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Morphological Variations of the Nasopalatine Canal and Incisive Foramen Using Cone-Beam Computed Tomography: A Cross-Sectional Study

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Running title

CBCT Assessment of Nasopalatine Canal and Incisive Foramen Variations

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Abstract

Background

Variations in the morphology and dimensions of the NPC and incisive foramen may influence surgical procedures such as implant placement, orthognathic surgery, and other interventions performed in the premaxillary region. Cone-beam computed tomography (CBCT) provides accurate three-dimensional evaluation of these anatomical structures. This study aimed to evaluate the frequency of different anatomical types of the nasopalatine canal and incisive foramen and their related factors using CBCT images in Iranian Population.

Materials and Methods

This analytical cross-sectional study evaluated 180 CBCT images (90 males, 90 females) from patients referred to the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Islamic Azad University of Tehran. Sagittal, axial, and coronal sections were used to assess NPC dimensions, curvature, angular orientation, and incisive foramen morphology. Data were analyzed using Chi-square and independent sample t-tests.

Results

The most common anatomical type of the nasopalatine canal was Type A in both genders. No significant association was found between canal morphology and gender. The round shape was the most frequent form of the incisive foramen in both males and females. Significant differences were observed between males and females regarding the anteroposterior ($p=0.003$) and mediolateral diameters of the incisive foramen ($p=0.041$) ($p<0.05$).

Conclusion

Considerable anatomical variations exist in the morphology and dimensions of the nasopalatine canal and incisive foramen. Accurate CBCT evaluation before surgical procedures in the anterior maxillary region is strongly recommended to minimize complications and improve treatment planning.

Keywords: Nasopalatine canal; Incisive foramen; Cone-beam computed tomography; Maxilla; Morphology

Introduction

The premaxillary region is one of the most common areas exposed to trauma and tooth loss. This region plays a fundamental role in esthetics, phonetics, and biomechanics. Among the important anatomical landmarks of this area is the nasopalatine canal (NPC), also known as the incisive canal [1, 2]. It consists of the incisive foramen (IF), located beneath the incisive papilla, and the nasal openings known as the foramina of Stenson (FS). The nasopalatine nerve and the terminal branch of the descending palatine artery pass through this canal [3, 4].

Radiographically, the incisive foramen appears as a radiolucent area with variable shapes such as round, oval, or heart-shaped. The canal contains the nasopalatine nerve and accompanying blood vessels and is clinically important because of its association with nasopalatine duct cysts [3, 5].

The morphology and topography of the nasopalatine canal and incisive foramen may affect surgical and prosthetic treatment planning including implant surgery, orthognathic surgery, orthodontic treatment, and management of traumatic lesions [6, 7]. Implant placement in close proximity to the nasopalatine canal may compromise osseointegration and increase the risk of neurovascular complications, including sensory disturbances. Therefore, accurate preoperative evaluation of NPC morphology and dimensions is essential for minimizing surgical complications and improving treatment outcomes [8–10].

Several imaging modalities have been used for evaluation of the anterior maxilla. Although these imaging techniques can visualize the nasopalatine canal, conventional two-dimensional radiographic methods have inherent limitations such as distortion, magnification, superimposition, and tomographic artifacts, which may negatively affect accurate evaluation of anatomical variations [11–13].

Cone-beam computed tomography (CBCT) can significantly facilitate precise identification of craniofacial structures and accurate determination of the configuration and position of the nasopalatine canal and incisive foramen. In addition, CBCT provides three-dimensional visualization of these anatomical structures [11–14].

Considering the anatomical variations in the size, shape, location, and number of foramina among different ethnic and geographic population, accurate radiographic evaluation of the anterior maxilla is essential. Therefore the American Academy of Oral and Maxillofacial Radiology recommends cross-sectional imaging using CBCT for implant site assessment and diagnostic information [15, 16].

To the best of our knowledge, no studies have evaluated the frequency of different types of nasopalatine canal and incisive foramen and their related factors using CBCT images of Tehran-based population. Hence, the present study aims to evaluate the morphological variations of the nasopalatine canal and incisive foramen in CBCT Images of patients referred to Azad Tehran University, Faculty of Dentistry.

Materials & Methods

Study Design

This analytical cross-sectional study was conducted using CBCT images obtained from patients referred to the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Islamic Azad University of Tehran.

Sample Size and Study Population

Sample size was determined using multiple regression power analysis in PASS 11 software, with $\alpha = 0.05$, $\beta = 0.2$, and $R^2 = 0.1$ for two independent variables, yielding a minimum required sample size of 90 CBCT images per gender. A total of 180 CBCT images, including images from 90 male and 90 female patients were evaluated. The samples were selected from archived CBCT records according to the inclusion and exclusion criteria.

- The *Inclusion criteria* were as follows: 1) Age above 18 years 2) Availability of CBCT images of the anterior maxilla 3) Absence of previous maxillary surgery 3) No history of orthodontic treatment
- The *Exclusion criteria* were as follows: 1) Poor image quality or artifacts 2) Severe alveolar ridge atrophy 3) Missing or supernumerary maxillary incisors 4) Prosthetic treatment in the anterior maxilla 5) History of trauma in the maxillary incisor region 6) Pathological lesions in the nasopalatine area 7) Impacted teeth in the anterior maxilla 8) Cleft lip or palate 9) Metabolic, inflammatory, or developmental jaw diseases 10) Presence of implants or bone grafts in the premaxillary region

CBCT Evaluation

All CBCT images were obtained using a 3D Papaya CBCT unit (Genoray, South Korea) with a field of view (FOV) of 14×8 or 14×14 cm, voxel size of 0.175 mm, and exposure parameters of 60–90 kVp and 4–12 mA. Images were processed and analyzed using OnDemand software (CyberMed, Korea). Axial, coronal, and sagittal sections were reconstructed at a slice thickness of 0.5 mm. All images were assessed by a final-year dental student under the supervision of an oral and maxillofacial radiologist with a minimum of 10 years of experience. Patient age and gender were recorded.

The following parameters were evaluated:

Sagittal plane measurements

- NPC length

Measured from the center of the incisive foramen to the center of the nasopalatine foramen.

- NPC diameter

The nasal opening diameter (Stensen foramen) was measured as the distance between the anterior and posterior borders of the NPC at its nasal aperture.

- NPC angle relative to the horizontal plane

Measured from the angle between the longitudinal axis of the canal and the nasal floor (ANS–PNS line).

- NPC curvature

Canal curvature was classified into four types: vertical-curved, vertical, oblique, and oblique-curved. The nasal floor served as the horizontal reference. Canals with an axis deviating $\geq 10^\circ$ from the vertical were classified as oblique; those deviating $< 10^\circ$ were classified as vertical. Straight or curved canals were further determined based on the curvature of the palatal canal wall.

- Anteroposterior (AP) diameter of the nasal foramen

The AP diameter of the nasal foramen was measured as the distance between its anterior and posterior borders

- Oral opening diameter of the incisive foramen.

Measured as the distance between the anterior and posterior borders of the NPC at its oral opening (**Figure 1 and 2**).

Axial plane measurements

- Shape of the incisive foramen.

The shape of the incisive foramen was categorized as round, oval, heart-shaped, triangular (Lobular) (**Figure 3**).

- Mediolateral diameter of the incisive foramen.

The mediolateral diameter of the incisive foramen was measured on axial CBCT sections (**Figure 4**).

Coronal plane measurements

- Anatomical type of the nasopalatine canal

The anatomical classification of the canal was based on the classification proposed by Bornstein et al.[17] (**Figure 5**):

Type A: Single canal

Type B: Two parallel canals

Type C: Y-type, with a single oral opening at the incisive foramen and two or more nasal openings at the foramina of Stensen.

Statistical Analysis

Data were analyzed using SPSS software (SPSS Inc., Chicago, IL, USA). Quantitative variables were expressed as mean $\pm$ standard deviation (SD), while qualitative variables were presented as frequency and percentage. The Kolmogorov-Smirnov test was used to assess the normality of data distribution. Chi-square and independent sample t-tests were used for statistical analysis. A p-value less than 0.05 was considered statistically significant.

Clinical trial number: Not Applicable.

Ethical Considerations

The present study was approved by the Ethics Committee of Islamic Azad University of Medical Sciences, Tehran, Iran under the code IR.IAU.DENTAL.REC.1402.137. All intellectual and

material rights belong to the institution. Patient information remained confidential, and all CBCT images were evaluated anonymously.

Results

Study Population

This study evaluated CBCT images of 180 patients, including 90 males and 90 females.

Morphometry of the Nasopalatine Canal

The anatomical configuration of the nasopalatine canal was predominantly Type A in both genders (75%). In males, Type B was the second most common type (13.3%), followed by Type C (10%). In females, Type C was the second most common type (14.4%), followed by Type B (12.2%). According to the Pearson Chi-square test, no significant association was observed between the anatomical type of the nasopalatine canal and gender ($p = 0.658$) (**Table 1**).

The curvature pattern of the nasopalatine canal was predominantly oblique in males (43.3%) and oblique-curved in females (45.6%). In males, the second most common pattern was oblique-curved (38.9%), whereas in females the oblique pattern was the second most common type (38.9%). The vertical-curved pattern showed the lowest frequency in both genders, accounting for 1.1% in males and 2.2% in females. Based on the Pearson Chi-square test, no significant relationship was found between the curvature pattern of the nasopalatine canal and gender ($p = 0.716$) (**Table 2**).

The mean *nasopalatine canal length* was 11.87 ± 3.17 mm, while the mean *angle between the canal and the horizontal plane* was 111.94 ± 11.34 degrees. In addition, the mean *canal curvature angle* was 21.94 ± 11.34 degrees. According to the independent sample t-test, no statistically significant differences were observed between males and females regarding canal length ($p = 0.607$), angle between the canal and the horizontal plane ($p = 0.411$), or canal curvature ($p = 0.411$) (**Table 3**).

Morphometry of the Incisive Foramen

Shape of the incisive foramen was predominantly round in both genders (52.8%). In males, the oval shape was the second most common form (18.9%), whereas in females the heart-shaped form was the second most frequent type (17.8%). The triangular (Lobular) shape was the third most common form in males (15.6%), while the oval shape ranked third in females (16.7%). The heart-shaped form had the lowest prevalence in males (11.1%), whereas the triangular (Lobular) form showed the lowest prevalence in females (14.4%). Pearson Chi-square analysis demonstrated no significant association between incisive foramen shape and gender ($p = 0.650$) (**Table 4**).

The mean *diameter of the incisive foramen* at the nasal opening was 3.01 ± 1.08 mm, whereas the mean diameter at the oral opening was 6.02 ± 1.86 mm (the diameter was measured at the most inferior/oral margin of the incisive foramen). No significant differences were observed between males and females regarding the diameter at the nasal opening ($p = 0.424$) or oral opening ($p = 0.893$). However, the mean anteroposterior diameter was 3.48 ± 1.27 mm and the

mean mediolateral diameter was 3.78 ± 1.27 mm, both of which were significantly greater in males than females ($p = 0.003$ and $p = 0.041$) (**Table 5**).

Discussion

The nasopalatine canal (NPC) and incisive foramen are important anatomical structures in the anterior maxilla because of their close relationship with adjacent teeth, alveolar bone, and implant placement sites. Anatomical variations in this region may contribute to surgical complications such as implant failure, sensory disturbances, root resorption, orthodontic complications, and prosthetic treatment challenges. Therefore, precise evaluation of the NPC and incisive foramen is essential before surgical and prosthetic procedures [1–3, 5]

Different imaging modalities have previously been used for evaluation of the NPC, including multislice computed tomography (MSCT), magnetic resonance imaging (MRI), micro-computed tomography, and cone-beam computed tomography (CBCT) [2, 7, 11, 18–22]. Conventional two-dimensional methods such as lateral cephalometry may demonstrate the presence of the NPC; however, accurate assessment of canal morphology, dimensions, and location remains limited because of magnification, distortion, and superimposition [23, 24]. Among the available imaging modalities, CBCT provides accurate three-dimensional evaluation of the nasopalatine canal and incisive foramen and allows precise assessment of their anatomical characteristics [11, 14].

Most previous CBCT studies have reported Y-shaped canals as the predominant NPC configuration; however, studies conducted in Iranian and some Middle Eastern populations have demonstrated a higher prevalence of single canal morphology. These differences may reflect ethnic and population-based anatomical variations in addition to methodological differences such as sample size, imaging protocols, and CBCT slice thickness [25–28].

Compared with several previous investigations, the present study included a relatively balanced sample of males and females, which may improve the reliability of gender-based comparisons. Variations among studies may also be influenced by differences in age distribution, geographic background, imaging techniques, and criteria used for NPC classification and measurement.

One of the major strengths of the present study was the simultaneous morphometric and morphological evaluation of the nasopalatine canal and incisive foramen in a Tehran-based population using CBCT imaging. These findings may have important clinical implications for implant placement, orthodontic mini-screw insertion, and other surgical procedures involving the anterior maxilla.

The present analytical cross-sectional study illustrated that incisive foramen most commonly exhibits a round shape in both genders, with no significant association between foramen morphology and gender. However, the significantly greater anteroposterior and mediolateral diameters of the incisive foramen observed in males may be related to gender-based differences in craniofacial skeletal dimensions and maxillary bone volume. Clinically, these anatomical variations may affect the available bone volume in the anterior maxilla and should therefore be

carefully considered during implant treatment planning. these results are consistent with previous studies reporting larger incisive foramen dimensions in males [7, 29, 30].

Considerable anatomical variations of the NPC were also observed. Type A (single canal) was the predominant configuration in both genders, followed by Types C and B, with no significant association between NPC morphology and gender. In contrast, several previous studies identified Y-shaped canals as the most common NPC configuration. Similar findings were reported by Bornstein et al., Safi et al., Khojastepour et al., Gibas-Stanek et al., and Bahşi et al. in different populations [2, 7, 18, 31]. These discrepancies may be related to ethnic diversity, sample size, imaging protocols, and variations in CBCT slice thickness or head positioning during image acquisition.

Regarding NPC curvature, the oblique pattern was the most common morphology in males, whereas the oblique-curved type predominated in females. The vertical-curved configuration showed the lowest prevalence in both genders. Comparable findings have been reported by Safi et al., Fernandez et al., Thakur et al., and Al-Amery et al. [2, 4, 32, 33]. The mean angular orientation of the NPC relative to the horizontal plane was generally comparable to previous investigations. Safi et al., Fernandez et al., and Thakur et al. also reported similar angular measurements [2, 4, 32]. Minor variations among studies may be attributed to differences in measurement techniques and plane orientation before measurement. Notably, the minimum recorded NPC curvature angle in the present study was -2.30° , indicating that a small subset of canals exhibited an anteriorly directed curvature rather than the typical posterior deflection. In the present measurement system, a negative curvature angle denotes a canal whose apex curves anteriorly (toward the labial cortex) rather than posteriorly; such an atypical trajectory may complicate implant planning by reducing the available bone anterior to the canal and increasing the risk of unintended neurovascular involvement.

Accurate assessment of NPC dimension is clinically important for implant placement. No significant gender difference was observed in NPC length. Similar findings were reported by Bahşi et al. and Tafakhori et al., whereas Khojastepour et al., Safi et al., and Yülek et al. found significantly greater canal lengths in males [2, 7, 18–20], consistent with other Iranian cohorts [29, 30, 34–36].

Table 6 Compares key NPC morphometric parameters with selected Iranian and international CBCT studies. The mean NPC length (11.87 ± 3.17 mm) was consistent with Tafakhori et al. (11.17 ± 2.50 mm) and Kajan et al., somewhat shorter than Safi et al. (12.85 ± 2.63 mm), and higher than Panjnoush et al. (10.19 ± 2.28 mm), differences that may reflect regional anatomical variation or methodological inconsistencies in defining canal boundaries. Regarding canal morphology, the present study identified Type A (single canal) as the predominant configuration (75%), in contrast to Safi et al. and Kajan et al., who reported Y-shaped canals as the most frequent type, likely reflecting ethnic and regional variation within the Iranian population as well as differences in classification systems and imaging protocols. The oral opening diameter of the incisive foramen (6.02 ± 1.86 mm) was notably larger than values reported by Panjnoush et al. (2.98 ± 1.01 mm) and Kajan et al. (3.17 ± 1.01 mm), attributable to the measurement landmark used in the present study, where the diameter was recorded at the most inferior oral margin of the

foramen, which is anatomically wider than mid-canal measurements employed in prior investigations [2, 19, 30, 35].

Differences in NPC measurements among studies may be explained by ethnic and demographic variations, sample selection, radiographic methods, and inconsistencies in defining canal boundaries and reference planes during CBCT analysis.

The present study had some limitations. Its cross-sectional design precludes the establishment of causal relationships, and the single-center sample may limit the generalizability of findings to broader populations. Furthermore, the potential influence of age on the morphology and dimensions of the nasopalatine canal and incisive foramen was not examined.

Conclusion

Overall, the findings of the present study emphasize the importance of careful CBCT evaluation of the nasopalatine canal and incisive foramen before procedures such as implant placement, mini-screw insertion, and other surgical interventions in the anterior maxilla. Accurate assessment of anatomical variations may help reduce complications and improve treatment outcomes.

Ethics approval and consent to participate

This cross-sectional study was approved by the Ethics Committee of the Faculty of Dentistry, Islamic Azad University, Tehran Medical Sciences Branch, Tehran, Iran (**Approval No. IR.IAU.DENTAL.REC.1402.137**), and was conducted in accordance with the ethical standards of the Declaration of Helsinki. Patient data were fully anonymised, and informed consent was waived given the retrospective nature of the study.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article and its supplementary information files. The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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No funding was received for this study.

Authors' contributions

SS and LH contributed to study concepts and design. SS and AA performed data acquisition, data analysis and interpretation, and statistical analysis. All authors contributed to quality control

of data, manuscript preparation, editing, and review. All authors read and approved the final manuscript

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Figure legends

Figure 1. CBCT image in the sagittal plane to demonstrate how to measure the angle of curved and straight nasopalatine canals.

Figure 2. Sagittal plane measurements: 1. Canal diameter in Nasal opening 2. Canal diameter in Oral opening 3. Nasopalatine canal length 4. Posterior-anterior diameter of incisive foramen

Figure 3. Shape of the incisive foramen in axial sections of CBCT images A. Round. B. Oval. C. Heart D. Triangular (Lobular)

Figure 4. Mediolateral diameter of the incisive foramen

Figure 5. Anatomical classification of NPC morphology single canal (type A), two separate canals (type B), and Y-shaped canal (type C).

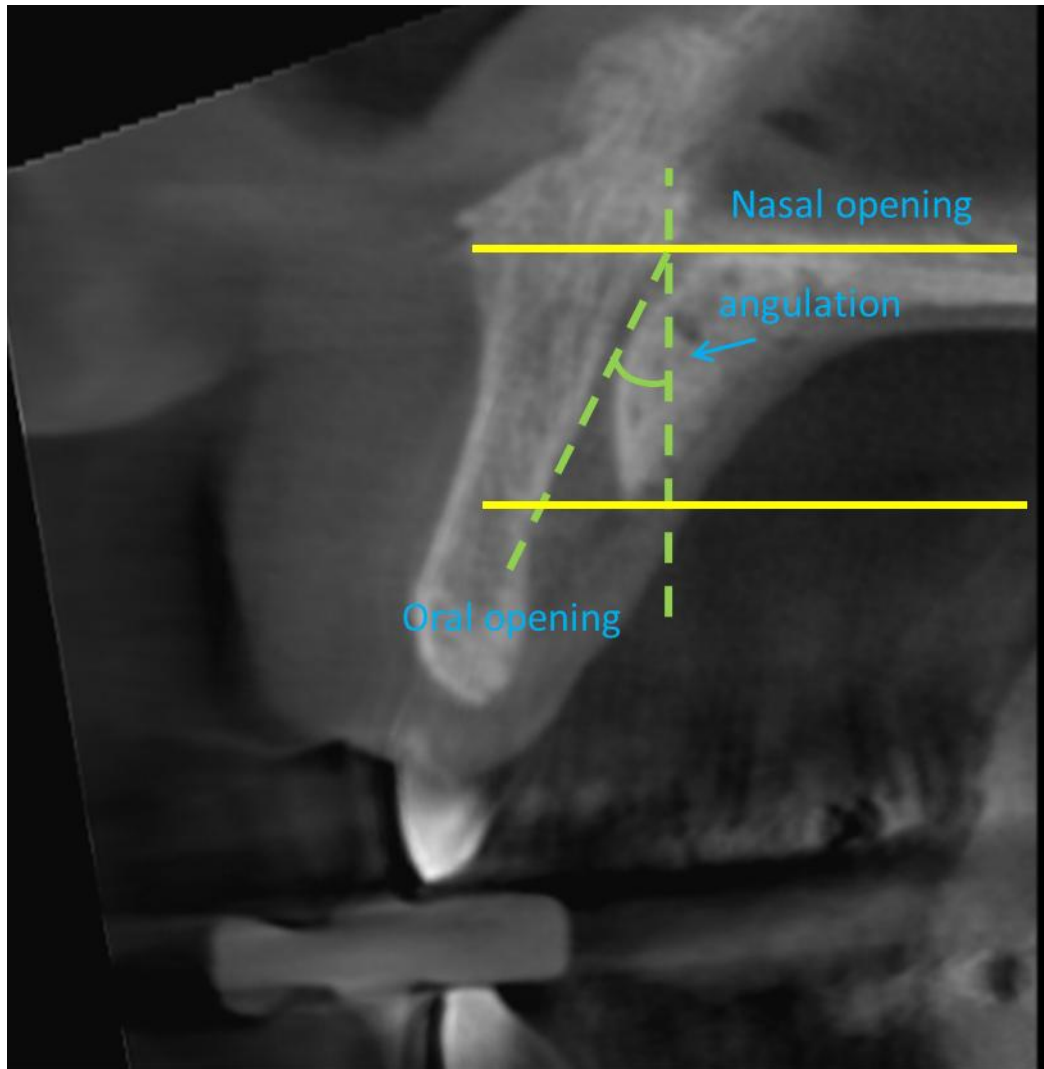


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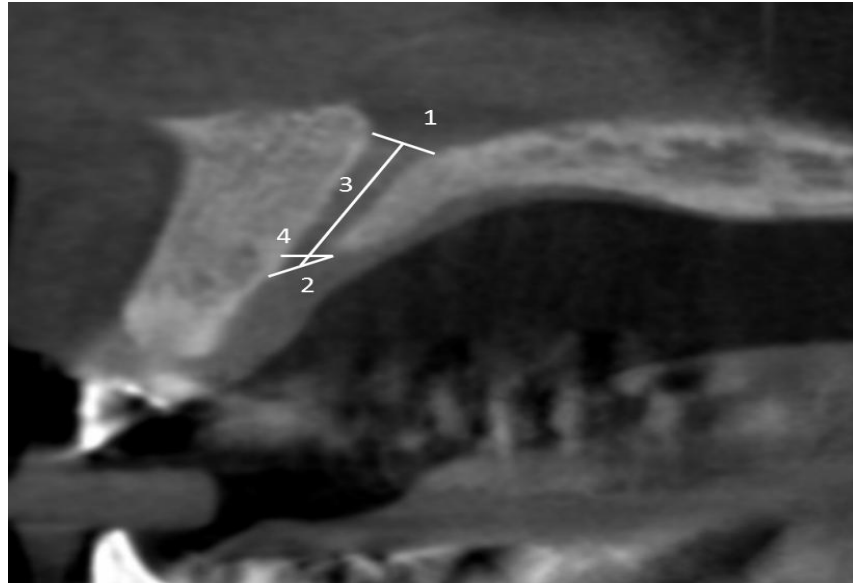


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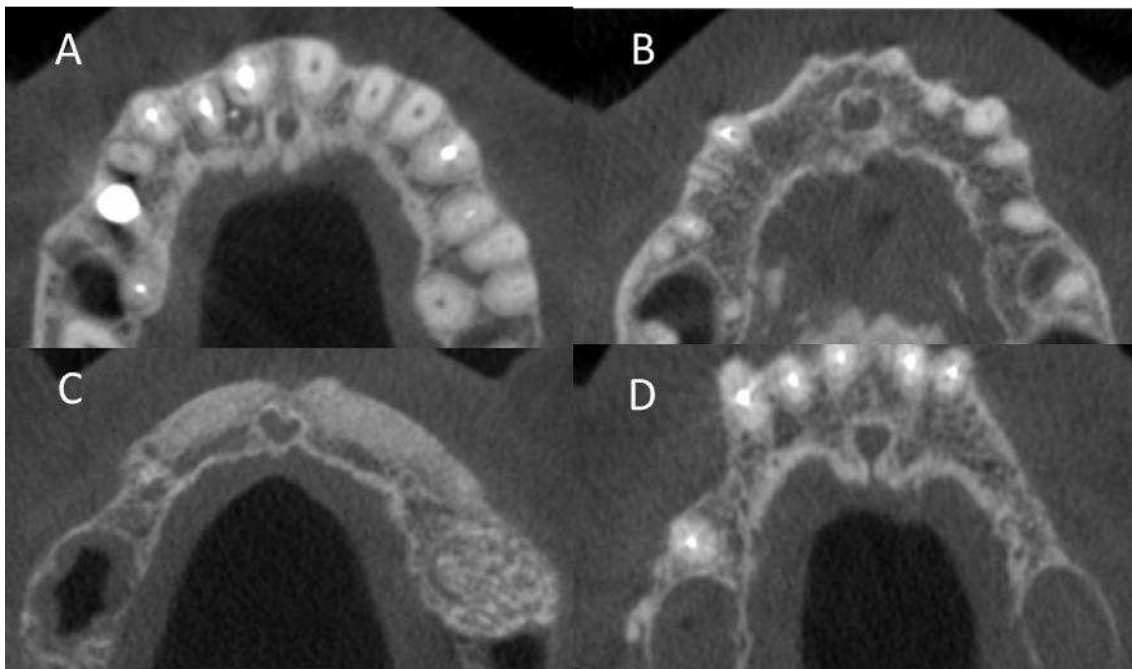


Figure 3. Shape of the incisive foramen in axial sections of CBCT images A. Round. B. Oval. C. Heart D. Triangular (Lobular1)

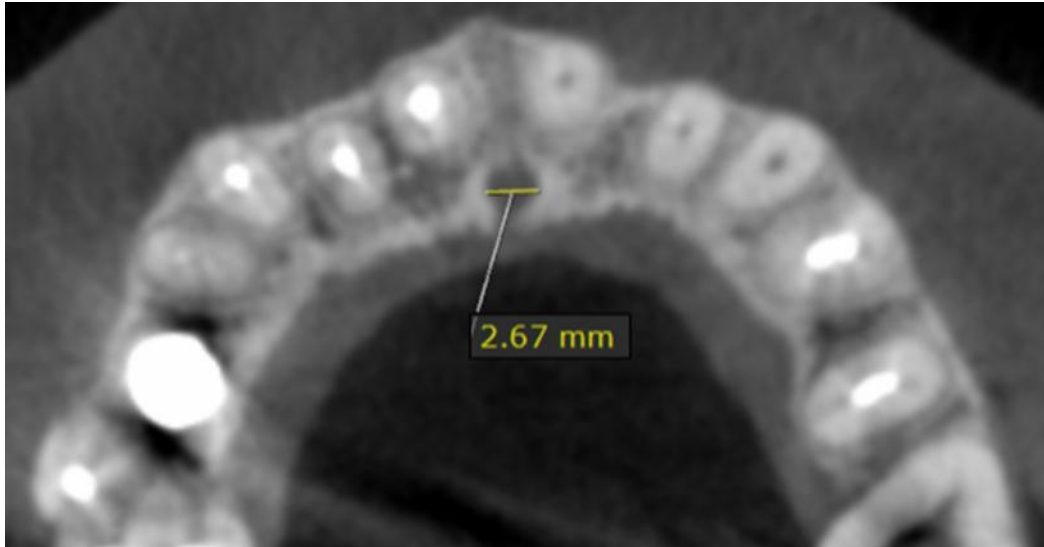


Figure 4. Mediolateral diameter of the incisive foramen

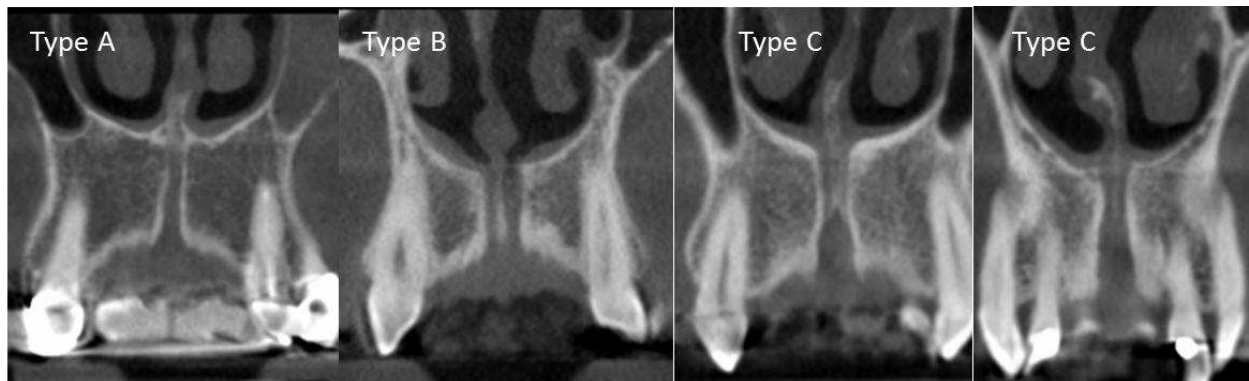


Figure 5. Anatomical classification of NPC morphology single canal (type A), two separate canals (type B), and Y-shaped canal (type C).

Tables

Table 1: Frequency of NPC Anatomic Types and Incisive Foramen by Gender				
Gender	NPC Anatomic Types			P value*
	A	B	C	
Male	69 (76.7%)	12 (13.3%)	9 (10%)	0.658
Female	66 (73.3%)	11 (12.2%)	13 (14.4%)	
Total	135 (75%)	23 (12.8%)	22 (12.2%)	

*Type A: Single canal | Type B: Two parallel canals | Type C: Y-type (canals with one oral opening (incisive foramen) and two or three nasal openings (foramen of stensen) | * Pearson Chi-Square*

Table 2: Frequency of NPC or Incisive foramen Curve Types by Gender					
Gender	NPC Canal Curve				P value*
	Vertical-Curved	Vertical	Oblique	Oblique-Curved	
Male	1 (1.1%)	15 (16.7%)	39 (43.3%)	35 (38.9%)	0.716
Female	2 (2.2%)	12 (13.3%)	35 (38.9%)	41 (45.6%)	
Total	3 (1.7%)	27 (15%)	74 (41.1%)	76 (42.2%)	

** Pearson Chi-Square*

Table-3: Descriptive Statistics of NPC Dimensions by Gender

Variables	Gender	Mean	Std. Dev.	Min	Max	P value*
NPC Canal Length (mm)	Male	11.99	3.28	5.74	18.21	0.607
	Female	11.74	3.06	5.6	18	
	Total	11.87	3.17	5.6	18.21	
Angle between NPC and the horizontal plane (degrees)	Male	111.25	11.73	87.70	133.10	0.411
	Female	112.64	10.97	88.30	132.10	
	Total	111.94	11.34	87.70	133.10	
NPC Curvature Angle (degrees)	Male	21.24	11.72	-2.30	43.1	0.411
	Female	22.64	10.97	-1.70	42.1	
	Total	21.94	11.34	-2.30	43.1	

* Independent Sample T Test

Table 4: Frequency of Incisive Foramen Shape by Gender

Gender	Incisive Foramen Shape				P value*
	Round	Oval	Heart-Shaped	Triangular (Lobular)	
Male	49 (54.4%)	17 (18.9%)	10 (11.1%)	14 (15.6%)	0.650
Female	46 (51.1%)	15 (16.4%)	16 (17.8%)	13 (14.4%)	
Total	95 (52.8%)	32 (17.8%)	26 (14.4%)	27 (15%)	

* Pearson Chi-Square

Table 5: Descriptive Statistics of Incisive Foramen Dimensions by Gender

Variables	Gender	Mean	Std. Dev.	Min	Max	P value*
Incisive Foramen Diameter – Nasal Opening	Male	3.08	1.18	1.01	5.20	0.424
	Female	2.95	0.98	1.08	6.50	
	Total	3.01	1.08	1.01	6.50	
Incisive Foramen Diameter – Oral Opening	Male	6.00	1.85	2.94	10.18	0.893
	Female	6.04	1.89	2.69	10.20	
	Total	6.02	1.86	2.69	10.20	
Anteroposterior Diameter of Incisive Foramen (AP)	Male	3.76	1.28	1.29	6.62	0.003
	Female	3.20	1.20	1.10	5.94	
	Total	3.48	1.27	1.10	6.62	
Mesiodistal Diameter of Incisive Foramen	Male	3.98	1.39	2.06	10.35	0.041
	Female	3.59	1.12	1.80	8.31	
	Total	3.78	1.27	1.80	10.35	

** Independent Sample T Test*

Table 6: Comparison of NPC Morphometric Parameters Across Key Iranian and International CBCT Studies

Author / Year	Population	n	NPC Length (mm)	Canal Type (most common)	IF Diameter (mm)	Measurement Method
Present study, 2022–23	Tehran, Iran	180	11.87 ± 3.17	Type A (single, 75%)	6.02 ± 1.86 (oral opening)	CBCT (D3 Papaya)
Tafakhori et al., 2023	Rafsanjan, Iran	285	11.17 ± 2.50	Hourglass	3.4 ± 1.2 (labiopalatal) 3.6 ± 1.2 (mesiodistal)	CBCT
Panjnough et al., 2016	Tehran, Iran	300	10.19 ± 2.28	Cylindrical	2.98 ± 1.01 (incisive F.) 2.70 ± 1.0 (Stenson F.)	CBCT
Kajan et al., 2015	Guilan, Iran	198	Not reported separately	Y-shaped	3.17 ± 1.01 (oral opening)	CBCT
Safi et al., 2017	Iran (mixed)	326	12.85 ± 2.63	Cylindrical (Y-type coronal)	Not reported	CBCT

IF = incisive foramen; NPC = nasopalatine canal; CBCT = cone-beam computed tomography. IF diameter figures represent the oral opening or equivalent measurement as reported by each study.

Supplementary Files

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- [figure0.png](#)