DOI: 10.7860/JCDR/2025/76965.21208

Original Article

Forensic Section

Morphological Variations in the Greater Palatine Canal and Foramen Assessed using Cone Beam Computed Tomography: A Retrospective Observational Study

SINDHUJA YERRAPRAGADA[1], SUDHAKARA REDDY[2], JYOTHIRMAI KONERU[3], BEERABOINA ANANDA BABU[4], BUDUMURU RAMESH KUMAR[5], VINUTNA NANDA MATTA[6]

ABSTRACT

Introduction: The Greater Palatine Foramen (GPF), a key structure in the hard palate, serves as a critical anatomical landmark connecting the Pterygopalatine Fossa (PF) to the oral cavity via the Greater Palatine Canal (GPC). The PF contains essential structures, including the maxillary nerve, its branches, the pterygopalatine ganglion and maxillary artery.

Aim: To assess the morphological and morphometric variations of GPF and canal by using Cone Beam Computed Tomography (CBCT).

Materials and Methods: This retrospective observational study was conducted in the Department of Oral Medicine and Radiology, at Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India in a time of six months, data collection from May 2024 to September 2024 and analysis in October 2024. A total of 100 scans of maxillary arch were analysed. CBCT images covering the full arch maxilla within the age range of 20 to 70 years were included. Parameters such as the shape of the foramen and distance from GPF centre to Mid-Maxillary Suture (MMS) and Anterior Nasal Spine (ANS) in axial sections and shape of the canal in sagittal sections were evaluated on both right and left-sides and compared between genders.

Results: A statistically significant differences were observed in the mean distance from the GPF to the MMS on the right-side for both genders p-value=0.001. The most common shape of the GPC was straight with frequency of 22% on both right and left-sides in males and 14%, 17% on right and left-sides respectively in females in the sagittal plane and oval with a frequency of 17%- right, 18%- left-side in males and 13%- right, 11%- left in females in the axial plane. Regarding the location of the GPF in relation to molars, the most prevalent position was E, with a frequency of 24%- right and left-sides in males, 23%- on both right and left-sides in females, where the GPF is distal to the upper third molar.

Conclusion: The study emphasises the importance of morphometric variations in dental procedures, using CBCT for accurate assessment and improved surgical precision. CBCT, which offers precise three-dimensional imaging that improves surgical planning, patient safety and diagnostic accuracy, is essential for precisely evaluating these variances.

Keywords: Anterior nasal spine, Greater palatine foramen, Mid palatal suture/mid maxillary suture

INTRODUCTION

Anatomically, the PF and the oral cavity are connected by the GPC. The maxillary nerve and its branches, the venous rami, the maxillary artery and the pterygopalatine ganglion are all located within the PF [1]. The palatine processes of the maxilla and the horizontal plates of the palatine bone unite to form the hard palate and a clearly defined suture separates the location of these bony structures. The maxillofacial skeleton has significant bony foramina that serve as entrance points for the neuro-vascular system [2]. The two most significant bony foramina in the hard palate are the GPF and the Lesser Palatine Foramen (LPF) [2].

The greater palatine neurovascular bundle exits the hard palate's vault through the GPF, situated towards the rear and sides of the bony palate. This foramen marks the terminus of the GPC, through which pass the greater palatine vessels (branches of the maxillary artery) and the Greater Palatine Nerve (GPN) (a branch of the maxillary division of the trigeminal nerve), originating from the PF [3]. It supplies the palatine mucous and the periodontal tissue of posterior dentition and runs forward in a groove almost up to the incisor teeth where it anastomoses with branches of the nasopalatine bundle [4]. The most credible approach for maxillary nerve block is by anaesthetising in the PF via the GPC [5]. The existence of morphoanatomical variations in the (GPC) anatomy may restrict needle insertion, highlighting the essential need for comprehensive anatomical studies of the GPC. Thus, anatomical accuracy is crucial for minimising the complications [6] and CBCT is such a tool that helps in assessing anatomical variations.

The present study aimed to assess the morphometric variations of the GPF and canal using CBCT. The objectives included determining the shape of the GPF and measuring its distance from the MMS and ANS in axial sections on both the right and left-sides among males and females. Additionally, to evaluate the shape of the GPC in the sagittal section for both sides and genders, as well as to analyse the relative position of the GPF in relation to maxillary molars.

MATERIALS AND METHODS

This retrospective observational study was conducted in the Department of Oral Medicine and Radiology at Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India in a period of six months, with data collection from May 2024 to September 2024 and analysis in October 2024 after getting approval from institutional review board with no IECVDC/24/PG01/OMR/IVT/59.

Inclusion criteria: CBCTS including full maxilla and CBCTs of patients with age 20 to 70 years were included in the study.

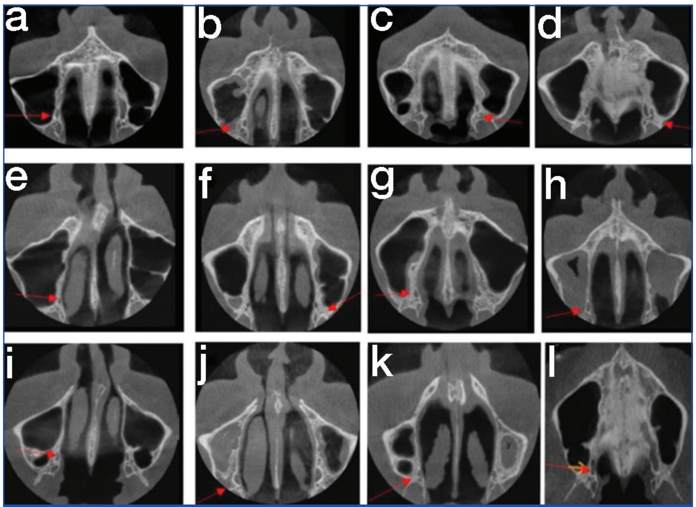
Exclusion criteria: CBCTs with any trauma in region of interest, craniofacial, orthognathic surgery done in the region of interest, dental implants in the region of interest, absence of GPF, and any pathologies were excluded form the study.

Sample size calculation: Calculations to determine the sample size was performed for the difference in distance from GPF to ANS as the primary outcome using G* power 3.1.9.4 software. The calculations were based on correlation value of 0.5892 based on the results of pilot study, an alpha level of 0.05 and the desired power of 80%. The estimated sample size was 94. The final sample size was rounded to 100. Thus, 100 CBCT scans, 50 males, 50 females from the archives of radiology were selected for the study.

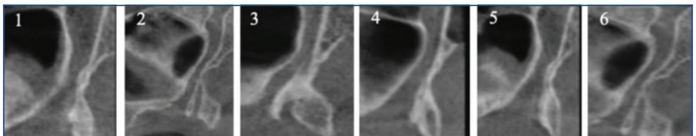
Image evaluation: A CRANEX 3D SOREDEX machine with SCANORA 5.2 software with exposure parameters set at 10 mA, 90 kVp and 4.9s was used to obtain the image of 6×8 Field of View (FOV). Once the image was captured using this device, the image was automatically downloaded into the ONDEMAND 3D viewer.

Anatomic variations of GPCs were assessed in sagittal and axial planes of CBCT scans on both sides (right and left).

Various classifications of GPCs anatomic variants in axial and sagittal slices in [Table/Fig-1,2].



[Table/Fig-1]: Axial slices, the anatomic variants of the GPF were classified into 12 groups according to GPF bone morpho-logical: (a) slit; (b) oval; (c) smoke; (d) banana; (e) diamond; (f) triangle; (g) tear drop; (h) drop of water; (i) kidney; (j) crescent; (k) round; and (l) figure eight.



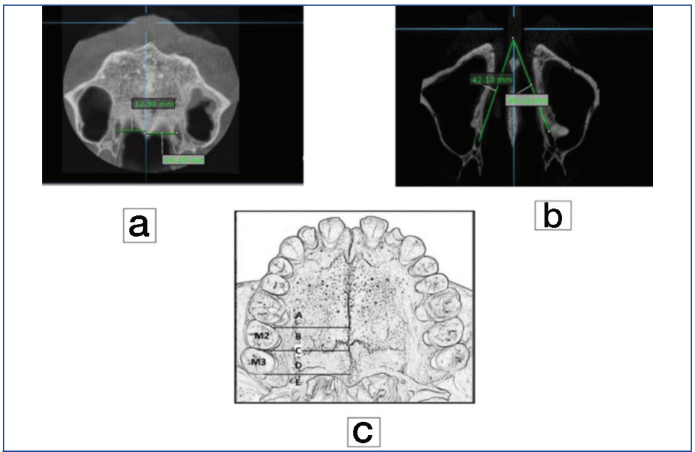
[Table/Fig-2]: In sagittal slices, the anatomic variants of the GPC were classified into six groups: (1) curve; (2) "E" shape; (3) "$"; (4) straight shape; (5) hourglass shape; and (6) water fall.

With respect to GPF

- Determining the axial sectional distance, on both the left and right-sides, between the GPF centre and the ANS [Table/Fig-3a].
- Determining the axial sectional distance, on both the left and right-sides, between the GPF centre and the MMS [Table/Fig-3b].
- Relationship of GPF to the upper molars as described by Ajmani ML (1994) [Table/Fig-3c] [7].

STATISTICAL ANALYSIS

The data was entered in excel sheets and transferred into Statistical Package for the Social Sciences (SPSS) software version 26.0 (IBM CHICAGO). Normality of the data was checked using the Shiprowilk test. Descriptive and inferential statistics were done. Qualitative data was presented as frequencies and percentages and quantitative data was presented as mean±SD. Chi-square test was done to know the association between gender and parameters- distance from Middle Palatal Suture (MPS) to GPF and ANS to GPF. Receiver Operating Curve (ROC) was prepared. A p-value of ≤0.05 was considered statistically significant.



[Table/Fig-3]: a- GPF relation to ANS, b- GPF relation to MMS, c- relation of GPF to maxillary molars.
In between upper first and second molar- A; In upper second molar mid line- B; In between the upper second and third molar- C; In upper third molar midline- D; Distal to upper third molar- E.

RESULTS

Out of 100 CBCTs that met inclusion criteria 50 were males and 50 were females.

With respect to distance from GPF to MMS: The mean distance from GPF centre to middle palatal suture on right-side in males was 16.24 and females was 15.22, which was statistically significant with a p-value of 0.001 [Table/Fig-4].

Parameters	Gender	Mean±Std. Deviation	Wilks' Lambda	F	df1	df2	p-value
GPF- MPS RT	Male	16.24±1.72	0.893	11.750	1	98	0.001*
	Female	15.22±1.19					
GPF- MPS LT	Male	15.95±1.79	0.992	0.834	1	98	0.363
	Female	15.66±1.33					
GPF- ANS RT	Male	47.80±3.95	0.998	0.198	1	98	0.657
	Female	47.44±4.13					
GPF- ANS LT	Male	48.22±3.50	1.000	0.044	1	98	0.835
	Female	48.05±4.70					

[Table/Fig-4]: Association between gender and the parameters - distance from MPS to GPF and ANS to GPF.
Test done- Chi-square test

[Table/Fig-5] shows discriminant function coefficients to differentiate between two genders and the variable like d- GPF to MMS right-side showed strongest predilection. Based on this discrimination value regression equation was derived-

-10.367+. GPF to MPS RT (0.671)+GPF-MPS LT (0.072)+GPF-ANS RT (-0.030)+GPF-ANS LT (0.002).

Area under the ROC curve- The distance from GPF to MPS on right-side showed 74% sensitivity, 50% specificity. On left-side showed 62% sensitivity, 50% specificity [Table/Fig-6,7].

With respect to location of GPF: In relation to molars, the most prevalent was E i.e., the location of GPF is distal to the upper third molar, in both genders and on both sides followed by D i.e., location of GPF is in the midline of upper third molar in both genders and on both sides [Table/Fig-8].

With respect to shape of GPC in sagittal plane: The most prevalent was straight shaped canal in both genders on both sides followed by curved canal [Table/Fig-9].

With respect to shape of canal in axial plane: On both right and left-side the most prevalent was oval in both males and females [Table/Fig-10].

DISCUSSION

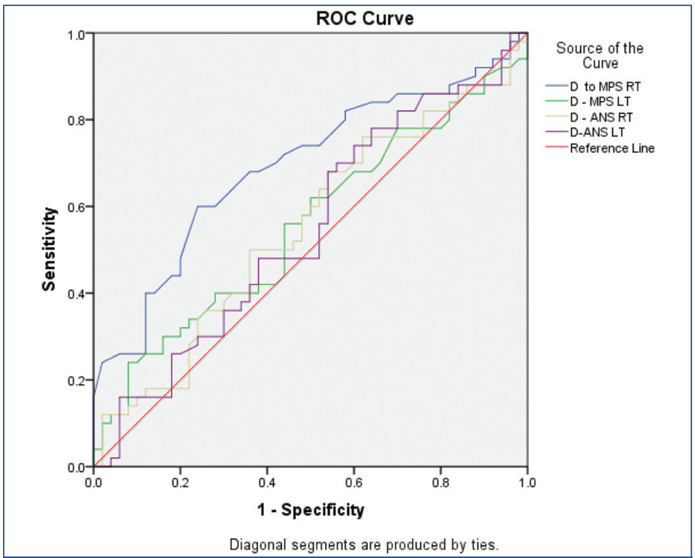
Till date, studies in anaesthesiology and surgery have provided broad overviews of the localisation of GPF and GPC, which has

Parameters	Unstd. Coeff	Str. Matrix	Std. Coeff	Group centroids		Section point	Predicted group membership		
				Male	Female		Male	Female	Overall
GPF- MPS RT	0.67	1	1	0.343	-0.343	0	68	62	65
GPF- MPS LT	0.63	1	1	0.091	-0.091	0	56	56	56
GPF- ANS RT	0.24	1	1	0.045	-0.045	0	58	50	54
GPF- ANS LT	0.24	1	1	0.021	-0.021	0	48	48	48

[Table/Fig-5]: Discriminant function coefficients to differentiate between two genders.

Parameters	Area under the curve	Std. Error	p-value	Asymptotic 95% CI		Sensitivity	Specificity
				Lower bound	Upper bound		
GPF- MPS RT	0.691	0.053	0.001*	0.587	0.796	74	50
GPF- MPS LT	0.555	0.058	0.340	0.442	0.669	62	50
GPF- ANS RT	0.550	0.058	0.385	0.437	0.664	58	50
GPF- ANS LT	0.546	0.058	0.428	0.432	0.660	52	48

[Table/Fig-6]: Sensitivity and specificity of the parameters.



[Table/Fig-7]: ROC curve.

GPF – Molar roots				
	Males		Females	
	Right	Left	Right	Left
Classification	Prevalence	Prevalence	Prevalence	Prevalence
A	(0)	(0)	(1)	(0)
B	(0)	(0)	(0)	(0)
C	(8)	(5)	(5)	(8)
D	(21)	(21)	(21)	(19)
E	(24)	(24)	(23)	(23)

[Table/Fig-8]: Prevalence of GPF with respect to molars.

Sagittal				
	Males		Females	
	Right	Left	Right	Left
Shape	Prevalence	Prevalence	Prevalence	Prevalence
Curved	(14)	(15)	(17)	(13)
E shape	(2)	(4)	(4)	(3)
F shape	(2)	(0)	(2)	(1)
Hour glass	(9)	(9)	(13)	(14)
Straight	(22)	(22)	(14)	(17)
Water fall	(1)	(0)	(3)	(0)

[Table/Fig-9]: Shape of prevalence of GPC in sagittal sections.

Axial				
	Males		Females	
	Right	Left	Right	Left
Shape	Prevalence	Prevalence	Prevalence	Prevalence
Banana	(0)	(1)	(1)	(2)
Diamond	(6)	(3)	(6)	(6)
Drop of water	(4)	(6)	(5)	(5)
Figure of eight	(0)	(1)	(1)	(0)
Kidney	(1)	(0)	(0)	(0)
Oval	(17)	(18)	(13)	(11)
Round	(3)	(2)	(3)	(4)
Slit	(5)	(9)	(5)	(9)
Tear drop	(9)	(12)	(8)	(5)
Triangle	(5)	(4)	(8)	(6)

[Table/Fig-10]: Shape of prevalence of GPC in axial sections.

led to inconsistencies in physician training [8]. Despite numerous investigations into the locating and morphometric features of GPF and GPC, several of these works highlight ongoing challenges in accurately pinpointing these structures in clinical practice [9].

Howard-Swirzinski K et al., identified three distinct pathways, predominantly observed GPCS as a direction; anterior from PF [10]. In contrast, Sheikhi M et al., introduced novel sagittal plane orientation, noting that the majority of canals exhibited an inferior and anterior-inferior direction throughout [11]. However, this study focuses not on the sagittal slice directions of each canal, but rather on morphoanatomical variations of GPCs and their relationships with nearby anatomical structures.

The mean distance from GPF to MMS right-side in males was 16.24 and females was 15.22 with statistical difference, which coincides with a study done by Christy W et al., and revealed distance between GPC and MMS left (male: 15.1625, female: 14.5350) and which was in contradictory with a study done by Wang TM et al., where he concluded the average distance was 16.00±0.14 mm [12,13].

When assessed in the anteroposterior direction from GPF to ANS, present study concluded no statistically significant results on the right and left-sides and among males and females which does not coincide with results done by Fonseka MC et al., where ANS among the female cohort was 45.696 mm±2.078 and 44.811 mm±2.587 for the right and left-side where as the values for the male group was 48.373 mm±3/115 and 47.60 mm±3.388 for the right and left-sides which showed statistically significant results [2]. In a study done by Ikuta CR et al., on Brazilian population on distance from GPF to ANS, there was a disparity of around 3 mm in between males and females where in the male gender the GPF was more in distance from ANS in comparison to the female gender [14], where as present study concluded no statistically significant difference.

A study done by Ajankar VP et al., in the Indian population on 86 dry skulls, found that the position of the GPF was predominantly opposite 3^{rd} molar followed by between the maxillary 2^{nd} and 3^{rd} molars [15]. This aligns with the present study and also with Tomaszewska IM et al., who similarly found that the GPF is frequently positioned opposite the third maxillary molar (M3) [16].

When shape of GPC was assessed in the sagittal plane most prevalent was straight followed by curved whereas Rapado-González O et al. and Howard-Swirzinski K et al., found most prevalent was hourglass which was not in accordance with present study results [1,10].

For a comprehensive comparison, [Table/Fig-11] presents the most frequently reported GPC shapes across various studies in the literature [7,15,17-23].

Study	Sample size	Shape
Ajmani ML, 1994 [7]	99	Cresent
Methathrathip D et al., 2005 [17]	105	Oval
Lopes PTC et al., 2011 [18]	94	Oval
Vinay K et al., 2012 [19]	60	Oval
Nimigean V et al., 2013 [20]	100	Oval
Anjankar VP et al., 2014 [15]	86	Oval
Ortug A and Uzel M, 2019 [21]	80	Oval
Kim DW et al., 2023 [22]	Meta analysis	Oval
Maryins T et al., 2025 [23]	100	Oval
Present study, (2025)	100	Oval

[Table/Fig-11]: Most frequently reported GPC shapes across various studies in the literature [7,15,17-23].

A comprehensive understanding of the GPC is crucial for planning anaesthesia in diverse surgical and dental procedures, given potential for morphological variations [10]. The innervation and vascularisation of the GPC are confined to its bony morphology, extending from pterygoid fossa to its opening on the palate through the GPF. Before undertaking surgical treatments, it is essential to assess the complications associated with blocking the GPN and understand its morphology [1].

Limitation(s)

CBCT scans may present artifacts, resolution limitations, or minor distortions that could impact the accuracy of shape classification and distance measurements, potentially leading to minor errors in data interpretation.

CONCLUSION(S)

The present study highlighted the morphometric variations of the GPF and canal, emphasising their clinical significance in improving surgical precision, optimising local anaesthesia and minimising procedural complications in dental and maxillofacial interventions. CBCT plays a vital role in accurately assessing these variations, providing detailed three-dimensional imaging that enhances diagnostic accuracy, surgical planning and patient safety.

REFERENCES

[1] Rapado-González O, Suárez-Quintanilla JA, Suárez-Cunqueiro MM. Anatomical variations of the greater palatine canal in cone-beam computed tomography. Surg Radiol Anat. 2017;39(7):717-23.
[2] Fonseka MC, Hettiarachchi PK, Jayasinghe RM, Jayasinghe RD, Nanayakkara CD. A cone beam computed tomographic analysis of the greater palatine foramen in a cohort of Sri Lankans. J Oral Biol Craniofac Res. 2019;9(4):306-10.
[3] Williams PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE. Gray's Anatomy: The Anatomical Basis of Medicine and Surgery. 38th ed. New York, Churchill Livingstone, 2000.
[4] Fu JH, Hasso DG, Yeh CY, Leong DJM, Chan HL, Wang HL. The accuracy of identifying the greater palatine neurovascular bundle: A cadaver study. J Periodontol. 2011;82:1000-06.
[5] Lepere A. Maxillary nerve block via the greater palatine canal: New look at an old technique. Anaesth Pain Contr Dent. 1993;2:195-97.
[6] Hawkins JM, Isen D. Maxillary nerve block: The ptery-gopalitine canal approach. J Calif Dent Assoc. 1998;26:658-64.
[7] Ajmani ML. Anatomical variation in position of the greater palatine foramen in the adult human skull. J Anat. 1994;184(Pt 3)(Pt 3):635-37. PMID: 7928651; PMCID: PMC1259972.
[8] Vinay K, Beena D, Vishal K. Morphometric analysis of the greater palatine foramen in south Indian adult skulls. Int J Basic Appl Med Sci. 2012;2:05-08.
[9] Hafeez NS, Sondekoppam RV, Ganapathy S, Armstrong JE, Shimizu M, Johnson M, et al. Ultra-sound-guided greater palatine nerve block: A case series of anatomical descriptions and clinical evaluations. Anaesth Analg. 2014;119:726-30.
[10] Howard-Swirzinski K, Edwards PC, Saini TS, Norton NS. Length and geometric patterns of the greater palatine canal observed in cone beam computed tomography. Int J Dent. 2010;2010:292753.
[11] Sheikhi M, Zamaninaser A, Jalalian F. Length and anatomic routes of the greater palatine canal as observed by cone beam computed tomography. Dent Res J (Isfahan). 2013;10:155-61.
[12] Christy W, Annapoorani S, Thambi T. Morphometric analysis of greater palatine foramen and the adjacent structures: Forensic odontology study using CBCT. J Clin Diagn Res. 2023;17(6):ZC04-ZC09.
[13] Wang TM, Kuo KJ, Shih C, Ho LL, Liu JC. Assessment of the relative locations of the greater palatine foramen in adult Chinese skulls. Cells Tissues Organs. 1988;132(3):182-86.
[14] Ikuta CR, Cardoso CL, Ferreira-Júnior O, Lauris JR, Souza PH, Rubira-Bullen IR. Position of the greater palatine foramen: An anatomical study through cone beam computed tomography images. Surg Radiol Anat. 2013;35(9):837-42.
[15] Ajankar VP, Gupta SD, Nair S, Thaduri N, Trivedi GN, Budhiraja GN. Analysis of position of greater palatine foramen in central Indian adult skulls: A consideration for maxillary nerve block. J Pharmaceut Biololg Res. 2014;2(1):51-54.
[16] Tomaszewska IM, Frączek P, Gomulska M, Pliczko M, Sliwińska A, Sałapa K, et al. Sex determination based on the analysis of a contemporary Polish population's palatine bones: A computed tomography study of 1,200 patients. Folia Morphol (Warsz). 2014;73:462-68.
[17] Methathrathip D, Apinhasmit W, Chompoopong S, Lertsirithong A, Ariyawatkul T, Sangvichien S. Anatomy of greater palatine foramen and canal and pterygopalatine fossa in Thais: Considerations for maxillary nerve block. Surg Radiol Anat. 2005;27:511-16.
[18] Lopes PTC, Santos AMPV, Pereira GAM, Oliveira VCBD. Morphometric analysis of the greater palatine foramen in dry Southern Brazilian adult skulls. Int J Morphol. 2011;29:420-23.
[19] Vinay K, Beena D, Vishal K. Morphometric analysis of the greater palatine foramen in south Indian adult skulls. Int J Basic Appl Med Sci. 2012;2(3):05-08.
[20] Nimigean V, Nimigean VR, Buţincu L, Sălăvăstru DI, Podoleanu L. Anatomical and clinical considerations regarding the greater palatine foramen. Rom J Morphol Embryol. 2013;54:779-83.
[21] Ortug A, Uzel M. Greater palatine foramen: Assessment with palatal index, shape, number and gender. Folia Morphol (Warsz). 2019;78(2):371-77.
[22] Kim DW, Tempski J, Surma J, Ratusznik J, Raputa W, Świerczek I, et al. Anatomy of the greater palatine foramen and canal and their clinical significance in relation to the greater palatine artery: A systematic review and meta-analysis. Surg Radiol Anat. 2023;45(2):101-19.
[23] Martins T, Guedes V, Martins E, Mesquita P. Morphometric analysis of the greater palatine foramen: A CBCT study in Portugal. Surg Radiol Anat. 2025;47(1):64.

PARTICULARS OF CONTRIBUTORS:
1. Postgraduate Student, Department of Oral Medicine and Radiology, Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India.
2. Senior Professor, Vice Principal, Department of Oral Medicine and Radiology, Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India.
3. Professor and Head, Department of Oral Medicine and Radiology, Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India.
4. Associate Professor, Department of Oral Medicine and Radiology, Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India.
5. Senior Lecturer, Department of Oral Medicine and Radiology, Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India.
6. Postgraduate Student, Department of Oral Medicine and Radiology, Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Sindhuja Yerrapragada,
Room No. 1, Vishnu Dental College, Vishnupur, Bhimavaram, Andhra Pradesh, India.
E-mail: sindhuja.yerrapragada@vdc.edu.in

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Nov 24, 2024
- Manual Googling: Mar 03, 2025
- iThenticate Software: Mar 05, 2025 (7%)

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. Yes

Date of Submission: **Nov 23, 2024**
Date of Peer Review: **Feb 03, 2025**
Date of Acceptance: **Mar 07, 2025**
Date of Publishing: **Jul 01, 2025**