DOI: 10.7860/JCDR/2026/81417.23628

Original Article

Dentistry Section

Radiographic Evaluation of Gender-related Differences in the Morphology and Dimensions of the Nasopalatine Canal using Cone Beam Computed Tomography: A Retrospective Cross-sectional Study

YASHIKA JAIN[1], RENITA LORINA CASTELINO[2], G SUBHAS BABU[3], VIDYA AJILA[4], K SMRITHY SIVADAS[5]

ABSTRACT

Introduction: The Nasopalatine Canal (NPC) is a vital structure in the anterior maxilla that contains the neurovascular bundle for the blood and nerve supply. It shows considerable anatomical variation, which influences the surgical and implant procedures in the anterior maxilla. Thus, with the help of Cone Beam Computed Tomography (CBCT), these variations can be evaluated more precisely to enhance treatment planning and for positive clinical outcomes.

Aim: To evaluate the morphology and dimensions of NPC using CBCT and to determine the variability in relation to gender.

Materials and Methods: The present retrospective cross-sectional study was conducted in the Department of Oral Medicine and Radiology AB Shetty Memorial Institute of Dental Sciences for a period of one year from January 2024 to December 2024. A total of 200 CBCT scans in which complete NPC was visible were included in the study. The reconstructed sagittal sections were assessed for the shape, length, width at nasal and oral end, angulation and volume of NPC. Out of 200 scans, 100 were of females and 100 males with the age range of 20-70 years. The statistical analysis between the groups was done using unpaired t-test and One-way Analysis of Variance (ANOVA) test. The categorical data was compared using Chi-square test. The p-value less than 0.05 was considered significant.

Results: The most common shape was found to be cylindrical with no variation in relation to gender. The mean length of the canal was 13.56±2.3 mm in males and 11.6±2 mm in females, showing a statistically significant difference (p=0.001). Also, with advancement in age the length of the canal increased significantly (p=0.032). The width of the canal at oral end was greater with increase in age (p=0.001) and more in males than females (p=0.001) which was statistically significant. There was no significant difference in angulation and volume of canal in relation to age and gender.

Conclusion: The present study highlights the variation in the morphology and dimensions of the NPC. The cylindrical shape was the most common. With increasing age, the length and width of the canal tends to increase, being greater in males than in females. The canal volume is greater in males than in females and increases with age. The angulation of the canal, however, demonstrates no significant variation with either age or gender.

Keywords: Anatomy, Implant, Maxilla, Sagittal sections

INTRODUCTION

The nasal and oral cavity is connected by the NPC, a bony structure that contains the associated neurovascular bundle. It is also known as anterior palatine canal. Behind the maxillary central incisors is a circular opening known as the incisive foramen is present, which is the inferior (oral) end of the NPC. Usually, the canal's superior (nasal) end divides into foramen of Stensen. There have been reports of difficulties with the anatomy of the NPC during premaxilla surgical operations, including local anaesthetic and implant insertion for maxillary central incisors [1]. Surgical interventions in the NPC area have increased significantly, which makes it necessary to understand the anatomy of the NPC. It helps in proper treatment planning and to prevent injury to the neurovascular bundles during any surgical intervention. Thus, complications such as haemorrhage, paraesthesia, impaired healing or graft failure can be minimised.

Two-dimensional imaging provides limited information about the morphology of NPC as compared to three-dimensional imaging which provides more detailed information about NPC [2]. CBCT is one such imaging modality which is being widely used in the field of dentistry as diagnostic aid for implant placement and also for other surgical procedures. It provides comprehensive Three-dimensional (3D) data for assessment of variations seen in the several anatomical and vital structures of the maxillofacial region which includes the NPC [1]. The present study evaluated the shape as well as various dimensions of the canal in one section and their variations in relation to both age and gender.

The aim of this study was to evaluate the morphology and dimensions of NPC using CBCT and to determine the variability in relation to gender. The study also aimed to see the variations in the morphology of the NPC with an increase in age. The null hypothesis for the study is that there exhibits no variability in the morphology and dimensions of the NPC in relation to gender and age. The alternative hypothesis is that variations occur in the morphology and dimensions of NPC in relation to gender and age.

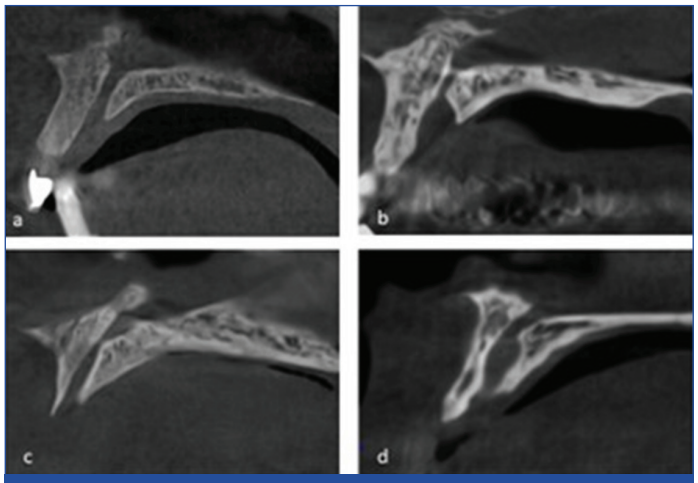
MATERIALS AND METHODS

The present retrospective cross-sectional study was conducted in the Department of Oral Medicine and Radiology at AB Shetty Memorial Institute of Dental Sciences for a period of one year from January to December 2024. The study was approved by Institutional Ethical Committee- Ref no. ETHICS/ABSMIDS/400/2023. Since the study was retrospective and time bound all the scans which met the inclusion criteria were included in the study with equal number of males and females.

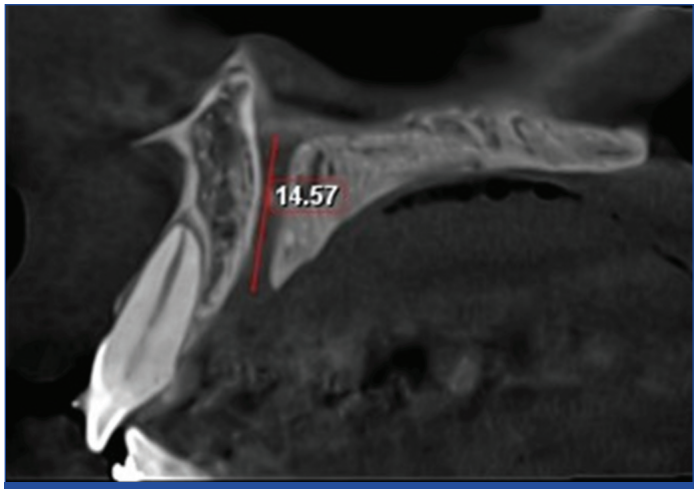
Inclusion and Exclusion criteria: A total of 200 CBCT scans were included from the Romexis software database which met the inclusion criteria during the period of one year [1]. The patients included were in the age range of 20-70 years in which the complete NPC was visible without any defect. CBCT images of cases of trauma, cyst or tumours, traumatic extraction, presence of impacted teeth, bone grafts or any surgical intervention in anatomical area of interest were excluded. All the CBCT scans included were obtained using the Planmeca 3D Mid (Helsinki, Finland) imaging unit with operating parameters of 90 Kv, 10 mA , voxel size 0.2 mm and FOV ranging from 8×8 cm to 16×10.2 cm and exposure time 8 sec to 13 sec. The software used for analysis of the images was PlanmecaRomexis 4.6.2.R.

Study Procedure

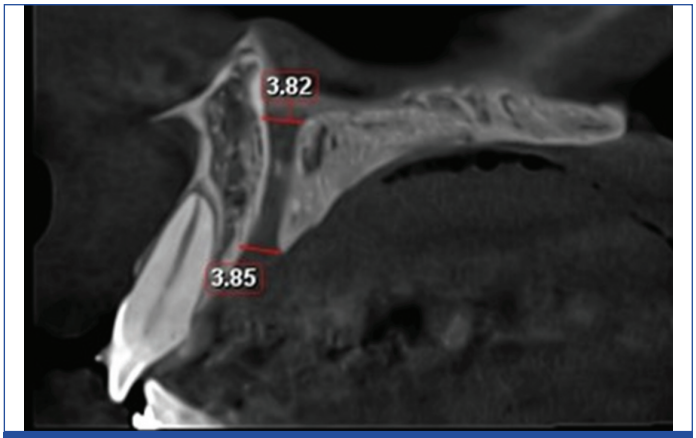
Evaluation of images: The reconstructed sagittal CBCT scans (1mm slice thickness) in which complete NPC was seen were evaluated for the shape, length, width at oral and nasal end, angulation and volume of NPC. The four different shapes evaluated were- cylindrical, funnel, hour glass, spindle [Table/Fig-1] [2]. The length was measured in millimetres from the nasal end till the oral end of NPC [Table/Fig-2]. The width was also measured in millimetres both at the nasal end and oral end of NPC [Table/Fig-3]. The angulation was measured in degrees at the point of intersection of line representing the long axis of NPC and the line drawn on the floor of the nasal fossa [Table/Fig-4] [2]. The volumetric analysis was performed in sagittal section by manual segmentation, by outlining the NPC on the sagittal sections manually and repeating the process until the full NPC is traced after which the software Planmeca 6.2.R automatically calculates the volume of the outlined area [Table/Fig-5] [1]. All the measurements were made and evaluated by two viewers at different times in standard viewing conditions, who were experienced Maxillofacial Radiologists with a minimum of 10 years of experience. In case of any discrepancy, third reviewer's was considered for evaluation. Intraclass correlation coefficient and Cohen's kappa were used to determine the intra-examiner reliability. It was found that all the variables considered in the study had excellent similarity [Table/Fig-6].



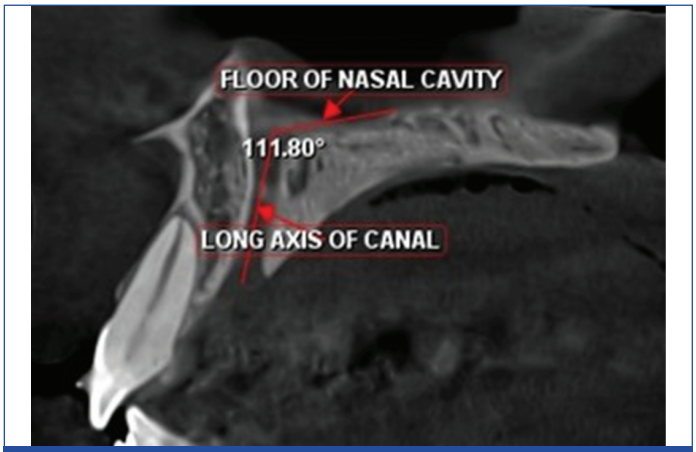
[Table/Fig-1]: Shape of the canal: a) cylindrical; b) funnel; c) hour glass; d) spindle.



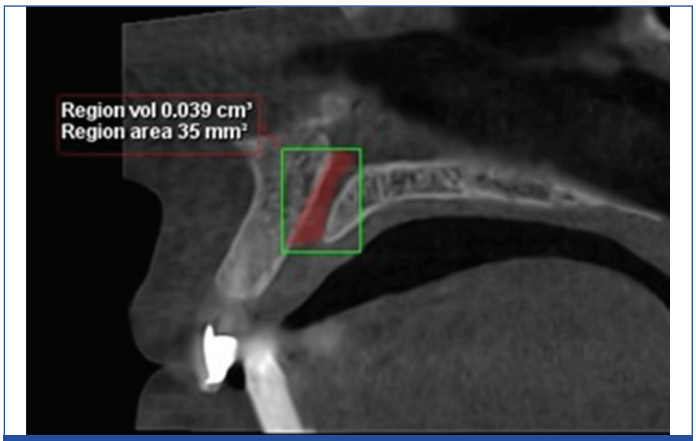
[Table/Fig-2]: Length of the canal.



[Table/Fig-3]: Width of the canal at nasal and oral end.



[Table/Fig-4]: Angulation of canal.



[Table/Fig-5]: Volume of the canal.

Parameters	Intraclass Correlation Coefficient	95% CI	p-value
Length of the canal (mm)	0.99	0.98-1.0	<0.001*
Width of canal at nasal end (mm)	0.99	0.99-1.0	<0.001*
Width of canal at oral end (mm)	0.98	0.97-0.99	<0.001*
Volume of Canal (in cm^3)	0.99	0.98-1.0	<0.001*
Angulation of Canal (in degrees)	0.99	0.98-1.0	<0.001*
Shape of the canal#	0.99		<0.001*

[Table/Fig-6]: Intra-examiner reliability of various parameters using the Intraclass correlation coefficient and Cohen's Kappa.
#Cohen's Kappa; *Statistically significant

STATISTICAL ANALYSIS

The data was analysed using Statistical Package for Social Sciences (SPSS) for Windows (version 26.0, IBM Corp., Armonk, NY). Continuous data between the groups was analysed using an unpaired t-test and one-way ANOVA. Categorical data was compared using the Chi-square test. Intraclass correlation coefficient and Cohen's kappa were used to assess the intra-examiner reliability for continuous and categorical data. Results were presented using graphs and tables. The level of significance was set at p≤0.05.

RESULTS

The study included CBCT images of 200 cases, out of which 100 were males and 100 were females. The mean age in males was 44.42±16.3 years and in females it was 41.34 2±13.18 years [Table/Fig-7]. It was found that there was no statistically significant difference in mean age of study participants between both the genders. The maximum number of participants was in the age group of 41-60 years [Table/Fig-8].

Gender	Number	Mean age in years	SD	t	p-value
Males	100	44.42	16.3	1.4	0.14
Females	100	41.34	13.18		NS

[Table/Fig-7]: Comparison of mean age of participants according to gender.
SD-standard deviation; NS-not significant using unpaired t-test

Age group	Number	Percentage
20-40 years	89	44.5
41-60 years	84	42
>61 years	27	13.5
Total	200	100

[Table/Fig-8]: Distribution of participants according to age groups.

Shape of the Canal

It was found that the most common shape of the canal was found out to be cylindrical then funnel and least common was spindle shaped [Table/Fig-9]. The cylindrical shape was the most common shape among both males and females. There was no association between gender and shape of the canal (p=0.12) [Table/Fig-10].

Shape of the canal	Number	Percentage
Cylindrical	117	58.5
Funnel	46	23
Hourglass	29	14.5
Spindle	8	4
Total	200	100

[Table/Fig-9]: Distribution of participants according to shape of the canal.

Shape of the canal	Males N (%)	Females N (%)	Total N	Chi-square	p-value
Cylindrical	54 (54)	63 (63)	117	5.76	0.12 NS
Funnel	30 (30)	16 (16)	46		
Hourglass	13 (13)	16 (16)	29		
Spindle	3 (3)	5 (5)	8		
Total	100 (100)	100 (100)	200		

[Table/Fig-10]: Distribution of gender and shape of the canal.
N-number; %-percentage; NS-not significant using Chi-square test

Dimensions of Nasopalatine Canal

Length of canal: The mean length of the canal (in mm) was 12.6±2.4 [Table/Fig-11]. It was found that there was significant increase in the length of canal with increase in age which was statistically significant (p=0.032) [Table/Fig-12]. Also, the length of canal was significantly more among males than females (p<0.001) [Table/Fig-13].

Dimensions	Mean±SD
Length of the canal (mm)	12.6±2.4
Width of canal at nasal end (mm)	2.5±0.96
Width of canal at oral end (mm)	3.52±1.05
Volume of canal (in cm^3)	0.068±0.06
Angulation of canal	125.04±9.3

[Table/Fig-11]: Mean dimensions of nasopalatine canal.
SD: Standard deviation

	20-40 years Mean±SD	41-60 years Mean±SD	>61 years Mean±SD	F	p-value
Length of the canal (mm)	12.09±2.5	12.99±2.3	13.09±2.5	3.5	0.032*
Width of canal at nasal end (mm)	2.4±0.96	2.48±0.99	2.66±0.85	0.402	0.67
Width of canal at oral end (mm)	3.2±0.8	3.71±1.08	4.01±1.19	9.19	0.001**
Volume of canal (in cm^3)	0.06±0.08	0.069±0.05	0.077±0.05	0.318	0.94
Angulation of canal (in degrees)	124.9±9.1	125.2±9.5	124.5±10.07	0.062	0.72

[Table/Fig-12]: Comparison of mean dimensions of Nasopalatine Canal (NPC) according to age groups.
SD: Standard deviation; **Statistically significant using One-way ANOVA

Dimensions	Males Mean±SD	Females Mean±SD	t	p-value
Length of the canal	13.56±2.3	11.6±2.2	5.8	0.001**
Width of the canal (nasal)	2.6±0.93	2.4±0.97	1.5	0.12
width of the canal (oral)	3.7±1.07	3.2±0.96	3.3	0.001**
Angulation	124.2±9.1	125.8±9.5	-1.2	0.21
Volume	0.073±0.05	0.063±0.08	1.05	0.29

[Table/Fig-13]: Comparison of mean dimensions of Nasopalatine Canal (NPC).
SD: Standard deviation; **Statistically significant using unpaired t-test.

Width of canal at nasal and oral end: The mean width at nasal end (in mm) was 2.5±0.96 and at oral end (in mm) was 3.52±1.05 [Table/Fig-11]. It was found that there was increase in the width of the canal at both nasal and oral end with increase in the age. The increase in the width at oral end was statistically significant. (p<0.001) [Table/Fig-12]. The males showed an increase in the width of canal at both nasal and oral end when compared to females with statistically significant increase at oral end (p<0.001) [Table/Fig-13].

Volume of canal: The mean volume of the canal (in cm^3) was 0.068±0.06 [Table/Fig-11]. It was found that there was increase in the volume of the NPC as the age increases [Table/Fig-12]. It was found that the volume of the NPC was more among males than females. The difference was not statistically significant (p=0.29) [Table/Fig-13].

Angulation of canal: The mean angulation of canal (in degree) was 125.04±9.3 [Table/Fig-11]. It was found that there was no significant difference in angulation of the NPC between different age groups. (p=0.72) [Table/Fig-12]. Also, there was no significant difference in the angulation of the NPC between both the genders [Table/Fig-13].

DISCUSSION

The NPC is an important anatomical structure and is in close proximity to the roots of maxillary central incisors. It is necessary that it is radiologically evaluated before any surgical procedure such as implant placement is done in the region of premaxilla in order to avoid any injury to the nerve and vessels thus preventing any

complications [3]. NPC shows lot of variations in their anatomy, morphology and dimensions.

In recent years CBCT imaging has emerged as an important radiodiagnostic aid in dentistry [4]. It offers great advantage over conventional radiography for evaluation of anatomical structures such as NPC, mental foramen, inferior alveolar nerve canal etc., by providing 3D visualisation of the structures. CBCT is less expensive and offers low radiation dose as compared to CT.

The study was conducted to evaluate the morphology and dimensions of NPC using CBCT and to determine the variability in relation to the gender. In the present study, the morphometric assessment was done in sagittal sections when compared with the other studies in literature as the complete length of canal, width and angulation can be visualised clearly in one section along with volume assessment and shape. The above parameters were considered in the study as they influence the surgical and prosthetic planning by determining the bone availability and increasing the risk of neurovascular injury if not properly assessed.

In the present study the most common shape was found to be cylindrical and least common was spindle shape in both males and females. These findings were similar to results of study done by Thakur AR et al., Rani K et al., Mraiwa N et al., and Koushal D et al., [2,5-7].

The average length of the NPC in present study was found to be 12.6 mm which was higher than the values obtained in other studies. The mean length in males was 13.56 mm and in females 11.6 mm which was nearly similar to study done by Soman C [8]. In males, length of NPC is significantly higher as compared to females indicating that gender variability is seen which was in agreement with the studies by Rao JB et al., Khojastepour L et al., and Safi Y et al., [9-11]. This gender variation could be attributed to larger craniofacial dimensions in males as compared to females. A significant increase in the length of NPC was seen with increase in the age which was in opposition to the study done by Fernandez-Alonso A et al., and Liang X et al., [12,13]. The variability seen in the results could be due to differences in ethnicity and the population included in the study and the difference in the orthogonal plane used in the study.

In the present study, it was observed that there was increase in the width of canal at both nasal and oral end with increase in the age. The increase in width at oral end along with age was statistically significant. The reason behind this is that with increase in age rate of bone resorption increases which leads to widening of canal. In males the width of the canal was more than females at both nasal end and oral end. Similar results were seen in the study done by Nemtoi A et al., Thakur AR et al., Khojastepour et al., [1,2,10]. These results were in opposition to the study done by Bajoria AA et al., in which there was decrease in width of canal with age at both nasal and oral end with more width in females than in males [14]. The width of canal at oral end was found to be significantly more in males than females which are consistent with the findings of Chatzipertos E et al., and Rao JB et al., who reported significantly greater width of canal at both the oral and nasal end in males compared to females [9,15].

In this study, the mean angulation of the canal in males was 124.2 and in females was 125.8 degrees. No significant difference was seen in the angulation of canal in relation with the age and gender. The mean value of the angulation of NPC in study by Bajoria AA et al., was 112.34 and 112.71 in males and females respectively which was lower than the values in the present study [14]. They also reported no correlation of angulation of canal with age and gender. Similar results were seen in the study by Thakur AR et al., [2].

The average volume of the canal in present study was 0.068±0.06 cm^3 which was lower than the value obtained by Nemtoi A et al., 0.62cm^3 [1]. The reason behind this may be the small sample size in present study and difference in method of volumetric analysis used. No relation was seen for the volume of canal with the age and gender.

The variations in the shape of canal necessitate the individualised approaches for various treatment procedures. Various shapes have different degree of risks of iatrogenic nerve injury during various dental treatment and surgical procedures such as funnel shape and hour glass shape are associated with higher risk of injury to nasopalatine nerve [16,17]. The increase in the width of the canal decreases the amount of supporting bone around it which affects the placement of implants in the anterior maxilla. The angulation of NPC affects the range of possible orthodontic tooth movement for maxillary anteriors [18]. Increased angulation and volume of NPC can restrict the ideal positioning of implants leading to complications and it also necessitates the need for bone augmentation.

The present study showed that significant variations are seen in the morphology and dimensions of NPC in relation to the age and gender. Thus, the null hypothesis was rejected. It is necessary to analyse these variations before performing any surgical procedure in the canal area to avoid complications. These findings have future implications for improving implant planning accuracy and minimising neurovascular complications and developing population-specific reference standards. In future, integration of CBCT data with AI-assisted analysis may further enable automated canal assessment and personalised treatment protocols. Further studies in future should consider all three planes (coronal, axial, sagittal) for the assessment of NPC to get more conclusive data and inferences.

Limitation(s)

The present study had a few limitations. The assessment of the canal was done only in the sagittal sections and not in other sections, such as coronal and axial, which also show variations in the parameters of the NPC. Further, any other confounding factors that could affect the morphology and dimensions of the NPC were not considered.

CONCLUSION(S)

In conclusion, the present study highlights the radiographic assessment of NPC using CBCT in terms of morphology and dimensions in sagittal plane. The differences in the results observed from the studies done in past could be due to the variation in the method of assessment used and population variation. The shape, length, width, angulation and volume of NPC are important parameters for assessment of any pathologies or prior to any intervention in this region using CBCT. The findings in this study showed that dimensions of NPC are affected by age and gender. Furthermore studies in future with larger sample size and additional parameters are needed for more detailed evaluation of NPC.

Acknowledgement

I would like to acknowledge statistician Kuldeep, whose statistical expertise was invaluable during the analysis and interpretation of the data that has been collected.

REFERENCES

[1] Nemtoi A, Sirghe AE, Nemtoi A, Dobrovat B, Poescu R, Haba D. CBCT analysis of the morphology and anatomical variants of the nasopalatine canal in north-eastern population of Romania. Rom J Oral Rehabil. 2019;11:213-27.
[2] Thakur AR, Burde K, Guttal K, Naikmasur VG. Anatomy and morphology of the nasopalatine canal using cone-beam computed tomography. Imaging Sci Dent. 2013;43:273-81.
[3] Romanos G, Mulham J, Morrow N, Farber AH, Mahdian M. Neurological risks during implant placement in the anterior maxilla and mandible: A literature review. J Oral Implantol. 2023;49:428-35.
[4] Acar B, Kamburoglu K. Morphological and volumetric evaluation of the nasopalatinal canal in a Turkish population using cone-beam computed tomography. Surg Radiol Anat. 2015;37:259-65.
[5] Rani K, Sudheer A, Kumari A, Singh A, Anand K, Singh K. Morphological variation of the nasopalatine canal: A cone-beam computed tomography study. J Indian Acad Oral Med Radiol. 2020;32:27-30.

[6] Mraiwa N, Jacobs R, Van Cleynenbreugel J, Sanderink G, Schutyser F, Suetens P, et al. The nasopalatine canal revisited using 2D and 3D CT imaging. Dentomaxillofac Radiol. 2004;33:396-402.
[7] Koushal D, Tangotra A. Morphological variation of nasopalatine canal: A cone-beam computed tomography study. Int J Radiol Diagn Imaging. 2022;5(4):47-51.
[8] Soman C. Assessment of the nasopalatine canal length and shape using cone-beam computed tomography: A retrospective morphometric study. Diagnostics. 2024;14:973.
[9] Rao JB, Tatuskar P, Pulla A, Kumar N, Patil SC, Tiwari I. Radiographic assessment of anatomy of Nasopalatine canal for dental implant placement: A cone beam computed tomographic study. J Contemp Dent Pract. 2018;19:301-05.
[10] Khojastepour L., Haghnegahdar AA., Keshtkar M. Morphology and dimensions of Nasopalatine canal: A radiographic analysis using cone beam computed tomography. J Dent Shiraz Univ Med Sci. 2017;18:244-50.
[11] Safi Y, Moshfeghi M, Rahimian S, Kheirkhahi M, Eslami Manouchehri M. Assessment of Nasopalatine canal anatomic variations using cone beam computed tomography in a Group of Iranian Population. Iran J Radiol. 2017;14:e37028.
[12] Fernández-Alonso A, Suárez-Quintanilla JA, MuineloLorenzo J, Bornstein MM, Blanco-Carrión A, SuárezCunqueiro MM. Three-dimensional study of nasopalatine canal morphology: A descriptive retrospective analysis using cone-beam computed tomography. Surg Radiol Anat. 2014;36:895-905.
[13] Liang X, Jacobs R, Martens W, Hu Y, Adriaensens P, Quirynen M, et al. Macro and microanatomical, histological and computed tomography-scan characterisation of the nasopalatine canal. J Clin Periodontol. 2009;36:598-603.
[14] Bajoria AA, Kochar T, Sangamesh NC, Mishra S, Rout P, Sonthalia A. Nasopalatine canal revisited: An insight to anterior maxillary implants. Open Journal of Stomatology. 2018;8:01-15.
[15] Chatzipetros E, Tsiklakis K, Donta C, Damaskos S, Angelopoulos C. Morphological assessment of nasopalatine canal using cone beam computed tomography: A retrospective study of 124 consecutive patients. Diagnostics. 2023;13:1787.
[16] Mohite SS, Kadam DS, Roy PP. Morphological analysis of length and shape of nasopalatine canal on human dry skulls. Journal of Chemical Health Risks. 2024;14(1):399-404.
[17] Arnaut A, Milanovic P, Vasiljevic M, Jovicic N, Vojinovic R, Selakovic D, et al. The shape of nasopalatine canal as a determining factor in therapeutic approach for orthodontic teeth movement-A CBCT study. Diagnostics (Basel). 2021;11(12):2345.
[18] Costa ED, Gaêta-Araujo H, de Oliveira Reis L, Cascante-Sequeira D, Brasil DM, Oliveira-Santos C, et al. Does the angulation between the maxillary central incisors and the nasopalatine canal differ among sagittal and vertical skeletal patterns? A CBCT study. Int Orthod. 2022;20(2):100636.

PARTICULARS OF CONTRIBUTORS:
1. Postgraduate Student, Department of Oral Medicine and Radiology, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), NITTE (Deemed to be University), Mangalore, Karnataka, India.
2. Reader, Department of Oral Medicine and Radiology, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), NITTE (Deemed to be University), Mangalore, Karnataka, India
3. Professor, Department of Oral Medicine and Radiology, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), NITTE (Deemed to be University), Mangalore, Karnataka, India.
4. Professor, Department of Oral Medicine and Radiology, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), NITTE (Deemed to be University), Mangalore, Karnataka, India.
5. Postgraduate Student, Department of Oral Medicine and Radiology, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), NITTE (Deemed to be University), Mangalore, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Renita Lorina Castelino,
Reader, Department of Oral Medicine and Radiology, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), NITTE (Deemed to be University),
Mangalore-575018, Karnataka, India.
E-mail: renita.castelino@yahoo.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jun 24, 2025
- Manual Googling: Jan 03, 2026
- iThenticate Software: Jan 06, 2026 (19%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Jun 19, 2025**
Date of Peer Review: **Oct 22, 2025**
Date of Acceptance: **Jan 08, 2026**
Date of Publishing: **Jun 01, 2026**