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ORIGINAL RESEARCH

ASSESSMENT OF ANATOMICAL VARIATIONS OF GREATER PALATINE FORAMEN IN A SAMPLE OF EGYPTIAN POPULATION USING CBCT: A CROSS-SECTIONAL STUDY

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ABSTRACT

Statement of problem: The greater palatine foramen (GPF) is an important landmark in oral surgery. Block anesthesia of the greater palatine nerve (GPN) is a very common procedure in numerous dental interventions involving the posterior maxilla. Procedures that may involve the GPF include orthognathic surgery, closure of oroantral/nasal fistulas, removal of pathological tissue, harvesting of palatal soft tissue grafts, and extraction of maxillary posterior teeth. However, these procedures are all performed close to, and thus may damage, vital anatomical structures, such as the greater palatine neurovascular complex. Therefore, it is important to assess the anatomical variations of the GPF to avoid hemorrhagic risks and anesthesia failures.

Aim of the study: To assess the anatomical variations (diameter and number) of the greater palatine foramen in a sample of Egyptian population using cone beam computed tomography.

Materials and method: This cross-sectional study evaluated 173 greater palatine foramina using cone beam computed tomography. Diameter and number of foramina were evaluated and recorded. Inter and intra observer agreement were done using Intraclass correlation coefficient.

Results: The mean diameter of GPF was 4.18 ± 0.90 mm.

Conclusion: The anteroposterior dimension of the greater palatine foramen is vital during orthognathic procedures, excision of pathological lesions, palatal soft tissue graft harvesting, and extraction of posterior maxillary teeth. Therefore, surgeons should handle this region with great care.

Keywords: Greater palatine foramen, Hard palate, GPF, Cone beam computed tomography, CBCT.

INTRODUCTION

The hard palate is an essential region of the skull; its gross anatomy and morphological variations have been of interest in many studies. The bones and dental structures of the palate are often preserved even in cases of serious damage at or following death [1].

Many important anatomical landmarks traverse the hard palate. The greater palatine nerve (GPN) emerges on the hard palate from the greater palatine foramen (GPF). It innervates the posterior section of the hard palate and runs forward in a groove up to the incisor teeth, where it meets the terminal filaments of the nasopalatine nerves[2]. The greater palatine artery (GPA) originates from the descending palatine branch of the maxillary artery in the pterygopalatine fossa (PPF), passes through the greater palatine canal (GPC) and also emerges from the GPF on the palatal aspect of the third maxillary molar, to reach the hard palate [3]. The lesser palatine foramina (LPF), usually two, lie behind the greater palatine foramen (GPF) and pierce the pyramidal process of the palatine bone, which is wedged between the lower ends of the medial and lateral pterygoid plates. The LPF transmit the lesser palatine vessels as well as the middle and posterior palatine nerves [4].

Block anesthesia of the greater palatine nerve (GPN) is a very common procedure in numerous dental

interventions involving the posterior maxilla. Procedures that may involve the GPF include orthognathic surgery, closure of oroantral/nasal fistulas, removal of pathological tissue, and extraction of maxillary posterior teeth. However, these procedures are all performed close to, and thus may damage, vital anatomical structures, such as the greater palatine neurovascular complex. Therefore, it is important to assess the anatomical variations of the GPF to avoid hemorrhage risks and anesthesia failures [5-7].

Since the greater palatine foramen represents a significant landmark in the palatine region, with important implications in the dental field, this in vivo cross-sectional study was carried out to show variations in the GPF diameter and number in an Egyptian subpopulation.

MATERIAL AND METHODS

Participants, Setting and Location

The present cross-sectional retrospective study was carried out in the Department of Oral and Maxillofacial Radiology, Cairo University, Cairo, Egypt. CBCT scans of Egyptian patients who have already been subjected to CBCT examination as part of their dental diagnosis and/or treatment planning were included according to the proposed eligibility criteria. All the CBCT images were scanned using CBCT machine, Planmeca ProMax® 3D Mid machine (Finland) at 90 kvp with 8 mA with different fields of view with voxel sizes of 0.2 and 0.4 mm.

Sample size calculation was done using Benchmark Six Sigma website and accepted by the institutional Medical Biostatistics unit. Based upon the results of Ikuta et al. (2013), where the mean diameter of the greater palatine foramen was 3.1 mm (±0.47), with an acceptable margin of error 7%, the minimum estimated sample size was 173 hemi-palates.

CBCT scans of Adult Egyptian population older than 18 years, showing the floor of the maxillary sinus, with no artifacts in the maxillary region were included. The images which have one of the following criteria were excluded from the study: (1) CBCT scans of completely edentulous maxilla; (2) patients with trauma, craniofacial surgery, orthognathic surgery and malignancies involving the maxillofacial region; (3) patients with cleft palate and other craniofacial anomalies. The collected CBCT scans were reviewed by two oral and maxillofacial radiologists using Planmeca Romexis software version 4.6.2.R.

Image Analysis

The following parameters were analyzed on CBCT images in the 3 main orthogonal planes (axial, coronal and sagittal):

1- Diameter of the greater palatine foramen.
2- Number of the greater palatine foramen.

Foramen detection and analysis

Upon identification of the eligible cases, scrolling through the axial plane was used as the initial step in foramen identification, with confirmation achieved using the other two orthogonal planes **(Fig.1 A, B, C).**

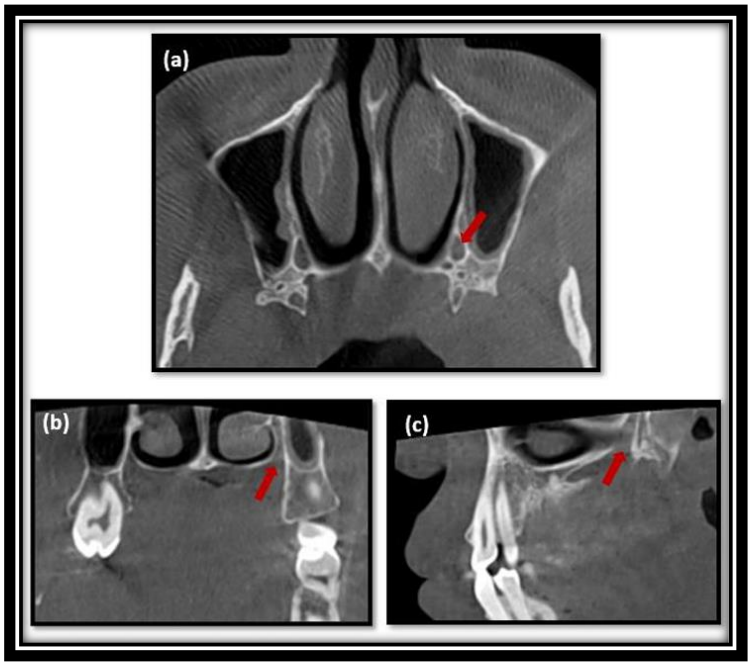

Figure 1. Axial (A), Coronal (B) and (C) sagittal views showing the greater palatine foramen.

With the help of the cursor, the intersection lines were oriented perpendicular to the foramen under investigation. Then through scrolling of different planes, the diameter, and number of the greater palatine foramina were analyzed.

Through the sagittal cut, we measured the anteroposterior dimension of the canal opening (GPF) **(Fig.2).**

CBCT images were interpreted by two oral radiologists independently; blinded from demographic data of the patients and from the results of each other. This step was done to avoid any source of biases, where one of them evaluated the images twice with a period of two weeks interval between the two reading sessions, to asses intra/inter-observer reliability.

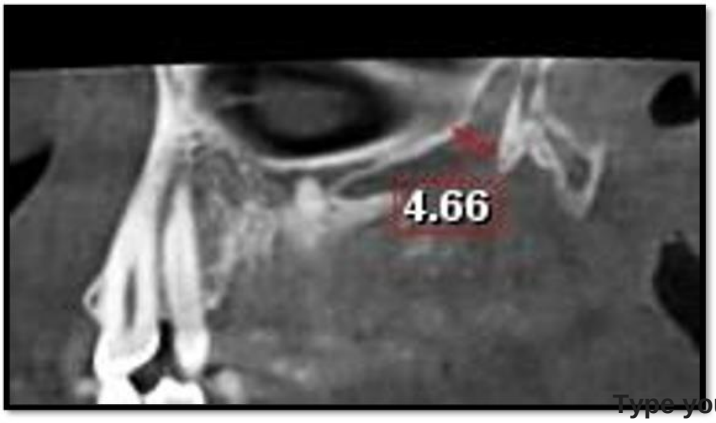

Figure 2. Sagittal view showing the diameter of the greater palatine foramen of 4.66 mm.

Statistical analysis

Data were analyzed using IBM SPSS advanced statistics (Statistical Package for Social Sciences), version 21 (SPSS Inc., Chicago, IL). Numerical data were described as mean and standard deviation or median and range. Categorical data were described as numbers and percentages. For comparing between male and female GPF / right and left sides GPF, Independent t test was used. Inter and intra observer agreement (reliability) were done using intra-class correlation coefficient (ICC).

RESULTS

This cross-sectional study examining 93 CBCT scans of an Egyptian subpopulation comprising 80 with full arches and 13 with hemi-palates. The cohort included 48 males and 45 females' patients. The study sample comprised 173 greater palatine foramina (GPF), as the number of GPF was one foramen in all hemi-palates, and no multiple foramina were recorded. (Table 1). We assessed 93 GPF in males and 80 in females. Regarding the sides, 88 on the right side and 85 on the left.

Table 1. Descriptive results of baseline data.

Baseline data of hemi-palates		Count	Column N %	P- value
Gender	Male	93	53.8%	**0.19**
	Female	80	46.2%	
Side	Right	88	50.9%	**0.72**
	Left	85	49.1%	

The diameter of the greater palatine foramen was measured and showed a range from 2.15 to 6.85 mm, with a median of 4.12 mm and a mean of 4.18 ± 0.90 mm.

Table (2) show the association between the diameter of the greater palatine foramen and gender. A comparison between male and female measurements was performed by using Independent t-test, which revealed that the diameter was significantly larger in males (4.58 ± 0.88 mm) than in females (3.72 ± 0.69 mm), with a mean difference of 0.86 mm (95% CI: 0.62–1.10, p = 0.0001), which showed a statistically significant gender difference.

Table 2. Association between the diameter of the greater palatine foramen and gender.

Greater palatine foramen	Gender				Independent t test				
	Male		Female		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P-value
	Mean	SD	Mean	SD			Lower	Upper	
Diameter	4.58	0.88	3.72	0.69	0.86	0.12	0.62	1.10	**0.0001***

Table (3) present the association between the diameter of the greater palatine foramen and side. A comparison between sides was performed by using Independent t test which revealed that the diameter measured 4.24 ± 0.92 mm on the right side and 4.11 ± 0.88 mm on the left side, with a mean difference of 0.13 mm (95% CI: –0.14 to 0.40, P = 0.357) with non-statistically significant side differences.

Table 3. Association between the diameter of the greater palatine foramen and side.

Greater palatine foramen	Side				Independent t test				
	Right		Left		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P-value
	Mean	SD	Mean	SD			Lower	Upper	
Diameter	4.24	0.92	4.11	0.88	0.13	0.14	-0.14	0.40	**0.357**

There was perfect intra-observer agreement (reliability) as shown in **Table 4** regarding all variables with **ICC (Intraclass correlation coefficient)** values ranging from 0.988 to 0.999 (p value < 0.0001) and from 0.983 to 0.963(p value <0.0001) in inter-observer reliability.

Table 4. ICC of intra-observer and inter-observer reliability.

	Intra-observer reliability				Inter-observer reliability			
Parameter	ICC	95% Confidence Interval		P- value	ICC	95% Confidence Interval		P- value
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
Diameter	0.988	0.984	0.991	<0.0001*	0.983	0.956	0.994	<0.0001*
Number	0.999	0.999	0.999	<0.0001*	0.963	0.900	0.986	<0.0001*

DISCUSSION

Ethnicity affects skull and maxillofacial morphometric analysis by contributing to significant differences in size and shape due to genetic and developmental variations [16].

Within the hard palate, the greater palatine foramen serves as a reliable and identifiable anatomical landmark; its precise dimensions vary between individuals, populations, and sexes[17]. Therefore, in this study, we assessed the number and diameter of GPF in an Egyptian subpopulation.

The diameter of the GPF in this study was measured in the sagittal view at the level of the foramen opening in the anteroposterior direction. This measurement approach was consistent with several methodologies [8,9]. The results of our study showed that the range of diameter of the greater palatine foramen was from 2.15 to 6.85mm and the mean was 4.18 ± 0.90 mm, which is consistent with the findings reported by Shalaby et al. (2015)[1] on Egyptian skulls, where the mean anteroposterior diameter of the GPF was 4.86 ± 0.9 mm.

In addition to that, in agreement with our findings, the morphometric characteristics of the greater palatine foramen diameter was reported by two systematic reviews, Tomaszewska et al. (2014) [10]and Kim et al. (2023) [11], reported diameters ranged between 4.5mm and 5.34 mm, respectively. Moreover, a study conducted on a North Cyprus subpopulation showed a 5.25 mm mean diameter of the greater palatine foramen [15].

However, in 2015, a study conducted on a Lebanese population demonstrated a higher diameter range of the GPF, ranging from 3.05 to 10.38 mm, which may

be attributed to differences in the imaging protocols employed in that study [8].

We found that male patients showed significantly higher diameters of GPF. The findings of Aoun et al. [(8)] in the Lebanese population and Fahrioglu et al. [15] in the North Cypriot population were in line with our results, whereas Ikuta et al. [5] reported no significant differences between males and females in the Brazilian population. In terms of lateralization, there were no statistically significant differences in the diameter between the right and left sides; these results are consistent with those reported by Shalaby et al. in Egyptian skulls [1].

With respect to the number of greater palatine foramina, we excluded all nearing lesser palatine foramina. As with respect to the sagittal plane, most GPCs should present with at least one LPC. Moreover, LPCs may have small bony bifurcations giving rise to numerous LPFs onto the palate, through which lesser palatine nervous rami emerge. In this sense, axial and sagittal slices make it possible to analyze LPCs with their principal LPF.

It is noteworthy that the presence of multiple GPFs holds clinical significance, as it may elevate the risk of bleeding and hematoma during surgical procedures and potentially results in ineffective anesthesia if not properly identified [(13)]. Moreover, the absence of the GPF also presents clinical challenges. It may restrict the ability to harvest implant tissue from the palate and limit options for reconstructive surgery [14].

Aligning with the results we observed, Shalaby et al. (2015) [1] and Gadallah et al. (2024) [12] reported that the greater palatine foramen was invariably observed bilaterally, with a single foramen on each side of the posterolateral region of the hard palate across all examined Egyptian skulls and CT scans.

In contrast, Cagimni et al. (2017)[14]reported the presence of double and triple foramina in 13% and 2% of specimens, respectively, while a unilateral absence of the GPF was observed in 2% of cases. This variation could be attributed to ethnic variability, as this study was done on the Anatolian population.

The study sample was limited to an Egyptian subpopulation in Cairo governorate only. The findings in our study proved similarities in foramen number and morphometric measurements regardless of the side. Regarding gender, there is a statistically significant difference in the diameter of the greater palatine foramen between males and females.

DECLARATION

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Competing interests

No competing interests.

Ethical approval

Not applicable

Patient consent

Not applicable

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