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Morphological and Morphometric Assessment of the Nasopalatine Canal in Egyptian Population Using CBCT

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Aim: To assess the morphology and anatomy of the nasopalatine canal (NPC) in axial, sagittal, and coronal sections and determine the impact of age and gender on the shape and anatomical variations of the NPC in the Egyptian population using cone-beam computed tomography (CBCT). To prevent any possible complications in this area.
Materials and methods: This retrospective cross-sectional study involves 200 subjects (100 male and 100 female patients aged 20 to 70 years) sample allocation into five groups. The NPC morphology and anatomic variations were evaluated in sagittal, coronal, and axial sections, and the variables obtained were statistically analyzed.
Results: In the sagittal section, no significant differences in NPC shape across age groups(p=0.073), with the cylindrical shape being the most common. Gender differences were significant for NPC length, SF, and MP widths, with males having larger measurements, but no difference was found in NPC shape. In coronal sections, no significant age-related differences for IF, MP, or SF widths or NPC shape, with the single (A) shape being predominant. Gender differences were only significant for MP width, with males showing a larger mean. In axial sections, no significant differences were found in the shape or number of SF (p=0.667 and 0.923, respectively), with the oval shape and one foramen being most common across all age groups and genders.
Conclusion: NPC exhibits a wide range of possible variants with different prevalences. Knowledge of these differences could reduce the frequency of any complication during dental procedures or facial surgery in the anterior maxilla.

Keywords: Maxilla, Cone beam computed tomography, Nasopalatine canal, Stenson foramen, Morphometric measurements.

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Introduction

The maxilla comprises numerous foramina and canals, so oral and maxillofacial surgeons must take caution when injecting local anesthesia and perform various surgical procedures in these regions. The nasopalatine canal (NPC) is situated in the anterior maxilla, one of the most frequently affected by trauma and bone or tooth loss. Also, the demand for precise radiological identification of anatomical landmarks has increased in recent years, driven by the growing use of dental implants in the anterior maxilla to meet higher aesthetic expectations. All of these factors may affect the NPC. [1,2,3]

The NPC is a vital connection between the palate and the nasal fossa. Due to its location behind the central incisors, it is commonly referred to as the incisive canal.[4] First comprehensively described by Stenson in 1683, the NPC typically runs beneath the central incisors' roots along the palate's midline.[5,6] Its opening, the incisive foramen (IF), lies beneath the incisive papilla and extends into the nasal cavity, ending at the nasal foramen, also known as Stenson's foramina (SF).[7,8] The NPC contains the terminal branch of the descending palatine artery and the nasopalatine nerve, which connect with the posterior septal branch of the sphenopalatine artery and the greater palatine nerve. It also houses fat, connective tissue, and minor salivary glands. The nasopalatine nerve supplies dual innervation to the primary palate by passing through the incisive foramen and the nasopalatine canal (NPC), innervating the palatal gingiva and the mucosa of the premaxilla. It then merges with the distribution of the greater palatine nerve. [3,9]

Therefore, evaluating the sizes and variances of the NPC is crucial when considering surgical procedures on the maxilla, such as cyst enucleation, extraction of impacted teeth, apical excision of central incisors, and rapid palatal enlargement with surgical support. [10,11] Furthermore, evaluating the NPC and its variations is critical to preventing postoperative complications during implant surgery, including bleeding, discomfort, altered sensation, and potential osseointegration failures. [12]

The location of NPC has been identified using various radiographic techniques, including spiral tomography, multi-slice computed tomography (MSCT), and two-dimensional (2D) approaches, such as intraoral radiography and panoramic tomography. [13,14] However, some intrinsic limitations of these methods, including overlap, distortion, and magnification, may make it more challenging to identify anatomic differences accurately. To improve diagnostic precision and facilitate the identification of anatomical boundaries, cone-beam computed tomography (CBCT) is recommended, as it provides a transition from two-dimensional (2D) to three-dimensional (3D) imaging. [10] CBCT images' cross-sectional nature and 3D reconstruction based on absolute coordinates allow them to assess oral and maxillofacial regions in oblique and multi-planner perspectives. [15] Because of its good image quality, excellent spatial resolution generated by the small voxel size, and relatively low radiation dose, CBCT has become the preferred volumetric 3D imaging method among general dentists and specialists. [15,16,17] Age and gender impacted the very diverse NPC size and morphology. [18] Because NPC type and characteristics are influenced by various factors, including race, geography, environment, age, habits, and genetics, there is no precise, standard classification for nasopalatine canal type and measurement. [19]

Consequently, this study aims to assess the relationship between the anatomy and morphology of the NPC and factors such as gender and age within a sample of the Egyptian population using CBCT.

Materials and methods

Ethical approval

Ethical approval was obtained from the Beni-suef University, Faculty of Dentistry, Ethical Committee (REC-FDBSU/T07122023-02/MM).

Study setting

This retrospective study used the CBCT records obtained from Beni-Suef University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology.

The scans were needed for several purposes, including preoperative implant planning, orthodontic and orthognathic assessments, and evaluating supernumerary teeth or impactions. Gender and age were also recorded at the same time.

Study design: a retrospective cross-sectional study

Sample size calculation: The sample size was calculated using Cleveland Clinic online sample size calculator (Expected mean of first group =10.19, Expected mean of second group=8.78, Population standard deviation =2.61) for the length of the nasopalatine canal in the sagittal section in different genders (male and female) according to Özeren et al. 2022. [10] Result in a total sample size of 108 (marginal error 0.05- confidence interval 95%). However, the sample size was elevated and reached 200 sample size.

Allocation of subjects into the test groups

The enrolled subjects were randomly allocated to the test groups using a computer-generated sequence with block randomization based on gender and age. The patients' data were kept secret in opaque and sequenced numbered envelopes until all measurements were completed.

200 scans (100 male and 100 female patients, aged 20 to 70 years) were retrospectively analyzed for nasopalatine canal (NPC) morphology and anatomical variations. The ages of the individuals in the sample group were based on the dates of their CBCT scans. These ages were categorized into five groups (equal number of scans in each group=20 scans): Group 1 (ages 20 to 30), Group 2 (ages 31 to 40), Group 3 (ages 41 to 50), Group 4 (ages 51 to 60), and Group 5 (ages 61 and older).

Imaging Procedures

All CBCT scans were performed using the Carestream Dental CS 8100 (USA) with the following operating parameters: 5 mA, 90 kV, voxel size of 150 µm, field of view (FOV) of 8x5 cm (maxillary arch), and an exposure time of 15 seconds. Reconstructed sagittal and coronal CBCT sections with a slice thickness of 1 mm were utilized to evaluate the anatomical structures of interest.

Eligibility criteria

Inclusion criteria: CBCT images with sufficient contrast and sharpness allowed for a clear view and assessment of the NPC and buccal osseous plate (BOP), among other osseous structures.

-Age from 20 to 70 years

-Medically free patients.

Exclusion criteria: The following exclusion criteria were applied, meaning that certain images could not be included in the study:

1. Presence of a fracture, unerupted tooth, pathological lesion, dental implant, bone graft, cleft lip/palate in the maxillary anterior region, or significant atrophy.
2. Previous surgical procedures in the relevant area, such as orthognathic surgery, cyst enucleation, or apical resection.
3. An artifact that obstructs the image's interpretation
4. Images with low quality.

Image Evaluation

Two Oral and Maxillofacial Radiologists with similar experience (6 years experience in the oral radiology department). Both assessors were blinded; they had no information regarding the gender or age of the examined subject. They independently assessed the pictures and gathered relevant data from reconstructed sagittal and coronal

CBCT sections following standard operating protocols.

Assessment of CBCT images

The axial, sagittal, and coronal sections of the CBCT images were analyzed based on the methodology described by Özeren et al. (2022) [10] Using Blue Sky Plan software version 4.1.

Assessment of the sagittal section

1- The widths of Stensen's foramen (SF), incisive foramen (IF), and mid-level point (MP) were measured in sagittal sections. The distance between the SF and IF midpoints was considered the NPC's length (Figure 1a).

2-The angle of the NPC was measured by drawing a line connecting the anterior nasal spine (ANS) and the posterior nasal spine (PNS). The sagittal sections determined the anterior angle between this line and the canal's course (Figure 1b).

Assessment of coronal section

1-The SF, IF, and MP widths were measured in coronal sections as in (Figure 1c)

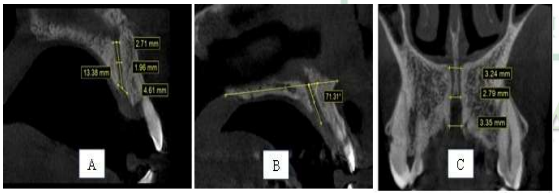

Figure 1: showed the NPC measurements in both sagittal and coronal sections. A: the widths of SF, the IF, the MP, and the length of the NPC in the sagittal section. B showed the measurement of the angle of the NPC in the sagittal section. C: The SF, IF, and MP widths measurements in the coronal section.

2-The NPC shapes were classified in the sagittal section into A (cylindrical), B (hourglass), C (cone), D (funnel), E (banana), and F (reverse funnel) (Figure 2 A-F).

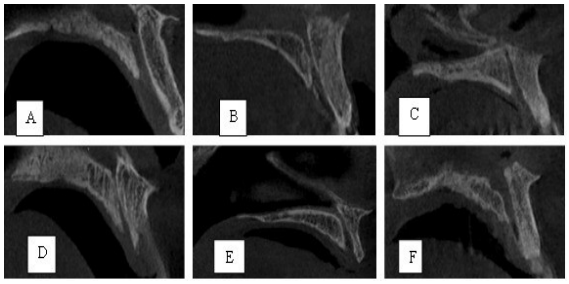

Figure 2: showed NPC shapes in the sagittal section: A (cylindrical), B (hourglass), C (cone), D (funnel), E (banana), and F (reverse funnel).

3- The shapes of NPC were classified in the coronal sections into A (single), B (two parallel), and C (Y type) (Figure 3 A-C).

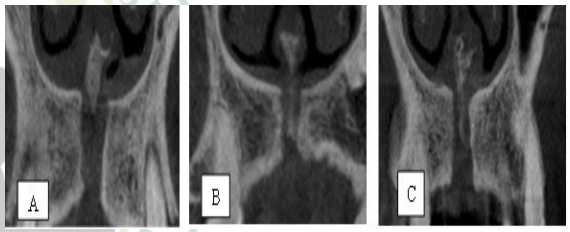

Figure 3: showed the NPC shapes in the coronal section: A (single), B (two parallel), and C (Y type).

4-In the axial section, the shape and number of SF were detected

a. The Shape of SF in the axial section was classified into A (Round), B (Oval), and C (Heart) (Figure 4a (A-C))

b. The number of SF in the axial section was classified into A (One), B (Two), C (Three), and D (Four) (Figure 4b (A-D))

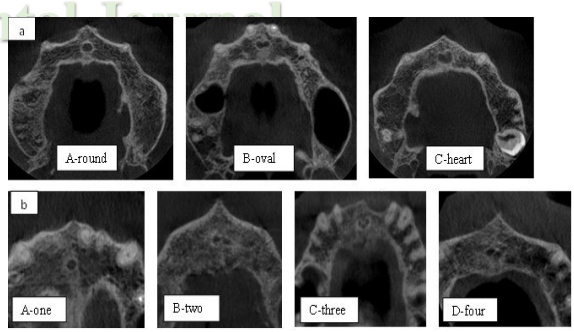

Figure 4: a- showed the shapes of SF in axial sections: A (round), B (oval), and C (heart). b- showed the numbers of SF in the axial section: A (one), B (two), C (three), and D (four).

Results

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests; data showed non-parametric (not-normal) distribution. For non-parametric data, the Kruskal Walis test was used to compare between more than two groups in non-related samples.

The Mann-Whitney test was used to compare two groups in non-related samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

To enhance the reliability of intra- and inter-observer agreement, a random sample of radiographs was re-evaluated independently by each observer two weeks after the initial assessments in each group. Intra- and inter-observer agreement was evaluated using the Intra-Class Correlation Coefficient (ICC), with values below 0.73 considered unacceptable, 0.73 to 0.9 good, and above 0.94 classified as excellent. Additionally, a Bland-Altman plot (differences-vs-means plot) was used to visualize the agreement between two quantitative measurements by analyzing the mean difference and constructing limits of agreement. [20]

In sagittal sections according to age:

Table 1 displays the measurements of IF, MP, and SF widths, NPC length, and NPC angle. No statistically significant differences were observed in the widths of IF, MP, and SF across age groups. In contrast, the NPC length and NPC angle exhibited statistically significant differences by age. The highest mean NPC length was recorded in Group 2, while Group 1 had the lowest mean value (p=0.030). Group 1 showed the highest mean value for the NPC angle, whereas Group 5 had the lowest (p=0.018). The greatest mean IF width was noted in Group 4, with Group 1 showing the lowest mean (p=0.120). Similarly, Group 4 had the highest mean MP width, while Group 1 had the lowest (p=0.855). Lastly, the highest mean value for SF width was found in Group 3, and the lowest was in Group 2 (p=0.559).

Table 1: The mean and standard deviation (SD) values of the NPC dimensions in the sagittal section at different groups according to age.

Variables	According to age Sagittal									
	IF		MP		SF		NP Length		NP Angle	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group 1 (30-20)	3.39 [a]	0.89	1.82 [a]	0.74	2.61 [a]	1.06	10.12 [b]	1.82	74.51 [a]	7.20
Group 2 (40-31)	3.43 [a]	0.75	1.87 [a]	0.67	2.52 [a]	1.02	11.50 [a]	2.46	72.67 [ab]	6.29
Group 3 (50-41)	3.68 [a]	1.06	1.97 [a]	0.70	2.88 [a]	1.22	11.33 [ab]	2.01	73.08 [ab]	7.26
Group 4 (60-51)	3.85 [a]	0.94	1.99 [a]	0.78	2.69 [a]	1.05	11.34 [ab]	2.56	72.18 [ab]	6.24
Group 5 61) and (over	3.68 [a]	0.88	1.93 [a]	0.87	2.53 [a]	1.07	10.78 [ab]	2.49	71.55 [b]	8.45
p-value	0.120ns		0.855ns		0.559ns		0.041*		0.039*	

significant (p<0.05) ns; non-significant (p>0.05)

There was no statistically significant difference in the shape of the NPC between (Group 1), (Group 2), (Group 3), (Group 4) and (Group 5) groups where (p=0.073). All groups showed the highest percentage in Cylindrical (A) shape (27.5 %), (37.5 %), (32.5 %), (52.5 %) and (37.5 %) respectively.

In sagittal sections, according to gender:

There is a statistically significant difference in the widths of SF and MP and the NPC length. The maximum widths of SF and MP were determined in male patients, and the NPC length was also greatest among male patients. However, no statistically significant difference was observed in gender for the IF width or NPC angle. Moreover, there was no statistically significant difference between the (Female) and (Male) groups and the shape of NPC in sagittal sections (p=0.189). Both groups (Female) and (Male) showed the highest percentage in cylindrical (A) shape (35 %) and (40%), respectively.

In coronal sections, according to age:

IF, MP, and SF widths did not exhibit statistically significant differences. For the IF, the highest mean value was found in Group 4, while the lowest was observed in Group 3. The MP showed the highest mean value in Group 1 and the lowest in Group 2. For the SF, the highest mean value was recorded in Group 1, whereas the lowest was in Group 5. Furthermore, according to the NPC shape, there was no statistically significant difference between (Group 1), (Group 2), (Group 3), (Group 4), and (Group 5), all groups had the highest percentages in Single (A) shape (42.5 %), (50 %), (50 %), (52.5 %), and (42.5 %), respectively.

In coronal sections, according to gender: There is a statistically significant difference in MP widths. However, no statistically significant differences were observed for the widths of the IF and SF. There was no statistically significant difference between female and male groups in the NPC shape (p=0.815). Both groups had the highest percentage in Single (A) shape (48 %) and (47 %), respectively.

In axial sections, according to age: There was no statistically significant difference in the shape of SF where (p=0.667). All groups (Group 1, Group 2, Group 3, Group 4, and Group 5) showed the highest percentage in Oval (B) shape (50 %), (52.5 %), (37.5 %), (40 %) and (55 %) respectively. Also, there was no statistically significant difference in the number of ST foramina (p=0.923). All groups (Group 1, Group 2, Group 3, Group 4, and Group 5) showed the highest percentage in the presence of one foramen with (57.5 %), (52.5 %), (52.5 %), (52.5 %) and (55 %) respectively.

In axial sections, according to gender, as in (Figure 5) showed A-The frequency values of the shape of SF. B- The frequency values of the number of SF.

A) Shape of ST: There was no statistically significant difference between (Female) and (Male) groups (p=0.177); both groups had the highest percentage in Oval (B) shape (49 %) and (45 %), respectively (Figure 5A).

B) Number of SF: There was no statistically significant difference between (Female) and (Male) groups (p=0.375); both groups had the highest percentage in the presence of one SF, with (51 %) and (57 %) respectively (Figure 5B).

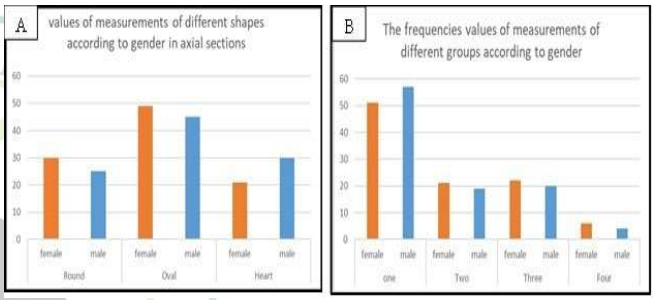

Figure 5: A-The frequency values of the shape of SF in axial sections according to gender. B- The frequency values of the number of SF in axial sections according to gender.

Discussion

Numerous researchers have examined the NPC using diverse approaches across different populations. Some studies were conducted on dry skulls, while others utilized imaging techniques, including two-dimensional and three-dimensional techniques. [21] This study used CBCT to investigate the morphology of the NPC in a sample of the Egyptian population. The findings provide valuable data for all dentists performing procedures in the anterior maxilla.

The study results showed that the IF, MP, and SF widths did not differ significantly in sagittal sections among the various age groups. This aligns with the findings of Bahşi et al., [22] Hakbilen and Magat[23], and Özçakır-Tomruk et al. [24], who also reported no statistically significant differences in the width of the NPC measured in the sagittal section across different ages. Their findings

suggest that these NPC widths might be relatively stable throughout adulthood.

While some studies reported variations, for instance, Khojastepour et al., based on 301 CBCT images of the Iranian population, and Friedrich et al., in their analysis of 200 CBCT images from the German population, found that the width of the NPC increases with age. This discrepancy could be due to ethnic variations in jaw development patterns.[25]

However, this study found a statistically significant difference in NPC length and angle based on age. The NPC length increased slightly with age, aligning with other populations' observations. For example, the study by Bajoria et al., based on 200 subjects aged between 19 and 67 years using CBCT, reported statistically significant differences in NPC length across the different age groups. [26]

This age-related lengthening could be attributed to physiological changes in the maxilla over time. The angle of NPC also revealed a statistically significant difference, displaying a minor decrease in the older age groups. This might be due to age-related remodeling of the bony structures surrounding the NPC.

The current study also identified a statistically significant difference in NPC length based on gender, with males having a longer NPC (11.66 mm) than females (10.37 mm). These results are consistent with the findings of Hakbilen and Magat[23], Linjawi et al., [27] and Jornet et al. [28] However, Mardinger et al. [29] and Song et al. [30] found similar canal lengths in males and females as 10.7 and 10.4mm, respectively. So, dentists must take this gender variation into account when performing surgical treatments on the anterior maxilla. By understanding the predicted length of the NPC, they may better provide anesthesia and prevent difficulties.

The present study showed no significant differences in NPC shape distribution between age groups or genders. This suggests that these morphological characteristics might be less influenced by age and sex within the Egyptian population. The most frequently observed NPC shapes in this study were cylindrical shapes. This finding follows previous research by Milanovic et al. [31], Fukuda et al. [32], and Mardinger et al. [29], who reported funnel and cylindrical shapes as the most common using CBCT; however, some studies reported different findings; for example, Etoz et al. [33] and Sekerci et al. [34] Found that the most common NPC was the hourglass-shaped.

Moreover, according to a study by Gil-Marques et al., the banana-shaped NPC was predominant. The observed variation in shape distribution could be due to sample demographics and the specific classification methods employed across different studies. [11]

Our results found no significant differences in the IF, MP, and SF widths across age groups in the coronal plane. This is consistent with the findings of Panjnoush et al. [17], based on 300 CBCT images in Tehran, Iran, and Ito et al.[35], based on 122 patients in Japan, using multidetector-row computed tomographic, reported that there was no statistically significant difference between IF and SF widths and age. Moreover, this study found no significant differences in NPC widths across age groups in the coronal plane, and some studies reported variations. For instance, Özeren Keşkek et al.[10] observed an increase in IF, SF, and MP width with age in a Turkish population using CBCT, where the widths of IF, MP, and SF were higher in individuals aged 61 and over.

According to gender the results showed a statistically significant difference in MP width based on gender, where this value was higher in men. This is consistent with Özeren Keşkek et al. reporting a statistically significant difference between the MP width and gender. In contrast, Ito et al.[35] reported no statistically significant difference between

the MP width and gender. On the other hand, our findings didn't find a significant difference in IF and SF width based on gender. This is consistent with Panjnoush et al.[17] and Ito et al.[35], who reported no statistically significant difference between IF and SF widths and gender.

In our study, the most frequently observed NPC shape variation in the coronal section was type A (single), with no statistically significant differences noted based on age or gender. Our findings align with previous research utilizing the Bornstein et al. [33] classification for NPC variations in coronal sections. Type A was also the most common finding in studies conducted by Panjnoush et al. [17], Özçakır-Tomruk et al. [24], Al Linjawi et al., [27] Etöz et al. [33], Sekerci et al. [34], Gönül et al. [36], and Bornstein et al. [37]

Conversely, Özeren Keşkek et al. [10] analyzed approximately 1,000 CBCT images from the Turkish population. They found that type C was the most prevalent among the NPC variations in the coronal section, occurring in 51.1% of cases. This is consistent with Safi Y et al. [38], Bahşi et al. [22], and Friedrich et al. [39]

A recent study by Thembi et al. [40] using CBCT in an Indian population found a significant association between gender and the shape of the NPC ($p < 0.05$), with males more likely to have Y-shaped canals. These findings are consistent with those of Güncü et al. [41], who analyzed 933 CT scans in Ankara, Turkey, and Rao et al. [42], who studied 460 CBCT images in Nalgonda, Telangana, India. These variations may be due to geographic distribution and convenience sampling taken in other studies, increased sample distribution compared to the current study, age group analysis, ethnic and racial differences, and variation in the observer's analysis.

The current findings showed that the SF is predominantly oval in axial sections, with no significant changes based on age. This is consistent with research by Gönül et al. [36] on a Turkish sample. However, other studies reported variations in SF morphology. For instance, Friedrich et al. [39] observed a higher frequency of round SF shapes in a German population. According to the number of SF in the axial plane, our findings showed a predominantly one foramen for the SF, with no significant changes based on age and gender. This is consistent with Thambi et al. [40], based on 650 results from CBCT scans in Chennai, India, who reported that most individuals had either a single or two openings, with three rare openings. On the other hand, Özeren Keşkek et al. analyzed 1,000 CBCT images from patients aged 20 to over 61 in the Turkish population. They found that in axial sections, two SFs were observed in 452 patients, one SF in 395 patients, three SFs in 140 patients, and four SFs in 13 patients. The number of SFs showed no statistically significant differences based on gender or age groups. [10]

There are some limitations to consider in this study. The retrospective nature limited our ability to control for certain factors that might influence NPC morphology, such as ethnicity and individual variations in jaw anatomy. Additionally, the sample size was relatively moderate, and future studies with larger and more diverse populations could provide more comprehensive insights.

Conclusion

This study provides significant data on the morphology of the NPC in the Egyptian population. The findings suggest that NPC width measurements might be relatively stable throughout adulthood, while NPC length and angle might exhibit slight variations with age. The most common NPC shapes were cylindrical, with no significant differences observed based on age or gender. The SF exhibited a predominantly oval shape, with no significant variations in shape or number across age groups. Future research with a larger and more diverse sample size is

recommended further to elucidate the NPC morphology in the Egyptian population and explore potential correlations with ethnicity and other factors.

By understanding the anatomical variations of the NPC, dental professionals can make more informed decisions, improve treatment outcomes, and minimize potential complications, particularly those involved in anesthesia delivery, minimizing nerve injury, safe implant placement, predicting post-operative sensory disturbances, and also awareness of the NPC's location can aid in the diagnosis of periapical infections related to upper central incisors.

Declarations

Funding

No financial funding was provided for this research.

Data Availability

All data included in this study are available from the corresponding author upon request.

Ethics Statement

Ethical approval was obtained from the Beni-suef University, Faculty of Dentistry, Ethical Committee (REC-FDBSU/T07122023-02/MM).

Competing interests

The authors declare no conflicts of interest.

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