

A cone beam computed tomographic analysis of the greater palatine foramen in a cohort of Sri Lankans

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ABSTRACT

Objectives: To determine the size and position of the Greater Palatine Foramen using CBCT

Materials and method: GPF was evaluated on 50 CBCTs which were obtained at the Division of Oral Medicine and Radiology, FDS, University of Peradeniya. The distance of each GPF to the mid maxillary suture (MMS), Anterior Nasal Spine (ANS), relationship of the GPF to the molar teeth and diameter were measured in different orthogonal planes using measurement tools integrated to the CBCT software.

Results: Mean diameter of the GPF in females and males were 3.72 mm for the right and 3.31 mm for the left and 4.56 mm and 4.30 mm. The antero-posterior distance measured from the ANS to mid GPF in axial sections among females was 45.70 mm and 44.81 mm for the right and left respectively whereas for males it was 48.37 mm and 47.6 mm. The distances in axial sections were 14.82 and 15.14 mm for right and left sides in females whereas in males it was 15.50 and 15.67 mm from the MMS. The same measurement in the coronal plane was 14.93 mm and 15.22 mm for females for the right and left GPF and was 15.63 mm and 15.49 mm in males respectively. There was a significant difference between the distance of ANS to the GPF on both sides and the diameters of GPF in both males and females ($p < 0.005$).

Conclusion: A significant difference was seen between the mean distance from the ANS to the GPF in left and right sides and the diameter of the GPF on the sides among the genders.

1. Introduction

The hard palate forms through the union of the palatine processes of the maxilla and the horizontal plates of the palatine bone. The junction of these bony processes is demarcated by a well defined suture. The hard palate consists of important bony foramina of which the Greater Palatine Foramen (GPF) and the Lesser Palatine Foramen (LPF) are considered most important. Bony foramina in the maxillofacial skeleton serves as a portal of entry to neuro-vascular apparatus. The greater palatine foramen is no exception to this scenario. This foramen is located postero-laterally, on either side of the bony palate represents the lower end of the greater palatine canal. The GPF transmits the greater palatine vessels which are branches of the maxillary artery and the greater palatine nerve which is a branch of the maxillary division of the trigeminal nerve from the pterygopalatine fossa. The LPF are located

within the pyramidal process of palatine bone posterior to the GPF and serves as the portal of entry of the lesser palatine nerve and vessels.^{1,2}

The anatomical location of the GPF is a valuable landmark for dentists, maxillofacial surgeons and ENT specialists. Exodontia of the maxillary posterior teeth may require anaesthesia of the greater palatine nerve. In addition surgical procedures involving the hard palate such as in cleft lip and palate repair, dissection due to malignancy or periodontal flap procedures require careful assessment and identification of the vital structures in the palate such as the Greater Palatine Vessels and Nerve. Although there are clear descriptions of the location of these structures certain variations are documented in this regard based on race and gender. Thus this information on variations in location, size and gender would have to be considered by clinicians in order to minimize the risk of damage to such structures which may lead to unforeseen complications.

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The position of the GPF has been assessed primarily through morphometric analysis of human skulls and through assessment and measurements using Cone Beam Computed Tomography imaging.

Multiple studies have demonstrated that the dimensions and relative position of the GPF vary between the genders and among different population groups^{3,4}. To ascertain its precise location various bony landmarks have been utilized. Significant variations have been reported in the literature with regard to the position of GPF in relation to the anterior nasal spine, posterior border of the hard palate and the mid palatine suture.^{3,4}

Moreover, the position of GPF in relation to maxillary molars has been shown to vary among population groups. In a study using 86 dry skulls of an Indian population, it has been noted that the GPF was located opposite the 3rd maxillary molar in 73.26% of the skulls.⁵ A similar study on a Chinese population has revealed that the location of the GPF was commonly seen between the maxillary second and third molars (48%) and lingual to the maxillary third molar (33.5%).⁶

With the advent of CBCT assessment of vital anatomic landmarks and structure have become more accurate in living individuals and many studies have shed light on the location, size, orientation and variations of the GPF.

A study done on a Lebanese population revealed that the GPF was located most frequently opposite the 3rd molar or distal to it in 56.9% of the patients assessed with an average diameter of 5.633 mm and 5.723 mm on the right and left respectively. The average distance to the midline maxillary suture (MMS) and the anterior nasal spine (ANS) was 16.228 mm and 48.294 mm on the right and 14.907 mm and 48.122 mm on the left, respectively.⁴ Analysis of 1200 CBCT images and 150 skulls in a Polish population has concluded that the GPF on average GPF was placed 15.9 ± 1.5 mm from the MMS and 3.0 ± 1.2 mm from the alveolar ridge. The average distance from the posterior nasal spine (PNS) was 17.0 ± 1.5 mm. A high percentage of 74.7% of GPF were positioned opposite the third maxillary molar. In their systematic review using meta analysis of 23 research papers fulfilling the inclusion criteria, it was concluded that the GPF was most frequently located opposite the maxillary 3rd molar. Furthermore, in locating the GPF in edentulous patient the MMS, PNS and Alveolar Ridge (AR) were considered the most important points in estimating its position.⁷

Another Indian study using computed tomography scans has shown that the GPF was located 38.38 mm from incisive fossa, 17.6 mm from posterior nasal spine and 18.38 mm from the inter-maxillary suture. It was also seen that the GPF was placed 5.03 mm from second molar and 5.28 mm from third molar. This study has shown a significant difference in the distances of GPF from incisive foramen and inter-maxillary suture between left and right sides. Further in 25 (56.8%) of the patients the GPF was located closer to the upper third molar.⁸

Thus it is seen that a considerable variation exists between the population of study, the left and right sides and the method of assessment. Thus clinicians have to be aware of the relative position of the GPF with reference to the race and its variations in position.

2. Objectives

2.1. The objectives of the present study was to

1. Analyze the of the Greater palatine foramen in relation to the mid-maxillary suture, alveolar ridge and incisive foramen.
2. Determine any variation in position between the left and right sides and the gender.

Therefore, the present study was undertaken to determine the dimensions of the GPF, and its position in relation to clinically relevant anatomical landmarks.

3. Materials and Methods

A total of 50 CBCT images of patients between the 21–30 years of age were selected randomly from the records of patients referred to Division of Oral Medicine and Radiology, Faculty of Dental Science, University of Peradeniya for cone-beam computer tomography imaging. Deidentified digital imaging and communications in medicine (DICOM) files were provided for assessment.

These images were retrospectively analyzed to determine the position of the GPF in relation to important anatomical landmarks like anterior nasal spine and mid maxillary suture. Images having a clearly imaged maxilla, with no gross malocclusions or cranio-facial anomalies were selected. Images of patients with incomplete clinical records, distorted images, patients who had undergone orthodontic corrections and patients with cleft lip and palate, maxillofacial trauma and other craniofacial anomalies were excluded.

All CBCT scans were performed using a Vatech CBCT scanner (Vatech Corporation, South Korea) using a range of 18–200 uSV, 60 to 90 kVp, and 2–15 mA allowing any adjustment within each FOV and voxel size under standard settings. The recording was carried out with minimal radiation exposure using the ALARA principle. The CBCT scans were interpreted by two calibrated observers in the three orthogonal planes using the minimum available slice thickness. Consensus was reached where there was a disagreement on the interpretation. Consent to the use of images for the study was taken from the patients prior to the CBCT scans. All imaging was examined using a 24 inch LCD screen in a dark room using the standard software. Ethical clearance for this study was obtained from the Research and Higher degrees committee of the Faculty of Dental Sciences, University of Peradeniya.

3.1. Measurements assessed

The following measurements in millimeters were obtained using the measurement tools integrated to the CBCT software

- 1) Distance from the centre of the GPF to the mid-maxillary suture (MMS) on the left side and right side on both axial and coronal sections
- 2) Distance from the centre of the GPF to the Anterior Nasal Spine (ANS) on the left and right side in axial sections
- 3) Diameter of the GPF on the left and right sides in sagittal sections
- 4) Relationship of the GPF to the upper molars as described by Ajmani (1994).⁹

Between the upper first and second molar – A

In the midline of the upper second molar – B

Between the upper second and third molar – C

In the midline of the upper third molar – D

Distal to the upper third molar – E

4. Results

Of the 50 CBCT's analyzing greater palatine foramina, 22 were of male patients and 28 were of female patients. The mean age of the subjects were 25.357 ± 3.582 years for the female population and 25.045 ± 3.154 years for the male population.

On the axial plane, the average distance from the mid-maxillary suture (MMS) to the middle of the GPF was $14.821 \text{ mm} \pm 1.333$ for females on the right side and $15.143 \text{ mm} \pm 1.677$ on the left side. The corresponding values for the male population was $15.505 \text{ mm} \pm 1.531$ and $15.668 \text{ mm} \pm 1.514$ on the right and left sides respectively. In the Coronal plane, the corresponding values for females on the right and left side were $14.925 \text{ mm} \pm 0.950$ and $15.229 \text{ mm} \pm 1.340$ whereas for males the values were $15.627 \text{ mm} \pm 1.544$ and $15.491 \text{ mm} \pm 1.356$ (Fig. 1).

In the antero-posterior direction, the distance of the GPF from the

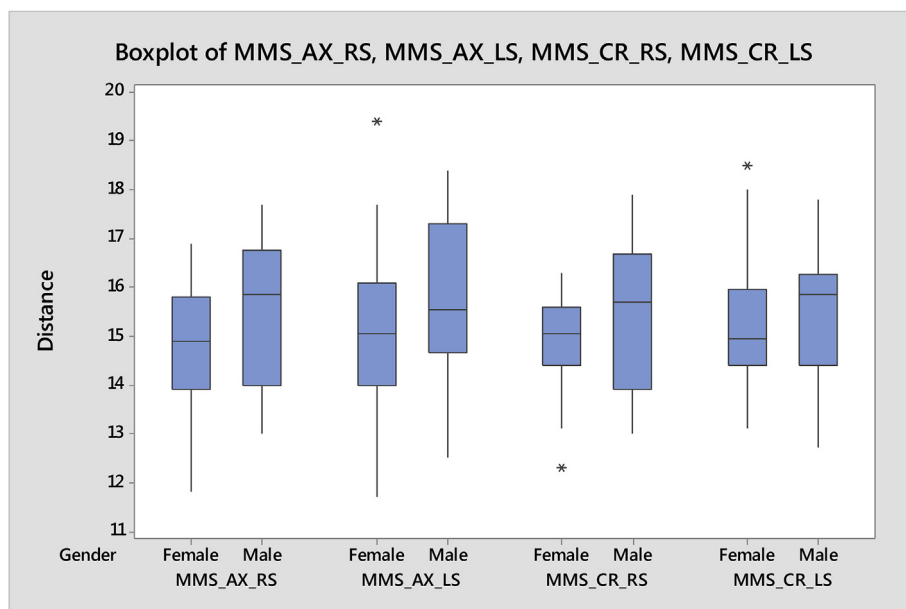


Fig. 1. Boxplot of the morphometry of the distance of the GPF from the MMS in the Axial and Coronal planes for female and male groups.

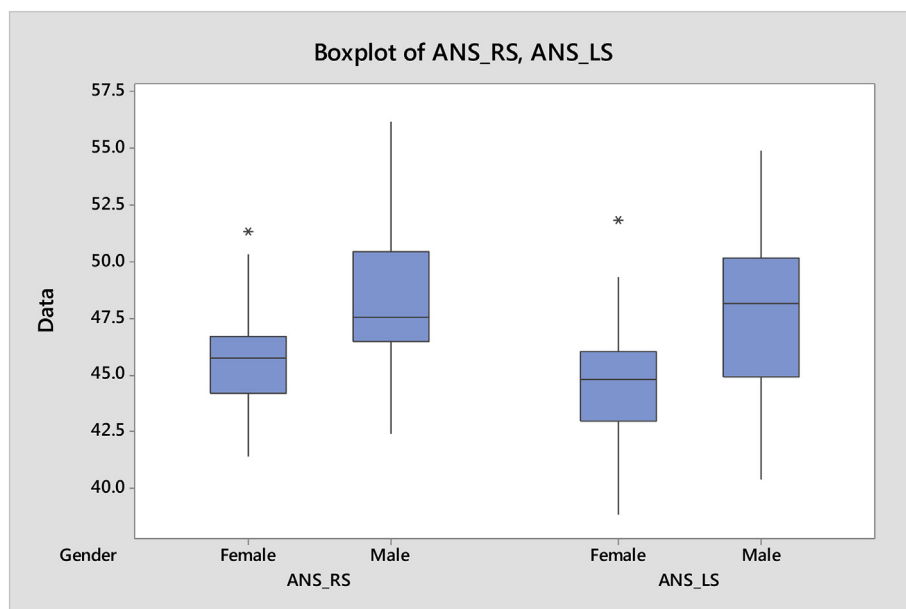


Fig. 2. Boxplot of the morphometry of the distance of the GPF from the ANS for female and male groups in axial sections.

anterior nasal spine (ANS) among the female cohort was $45.696 \text{ mm} \pm 2.078$ and $44.811 \text{ mm} \pm 2.587$ for the right and left side where as the values for the male group was $48.373 \text{ mm} \pm 3.115$ and $47.60 \text{ mm} \pm 3.388$ for the right and left sides (Fig. 2).

The diameter (DIAM) measurements were $3.729 \text{ mm} \pm 0.895$ and $3.311 \text{ mm} \pm 0.808$ for the female group on the right and left sides. In the male population the corresponding measurements were $5.559 \text{ mm} \pm 0.872$ and $4.300 \text{ mm} \pm 0.895$ for right and left sides (Fig. 3).

As there were significant correlations within the variable in each of the three categories (MMS, ANS and DIAM) during the initial assessment, a multivariate statistical analysis was used to find out the significant differences between the two gender groups. A one-way MANOVA was performed and found that there was a statistically significant difference in mean distances based on gender, F-statistics ($[8,41] = 3.978$, $p < 0.005$; Wilk's Λ statistics = 0.563). As the results

of MANOVA were statistically significant, follow-up tests were conducted, namely, univariate ANOVA, to find out the variables whose means are significantly different for the two groups. This revealed that the difference of the distance of the GPF from the ANS in both right ($p = 0.001$) and left sides ($p = 0.002$) between female and male groups were statistically significant. The difference of diameter of the GPF of the right ($p = 0.002$) and left sides ($p = 0.000$) among the female and male group was also found to be significant. None of the MMS distances were significantly different at the 0.05 level (Tables 1 and 2).

When the relationship to the molar teeth was assessed, 48% of the GPF in the right side was in between the second and third molar whereas a further 26% was placed in relation to the third molar. On the left side a majority of the GPF (34%) was placed between the second and third molar and 28% was placed in relation to the second molar. (Table 3). However, when the chi-squares test for the association of the position of GPF in relation to the position of molars was performed, the

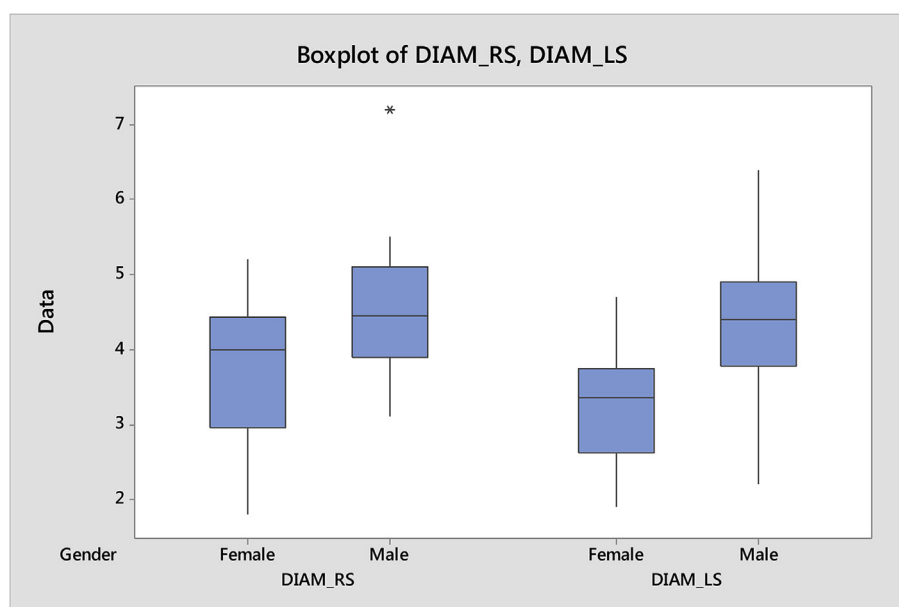


Fig. 3. Boxplot of the morphometry of the diameter of the GPF for female and male groups in sagittal sections.

Table 1

Calculated F statistics and the p-value for the univariate ANOVA on each distance and measurement of the GPF for female and male groups.

Source	Dependent Variable		F	Sig.
Gender	dimension1	MMS_AX_RS	2.838	.099
		MMS_AX_LS	1.315	.257
		MMS_CR_RS	3.918	.054
		MMS_CR_LS	.467	.498
		ANS_RS	13.221	.001
		ANS_LS	10.907	.002
		DIAM_RS	10.845	.002
		DIAM_LS	16.811	.000

Table 2

95% confidence intervals for the significant distances and measurements variables (ANS_RS, ANS_LS, DIAM_RS and DIAM_LS for the two genders.

Dependent Variable	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
ANS_RS	Female	45.696	.488	44.715	46.678
	Male	48.373	.551	47.265	49.480
ANS_LS	Female	44.811	.560	43.684	45.937
	Male	47.600	.632	46.329	48.871
DIAM_RS	Female	3.729	.167	3.392	4.065
	Male	4.559	.189	4.180	4.939
DIAM_LS	Female	3.311	.160	2.989	3.633
	Male	4.300	.181	3.937	4.663

results indicated that there is no significant association between the gender and position of the GPF in relation to molars on both left and right sides.

5. Discussion

Accurate assessment of the position of anatomical structures such as the GPF is vital for any clinician and would determine the success of both surgical procedures and anaesthetic technique. The earliest descriptions of the position of the GPF seen in the literature were by Matsuda in an east Indian population. The position of the GPF in these deliberations were that it lies 1.5 cm from the palatal midline and

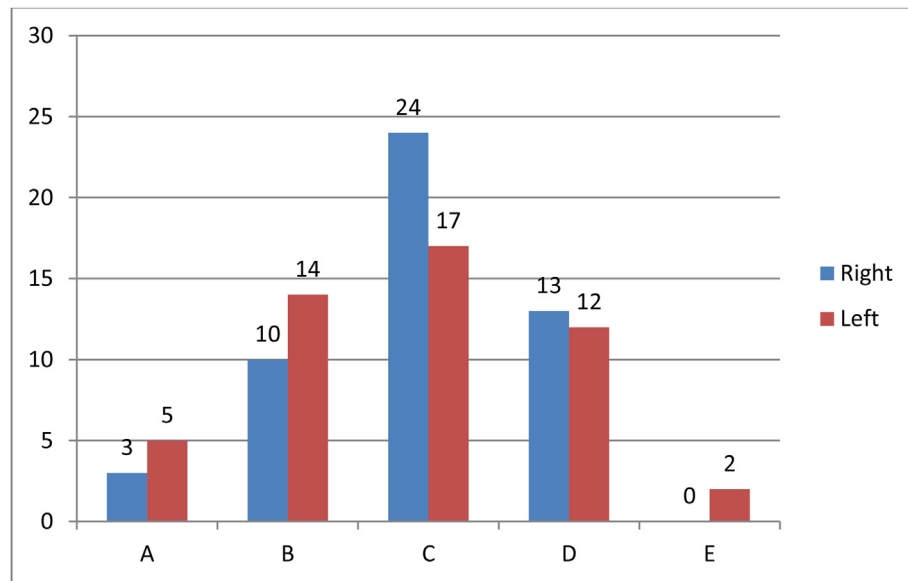
0.19 cm from the posterior border of the hard palate. His revelations also concluded that the common relationship of the GPF to the molar teeth was that it lied opposite the upper third molar in 57% of the skulls analyzed.¹⁰ The results of this study are comparable to these early studies in relation to the position of the GPF with reference to the MMS. However in the Chinese and mongoloid races, the distance seems to be almost a millimeter longer (16 mm).⁶ A study using cone beam computed tomography (CBCT) in a cohort of Brazilian patients revealed that on average, the diameter of the GPF, distance to both the Alveolar Ridge and the Mid Maxillary Suture were 3.1 mm; 7.9 and 15.3 mm. This study has also concluded that the GPF was more closely associated with the upper 3rd molar. Furthermore the direction of opening of the GPF was in an anterior direction.¹¹

When assessed in the antero-posterior dimension, there was a difference of around 3 mm between the male and female group where in the males the GPF was placed further from the anterior nasal spine (ANS) compared to the females. Statistical analysis revealed that this difference was significant with a p value of < 0.05. Thus it could be inferred that within the population of study the GPF lied further from the ANS in males compared to females. In similar studies this variation had not been reported. The antero-posterior measurements corroborate well with similar studies.^{4,7}

When the diameter of the GPF was considered it was revealed that the average diameter of the right and left sides of the female group was 3.729 mm and 3.311 mm respectively whereas for the males it was 5.559 mm 4.300 mm respectively. In general the right side GPF appeared larger than the left side in both genders and the difference between the male and female population was statistically significant. The female group had a smaller dimension compared to the males although statistically not significant. A Lebanese study has also concluded that the GPF is on average 5.633 mm in diameter. However this study showed that the left GPF was very slightly larger than the right though statistically not significant. The comparison of the difference in gender was not documented.⁴

The position of the GPF in relation to the molar teeth is commonly described as being in-between the second and third maxillary molars.¹² In a negroid population the position is described as being at the level of the 3rd maxillary molar.¹³ In the present study it was revealed that the most common relationship was that the GPF being in between the second and third maxillary molar in both genders followed by being opposite the upper third molar and the upper second molar. Thus in a

Table 3
Relationship of the GPF to the upper molar teeth.



clinical scenario, greater palatine anaesthesia would best be achieved by deposition of the anaesthetic agent in the region between the second and third molar.

In a study using 86 dry skulls of an Indian population, it has been noted that the GPF was located opposite the 3rd maxillary molar in 73.26% of the skulls. The mean distance of the GPF from the incisive foramen, posterior border of the palate and the mid-palatal suture has been 35.9 mm, 3.4 mm and 15.3 mm respectively.⁵ A similar study on 300 human skulls of east Indian origin revealed that the GPF was located 1.5 cm from the palatal midline and 0.19 cm from the posterior border of the hard palate. Further the foramen was located distal or in line with the 3rd molar in 57% of the cases with a mere 9.7% located in proximity to the second molar. The opening was in a inferior or vertical direction in a staggering 82% of the skulls.^{3,14} A study in a cohort of skulls from a chinese population had revealed that the mean distance of the GPF to the mid-sagittal plane of the hard palate was 16.00 mm, and 4.11 mm to the posterior border of the hard palate. The location of the GPF was commonly seen between the maxillary second and third molars (48%) and lingual to the maxillary third molar (33.5%).^{6,15}

Many studies have also assessed the direction of the orientation of the GPF where a majority was seen directed in an inferior or vertical orientation.^{3,14,15} However the orientation of the GPF was not assessed in the current study.

6. Conclusions

It is concluded that there is a significant difference between the mean distance from the anterior nasal spine to the GPF of the left side and right side and the diameter of the GPF on the left and right side among the genders. There is no significant association between the gender and the position of GPF in relation to position of molars in both sides.

Conflicts of interest

The authors declare that there is no conflict of interest with any

other industry, research or publisher.

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