 years (by 2.7 mm) and 5 to 7 years (by 1.6 mm). Furthermore, as children develop to the age group of 7 to 9 years, the mandibular foramen aligns with the occlusal plane and subsequently moves above it.

The most significant changes in the vertical dimension of the mandibular foramen among age groups occur between the age group of 9—11 years (1.5 mm above the occlusal plane) and 11—13 years (4.5 mm above the occlusal plane). Moreover, it appears that there is a growth spurt in the vertical dimension of the ramus of the mandible in the age group of 11 to 13 years, which is likely consistent with the overall growth spurt in the body.

Thangavelu et al. (2012), in their study, inconsistent with our study, showed that the mandibular foramen is slightly lower than the occlusal plane and suggested that due to the open position of the mouth during anesthesia, the needle entry point should be 10 mm higher than the occlusal plane [22]. In their study, Bhardwaj et al. (2014) demonstrated that as individuals age, the changes observed in the mandibular canal and mandibular foramen were deemed highly significant among all the study parameters which consistent with our results [23]. The results of Feuerstein et al. study (2020), which was conducted based on cone beam computed tomography (CBCT), showed that the mandibular foramen is 0.4 mm below the occlusal plane at the age of 3 to 5 years, and after that, it is at the level of the occlusal plane during the growth of the molars. Additionally, it will vary up to 2.9 mm above the occlusal plane in adulthood, which is in line with the present study [24]. According to Poonacha et al. (2010), the position of the mandibular foramen remains constant despite the vertical growth of the mandible. This is attributed to the lower alveolar nerve and the mandibular foramen acting as a tissue matrix and a growth factor for bone. Our study demonstrated different results, which can be attributed to differences in patient race, measurement tools, and references used [25]. In Shukla et al. study (2018), it was demonstrated that the injection needle entry point is situated below the occlusal plane during the ages of 3—4 years. However, at the ages of 5—7 years, it should be aligned with the occlusal plane, and above the plane at the age of 9 years. Additionally, the study found that the most significant vertical changes occurred during the ages of 12—13 years, which aligns with the findings of the current study [20].

Numerous studies have consistently demonstrated the significant influence of the growth spurt on the repositioning of the mandible, shifting it from below to above the occlusal plane. The initial placement of the mandibular foramen, whether higher or lower than the horizontal plane, can be attributed to various factors including race, the overall skull shape, the type of measurement tools used (manual or automatic), varying levels of magnification, and different in the reference plane (occlusal plane or alveolar ridge) [26].

The findings of our research indicate a significant disparity in the vertical distance between the lingula and the occlusal plane across various age groups, with the exception of the 7—9 years and 9—11 years age groups. Consequently, it can be concluded that the position of the mandibular hole shifts posteriorly in the anterior-posterior dimension from ages 3 to 7. Also, the position of the mandibular hole has little changes in the transverse dimension until the age of 11 years, and then from 11 to 13 years age, due to the growth spurt, it moves to the posterior side. Paryab et al. (2015), have shown that the mandibular foramen undergoes a consistent anterior movement as an individual ages [5].

Conversely, Lim et al. (2015), determined that the mandibular hole's horizontal position remains fixed in the middle of the ramus bone from ages 5 to 16 [27]. In the study of Movahhed et al. (2011), it was shown that in all age groups, the distance of the mandibular foramen from the anterior border of the ramus was greater than the posterior border, and the location of this anatomical landmark increased by 5.2 mm was moved posteriorly. The results of this study were similar to the present study [28].

CONCLUSION

Generally, the horizontal position of the mandibular foramen moves posteriorly with increasing age in all age groups by increasing the distance from the most anterior point on the anterior border of the ramus. Also, in the vertical dimension from 3 years old to 7 years old, the position of the mandibular foramen is below the occlusal plane, and after 7 years old, this position is at or above the occlusal plane. As a result, it is recommended that the injection needle should be in the sub-occlusal plane and closer to the anterior border of the ramus in patients under 7 years of age, and as children get older, the approximate needle entry point should be placed above the occlusal plane.

LIMITATION

Main limitations of this study is the use of panoramic radiography, which cannot be as accurate as 3D imaging, although panoramic radiography can convert a 3D object into a 2D image that is acceptable in terms of morphological proportions and on which the necessary measurements can be made.

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