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Anatomical variation in the position of the greater palatine foramen

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Abstract: The present study measured the position of the greater palatine foramen relative to adjacent anatomical landmarks in Brazilian skulls. The perpendicular distance of the greater palatine foramen to the midline maxillary suture in Brazilian skulls was about 14 mm and the distance of greater palatine foramen to the incisive foramen was approximately 36 mm. The distance of greater palatine foramen to the posterior border of the hard palate was approximately 3 mm, and the mean angle between the midline maxillary suture and the line from the incisive foramen and the greater palatine foramen was 22.71°. In almost 70% of the cases, the greater palatine foramen opened in an anterior direction. The mean palatine length was approximately 52 mm. In the greater majority of the skulls (93.81%), the greater palatine foramina were opposite or distal to the maxillary third molar. These data will be helpful in comparing these skulls to those from various other regions as well as comparing skulls of different races. It can also provide professionals with anatomical references, in order to block the maxillary division of the trigeminal nerve through the greater palatine foramen. Our results would help clinicians locate the greater palatine foramen in patients with and without upper molars. (J Oral Sci 52, 109-113, 2010)

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Introduction

The hard palate is an essential region of the skull formed by the two palatal processes of the maxilla and two horizontal plates of the palatine bones which are linked by a crucial suture formed by the junction of the four described bones (1,2).

Blocking of the maxillary division of the trigeminal nerve or its branches for local anesthesia is a common practice in maxillofacial surgery. The maxillary nerve block is an effective method of achieving profound anesthesia of the hemimaxilla. It is useful in procedures involving quadrant dentistry or in extensive maxillary surgical procedures. One of two approaches is available to gain access to the terminal point for anesthetic delivery – the greater palatine canal through the greater palatine foramen (GPF) and the high tuberosity. The major difficulty encountered with use of the respective techniques is locating the canal for the GPF technique and the higher incidence of hematoma for the high tuberosity (3).

The ability to better predict and easily anesthetize the maxillary nerve and its branches with a single injection could make it possible to perform surgical procedures, such as maxillary sinus elevation for dental implants in the posterior maxilla, as routine procedures in the private clinic (4). Patients accept this approach better than a technique that requires several injections (5). A common problem encountered with the use of the maxillary nerve block is the inability to obtain profound anesthesia, which is frequently caused by the operator's inability to find the

GPF (6). That is why description of the location of GPF is important. With the required knowledge and respect for the associated anatomy, the technique of maxillary nerve block through the GPF should be considered with greater ease and more confidence, when indicated.

The first description of the location of GPF was reported by Matsuda (7). Most textbooks locate the foramen only in a general way, e.g., near the lateral palatal border (2), in the posterolateral border (8), medial to the last molar (9) or opposite the last molar (10). Textbooks on anesthesia are somewhat more specific in relating the position of GPF to the molar teeth. Accordingly, this is stated to be opposite the maxillary second molar (11), opposite the maxillary third molar, or anywhere between the maxillary second and third molars (12).

The present study was undertaken to define the position of the GPF relative to several anatomical landmarks in the maxilla in Brazilian skulls.

Materials and Methods

The present study was conducted on 80 dry human skulls obtained from the Department of Human Anatomy, Biological Sciences Institute, Federal University of Minas Gerais, Belo Horizonte, Brazil.

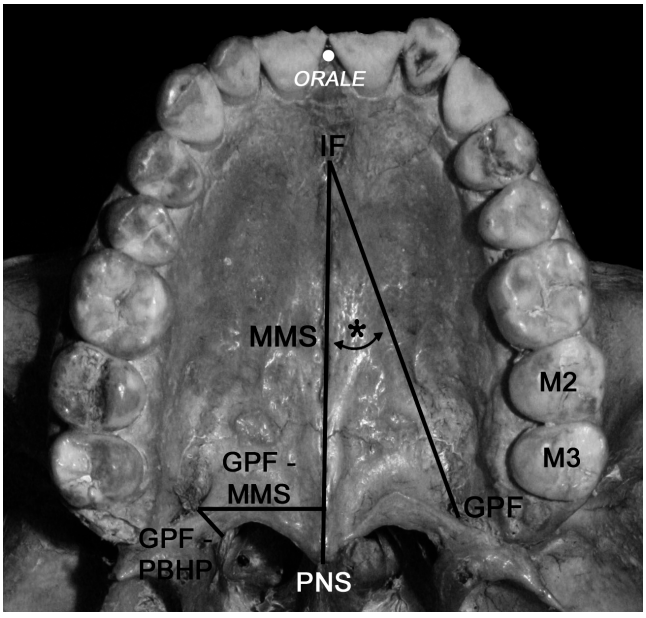

Fig. 1 Photograph of the hard palate. IF: incisive foramen; GPF: greater palatine foramen; PNS; posterior nasal spine; MMS: midline maxillary suture; *ORALE*: the point at the anterior end of the incisive suture located between the sockets of the two maxillary central incisors; M2: maxillary second molar; M3: maxillary third molar; GPF-MMS: perpendicular distance from the medial wall of the GPF to the MMS; GPF-PBHD: distance from the posterior wall of the GPF to the posterior border of the hard palate; *: angle between the MMS and the line from the IF and the GPF.

Unequivocal and well defined points were selected for evaluation. The following measurements and observations were made: (a) location of the foramen in relation to maxillary molar teeth, (b) perpendicular distance from the medial wall of the GPF to the midline maxillary suture (MMS), (c) distance from the posterior wall of the GPF to the posterior border of the hard palate (PBHP), (d) direction of opening of the foramen onto the palate, (e) distance from the anterior wall of the GPF to the posterior border of the incisive foramen, (f) the angle between the MMS and the line from the incisive foramen and the GPF, and (g) the palatine length.

In order to determine the direction of opening of the foramen onto the palate, a needle was inserted into the GPF. The direction was recorded as the direction of the greater palatine canal. The directions were recorded as: antero-medial, vertical, and anterior. The palatine length is the distance between the *orale* anteriorly (the *orale* is the point at the anterior end of the incisive suture located between the sockets of the two medial maxillary incisors) and the posterior nasal spine posteriorly. The location of the foramen with respect to the posterior border of the hard palate is the distance between the GPF and a line representing the lateral extension of the posterior border of the hard palate.

All measurements were done bilaterally and directly on the dry skulls, performed with a stainless steel metric digital caliper with 0.01-mm precision, and were carried out by the author, B.R.C. The angle was calculated on digital photographs using the VistaMetrix® software (SkillCrest, Version 1.36.0, 2009). Basic descriptive statistics were employed to analyze the data obtained using standard software (Excel®, Microsoft Corp.). The mean, standard deviation, minimum and maximum for each of the measurements were assessed. Differences between sides were analyzed using the Pearson's Chi-square test. Statistical differences were considered significant when the *P* value was less than 0.05.

The study was approved by the Research Ethics Committee of the Biological Sciences Institute, Federal University of Minas Gerais (ICB/UFMG).

Results

In the majority of the skulls (54.87%), the GPFs were opposite to the maxillary third molar, 38.94% of foramina were distal to the maxillary third molar, and 6.19% between the maxillary second and third molars. No foramina were found opposite the maxillary second molar. The mean

distance from the MMS to the GPF on the right side was 14.68 ± 1.56 mm (mean ± SD), and 14.44 ± 1.43 mm (mean ± SD) on the left side. The mean distance from the PBHP to the posterior wall of the GPF was 3.39 ± 1.11 mm (mean ± SD; minimum = 0.84 mm; maximum = 6.46 mm). These results are shown in Table 1 in comparison to other studies. As shown in Table 2, 69.38% of the GPF opened in an anterior direction. The mean palatine length was 52.40 ± 4.63 mm (mean ± SD; minimum = 47.88 mm ; maximum = 57.81mm).

Regarding the distance from the anterior wall of the GPF to the posterior border of the incisive foramen, the mean distance on the right side was 36.21 ± 3.16 mm (mean ± SD; minimum = 26.90 mm; maximum = 44.80 mm) and 36.52 ± 3.34 mm (mean ± SD; minimum = 27.67 mm; maximum = 46.19 mm) on the left side.

The mean angle between the MMS and the line from the incisive foramen and the GPF was 22.12° ± 2.71°on the right side (mean ± SD; minimum = 15.60° ; maximum = 31.00°) and 23.30° ± 2.53° (mean ± SD; minimum = 18.60° ; maximum = 34.10°) on the left side.

The statistical analysis indicated that there was no significant difference in the measurement between the right and left sides with regard to the distance of GPF to the midline, GPF to the incisive fosse, and GPF to the posterior border of hard palate ($P < 0.01$).

Discussion

The landmarks used in the present study for identification of the position of the GPF can be easily located in living subjects. Even when one molar tooth is absent, the GPF can be located accurately in relation to the molar teeth which are presented mesial or distal to it.

According to Slavkin et al. (13), the GPF is located 1-3 mm distal to the maxillary third molar in adult skulls. Westmoreland and Blanton (14) observed only 6% of foramina distal to the maxillary third molar. In the study by Ajmani (15), 48% of foramina in Nigerian and 64% in Indian skulls were located medial or opposite to the maxillary third molar. Saralaya and Nayak (16) observed this in 74.6% of the skulls. In Nigerian skulls, 13.1% of foramina were opposite the maxillary second molar (15), compared to only 0.4% encountered by Saralaya and Nayak (16). Westmoreland and Blanton (14) found 9.7% of foramina to be medial to the maxillary second molar. In a study on Kenyan skulls, 76% of cases showed the

Table 1 Comparison between studies on the relation of GPF to the maxillary molars, distance GPF-MMS and GPF-PBHP

Study	GPF-MMS (mm)		GPF-PBHP (mm)	Relation to maxillary molar (%)			
	Right	Left		2M	2M-3M	3M	3M distal
Westmoreland and Blanton, 1982 (14)	14.8	15.0	1.9	9.70	33.60	50.70	6.00
Langenegger et al., 1983 (19)				1.00	3.00	62.00	34.00
Hassanali and Mwaniki, 1984 (17)				10.40	13.60	76.00	0.00
Wang et al., 1988 (18)	16.0	16.0	4.11	17.00	48.50	33.50	0.00
Ajmani, 1994 (Nigerian skulls) (15)	*15.4		3.5	13.07	38.46	48.46	0.00
Ajmani, 1994 (Indian skulls) (15)	14.7	14.6	3.7	0.00	32.35	64.69	2.94
Jaffar and Hamadah, 2003 (22)	*15.7		4.86	12.00	19.00	55.00	14.00
Methathrathip et al., 2005 (20)	*16.2		2.1	7.00	14.10	71.90	7.00
Saralaya and Nayak, 2007 (16)	14.7	14.7	4.2	0.40	24.20	74.60	0.80
This study	14.68	14.44	3.39	0.00	6.19	54.87	38.94

* No distinction between right and left sides

Table 2 Comparison between studies on the direction of opening of the foramen onto the palate

Study	Nationality	Direction of opening of the foramen onto the palate (%)			
		Antero-medial	Anterior	Antero-lateral	Vertical
Westmoreland and Blanton, 1982 (14)	Indian		18.0		82.0
Hassanali and Mwaniki, 1984 (17)	Kenyan	76.0			24.0
Wang et al., 1988 (18)	Chinese		90.5		9.5
Ajmani, 1994 (15)	Nigerian	58.5		38.5	3.0
Ajmani, 1994 (15)	Indian	91.1	NA	NA	NA
Jaffar and Hamadah, 2003 (22)	Iraqi	60.0	36.0		4.0
Saralaya and Nayak, 2007 (16)	Indian	46.2	41.3	12.5	
This study	Brazilian	18.75	69.38	0.00	11.87

NA: Not available

location of GPF opposite the maxillary third molar (17). In Chinese skulls, the GPF was commonly located between the maxillary second and third molars (18). The most common position in relation to the maxillary third molar was also reported in East Indian, Negroid, Kenyan, Nigerian and Indian skulls (14,15,17,19). The present study indicated that the location of the GPF was variable, as reported by these former papers. In the majority of the skulls (54.87%), the GPFs were opposite to the maxillary third molar, 38.94% of foramina were distal to the maxillary third molar, and 6.19% between the maxillary second and third molars.

The distance from the MMS and PBHP to the GPF also showed a variation in the literature. According to Westmoreland and Blanton (14), the distance GPF-MMS on the right had a mean of 14.8 mm and 15.0 mm on the left. Ajmani (15) reported a distance of 15.4 mm from the sagittal plane in Nigerian skulls and 14.7 mm on the right and 14.6 mm on the left in Indian skulls. Saralaya and Nayak (16) found 14.7 mm on both sides; Wang et al. (18) reported a value of 16 mm. Methathrathip et al. (20) found 16.2 ± 1.3 mm lateral to the median sagittal plane in Thai skulls. The mean distance in the present study was the smallest when compared to these studies (Table 1). The distance from the PBHP to the foramen was 3.5 and 3.7 mm in Nigerian and Indian skulls, respectively (15). Westmoreland and Blanton (14) found a mean distance of 1.9 mm from the PBHP, Wang et al. (18) 4.11 mm, Saralaya and Nayak (16) 4.2 mm, and Methathrathip et al. (20) 2.1 ± 1.3 mm. Variability in location of the foramen may be due to sutural growth occurring between the maxilla and the palatine bone. The anteroposterior dimension of the palate increases with the eruption of the posterior teeth (13).

In order to probe the GPF to deliver injections, the direction of the greater palatine canal should be kept in mind. Ajmani (15) found that the opening of the foramen was directed inferiorly in an anteromedial direction in 38 (58.7%) Nigerian and in 31 (91.4%) Indian skulls. In a relatively large number of Nigerian skulls (38.7%), the opening of the foramen was directed anterolaterally, pointing towards the maxillary molars. Saralaya and Nayak (16) found it was forward and medially directed in 46.2% and forward in 41.3%. Westmoreland and Blanton (14) reported that the opening of the foramen was directed inferiorly (vertically) from the hard palate in 82% skulls. The comparison between these different studies and the present one concerning the direction of opening of the GPF onto the palate is found in Table 2. This variation may explain the occasional difficulty encountered while attempting to insert the point of needle into the GPF and pterygopalatine canal. Moreover, the frequency of anatomical obstruction of the needle increases with age (13).

Two measurements made here were compared to the findings of Saralaya and Nayak (16). The distance from the GPF to the incisive fosse was 37.3 mm on the left side and 37.2 mm on the right side in the study of Saralaya and Nayak (16), which was very similar to those of the present study. The mean angle between the MMS and the line from the incisive foramen and the GPF was almost equal on both sides (right = 22.12° ; left = 23.30°). Saralaya and Nayak (16) also found a small difference between the sides (right = 21.1° ; left = 21.2°). Knowledge of the mean value of this angle would help professionals determine the angle to be made by the needle for anesthetic infiltration into the GPF, considering easy determination of the MMS.

As different results were found in studies from different regions of the world (Kenya, United States, India, Iraq, Nigeria, China, Brazil), this may indicate that anthropologically the position of the greater palatine foramen differs between ethnic groups. However, it is also interesting to note that three studies from different regions of the same country (14-16), India, reported values that differed among themselves in the mean distance GPF-PBHP and for the variation in the direction of opening of the foramen on the palate, although the mean value did not vary for the distance GPF-MMS (Tables 1 and 2). This indicates that a large anatomical variation may also exist in the same population.

These data will be helpful in comparing the skulls with those from various other regions as well as comparing skulls of different races. It can also provide professionals with anatomical references, in order to block the maxillary division of the trigeminal nerve through the GPF. Not only does the needle traverse the shortest route than any technique to block the maxillary nerve, but it avoids the risk of a hematoma resulting from vein puncture of the pterygoid plexus as well as the possibility of injection into the pad of fat (21).

As it is important to locate the exact position of the GPF for many surgical procedures in the maxilla, it is clear that the observations made in the present study will be useful to clinicians. In living subjects, the molar teeth, the palatal midline, and the posterior border of hard palate are all easily identifiable. If the third molar is absent, its location can be estimated accurately using the relation to the remaining molars, or in an edentulous case, from the other landmarks including the palatal midline and the posterior border of the hard palate. It is evident, therefore, that using a combination of the above measurements, the location of the GPF can be plotted with accuracy.

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