

Morphometric Anatomical Variations of Greater Palatine Canal and its Clinical Implications: A Dry Human Skull StudyAravinth Mahesh M.S¹, Fasila. P Assis², Jesin Elsa Jose³, Rajesh S^{4*}¹Professor, Department of Anatomy, Noorul Islam college of Dental Sciences, Thiruvananthapuram, Kerala²Associate Professor, Department of Anatomy, Sree Gokulam Medical College, Vanjaramoodu, Trivandrum, Kerala³Professor, Department of Anatomy, Karakonnamm Medical College, Karakonnamm, Kerala⁴Professor, Department of Anatomy, Dhanalakshmi Srinivasan Medical College Perambalur- 621212 Tamilnadu

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Conflict of interest: Nil

Abstract:**Context:** Understanding the anatomical variations of the greater palatine foramen (GPF) is crucial for effectively administering regional anesthesia to areas innervated by the maxillary nerve during maxillofacial surgeries.**Objective:** To analyze the morphological characteristics of the GPF concerning nearby anatomical landmarks in the south Indian population.**Materials and Methods:** Thirty adult human skulls were examined to assess various GPF parameters on both sides of the hard palate, including location, angulation, and length of the greater palatine canal (GPC) for guiding a needle through the GPC to reach the pterygopalatine fossa (PPF).**Findings:** The average distance of the GPF from the mid-sagittal plane was 15.05mm on the left and 15.20mm on the right. Distances from the incisive fossa were 39.57mm on the left and 39.72mm on the right, while those from the distolateral margins of the hard palate's greatest concavity were 4.47mm on the left and 4.77mm on the right. Distances from the tip of the hamular process were 14.12mm on the left and 14.30mm on the right. The angulation of the GPC with the hard palate was measured at 55.54° on the left and with the midline at 14.79° on the left and 16.83° on the right. The mean length of the GPC and PPF was 28.9mm on the left and 29.19mm on the right. Needle insertion showed a 3.34% chance of penetrating the orbit and a 1.67% chance of reaching the cranial cavity. Comparatively, these measurements aligned closely with those of North and West Indian populations, exceeded those of Caucasians, were similar to Negroids, but were less than Mongoloids.**Conclusions:** Our investigation emphasizes the significance of using anatomical parameters to accurately locate the GPF for successful maxillary nerve block while minimizing potential complications.**Keywords:** Greater Palatine Foramen, Pterygopalatine Fossa, Maxillary Nerve Block, Morphometric Analysis.This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>) and the Budapest Open Access Initiative (<http://www.budapestopenaccessinitiative.org/read>), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.**Introduction**

The skill of a surgeon should include the ability to obtain successful local anaesthesia. This can be achieved by precisely locating the position of the anatomical structures for effectively performing regional anaesthesia [1]. Local infiltration of anaesthetic agents are uncomfortable to the patient due to reasons like multiple punctures, distortion of the tissue and margins of the landmark being obscured due to the swelling caused by the anaesthetic agent. When compared to local and general anaesthesia, regional anaesthesia has far more benefits during and after surgery [1,2]. Maxillary nerve block is said to be complicated in terms of its anatomical approach but equally it has a vast coverage while performing maxillo-facial

surgeries [2,3]. If operating dental surgeon has improper anatomical knowledge on position, angulation and length of greater palatine canal, there are high chances that he/she might injure nearby structures which will lead to dreadful complications [2,4]. Surgical and restorative manipulation within the maxilla can be achieved by accurate maxillary nerve block through greater palatine foramen, by which we can minimise physical and psychological trauma to the patients during and following the surgery[3]. Maxillary nerve block is performed during surgeries involving upper jaw and its related structures, surgeries like maxillary dental extraction, Caldwell-luc surgery, antrostomy, maxillary

fracture repair, and procedures involving soft and hard palate. Maxillary nerve neuralgia can also be treated by the same procedure [2,3]. Maxillary nerve block is achieved by reaching pterygopalatine fossa through greater palatine canal, thus by injecting local anaesthesia to maxillary nerve at pterygopalatine fossa as it exits out of foramen rotundum (Fig 1). 3,4 Even though

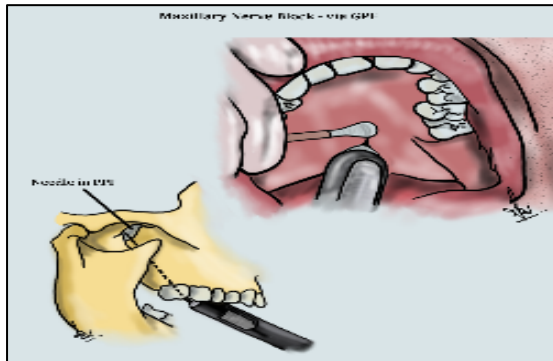


Figure 1: Maxillary nerve block

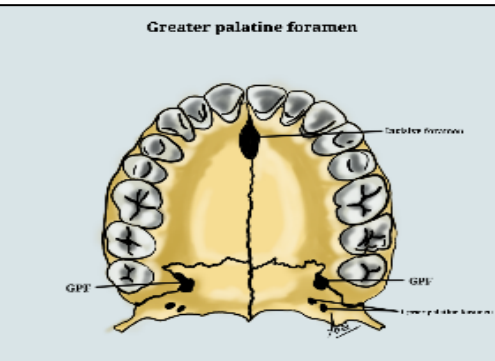


Figure 2: Greater Palatine foramen

Methodology:

Total of 30 adult, unsexed Indian dry skull bones from the state of Tamil Nadu in southern India were used for this study. All the skulls obtained for the study were well documented for race and all belonged to the natives of south India. All skulls included in the study were without any obvious pathological lesion or damages to the area concerned with the study. All skulls were of adults as evidenced by eruption of 3rd molar tooth and also by seeing fused basiocciput and basisphenoid.

Measurements were made using a vernier calliper with a range of 0–300 mm and a fine adjustment carriage with a least count of 0.02 mm.

Each measurement was taken twice by the same observer in order to reduce the errors in the observed values. For the purpose of identification, the skulls were numbered and the two sets of readings (right and left) were taken. To eliminate observer bias, the first set of values was not referred to while recording the second set of measurements.

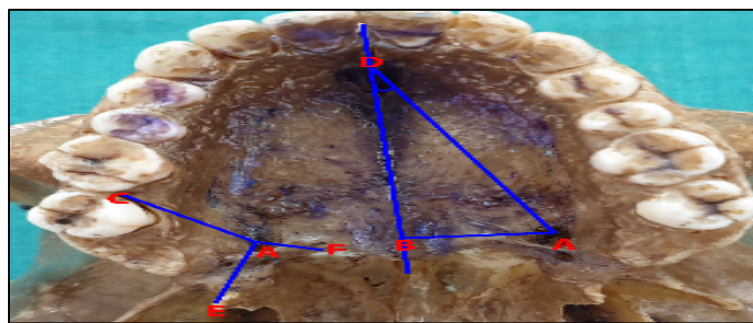


Figure 3: Methodology

Methods

1. Distance of greater palatine foramen (GPF):

a. Distance of GPF from mid sagittal plane (MSP): the measurement was taken with the help of a divider and vernier calliper. The perpendicular distance between the midpoint of the GPF and mid sagittal plane of palate was recorded. (fig-4a)

b. Distance of GPF from alveolar crest (AC): the measurement was taken with the help of a divider and vernier calliper. The perpendicular distance

between the midpoint of the GPF and alveolar crest of palate was recorded (fig-4b)

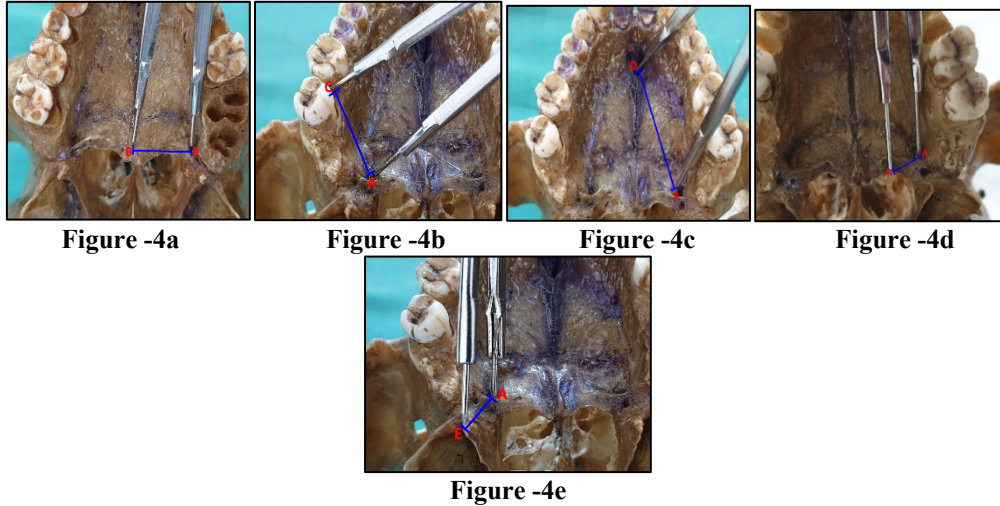
c. Distance of GPF from incisive fossa (IF): the measurement was taken with the help of a divider and measuring scale.

The distance between the midpoint of the GPF and the mid point of incisive fossa of the palate was recorded (fig-4c)

d. Distance of GPF from greatest concavity of distolateral margin of hard palate (DLM): The measurement was recorded using divider and

vernier caliper. The distance between the midpoint of GPF and the point of greatest concavity of the distolateral margin of hard palate was recorded (fig 4d) e. Distance of GPF from the tip of hamular process of pterygoid. The measurement was taken with the help of divider and vernier calliper.

Distance of midpoint of GPF from the tip of hamular process of pterygoid of the same side was recorded. Specimen with broken or visibly resorbed hamular process was not included in this study (fig-4e)

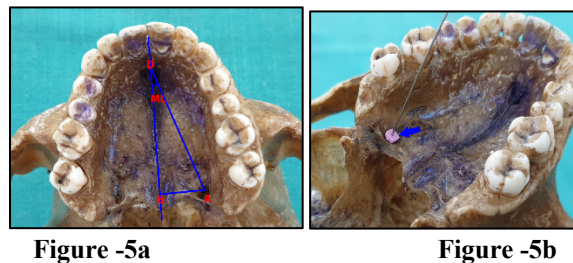


2. Angulation of GPC:

a. Angulation of GPC with midline: This was recorded with the help of protractor. The angle between the line joining midpoint of GPF with the midpoint of incisive foramen and the mid sagittal line passing through the incisive foramen was recorded (fig-5a) b. Angulation of GPC with hard

palate: A 25 gauge probe was inserted in the GPC and the angle made by the probe with the hard palate was measured using a protractor.(fig-5b) c. Angulation of GPC with vertical plane:

This was recorded with the help of protractor. The angle between the probe within the GPC and the vertical plane was recorded.

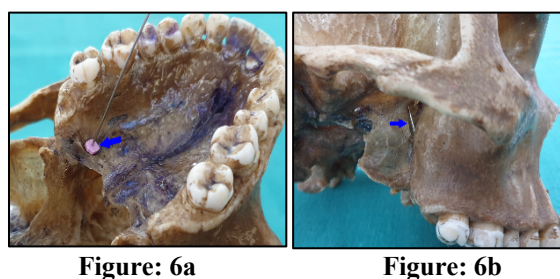


3. Length of GPC and PPF:

This was recorded with the help of 25 gauge orthodontic wire with rubber stopper and a measuring scale. The probe was inserted in to the GPC as far as possible till it reaches the inferior end of foramen rotundum, as it opens into

pterygopalatine fossa. Care was taken that the rubber stopper just touches the hard palate.

Then the probe was removed and the distance between the tip of the probe and the rubber stopper was measured using the measuring scale (fig-6a, 6b)



Results:

The present study revealed the following observations: Patency of left GPF was 93.3% and right GPF was 96.7%. Overall patency rate was 95%. Of the 60 cases, 2 left foramina and 1 right foramen was non-patent

Position of GPF with respect to the bony landmarks:

a. Distance of GPF from the mid sagittal plane: It ranged from 13 to 19 mm with a mean ± SD of 15.13 ± 1.55 mm. The values ranged between 1 and 19 on the left and 12 to 19 on the right side. The mean was 15.05 mm on left and 15.20 mm on right side with a standard deviation of 1.673 mm on left and 1.430 mm on right side

b. Distance of GPF from alveolar crest:

This ranged between 7 and 20 mm with mean SD of 12.976 ± 30.06 mm. The values ranged from 7 to 19 mm on left and from 7 to 20 mm on right. Mean

was 12.97 mm on both sides with a standard deviation of 2.951 on left and 3.178 on right

c. Distance of GPF from incisive fossa: This value ranged between 36 and 43mm on left and 36 and 44mm on right. Mean was 39.57 on left and 39.72 on right with a standard deviation of 2.136 and 2.384 respectively. Overall mean ± SD was 39.65 ± 2.26 mm

d. Distance of GPF from greatest concavity of disto lateral margin of hard palate: This value ranged from 3 to 7 mm on left and 3 and 8 mm on right with a mean ± SD of 4.47 ± 1.106 and 4.77 ± 1.369 respectively. On the whole values ranged between 3 and 8 mm with mean ± SD of 4.62 ± 1.24 mm

e. Distance of GPF from tip of the hamular process of pterygoid: The values ranged between 10 and 25 mm with the mean ± SD of 14.21 ± 3.41 mm. The values ranged between 10 and 25 mm on left and 9 and 22 mm on right with mean ± SD of 14.12 ± 3.365 and 14.30 ± 3.463 mm respectively.

Table 1: Distance of GPF from bony landmarks

S.No	Distance (mm)									
	MSP-GPF		AC-GPF		IF-GPF		DLM-GPF		HPP-GPF	
	L	R	L	R	L	R	L	R	L	R
1	15	16	10	7	42	43	5	5	14	16
2	12.5	15	15	16	40	42.5	5.5	7	17.5	17.5
3	16	17	16	15	42	43.5	4	4	16	15
4	1.5	16	12.5	14.5	43	42	3	4.5	11	11
5	15	15	14.5	15	40	39.5	4.5	5	10	10
6	15	14.5	10.5	10.5	39	39.5	3	4	9.5	9
7	15.5	15	14	11	40	41	6	6	13	14
8	14	15	13.5	14	42	41.5	5	3	12	13
9	15.5	15.5	10	12	38	37	3.5	5	13	10
10	14.5	15.5	13.5	14	36	38.5	3.5	4	16	16
11	16.5	16	18	20	40	38.5	6	5.5	25	21
12	16.5	17	13	13.5	38	40	6.5	6	22	22
13	15.5	15.5	14	12	39	39	6	6	16.5	13
14	16.5	16.5	7.5	6.5	43	42.5	3	4	13	21
15	19	16.5	18.5	19	36	36	5.5	5.5	17	22
16	14	14	14.5	12.5	39	40	5	7	12	12.5
17	14.5	14.5	16	16	38	39	5	4.5	13	12.5
18	14	14	8.5	8	37	37	3.5	3	10.5	13
19	14.5	15.5	12.5	12.5	39.5	36	5	8	16	13
20	18.5	18.5	18	16.5	40	39	6	6.5	11.5	12
21	14	14.5	12.5	13.5	36	35.5	3.5	3	12.5	12.5
22	13	12.5	12	12.5	40	39.5	4	5	11.5	11
23	13.5	14.5	10	11	36	35.5	3	3	12	14
24	16	17.5	11.5	11	43	43.5	3.5	3	13.5	12
25	15.5	16	7	7.5	42	43	3	2.5	15	13
26	12.5	13	10	11.5	38	39.5	4.5	4	12.5	13
27	14	15	12.5	14	41.5	40	5.5	5	14	15
28	15.5	15	13	13	39.5	39	5	5.5	15.5	15.5
29	13	13.5	15.5	14	40	42	3.5	4	16.5	16
30	13.5	12	15	15.5	39.5	39	4	4.5	12	13

Table 2: Descriptive statistics of measured distances of bony landmarks

Descriptive statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
L-MSP	30	13	19	15.05	1.673
R-MSP	30	12	19	15.20	1.430
L-AC	30	7	19	12.97	2.951
R-AC	30	7	20	12.97	3.178
L-IF	30	36	43	39.57	2.136
R-IF	30	36	44	39.72	2.384
L-DLM	30	3	7	4.47	1.106
R-DLM	30	3	8	4.77	1.369
L-HPP	30	10	25	14.12	3.365
R-HPP	30	9	22	14.30	3.463
Valid N (Listwise)	30				

Angulation of GPC:

Angulation of GPC with hard palate (HP): The values ranged between 47 and 66 degrees. The mean was 55.54 degrees with SD of 4.44 (mean \pm SD of 54.04 \pm 4.435 on left and 57.05 \pm 4.439 on right)

Angulation of GPC with vertical plane (VP): The values range between 2 and 14 degrees medially on left and 1 and 12 degrees medially on right. The mean \pm SD was 7.78 \pm 2.9 49 on left and 6.09 plus \pm 2.838 on right. Overall mean \pm SD was 6.94 \pm 2.89 degrees medially. Of the total, 30 cases examined, only one case showed a lateral angulation of six degrees on left and two degrees on right. Angulation of GPC with midline (ML):

The values ranged between 11 and 19 degrees on left and 12 and 20 degrees on right. The mean was 14.79 on left and 16.83 on right with SD of 2.351 and 2.01 respectively. The overall mean \pm SD was 15.81 \pm 2.18 degrees.

Length of GPC and PPF:

The length of GPC plus PPF ie. depth of injection ranged from 24 to 36 mm on left and 22 to 35mm on right. The mean SD was 28.9 \pm 3.24 on left and 29.1 9 \pm 3.4 3 on right. On the whole the mean was 29.04 mm with SD of 3.33 mm . Of the 60 specimens examined and probed, in one specimen the probe entered the middle cranial fossa in another case, bilateral penetration of orbit was demonstrated.

Table 3: Angulations and length of GPC+PPF

S.No	Angulation (degrees)						Length of GPC+PPF(mm)	
	GPC-HP		GPC-VP		GPF-ML		GPC+PPF	
	L	R	L	R	L	R	L	R
1	57	50	2	2	16	17.5	26	25
2	47	50	14	6	12	15.5	23.5	30
3	65	65	8.5	6	16	20	32	31.5
4	NA	NA	NA	NA	NA	NA	NA	NA
5	52.5	60	10	7.5	15	17.5	28	23
6	48	54	7	2.5	16	17	31	28
7	50	61	6L	2L	19	19	29.5	29
8	51	62	11	6.5	11	19	24	33
9	52	62	3.5	7	18.5	17.5	25	25
10	60	60	5	2.5	14	17	31	31
11	NA	62.5	NA	11	NA	13.5	NA	31.5
12	63	66	6	5.5	13.5	14	Enter O	Enter O
13	53.5	60.5	7.5	1.1	17.5	17.5	31	30.5
14	60.5	52.5	7.5	6.5	16	18	23.5	21.5
15	52.5	53	8.5	7	14	15	25.3	Enter C
16	52.5	56	5	4	12	19	22.5	29
17	55	58.5	9	8.5	16	16	30.5	26.5
18	53.5	60	10.5	11.5	11	18	27	26.5
19	52	54.5	11.5	7.5	13.5	15.5	35.5	34.5
20	56	59	7	3	15.5	19.5	28.5	28.5
21	54.5	56.5	12.5	9.5	14	17.5	29	34.5
22	51.5	53.5	10.5	6	15	17	27	31.5
23	52	51	8.5	8	11	12	29	28.5

24	57	55	8	7	17	16.5	31.5	29
25	50.5	51.5	6	4.5	13.5	15	30	27
26	48.5	54.5	5.5	4.5	19	18	31.5	31
27	60.5	60.5	10	11	16.5	18.5	35	35
28	53	56.5	7.5	8.5	15.5	17.5	28.5	32.5
29	52.5	55	5.5	3.5	14.5	17.5	29.5	29
30	52	54	2.5	2.5	11.5	12.5	25.5	26

Table 4: Descriptive statistics of measured angulations

Descriptive statistics					
	N	Minimum	Maximum	Mean	Std.Deviation
L-HP	28	47	65	24.04	4.435
R-HP	29	50	66	27.05	4.439
L-VP	27	2	14	7.78	2.949
R-VP	28	1	12	6.09	2.838
L-ML	28	11	19	14.79	2.351
R-ML	29	12	20	16.83	2.015
Valid N (Listwise)	27				

Table 5: Descriptive statistics of measured length of GPC+PPF

Descriptive statistics					
	N	Minimum	Maximum	Mean	Std.Deviation
L - PPF	27	24	36	28.90	3.243
R - PPF	27	22	35	29.19	3.425
Valid N (Listwise)	27				

Discussion

Position of GPF from mid sagittal plane: The distance of GPF from the mid sagittal plane in the present study was found to be 15.13 ± 1.55 mm which correlates well with that of study on East Indians (15mm) by Westmoreland et al.[5], (1982) and Nigerians (15.4mm) by Ajmani et al.[6], (1994) but slightly lesser than that of Chinese (16mm) by Wand et al.[7], (1988) and Thais (16.2mm) by Methethrathip et al [8], (2005) and slightly greater than that of Caucasians (14.8mm) by Westmoreland et al., (1982). Thus the South Indian population lies midway between Caucasian and Mongoloid races but comparable to the Negroids with respect to distance of GPF from the midline.

When comparing this with the previous studies on Indian skulls by Ajmani et al.[6], (1994) and Saralaya et al.[9], (2007) the distance in South Indian population is slightly higher (15.13mm compared to 14.7mm) reported both by Ajmani et al.[6],(1994) and Saralaya et al.[9], (2007) in North and West Indian population respectively.

Distance of GPF from Alveolar crest: In the present study it was found to be 12.97 ± 306 mm with a wide range of 7 to 20mm. this is slightly lesser than this in Thais (13.8 ± 2.4 mm) as reported by Methethrathip et al.[8], (2005). The range in Thais is even wider than the South Indian population (4.7 to 19.4mm in Thais when compared to 7 to 20mm in South Indians). This wide range may be attributed to the varying level of periodontal status in South Indian population as in

the case of Thais. So it is suggested to be extra cautious when selecting distance from alveolar crest as a measurement to localize the GPF. This landmark must be avoided whenever possible given the wide variation in periodontal status among different strata of South Indian population.

Distance of GPF from the incisive fossa: In the present study this was observed to be 39.65 ± 2.26 mm. This is slightly greater than that reported in the study on same population by Saralaya et al.[9], (2007) which was observed to be 37.3 ± 0.731 mm in the previous one.

This slight difference may be attributed to the fact that all the specimens in the present study came from East coast region of South India when compared to the skulls from the West coast region in previous study. Thus it may be concluded that the distance of GPF from incisive fossa is slightly greater in South Indian population of East coast than that of West coast.

Distance of GPF from greatest concavity of distolateral margin of hard palate: The mean was found to be 4.62 ± 1.24 mm in the present study which was slightly lesser than that of Thais (5.1 ± 1.3) as described by Methethrathip et al., (2005). This is in line with the slightly lesser values of distances from midsagittal plane and alveolar crest in South Indian population when compared to Thais.

Distance of GPF from the tip of the hamular process of pterygoid: The mean value in South Indian population as found in this study is $14.21 \pm$

3.41mm with a range between 10 and 25 mm. This is slightly greater than that found in Caucasian population by Malamed et al.[10], (1983) which was documented as 12mm. In Caucasian population, the range was wider but on lower end of the scale that is between 3 and 20mm compared to 10 and 25mm in South Indian population. This is again in line with higher values for the distance between midsagittal plane and GPF in South Indian population that the Caucasians.

Angulation of GPC: There are only limited studies in the literature describing the angulation of GPC in numerical values (Malamed et al.[10], 1983, Methethratip et al.[8], 2005). Most of the studies describe the angulation in general way i.e. vertical, antero-medial, antero-lateral etc. As far as the Indian population is concerned this can be considered as the first study describing the angulation in numerical values, hence might be very useful to clinicians attempting to negotiate the GPC with success.

Angulation of GPC with hard palate: The mean value in south Indian population is 55.54 ± 4.44 degrees anteriorly which is slightly lesser than that of Thais (57.9 ± 5.8 degrees) as described by Methethrathip et al.[8], 2005 and considerably greater than that found in Caucasians (45.88 degrees) by Malamed et al.[10], (1983). The range of values in the present study is 47 to 66 compared with the Thias which is 40 to 78 but the lower limit of the values are far higher than that of in Caucasians which is mentioned as 20 to 70. The inference is that the needle, while giving maxillary nerve block injection should be angulated more vertically in South Indian population that in Caucasians. Therefore the standard 45 degrees angulation of the needle described in anaesthesia textbook by Western authors Malamed et al.[10], in 1983 should be taken only with a note of caution by the clinicians working in south Indian set up.

Angulation of GPC with vertical plane: Description of this angle in numerical value is rare in the literature. It has been done by Methethrathip et al.[8], (2005) among the Thai population and it was documented to be 6.7 ± 5.2 degrees medially. In the present study among Indian population, it was observed to be 6.94 ± 2.89 degrees medially, more or less the same. Other authors have described the angulation only in general terms than in numerical values. In the present study, the angulation of GPC was found to be antero-medial in 96.66% and antero-lateral in 3.34%. In no case, vertical angulation was observed in the present study. Cheung et al.[11], (1998) described vertical

angulation in Chinese population, but the angulation was described to be anteriorly directed in 90.5% and vertically in only 9.5%. In caucasian population, the angulation was found to be predominantly vertical (82%) as described by Cambell et al.[12] and Westermoreland et al.[8] . As far as Indian population is concerned, Ajmani et al., (1994) found that 91.4% antero-medial angulation, which is more or less equal to that found in the present study. But Saralaya et al.[9] (2007) working on western Indian population observed that only 46.2% of GPC showed antero-medial angulation while 41.3% showed vertical and 12.5% showed antero-lateral angulation. This is different from that observed in the present study on South Indian population reminding once again the regional variations within the country. This might explain the difficulty encountered in negotiating the canal at times. When it comes to discussion on maxillary nerve block, the racial and regional origin of the patient should be well kept in mind.

Angulation of GPF with midline: This angulation is measured as this is an additional criterion that may help in localizing the location of the greater palatine foramen in addition to the already described distance from the bony landmarks. The value was found to be 15.81 ± 2.18 degrees with a range of 11 to 20 degrees, which is lesser than that found in western Indian population by Saralaya et al.[9]. The data again brings out the wide discrepancy in the location of GPF between western and south Indian population.

Length of GPC and PPF: It is the actual depth of injection necessary to reach the maxillary nerve exiting the foramen rotundum. It was found to be 29.7 ± 4.2 mm in Thai population by Methethrathip et al.[8] which is very close to that found in the present study (29.04 ± 3.33 mm) in south Indian population. In the present study it was observed that of the 60 specimens, two specimens showed penetration of orbit by the probe and in one case the probe entered middle cranial fossa. This gives the possibility of needle entering the orbit at 3.34% and cranial cavity at 1.67%. These values are much lesser than that found in Thai population by Methethrathip et al.[8] that is 31.7% penetrating orbit and 8.7% penetrating cranial cavity. This suggests that the approach to block maxillary nerve through greater palatine canal is safer. The average length of the greater palatine canal was 29 mm (± 3 mm), with a range from 22 to 40 mm. In the sagittal view, the canal travelled most frequently at an anterior-inferior angle (92.9%) as described by Malamed et al. [10]

Table 6: Comparison of measurements between different populations

	South-India (Present study)	East Indians	Nigerians	Chinese	Thais	Caucasians	North Indian	West Indian
Measured distances (mm)								
MSP-GPF	15.13	15	15.4	16	16.2	14.8	14.7	14.7
AC-GPF	12.97				13.8			
IF-GPF	39.65							37.3
IF-DLM	4.62				5.1			
HPP-GPF	14.21					12		
Measured Angulations (degrees)								
GPC-HP	55.54				57.9	45.88		
GPC-VP	6.94				6.7			
GPF-ML	15.81							
Measured length (mm)								
GPC+PPF	29.04				29.7			

Conclusion

This study reconfirms the fact that position of GPF, length and angulation of GPC are highly population specific. This study also confirms that the maxillary nerve block via greater palatine foramen is relatively easier and free from complications when it comes to south Indian population.

Maxillary nerve block can be given by first locating the GPF with the help of measurements discussed in this study and inserting a 25 gauge needle in to GPF in an antero-medial direction at an angle of 50 to 60 degrees from the hard palate and 6 to 7 degrees medially from the vertical plane.

After reaching a depth of 29 mm, the anaesthetic solution can be deposited after proper aspiration

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