

Assessment And Correlation Of The Anatomic Location Of The Greater Palatine Foramen With Shape, Number And Gender In Adult Indian Skulls: A Cross Sectional Study

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ABSTRACT

Background: The Greater palatine foramen (GPF) is a neurovascular pathway in the oral cavity that transmits the greater palatine nerve and the descending palatine vessels. The aim of this present study was to assess and correlate the anatomic location of GPF with shape, number and gender in adult Indian skulls.

Materials and Methods: 89 intact adult skulls were studied, and measurements were taken using Vernier callipers. The statistical analysis was done using the chi-square test and the Independent t-Test.

Result: The majority of GPF was found in the 3rd molar region (61.8%) (n=34) and in females at 62.9% (n=22). In males, GPF was found behind the 3rd molar in 18.2% (n=10) of skulls and 17.1% in females (n=6). GPF was found between the 2nd and 3rd molars in 20% of male skulls (n=11) and 20% in female skulls (n=7). The average palatal index (PI) of the 47 measurable adult males was 86.96 ± 8.31 , whereas the PI of the 42 measurable adult females was calculated to be 78.15 ± 5.87 . An oval-shaped GPF was observed bilaterally in all palates of the skulls. No correlation was found in the number and shape of GPF in either of the gender.

Conclusion: The GPF was predominantly found in the third molar region, regardless of shape, number, and gender, in all the Indian skulls. This information aids the clinician in identifying the area to anesthetize for palatal anesthesia during various dental and clinical procedures.

Keywords: Skull, greater palatine foramen, mid palatine suture, lesser palatine foramen, incisive foramen.

INTRODUCTION

The greater and the lesser palatine vessels and nerves innervate the hard and the soft palate. The Greater palatine artery (GPA) is the main vessel supplying the soft and hard tissue of the hard palate. The GPA, branch of descending palatine artery, originates from The Greater palatine foramen (GPF) which lies in the pterygopalatine fossa after it

traverses the Greater Palatine Canal. The Greater palatine nerve (GPN) is a branch of the Pterygopalatine ganglion which descends through the Greater Palatine Canal with the Descending Palatine Artery and emerges upon the hard palate through GPF. The location of the greater palatine

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foramen (GPF) can be palpated at the opposite of the 3rd molar region.[1]

Awareness regarding the exact location of GPF can be useful for giving local block of palatal nerves. Careful and efficient planning is possible with well-informed understanding of anatomy of these areas for successful execution of surgical procedures. Indian skulls can be differentiated from that of others from the knowledge of Palatine Index and Palatine Height Index. A thorough understanding of the location and structure of the palatine foramen is crucial for oro- maxillofacial surgeons and dentists when administering localized anesthesia to the

MATERIALS AND METHODS

The present study was conducted in the Department of Periodontology, where 89 intact adult human skulls of both sexes, without any developmental disorders, were collected with permission and studied. Measurements were taken with the help of a Digital Vernier Caliper (INSIZE). Palates were photographed from multiple views. Each parameter was measured and the average was recorded. Various measurements were taken, including the following parameters:

- the distance from the GPF to the posterior nasal spine (PNS). (Fig.1)
- the distance from the greater palatine foramen (GPF) to the nearest maxillary molar (MM). (Fig.2)
- the distance from the GPF to the incisive foramen (IF). (Fig.4)
- Major Landmarks of Maxilla (Fig.5)
- Calculation of the palatal index (PI) and classification of palatal shape.
- Assessment of the shape and number of GPF on both sides.
- Count of the lesser palatine foramina (LPF) bilaterally.

Palatine Length: This is the distance measured from the orale (the point located at the anterior end of the incisive suture between the sockets of the two central maxillary incisors) to the posterior nasal spine at the back. (Fig. 6)

maxillary teeth, as it helps prevent damage to the nerves and blood vessels in the hard palate. Procedures like upper tooth extractions, maxillary dental implants, hemi-maxillectomies, orthognathic surgeries, management of Le Fort fractures, and cleft palate repairs require in depth knowledge and utmost precautions of these important landmarks.[2]

Injury or attempts to stop hemorrhage from GPA can cause excessive bleeding leading to palatal tissue necrosis, postoperative pseudo aneurysm. Injury to the GPN can cause paresthesia or insufficient anesthesia of ipsilateral hard palate.[1]

Palatine Breadth: This measurement is taken between the inner edges of the sockets of the upper second molars, also referred to as the endomalaria. (Fig.3)

Palatine Height: The maximum arch of the palate is measured from the line connecting the two endomalaria points.

To assess the palatal dimensions, the following indices were calculated based on the method used by Hassanali and Mwaniki. [3]

Palatine Index (PI):

Palatine Index (PI): (Palatine breadth x 100) / Palatine Length

The palate's width is determined using the index which represents the ratio of the palatine breadth to the palatine length as a percentage. The PI values categorize the palate as follows:

1. A PI of 79% or lower indicates a narrow palate (Leptostaphyline).
2. A PI between 80% and 84.9% signifies an intermediate palate (Mesostaphyline).
3. A PI of 85% or higher denotes a wide palate (Brachystaphyline).

The human hard palate has been classified as Leptostaphyline (narrow palate with an index < 80%), Mesostaphyline (intermediate palate with an index of 80 – 85%), and Brachystaphyline (wide palate with an index > 85%). In this respect, the aim of this study is to determine the location of GPF,

evaluate its shape, number, and distribution across genders, and observe its relationship with the palatal index. It is believed that the obtained results will contribute significantly to clinical success in maxillofacial and oral surgeries, enhance knowledge about regional anesthesia, and establish a basic index for anthropomorphological studies. The statistical analysis was conducted using the chi-square test and independent t-test. Numerical data were presented as means and standard deviations, while categorical data were expressed as frequencies and percentages. The metrical parameters in males and females were measured using independent t-tests. A p-value of less than 5% was considered significant.

Since the measurements followed a normal distribution, they were presented as mean $\pm$ standard deviation (AVG $\pm$ SD) and the range (minimum–maximum, min–max). Categorical variables, such as sex and palate type, were reported as numerical values (percentages). An unpaired t-test was applied to analyze the variance in right and left GPF measurements based on sex.



Fig 1: GPF to Posterior Nasal Spine.



Fig 2: GPF to nearest maxillary molar.

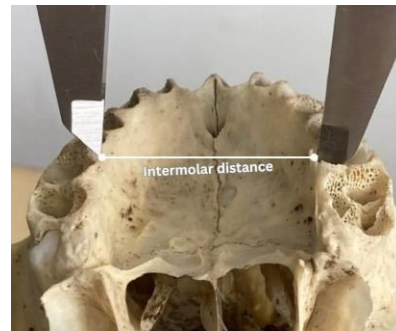


Fig 3: Intermolar Distance

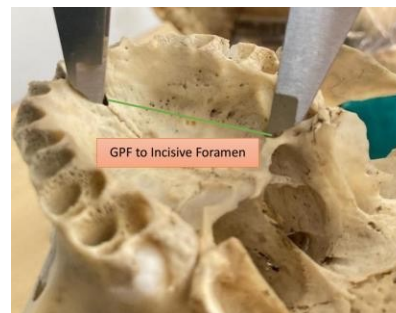


Fig 4: GPF to Incisive Foramen.

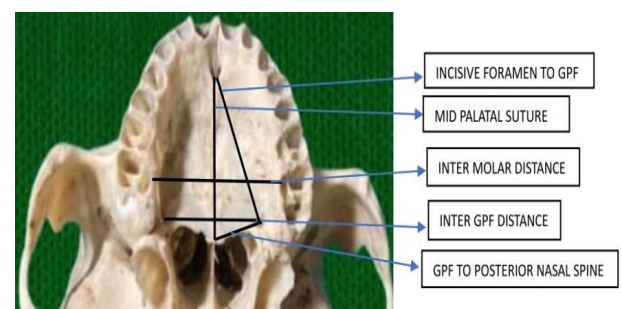


Fig 5: Major landmarks of maxilla



Fig 6: Palatine Length.

RESULTS

In this current study group, 89 dry human skulls were examined, including 47 male and 42 female skulls. A comparative assessment of the anatomic location of the greater palatine foramen according

to palatal shape and gender was performed (Table I, Graph A), along with a comparative assessment of metrical parameters based on gender in this study (Table II, Group B). Additionally, the variation in the distribution of the anatomic location of the greater palatine foramen in males and females across different types of palate was analyzed (Graph C). The applied test was the Chi-square test. In males, the majority of the greater palatine foramen was found in the 3rd molar region (61.8%) (n=34), while in females, it was found in 62.9% (n=22). In males, the greater palatine foramen was located behind the 3rd molar in 18.2% (n=10) of skulls and in 17.1% (n=6) of females. The greater palatine foramen was found between the 2nd and 3rd molars in 20% of male skulls (n=11) and 20% of female skulls (n=7) (Table 1). Accordingly, the average palatal index (PI) of the 47 measurable adult males was 86.96 ± 8.31 , whereas the PI of the 42 measurable adult females was calculated to be 78.15 ± 5.87 . It was found that the PI values of adult males were statistically significantly higher than those of adult females (Table 2). However, there was no significant difference regarding the greater palatine foramen's relation to the posterior nasal spine, incisive foramen, and palatal length. In this study, the average distance from the greater palatine foramen to the closest maxillary molar was 9.76 ± 2.83 mm in males and 8.43 ± 2.23 mm in females. The distance from the greater palatine foramen to the mid-palatal suture averaged 14.05 ± 2.01 mm in males and 12.97 ± 1.41 mm in females. The distance from the greater palatine foramen to the paranasal sinus was found to be 14.41 ± 1.80 mm in males and 14.62 ± 2.20 mm in females. Furthermore, the distance from the greater palatine foramen to the incisive foramen was found to be 35.75 ± 4.01 mm in males and 36.58 ± 4 .

Table 1: Table 1: Variation in the distribution of location of the Greater Palatine Foramen in males and females in different types of palate

Independent variables	Anatomic location of greater palatine foramen			p-value
	Third molar	Behind third molar	Between second and third molar	
Gender				
Male	34 (61.8)	10 (18.2)	11 (20)	0.992
Female	22 (62.9)	6 (17.1)	7 (20)	
Palatal Shape				
Brachystaphyline	16 (61.5)	3 (11.5)	7 (26.7)	0.687
Leptostaphyline	26 (65)	7 (17.5)	7 (17.5)	

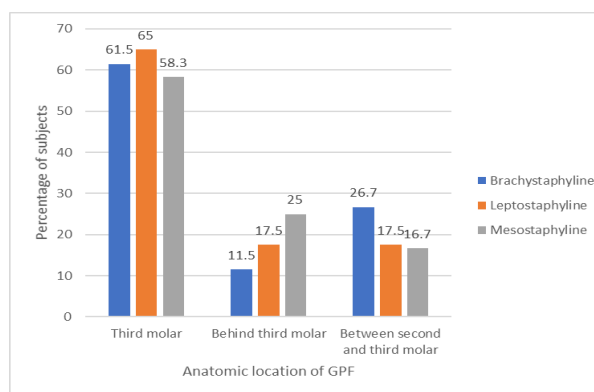
Mesostaphyline	14 (58.3)	6 (25)	4 (16.7)	
Total	56 (62.2)	16 (17.8)	18 (20)	90 (100)

Footnote: p value – probability value, $p \leq 0.05$ – statistically significant value

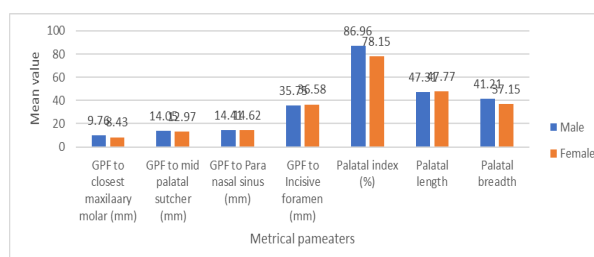
Table 2: Mean values of location of GPF with respect to closest maxillary molar, mid palatal suture, Palatal Index and Palatal Breadth of male and female.

Metrical parameters	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)	p-value	Total (Mean $\pm$ SD)
GPF to closest maxillary molar (mm)	9.76 ± 2.83	8.43 ± 2.23	0.021*	9.25 ± 2.68
GPF to mid palatal suture (mm)	14.05 ± 2.01	12.97 ± 1.41	0.007*	13.63 ± 1.87
GPF to Paranasal sinus (mm)	14.41 ± 1.80	14.62 ± 2.20	0.609	14.49 ± 1.96
GPF to Incisive foramen (mm)	35.75 ± 4.01	36.58 ± 4.85	0.383	36.07 ± 4.35
Palatal index (%)	86.96 ± 8.31	78.15 ± 5.87	0.000*	83.54 ± 8.58
Palatal length	47.31 ± 4.87	47.77 ± 5.84	0.692	47.49 ± 5.24
Palatal breadth	41.21 ± 5.02	37.15 ± 3.84	0.000*	39.63 ± 4.99

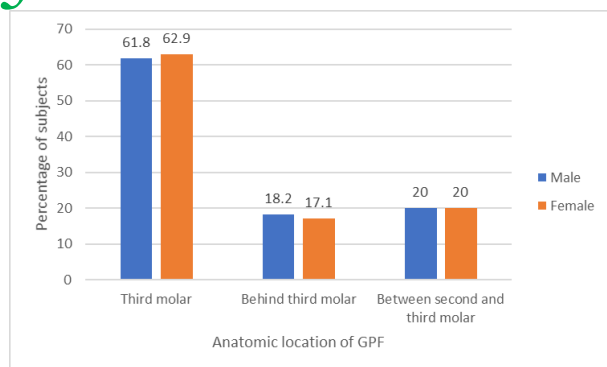
Footnote: p value – probability value, $p \leq 0.05$ – statistically significant value



Graph A: Comparative assessment of anatomic location of greater palatine foramen according to palatal shape.



Graph B: Comparative assessment of metrical parameters according to gender.



Graph C: Comparative assessment of anatomic location of greater palatine foramen according to gender

DISCUSSION

Hard and soft palate innervation is supplied by different branches of trigeminal nerves. The trigeminal nerve has three main branches: the ophthalmic, maxillary, and mandibular nerves. Among these, the maxillary branch gives off the greater palatine and nasopalatine nerves which supply the hard palate whereas the lesser palatine nerve innervates the soft palate. These areas innervate the specific part of the palate areas via the greater (GPF) and lesser palatine foramen (LPF).

Nevin[4] first described the anesthetic blocking of the greater palatine nerve for surgical procedures involving maxillary molars, sinus and nasal region in 1927. However, it was not easy to determine the exact location of greater palatine foramen to anesthetize the areas concerned at the time of surgical procedures. Research indicates that successful palatal anesthesia is only achieved by thorough knowledge location of greater palatine foramen.[5] Precise knowledge of greater palatine foramen (GPF) and greater palatine canal (GPC) anatomy is necessary to avoid injury to the greater palatine artery (GPA) when performing a variety of dental surgical procedures. The GPF is a major neurovascular opening in the oral cavity, carrying sensation and circulation related to gums, palate, and nasal cavity, maxillary nerve blocks, hemostatic procedures, and the treatment of neuralgia. [6]

Locating the greater palatine foramen forms an integral part of anesthesia when operating during maxillofacial procedures, including restorative treatments, periodontal surgery such as free vascular flaps, and oral surgeries related to cleft

palate or maxillary sinus involving surgeries [7] Piagkou et al. [8] 2012 elaborated that GPF can also form a link to association to the pterygopalatine ganglion. This information can be used in stroke patients to reduce the stroke's effect, to manage symptoms patients associate with cluster and migraine headaches, as well as conditions such as cerebral vasospasm. [9] In depth knowledge about GPF is very crucial as this is the most important site in the palate, having the greatest and most precise representation in the somatosensory cortex [10]

Also, detailed anatomy knowledge is required for research related to craniofacial growth. [11] Another factor to be considered being the developmental process of the transverse palatine suture guides the distance to be developed between the maxillary molars and premolars. [12] Tomaszewska et al. [13] mentioned that previous researches reported different information on location of GPF as lateral border of posterolateral margin [14] medial to last molar teeth [15] or in front of last molar teeth. [16] Seldin et al. stated that anesthesia books state the location little more detailed but variable as in front of second maxillary molar teeth [17], third maxillary molar teeth or anywhere close to second and third molars. [18]

It is seen through extensive previous researches that numerous attempts have been made in the past to locate the exact location of GPF for surgical procedures to be performed at areas involving the palate. It is also concluded by Canter SR et al.[19] that this position of GPF varies with gender and ethnicity of the population. For example, it varies between Mongolian [20] Caucasians [21] and African population [22].

In this respect, the aim of this study was to determine the location of GPF evaluate its shape, number and distribution across genders and observe relation with palatal index (PI). In the current study, the subjects were also classified according to their palate types. The sample were also grouped as leptostaphyline (narrow), mesostaphyline (medium) and brachystaphyline (wide) in this study while evaluating their PI.

The first attempt to reference the GPF to other anatomical points was undertaken by Matsuda [23] on a sample of 380 skulls with mixed ethnicity. Out of 89 skulls 47 were male cranium and the mean

values of palatal indices (PI) were 84.12 ± 8.25 and 42 female craniums were observed which showed PI of 76.12 ± 8.26 . GPF was oval shape 58.2% males and 64% in females. The location of GPF was observed bilaterally and near the upper 3rd molar in both males and females. No correlation was observed in relation to GPF number, shape and gender.

In this study the parameters GPF to closest maxillary molar, GPF to mid palatal suture and palatal index in males was found significant ($< 0.05\%$). It was found that the PI values of adult males were significantly higher than that of females. This data agrees with Ortug. A. et al. 62.2% skulls showed GPF at the 3rd molar ($n=56$), 17.8% showed behind 3rd molar ($n=16$) and GPF was found between 2nd and 3rd molar in 20% of skulls ($n=18$). Similar results have been obtained by Dave et. al.[24] and Badshah M. et. al. [25] but contradicts Ajmani et. al. [21]

On the basis of systematic review conducted and it was demonstrated that the GPF is most often located opposite the third maxillary molar in majority of populations. It is unsaid that the maxillary molars are the best landmarks for locating the GPF. In edentulous patients the most useful points for approximating the position of the GPF are the alveolar ridge, midline maxillary suture and the posterior nasal spine. This knowledge about GPF helps periodontists to locate the ideal location for harvesting a palatal graft as it is recommended not to cross the distal surface of the second maxillary molar. [13]

CONCLUSION

This study was conducted on Indian skulls with the belief that understanding the location of the greater palatine foramen (GPF) in various palatal shapes would assist clinicians in achieving effective greater palatine anesthesia and in preventing inadvertent damage to the greater palatine vessels during the harvesting of free gingival grafts or during sinus closure. The maxillary molars serve as the best landmark for locating the GPF. In edentulous areas, the most reliable method for locating the GPF involves using the alveolar ridge, the midline maxillary suture, and the posterior nasal spine. Further investigations using newer imaging techniques, such as cone beam computed

tomography (CBCT), are necessary with a larger sample size conducted on anatomical data across different ethnicities and populations to obtain more precise information and knowledge for improved surgical outcomes.

REFERENCES

1. Kim DW, Tempiski J, Surma J, Ratusznik J, Raputa W, Świerczek I, Pękala JR, Tomaszewska IM. 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;45:101-119.
2. Nimigean V, Nimigean VR, Buşincu LA, Sălăvăstru DI, Podoleanu L. Anatomical and clinical considerations regarding the greater palatine foramen. *Rom J Morphol Embryol.* 2013;54:779-783.
3. Shalaby S, Eid E, Sarg N, Sewilam A. Morphometric analysis of hard palate in Egyptian skulls. *Benha Medical Journal.* 2015;32: :59-72
4. Nevin M, Puterbaugh PG. Conduction, Infiltration, and General Anesthesia in Dentistry. 4th ed. Brooklyn: Dental Items Interest Pub. 1938.
5. Douglas R, Wormald PJ. Pterygopalatine fossa infiltration through the greater palatine foramen: where to bend the needle. *The Laryngoscope.* 2006;116: 1255-1257.
6. Gibelli D, Borlando A, Dolci C, Pucciarelli V, Cattaneo C, Sforza C. Anatomical characteristics of greater palatine foramen: a novel point of view. *Surg Radiol Anat.* 2017;39:1359-1368.
7. Ducic Y, Herford AS. The use of palatal island flaps as an adjunct to microvascular free tissue transfer for reconstruction of complex oromandibular defects. *The Laryngoscope.* 2001;111:1666-1669
8. Piagkou M, Xanthos T, Anagnostopoulou S, Demesticha T, Kotsiomitris E, Piagkos G, Protogerou V, Lappas D, Skandalakis P, Johnson EO. Anatomical variation and morphology in the position of the palatine foramina in adult human skulls from Greece. *J Craniomaxillofac Surg.* 2012;40:e206-e210.

9. Oluigbo CO, Makonnen G, Narouze S, Rezai A.R. Sphenopalatine ganglion interventions: technical aspects and application. *Prog Neurol Surg*. 2011;24:171–179.
10. Bessho H, Shibukawa Y, Shintani M, Yajima Y, Suzuki T, Shibahara T. Localization of palatal area in human somatosensory cortex. *J Dent Res*. 2007;86:265–270.
11. Jones RG. The reduction of bleeding in hare-lip and cleft palate surgery. *Br J Anaesth*. 1962;34:481–488.
12. Harnet JC, Lombardi T, Lutz JC, Meyer P, Kahn J-L. Sagittal craniofacial growth evaluated on children dry skulls using V2 and V3 canal openings as references. *Surg Radiol Anat*. 2007;29:589–594.
13. Tomaszewska IM, Tomaszewski KA, Kmiolek EK, Pena IZ, Urbanik A, Nowakowski M, Walocha JA. Anatomical landmarks for the localization of the greater palatine foramen--a study of 1200 head CTs, 150 dry skulls, systematic review of literature and meta-analysis. *J Anat*. 2014; 225: 419–435.
14. Gardner E, Gray DJ, Rahilly R. *Anatomy: a regional study of human structure*. 4th edition. Philadelphia: WB Saunders. 1975.
15. Moore KL. *Clinically Oriented Anatomy*. 5th ed. Williams and Wilkins, Baltimore 2006: 886–996.
16. Romanes GJ. *Cunningham Textbook of Anatomy*. 12th ed. New York: Oxford University Press. 1981.
17. Seldin H. *Practical Anesthesia for Dental and Oral Surgery, Local and General*. Philadelphia: Lea & Febiger. 1942.
18. Shane SME. *Principles of Sedation, Local, and General Anesthesia in Dentistry*. Springfield: Thomas. 1975.
19. Canter SR, Slavkin HC, Canter MR. Anatomical study of pterygopalatine fossa and canal: considerations applicable to the anesthetization of the second division of the fifth cranial nerve. *J Oral Surg Anesth Hosp Dent Serv*. 1964;22:318–323.
20. Chentanez V, Kaweewongprasert S, Thunvarachorn P, Kaweewongprasert S, Punrut N. Position of greater palatine foramens, length and direction of greater palatine canals: anatomic study of 120 adult human skulls. *Chula Med J*. 1985; 29: 1187–97.
21. Ajmani ML. Anatomical variation in position of the greater palatine foramen in the adult human skull. *J Anat*. 1994; 184: 635–637.
22. Hassanali J, Mwaniki D. Palatal analysis and osteology of the hard palate of the Kenyan African skulls. *Anat Rec*. 1984; 209: 273–280.
23. Matsuda Y. Location of the dental foramina in human skulls from statistical observations. *Int J Orthod Oral Surg Radiogr*. 1927;13:299–305.
24. Dave MR, Yagain VK, Anadkat S. Variaciones Anatómicas en la Posición del Foramen Palatino Mayor en Cráneos Humanos Adultos y su Significación Clínica. *International Journal of Morphology*. 2013, 31:578-83.
25. Badshah M, Soames R, Khan MJ, Hasnain J. Morphology of the human hard palate: a study on dry skulls. *Italian Journal of Anatomy and Embryology*. 2018, 9:55-63.
26. Ortug A, Uzel M. Greater palatine foramen: assessment with palatal index, shape, number and gender. *Folia Morphol (Warsz)*. 2019;78:371-377.