IF : 4.547 | IC Value 80.26

VOLUME-6, ISSUE-12, DECEMBER-2017 • ISSN No 2277 - 8160

Original Research Paper

Anatomy

TOPOGRAPHY OF THE GREATER PALATINE FORAMEN IN NORTH INDIAN POPULATION: KEY TO SUCCESSFUL MAXILLARY NERVE BLOCK.

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ABSTRACT Knowledge of anatomy of the Greater Palatine Foramen (GPF) is important as regards maxillary nerve block for various dental and craniomaxillofacial surgeries. This study analyzed the topography of the GPF with respect to well established bony landmarks. 110 dry skulls of North Indian origin were studied using direct measurements and computerized image analysis and statistical analysis. The values were compared with other studies on skulls of different ethnical origins.

The GPF was situated opposite the 3rd maxillary molar in 70.83% cases. The direction of opening on to hard palate was mostly anteromedial. The mean distances of the GPF from the mid sagittal plane (MSP), incisive foramen (IF) and the posterior border of hard palate were 14.17mm, 34.26 mm and 4.3 mm, respectively. The mean angle between the MSP and the line joining GPF and IF was 22.45°.

This study would serve as a guide to the clinicians in localizing the GPF with greater accuracy and improve the success rate of maxillary nerve blocks.

KEYWORDS : Greater palatine foramen, skull, hard palate, maxillary nerve block.

INTRODUCTION:

The greater palatine foramen lies near the lateral palatal border behind the transverse palatine suture with the greater palatine nerve and vessels traversing through it. The principal nerve that supplies the palate is the greater palatine nerve, which descends through the greater palatine canal (GPC), emerges on the hard palate at the greater palatine foramen (GPF) and runs forward in a groove almost up to the incisor teeth where it communicates with the terminal filaments of the nasopalatine nerve. This nerve, is a branch of the maxillary nerve and it enters the palate at the incisive foramen and supplies the anterior part of the hard palate. The middle and posterior (lesser) palatine nerves diverge from the GPC and emerge through the lesser palatine foramina (LPF) to supply the uvula, tonsil and soft palate. [1]

In order to achieve anaesthesia of the maxillary teeth, maxillary gingiva and palatal tissue, the maxillary division of the trigeminal nerve is blocked. This nerve can be approached by two different intraoral routes: the greater palatine canal route and the high tuberosity approach. In the GPC route, a needle is inserted through the GPC and the anaesthetic agent is released when the needle reaches the inferior part of the pterygopalatine fossa. This approach involves minimal risk, the needle traverses the shortest possible pathway and the success rate is high. [2] In the high tuberosity approach, a needle is inserted in a superomedial and posterior direction in the buccal sulcus along the infratemporal surface of the maxilla to reach the PPF. This involves a comparatively higher risk of haematoma as the pterygoid venous plexus is located in its vicinity. Also, sometimes, there is lack of profound anaesthesia in case of the high tuberosity approach. [3]

The key to successfully block the maxillary and the greater palatine nerves, is accurate localization of the GPF. However, a review of the available literature shows variations in the location of GPF. In 1927, the first description of the location of GPF was given by Matsuda Y. [4] Most textbooks locate the foramen only in a general way, e.g., near the lateral palatal border, in the posterolateral border, medial to the last molar or opposite the last molar. [5, 6] Some of the standard textbooks of anaesthesia describe the location of GPF more specifically as opposite the maxillary second molar, opposite the maxillary third molar, or between the maxillary second and third molars. [7,8] Hence, the aim of this study is to define the position of the GPF in relation to certain clinically identifiable fixed anatomical reference points. The observations made in the present study were then compared with the already existing studies of the skulls of other regions and of different races.

MATERIAL AND METHOD:

This observational study was conducted on 110 dry human skulls of Indian origin. We included only those skulls in the study which were devoid of any obvious pathology. We chose to evaluate well defined points that can enable the clinician to approach the greater palatine foramen with utmost accuracy.

Direct Observation:

The following measurements were taken (Fig. 1):

1. Location of the GPF in relation to the maxillary molar teeth.
2. Patency of GPC. To check the patency of the GPC, we observed the ease of passage of a 26 gauge needle into the foramen.
3. Direction of opening of the greater palatine canal into the oral cavity. It was observed by inserting a 26 gauge needle into the greater palatine canal. The directions were recorded as anteromedial, anterolateral, anterior or vertical.
4. The palatine length. It was measured as the distance between a point on the anterior end of incisive suture and the posterior nasal spine.
5. Distance of medial wall of GPF from median sagittal plane (MSP).
6. Distance between the anterior wall of GPF and the posterior wall of incisive foramen (IF).
7. Distance of posterior wall of GPF from the point of maximum concavity on the posterior border of hard palate (PH).
8. Presence of any bony prominences in the GPC.
9. Number of lesser palatine foramina (LPF).

All the skulls were numbered for identification. The measurements were taken bilaterally (except the palatine length) using a Digital Vernier callipers with a range of 0 to 150 mm with a least count of 0.02 mm. Each measurement was taken by two different observers and in case of any discrepancy, the mean was calculated. To avoid any observer bias, the second observer was kept oblivious of the value obtained by the first observer. All linear measurements were taken in millimetres (mm).

Computerized Image Analysis:

We took digital photographs of the norma basalis for each skull. These images were analysed using "Image J" software compatible with Windows 7 in order to calculate the angle between the Mid

Sagittal Plane (MSP) and the line joining incisive foramen (IF) to GPF angle on both the right and left sides.

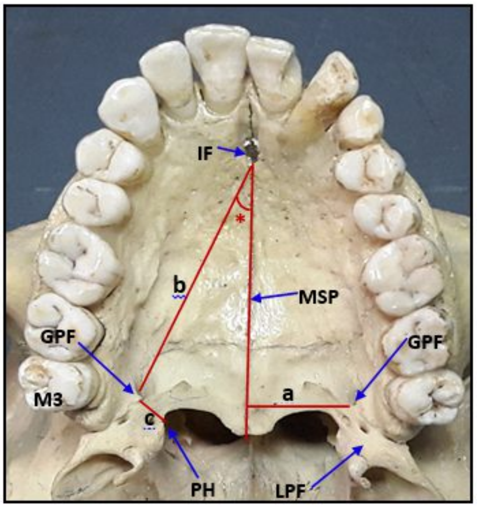

Fig 1: Photograph of the ventral surface of the hard palate. IF = Incisive Foramen, GPF = Greater Palatine Foramen, LPF = Lesser Palatine Foramen, M3 = Third Maxillary Molar, PH = Posterior Border of Hard Palate. 'a' = Distance of medial wall of GPF from median sagittal plane (MSP), 'b'= Distance between the anterior wall of GPF and the posterior wall of incisive foramen., 'c'= Distance of posterior wall of GPF from the point of maximum concavity on the posterior border of hard palate (PH), '*'= Angle between the Mid Sagittal Plane (MSP) and the line joining incisive foramen to GPF.

STATISTICS

For all the values measured, the mean and the standard deviation were calculated using Microsoft excel 2013 software. A comparison of the right and left values was done with the student's unpaired t test using Graphpad software. The two tailed p value was calculated to see if the values obtained from the right and left sides were significantly different.

OBSERVATIONS

It was noted that, out of the 220 foramina studied in the 110 skulls, the greater palatine foramen was located opposite the third maxillary molar in 70.83% of the cases, at the junction of 2nd and 3rd molar in 27.5% of the cases, and, opposite the 2nd molar in 1.67 % cases (Table 1).

Table 1: Variations in the location of GPF with respect to maxillary molars.

	Opposite 2nd molar. n (%)	Junction of 2nd & 3rd molar. n (%)	Opposite 3rd molar. n (%)
Right (n=60)	0 (0)	16 (26.67)	44(73.33)
Left (n=60)	2 (3.3)	17 (28.33)	41(68.33)
Total (n=120)	2 (1.67)	33 (27.5)	85(70.83)

(n = Number of cases)

The GPC was patent in all the skulls. The direction of opening of the GPC into the oral cavity was anteromedial in 54.17% of the cases and anterior in 45.83% cases and none of the cases showed vertical or anterolateral direction. The mean palatine length was 39.96 ± 5.58mm (Mean ± Standard deviation, S.D.). The mean distance of medial wall of GPF from Mid Sagittal Plane (MSP) was 14.27 ± 1.27 mm (Mean ± S.D.) on the right side and 14.08 ± 1.19 mm on the left side. The mean distance between the anterior wall of GPF and the posterior wall of incisive foramen was 34.28 ± 3.72mm (Mean ± S.D.) on the right side and 34.24 ± 4.02mm (Mean ± S.D.) on the left side. The mean distance of posterior wall of GPF from posterior border of hard palate was 4.22 ± 1.18mm (Mean ± S.D.) on the right side and 4.38 ± 1.22mm (Mean ± S.D.) on the left side. The mean angle between the MSP and the line joining incisive foramen to GPF 22.34 ± 1.97° (Mean ± S.D.) on the right side and, 22.57 ± 2.41° (Mean ± S.D.) on the left side (Table 2). Two of the skulls had the presence of a bony spur within the GPC, both on the left side (Fig. 2).

Fig. 2: Photograph showing the ventral surface of hard palate. A bony spur is seen (arrow) in the greater palatine canal on the left side.

Table 2: Distance of the greater palatine foramen from various prominent bony landmarks.

	RIGHT		LEFT		TOTAL		
	Mean	SD	Mean	SD	Mean	SD	p value
GPF to midsagittal plane (mm)	14.27	1.27	14.08	1.19	14.17	1.86	0.5641
GPF to incisive fossa (mm)	34.28	3.72	34.24	4.02	34.26	3.87	0.9637
GPF to posterior border of hard palate (mm)	4.22	1.18	4.38	1.22	4.34	1.20	0.5580
Angle between GPF & midline (0)	22.34	1.97	22.57	2.41	22.45	2.20	0.6466

(SD = Standard Deviation, °- Degree, mm- Millimetre)

As far as the lesser palatine foramina are concerned, it was present on the right side in all the skulls, but it was absent on the left side in two skulls (Fig. 3a). The number of LPF was quite variable. 39% of the cases had one LPF, 41.5% cases had two LPF, 14.62% had three LPF while 4.88% cases had four LPF. Also, we found that there is no symmetry in the number of LPF on the two sides (Fig. 3b).

Fig. 3: Photograph showing the ventral surface of hard palate. (3a) Showing two lesser palatine foramina (LPF) on the right side (white arrows) and absence of LPF on the left side. (3b) Showing bilateral asymmetry in the number of LPF (three on the right side and four on the left side, black arrows)

On applying the Student's unpaired t test, it was found that there was no statistically significant difference between the values of the right and left side for the distance between medial wall of GPF and mid sagittal plane (two tailed p value = 0.5641), distance between the anterior wall of GPF from the posterior wall of incisive foramen (two tailed p value = 0.9637), distance of posterior wall of GPF from posterior border of hard palate (two tailed p value = 0.5580) and the angle between the Mid Sagittal Plane (MSP) and the line joining incisive foramen to GPF (two tailed p value = 0.6466).

DISCUSSION

During various dental procedures and oral surgeries such as cleft palate repair, the greater palatine nerve has to be blocked. The GPC approach is also used to give local injection into the greater palatine canal to regulate posterior bleeding in septorhinoplasty and sinus surgeries. [9, 10] A double blind prospective randomised trial was conducted by Kamath et al to compare pethidine and bilateral GPN block (using bupivacaine) in children undergoing cleft palate repair. They found that GPN block had several advantages such as superior recovery, better pain scores and good post-operative analgesia. It is also easier to perform with a good success rate. [11] The greater palatine canal is accessed through the GPF in order to reach the PPF and block the maxillary nerve. This is required in cases of repair of maxillary trauma, elevation of the maxillary sinus for dental implants and in treatment of chronic maxillofacial pain syndromes. Hence, accurate localization of the greater palatine foramen is of immense importance to dentists, oral maxillofacial surgeons and otorhinolaryngologists. Any error in doing so leads to adverse effects. For example, a surgeon may go beyond the posterior margin of the hard palate, thereby, depositing the anaesthetic in the nasopharynx. [12] Improper penetration into the GPC may lead to lack of profound anaesthesia.

In this study, the GPF was located opposite to the third maxillary molar in majority of the skulls (70.83%) on both the sides, and rarely opposite the second molar (3.3%). This is corroborated by other authors who studied Indian skulls, namely, Ajmani ML (1994) (64.7% opposite 3rd molar), Saralaya and Nayak (2007) (74.6% opposite 3rd maxillary molar) and Jotania et al (2013) (78.3% opposite 3rd maxillary molar). [13, 14, 15] Thus, we conclude that the maxillary molars especially the third molar serve as an important guiding landmark for the GPF in Indian population. However, this cannot be generalised to other races. A study on Chinese skulls reported that the GPF was located opposite the second maxillary molar in as high as 17% cases. [16] In the Caucasian European population, GPF was found opposite 2nd molar in 9% cases, in the Greek population, this location was found in 16.8% cases and in Polish population this value has been reported to be 16.3% (Table 3). [17, 18, 19] Such variations could be attributed to different degrees of sutural growth at the palatomaxillary suture and appositional growth at the posterior border of maxilla in the different races. Also, there are changes in position of the GPF with age. As the eruption of molar teeth occurs, the position of the GPF moves posteriorly. [20]

The direction of opening of the GPC is of clinical significance when one has to approach the foramen rotundum to block the maxillary nerve. An anteromedial direction of opening of the GPC into the oral cavity was clearly more common (54.17%) in our study. However, Saralaya and Nayak reported that there was not much difference in the number of cases with anteromedial (46.2%) and anterior (41.3%) direction in the Indian population. [14] The difference could be attributed to the fact that our study included skulls from Northern Indian subcontinent whereas, Saralaya and Nayak did the study on skulls from Southern India. It implies that regional variations are present even within the Indian population. Most of the studies on different races report that the direction of opening of GPC onto the hard palate as anteromedial (Table 3).

Table 3: Comparison of data available in literature regarding the relation of GPF from maxillary molars and the direction of opening of GPF onto the hard palate

STUDY (Year)	STUDY POPULATION	Relation to maxillary molar (%)				Direction of opening of GPF onto the palate			
		2nd molar	2nd-3rd molar junction	3rd molar	Distal to 3rd molar	A	AM	AL	V
Our Study (2015)	Indian	1.67	27.5	70.83	-----	45.83	54.17	0	0
Tomaszewska IM et al (2014)	Polish	16.3	6.8	74.7	2.2	7.4	82.6	3.8	5.2
Jotania (2013)	Indian	4.2	11.75	78.3	----				
Sharma and Garud (2013)	Indian	8.63	-----	73.38	17.99	2.02	49.49	3.54	44.95
Nimigean et al (2013)	Caucasian European	9	15	73	3	13	82		5
Piagkou et al(2011)	Greek	16.8	-----	76.2	7.45	NA	NA	NA	NA
Saralaya and Nayak (2007)	Indian	0.4	24.2	74.6	0.8	41.3	46.2	12.5	NA
Methathrathip et al (2005)	Thai	5.6	23.1	64.4	6.9	97.6	----	----	2.4
Ajmani (1994)	Indian	----	32.35	64.69	2.94	NA	91.4	NA	NA
Ajmani (1994)	Nigerian	----	38.46	48.46	----	NA	58.7	38.7	NA
Wang et al (1988)	Chinese	17	48.5	33.5	0	91	----	----	9

(A- anterior, AM-anteromedial, AL-anterolateral, V-vertical, NA- Not available, %- Percent)

The mid sagittal plane is easily identifiable in patients owing to the presence of an overlying pale strip of mucosa. Hence, the distance of GPF from MSP becomes an easy landmark to locate the GPF. The mean distance of the GPF from the midsagittal plane (MSP) in our study (14.17 mm) was comparable to that found in other studies on Indian skulls and European population. [13, 14, 17, 18] However, the other populations show different values. This distance was reported to be 15.3 mm in the Greek population, 16.2 ± 1.3 mm in Thai population, 16.2 ± 1.3 mm in Koreans. [18, 22, 23] Hence, distance of GPF from midsagittal plane shows variations in different races, but, we can safely assume that in the Indian population, GPF is usually located at a distance of 14-15 mm from the midsagittal plane (Table 4).

Table 4: Comparison of data available in literature regarding the distance of GPF from MSP, PH, IF and the angle between the MSP and the line joining incisive foramen to GPF.

STUDY (YEAR)	STUDY POPULATION	Distance from MSP (mm)	Distance from PBHP (mm)	Distance from IF (mm)	Angle (°)
Our study (2015)	Indian	14.17	4.30	34.26	22.45
Tomaszewska IM et al (2014)	Polish	15.9	4.8	34.2	26.2
Sharma NA and Garud RS (2013)	Indian	14.71	3.42	35.42	20.65
Nimigean et al (2013)	Caucasian European	14.5	4.4	NA	NA
Piagkou M et al(2011)	Greek	15.3	4.65	NA	NA
Saralaya V and Nayak SR (2007)	Indian	14.7	4.2	37.3	21.1

Methathrathip D et al (2005)	Thai	16.2	2.1	NA	NA
Ajmani ML (1994)	Nigerian	15.4	3.5	NA	NA
Ajmani ML (1994)	Indian	14.7	3.7	NA	NA
Wang et al (1988)	Chinese	16	4.11	NA	NA

(MSP- Mid sagittal plane, PH- posterior border of hard palate, IF- Incisive fossa, °- Degree, mm- Millimetre)

The mean distance of the GPF from PBHP is also quite variable in different races, ranging from 4.65 mm in the Greek skulls to 2.1 mm in the Thai skulls (Table 4). There are very few authors that have studied the angle between the Mid Sagittal Plane (MSP) and the line joining IF to GPF. The value of this angle is quite consistent in the Indian studies (ranging from 20.65° - 22.45°). [14,21] However, the Polish population shows remarkable difference (26.2°) from the Indian skulls (Table 4). [19]

The presence of a bony spur projecting inside the GPC can lead to compression of the neurovascular bundle. There are very few studies on Indian skulls that have studied the occurrence of such bony projections. One of such studies states the incidence to be as high as 35.3% in the Indian population which is in stark contrast to our study. [13]

It is best to block the maxillary nerve close to foramen rotundum. In order to do so, the depth to which the needle has to be inserted is of critical importance. Canter et al found that the average height of the orbit correlated well with the length of GPC in Caucasian and Negroid skulls. [24] However, Methathrathip et al have reported that, in the Thai population, when the maxillary nerve is to be blocked close to foramen rotundum, the needle is should be inserted to a depth calculated by adding the length of the GPC and the average palatal mucosal thickness. [22] These population diversities are important and error can lead to passage of the needle into the orbit causing diplopia of the ipsilateral eye. [25]

The number of LPF is inconstant. It varies from one to four as reported by Saralaya and Nayak. They have reported an average of 1.8 LPF on the left side and 1.9 on the right side. They also found that two skulls did not have any LPF on the right side. [14] Hassanali and Mwaniki have observed as many as five LPF on the left side in 0.84% of the 125 Kenyan skulls that they studied. They stated that placing the needle behind the GPF may lead to blockage of one lesser palatine nerve thereby causing anaesthesia in the soft palate and gagging sensation. [26] Thus, the anatomy of the GPF shows considerable variations among the different ethnic groups. Such variations must always be kept in mind during the various surgical procedures. The greater palatine nerve, greater palatine vessels and the pterygopalatine ganglion, all are accessed via the GPF and the canal. Hence, a detailed knowledge of the anatomy of the GPF is of immense importance.

To summarise, we can say that the maxillary molars, posterior palatal border and the midline sagittal suture are significant landmarks that help to localise the GPF. However, the ethnical variations must be kept in mind as they may lead to difficulty in local and regional anaesthesia. Our findings and the comparisons with other populations may contribute to a better success rate in dental procedures and oral maxillofacial surgeries.

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