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Topographic evaluation and location of the greater palatine foramen in dry skulls

Jhonatan Thiago Lacerda-Santos[1] | Gélica Lima Granja[1] | Rosifrance Vidal de Oliveira Santos[1] | Djanilson Barbosa Marinho Júnior[1] | Gabriel Mendes Valério[1] | Silvestre Estrela da Silva Júnior[1] | Jalber Almeida dos Santos[1]

[1] UNIFIP, Campina Grande, Paraíba, Brasil

Aim: To evaluate the anatomical location of the GPF in macerated skulls by means of linear measurements and anatomical structures, in turn providing information that can aid dentists when performing anesthetic and surgical techniques.

Methods: An experimental *ex vivo* study was performed. The sample consisted of 55 dry skulls. Measurements were taken on the topography of the GPF: a) distance from the GPF to the median palatine suture (MPS); b) distance from the GPF to the posterior nasal spine (PNS); c) distance from the GPF to the center of the incisive foramen (IF); d) distance from the GPF to the alveolar ridge (AR); and e) distance between the right and left GPFs. The Mann-Whitney and Pearson's Chi-Square tests were performed ($\alpha = 5\%$).

Results: It was noted that the distance between the left and right GPFs, from the GPF to the PNS and to the IF were greater in female skulls ($p < 0.05$). In addition, it was possible to verify that the distances from the left and right GPFs to the AR and to the PNS were greater in male skulls. In relation to molars, no association was found between gender and the location of the GPF.

Conclusion: Using varied anatomical structures, differences were found in the location of the GPF in both female and male skulls.

Uniterms: palate, hard; surgery, oral; molar; maxillary nerve; skull.

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INTRODUCTION

Third molar (3M) extraction is recommended when impaction, a need for orthodontic space, the presence of cysts, crowding, dental caries, prosthetic rehabilitation, periodontal disease, external root resorption, and pericoronaritis are identified[1-4]. Consequently, 3M extraction is a common practice in dental offices[1,5].

The anesthetic block of maxillary nerve branches is widely performed in dental surgery[6]. The maxillary nerve and its divisions sensorially innervate the teeth of the maxilla, hard and soft palate, gingival mucosa, mucosa of the nasal cavity and sinuses, and the skin of the mid-face area[7,8].

The palatine bone presents two small openings, called Greater Palatine Foramen (GPF) and Lesser Palatine Foramen (LPF), which conduct neurovascular bundles[9]. These foramens are the passage for the greater and lesser palatine arteries, originating from the descending palatine artery, a branch of the maxillary artery, to the greater palatine nerve (GPN). Less commonly, these originate from the pterygopalatine ganglion, a branch of the maxillary nerve, which descends from the

Corresponding author:
Jhonatan Thiago Lacerda-Santos
Av. Floriano Peixoto, 3333, Santa Rosa, Campina Grande, Paraíba, Brasil. Phone: (83) 3065-3881.
E-mail: thiiagolacerda@gmail.com

trigeminal ganglion[8,10,11]. The greater palatine nerve descends through the pterygopalatine canal and appears on the hard palate through the greater palatine foramen, which is generally located at a point around 1 cm from the midpalatal line, immediately distal to the second molar[12].

Studies have shown that the maxillary third molars are the best reference to locate the GPF, since, in most of the world's populations, they are usually located close to the third molar[12,13].

In this context, knowledge of the anatomical region of the GPF is important because it is treated in several procedures, including anesthesiology, the connective tissue sampling area, maxillary molar extraction, or the flap donor site for oronasal and buccosinusal communication closure[8,9,13,14]. Therefore, the location and variation of the palatine foramens are important in order to avoid surgical hemorrhage accidents, complications during surgical procedures, and anesthetic failure[7,15,16].

In view of the above, this research aimed to evaluate the anatomical location of the GPF in macerated skulls, providing information to aid in anesthetic and surgical techniques performed on the palate.

MATERIALS AND METHODS

This study was conducted in accordance with Resolution No. 466 of December 12, 2012, and approved by a local Research Ethics Committee, logged under reference number 3.094.221. An experimental study, *ex vivo* laboratorial type, was performed applying a descriptive and analytical approach. The study was carried out in the Anatomy Laboratory of a University Center located in Paraíba, Brazil.

The sample consisted of all skulls that met the research eligibility criteria. Skulls in good condition were included, which enabled the evaluation of the GPF and the anatomical reference structures. Skulls lacking second and third molars, signs of trauma, fractures, or bone anomalies that could compromise the analyses were excluded from the study.

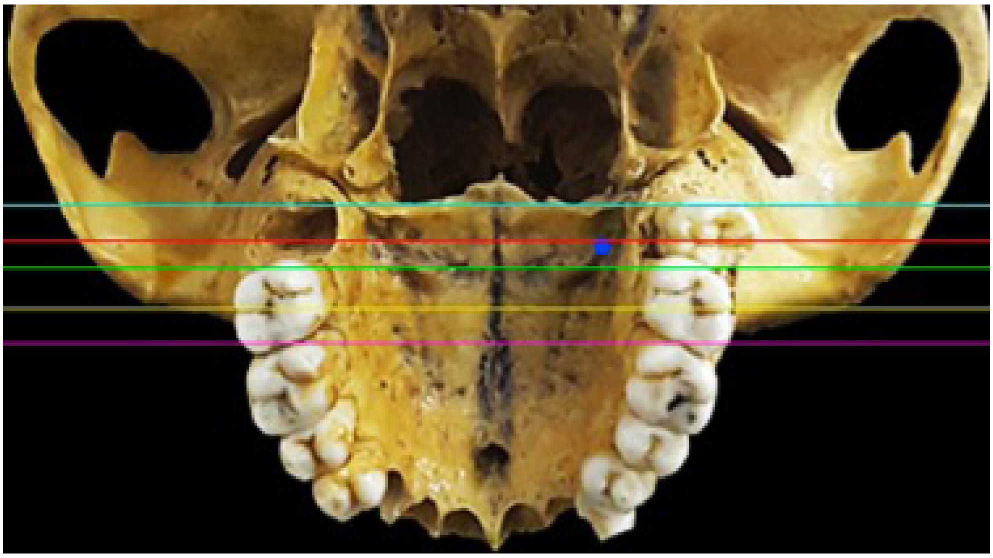
Data collection was conducted in February 2019 and March 2022, by two properly trained examiners. For the collection of linear measurements, a dry-point compass and a digital caliper were used, which was reset to zero for each measurement. First, sexual dimorphism was identified using the criteria proposed by Vanrell (2012)[17].

After identification, measurements were taken to collect information about the topography of the GPF: a) distance from the GPF to the median palatine suture (MPS); b) distance from the GPF to the posterior nasal spine (PNS); c) distance from the GPF to the center of the incisive foramen (IF); d) distance from the GPF to the alveolar ridge (AR); and e) distance between right GPF and left GPF[13] (Figure 1).

Figure 1. Measurements of the GPF to anatomical reference structures.

The position of the GPF related to the maxillary molars was also evaluated from the reference points: I) mesial of the second molar (2M); II) a line passing through the midpoint between the mesial and the distal of the 2M; III) distal of the 2M; IV) a line passing through the midpoint between the mesial and the distal of the Third Molar (3M); and V) the distal of the 3M[13] (Figure 2).

Figure 2. Representation of the location of the GPF in relation to the molars.



The data was analyzed using the Statistical Package for Social Science (SPSS), version 22.0 for Windows. The Z test was performed to analyze the distribution of the data, and it was found that the data did not present normality ($p>1.96$). Next, the Mann-Whitney test was performed to evaluate the association between gender and cranial measurements. Pearson's chi-square test was also used to verify the association between gender and the position of the GPF in relation to the maxillary molars. The significance level was set at 5% ($p < 0.05$).

RESULTS

The sample consisted of 55 macerated skulls, of which 30 (54.5%) were female and 25 (45.5%) were male. The linear measurements referring to the topographic location of the right and left GPF are shown in table 1.

Table 1. Presentation of the GPF measurements in relation to intraoral reference points.

Parameter	N	M (SD)
Distance between right and left GPFs	55	31.25 (1.87)
Distance from the GPF to the MPS		
Right	55	15.56 (1.25)
Left	55	15.34 (1.07)
Distance from the GPF to the IF		
Right	55	39.38 (3.37)
Left	55	39.28 (3.16)
Distance from the GPF to the AR		
Right	55	9.93 (1.96)
Left	55	9.47 (1.37)
Distance from the GPF to the PNS		
Right	55	15.31 (1.49)
Left	55	15.30 (1.53)

M = mean; SD = standard deviation; GPF = greater palatine foramen; MPS = median palatine suture; IF = incisive foramen; AR = alveolar ridge; PNS = posterior nasal spine.

It was observed that the measurement between the right and left GPF, the distance from the right and left GPF to the MPS, and the distance from the GPF to the IF on the left side were only greater in female skulls (p < 0,05). In addition, it was possible to verify that the distances from the right and left GPF to the AR and to the PNS were greater in male skulls (Table 2).

Table 2. Association between the GPF location and gender.

Parameter		**Female** Me (Min - Max)	**Male** Me (Min - Max)	p-value
Between Right and Left GPF (mm)	-	31.75 (29.79 – 34.42)	30.44 (26.13 – 32.72)	0.001*
GPF to MPS (mm)	Right	15.82 (14.48 – 19.54)	14.70 (13.89 – 16.33)	0.001*
	Left	15.86 (13.04 – 17.44)	15.13 (13.08 – 16.00)	0.003*
GPF to IF (mm)	Right	38.85 (35.00 – 45.64)	38.48 (34.31 – 44.92)	0.057
	Left	40.70 (35.00 – 45.46)	38.48 (32.50 – 42.74)	0.033*
GPF to AR (mm)	Right	8.49 (5.40 – 11.58)	11.42 (8.28 – 13.34)	0.001*
	Left	9.46 (5.50 – 10.06)	10.62 (6.93 – 11.57)	0.001*
GPF to PNS (mm)	Right	15.00 (11.00 – 17.00)	16.00 (14.00 – 17.50)	0.002*
	Left	15.00 (11.50 – 17.00)	16.50 (13.00 – 17.50)	0.001*

Me = median; Min = minimum value; Max = maximum value; GPF = greater palatine foramen; MPS = median palatine suture; IF = incisive foramen; AR = alveolar ridge; PNS = posterior nasal spine.

Regarding the location of the GPF in relation to the maxillary molars, it was found that, in the majority of the sample, the foramen was situated between the mesial and the distal of the 3M (61.8% right GPF and 56.4% left GPF) (Table 3).

Table 3. Location of the greater palatine foramen in relation to the maxillary molars.

Location of the GPF	**Right** n (%)	**Left** n (%)
Distal of the 2M	3 (5.5)	4 (7.3)
Between the mesial and the distal of the 3M	34 (61.8)	31 (56.4)
Distal of the 3M	18 (32.7)	20 (36.4)
Total	55 (100.0)	55 (100.0)

No significant association was found between gender and the location of the GPF in relation to maxillary molars, which, for both sexes, was located between the mesial and the distal of the 3M (Table 4).

Table 4. Association between gender and the location of the greater palatine foramen in relation to maxillary molars.

Gender	**Distal of the 2M**		**Between the mesial and the distal of the 3M**		**Distal of the 3M**		**P-value**
	Right n (%)	**Left** n (%)	**Right** n (%)	**Left** n (%)	**Right** n (%)	**Left** n (%)	
Female	1 (3.3)	1 (3.3)	21 (70.0)	19 (63.3)	8 (26.7)	10 (33.3)	0.36
Male	2 (8.0)	3 (12.0)	13 (52.0)	12 (48.0)	10 (40.0)	10 (40.0)	0.34

DISCUSSION

The present study showed that the measurement between the right and left GPF, the distance from the right and left GPF to the MPS, and the distance from the GPF to the IF proved to be greater in the female skulls. Furthermore, it was found that the distances from the right and left GPF to the AR and to the PNS were greater in the male skulls.

It is well-known that the blockade of the GPN is commonly performed in clinical dental practice. Therefore, the knowledge of anatomical parameters enables the dentist to perform anesthetic techniques properly, collect connective tissue from the palate, perform the extraction of the maxillary molars, install mini-implants, as well as establish human identification. To aid in the execution of procedures performed on the palate, some studies have verified the location of the GPF based on anatomical reference structures in different population groups[2,6,9,11,13,18-22].

Ajmani's[18] study (1994) conducted with 65 Nigerian and 34 Indian skulls observed that the GPF was often located in the mesial of the 3M in the Nigerians and between the mesial and the distal of the 3M in the Indians. The studies by Piagkou et al. (2012)[19] and Cagimni et al. (2016)[9] found that, in most of the sample, the GPF was situated at the distal of the 3M. Other studies observed that the GPF was located between the mesial and the distal of the 3M[13,22,23]. One study conducted on dry skulls from the southeast of Brazil observed that most GPFs were located at the distal of the 3M[6]. However, in the present study, the GPF was found to be predominantly located between the mesial and the distal of the 3M, that is, a little further forward in relation to Chrcanovic and Custodio's[6] study. It is important to remember that Brazil has one of the largest miscegenated populations of the world, with great variability between people[2], justifying the differences found in their study.

However, in cases of the absence of the maxillary molars, other anatomical references should be performed, based on structures that undergo minimal variation over the years. In the present study, it was observed that the measurements from the GPF to the MPS, and the distance from the GPF to the IF were greater only in the female gender, and that the distances from the GPF to the AR and to the PNS were greater among males. Other studies in different populations have also observed this difference[6,9,11,23]. However, one study conducted on adult skulls from Greece found that the distances from the right and left GPF to the MPS were equidistant, with an average of 1.53cm[19] (±0,53), which is similar to Tavelli›s[22] results. Another study conducted on 150 dry skulls and 1,200 cone-beam computed tomography (CBCT) scans observed that the right GPF was at a distance of 34 mm (±3.0), while the left was at a distance of 34.3mm (±3,1) from the IF. The results of Cagimni's[9] study showed no difference between the distance from the right and left GPF to the IF, presenting approximately 40.6mm. A systematic review and meta-analysis study found that the average distance between the GPF and the IF was 35.8 mm (±3.4). Such differences can be explained by racial differences between the populations. However, some authors do not agree with this explanation and attribute this difference to the different methods of evaluating the position of the GPF[13]. Therefore, new studies are warranted in an attempt to establish a standard for these methods.

The anatomical differences observed in the analyzed skulls are important to guide dentists in their clinical decision-making, thus avoiding complications in the trans and postoperative periods, as well as in the identification of corpses for criminalistic purposes.

It is important to emphasize that the use of CBCT images is quite relevant for the identification of anatomical structures, nevertheless, this method has some limitations regarding the inclination of the plane to locate the GPF, which can cause small differences in the linear measurements. In this context, the macerated skulls allow for a greater visualization and identification of anatomical structures, thus providing reliable results.

This study has limitations regarding its sample size, however, this work did establish metrics in the oral cavity that will be of use during procedures performed on the hard palate, reducing surgery time and avoiding complications. However, due to ethnic variations, it is suggested that further studies should be conducted on larger samples, considering the facial features of each individual.

The importance of the GPF's location is undeniable. In this light, the present study established metric parameters in the oral cavity that will aid dentists during procedures performed on the hard palate, thereby diminishing surgery time and avoiding complications. However, due to ethnic variations, it is recommended that further studies should be conducted on larger samples, considering the facial features of each individual.

CONCLUSION

It can therefore be concluded that there are differences in the location of the GPF in female and male skulls. The results of this study provided intraoral reference points necessary to identify the position of the GPF, even in edentulous populations.

CONFLICTS OF INTEREST

"No conflict of interest to declare".

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AUTHORS' CONTRIBUTIONS

Jhonatan Thiago Lacerda-Santos: Conception, Methodology, Investigation, Formal Analysis, Writing - Review and Editing, and Supervision; **Gélica Lima Granja:** Formal Analysis, Data Curation, Investigation, Writing - Review and Editing; **Rosifrance Vidal de Oliveira Santos:** Methodology, Investigation, Writing - Original Draft Preparation; **Rosifrance Vidal de Oliveira Santos:** Methodology, Investigation, Writing - Original Draft Preparation; **Gabriel Mendes Valério:** Methodology, Investigation, Writing - Original Draft Preparation; **Silvestre Estrela da Silva Júnior:** Methodology, Investigation, Writing - Review and Editing; **Jalber Almeida dos Santos:** Conception, Methodology, Investigation, Writing - Review and Editing, and Supervision.

ORCID

Jhonatan Thiago Lacerda-Santos 0000-0003-0295-9939
Gélica Lima Granja 0000-0001-6655-4696
Rosifrance Vidal de Oliveira Santos 0009-0005-6205-7015
Djanilson Barbosa Marinho Júnior 0009-0004-4715-6755
Gabriel Mendes Valério 0009-0003-7688-9272
Silvestre Estrela da Silva Júnior 0000-0003-4999-1979
Jalber Almeida dos Santos 0000-0003-2948-0477

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