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Original Research Article

Morphological and morphometric study of hard palate in Indian population

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Abstract

Aim of study: The hard palate is an essential part of the human skull and plays an important role in the passive articulation of speech. The present study aimed to determine morphometric study of hard palate, location of the position of the greater palatine foramen (GPF) in relation to maxillary molars and number of lesser palatine foramina (LPF).
Materials and Methods: 86 dried unsexed adult Indian skulls procured from the Department of Anatomy, University College of Medical Sciences, Delhi, India. The length, breadth, and height of the hard palate were measured and Palatine indices were calculated. Observations were made on the positional relationship of GPF and number of LPF.
Results: Palatal length and breadth showed highly significant difference whereas no significant difference was found in palatal height between both sexes. The palatine Index showed that majority of the skulls had narrow palate. The greater palatine foramen was found to be at the level of third molar in 59%, in between second and third molars in 35%, at the level of second molar in 5% and 1% were situated behind third molar. In majority of the skulls (6o %) only one lesser palatine foramen was found and about 34% of the skulls had two lesser palatine foramina and 3% of skulls had 3 lesser palatine foramina.
Conclusion: These observations can be utilized for anthropological studies, greater palatine nerve block, and surgical procedures in hard palate.
Keywords: Hard palate; Palatine index; Greater palatine foramen; Lesser palatine foramen.

1. Introduction

The hard palate is an essential region of the skull formed by the palatine processes of the maxillae and two horizontal plates of the palatine bones which are linked by a cruciform suture formed at their junction [1, 2]. The hard palate plays an important role in the passive articulation of speech, therefore morphological variations in the bony palate is of great clinical significance [3].

The hard palate and its sutures are structures of the utmost importance because they are subject to a cleft palate related defect of the maxilla and palatine bones [4]. Procedures such as nasopharyngoscopy and nasogastric intubation will need a precise knowledge of normal structure and dimensions of these regions for meticulous manipulation and better designing of instruments [5]. Morphometric and anatomical knowledge of the hard palate is required as guidelines for medical practitioners.

Matsuda (1927) was the first to report on the localization of the GPF [6]. The majority of textbooks still locate the GPF in a very general way e.g. near the lateral or posterolateral palatal border, medial or opposite the third maxillary molar (M3) [7]. Anesthesia textbooks seem to be a little more specific in that matter loosely positioning the GPF in relation to the maxillary molars [8]. However inconsistency in anatomy textbooks concerning the precise location of the greater palatine foramen, as well as details of palate structures, was the underlying basis of this study examining the hard palate using both qualitative and quantitative observation. Dentists, anesthetists and maxillofacial surgeons need to know the location of the foramina in order to carry out accurate nerve block of the Maxillary nerve during procedures such as upper tooth extraction, maxillary dental implants, orthognathic surgery and cleft palate surgery [9]. Metric studies of the hard palate help in accurate localization of the greater palatine foramen (GPF).

The hard palate is a neglected area in the field of anatomical research as there is little morphological or metric analysis carried out in this area. Moreover, this population-based study may provide an essential data for the comparative analysis of different populations. Hence the present study was performed to determine the palatine length, breadth, height, palatine index and palatine height index. These data will be useful to surgeons, clinicians, anatomists and anthropologists.

2. Materials and Methods

The study was conducted in 86 dried, unsexed, adult Indian skulls procured from the Department of Anatomy of University College of Medical Science, Dilshad Garden, Delhi, India and the first year MBBS medical students of the same college. The sample of the study is conducted from the year 2007-2010. As the criteria of inclusion, none of the skulls were with anomalies, fractures or any pathology that might affect the normal measurements. Vernier calipers accurate to 0.1mm were used to measure the length, breadth and height of the hard palate. Two individuals measured the parameters independently with predetermined procedures to prevent inter-observer and intra-observer error.

For the qualitative study the following were determined bilaterally:

(I) Position of the greater palatine foramen (GPF) in relation to the maxillary molars

(II) Number of the lesser palatine foramen (LPF).

The quantitative measurements comprised:

1) Palatine length: Distance between the orale anteriorly (point at the anterior end of the incisive suture located between the sockets of two medial maxillary incisors) to posterior nasal spine posteriorly. (Figure 1)
2) Palatine breadth: Distance between the inner borders of the sockets of the upper second molars (endomalaria). (Figure 1)
3) Palatine height: Maximum arching of palate from the line connecting the two endomalaria.

The following indices were calculated according to the method followed by Hassanali and Mwaniki [10]: the palatine index (PI) and the palatine height index (PHI).

Palatine index (PI): was calculated by using the formula: Palatine breadth × 100/ Palatine length

The palatine index (PI) is the ratio of the palatine breadth to the palatine length expressed as a percentage. The values of the PI indicate the width of the palate.

1. When the PI range was 79% or less, the hard palate was narrow (Leptostaphyline)
2. When the PI range was 80–84.9%, the hard palate was intermediate (Mesostaphyline)
3. When the PI range was 85% or more, the hard palate was wide (Brachystaphyline).

Palatine height index (PHI): was calculated by using the formula: Palatine height X 100/ Palatine breadth

The palatine height index (PHI) is the ratio of palatine height to the palatine breadth expressed as a percentage. It indicates the characteristic arching of the palates.

1) When the PHI was 27.9% or less, the hard palate was low (Chamestaphyline)
2) When it was 28–39.9%, the hard palate was intermediate (Orthostaphyline)
3) When it was 40% or more, the hard palate was deep (Hypsistaphyline).

The relationship of the position of greater palatine foramen (GPF) with maxillary molars and number of lesser palatine foramen was noted.

2.1 Statistical analysis

Basic descriptive statistics were employed to analyze the data using SPSS (SPSS Inc., Chicago, Illinois, USA). The mean, SD, and range for each of the measurements were assessed. Comparison of the values of all measurements was made in terms of the sides in each subject, as well as comparisons between sexes. All the findings were tabulated and analyzed statistically using Student's t-test. The statistical differences were considered significant when the P value was less than 0.01.

3. Result

Table I depicts the palatal dimensions (length, width, and height) in the study sample. There is statistically significance difference in the morphology and dimensions between female and male palatal length and breadth. Male seems to have greater palatal length (52.5 ± 0.37) and breadth (36.51 ± 0.27) compared to female palatal length (48.1 ± 0.36) and breadth (32.33 ± 0.20). On the other hand height of the palate in male is (16.81 ± 2.7) compared to the female (14.2 ± 0.20), with no statistical significant difference between both sexes.

The palatine index (PI) showed that 62% narrow palate (leptostaphyline), 24% intermediate palate (mesostaphyline) and 14% of the total sample of male skulls had wide palate (Brachystaphyline), whereas in female skulls had 58% narrow palate (leptostaphyline), 27% intermediate palate (mesostaphyline) and approximately 15% of the total sample of female skulls had wide palate (Brachystaphyline) palates were present (Table 2). There was a statistical significant difference between both sexes ($P < 0.01$).

The palatine height index (PHI) showed that 40% of the total sample of male skulls had low or flat (chamestaphyline), 48% intermediate arching (orthostaphyline) and 12% high arched (Hypsistaphyline) palates whereas in female skulls approximately 41% of the total sample of female skulls had low (chamestaphyline), 44% intermediate (orthostaphyline) and 15% high (Hypsistaphyline) palates were present (Table 3). There was a statistical significant difference between both sexes (P < 0.01).

Greater palatine foramina (GPF) is present bilaterally, one on each side on the posterolateral aspects of the hard palate in all skulls. The relationship of the GPF to the maxillary molars was variable (Table 4). In majority of skulls (59%), the GPF's were opposite to third molar, whereas 35% showed GPF between the second and third molars. In 5% of the skulls, the GPF was located at the level of second molar, and approximately 1% were situated behind third molar (Table 4).

The numbers of lesser palatine foramina (LPF) on both sides were not symmetrical, and varied from one to three. In majority, approximately 71% on right side and 49% on left side had only one lesser palatine foramen (LPF) found. Lesser palatine foramen is present in paired on the in 45% on left side and 22% on right side of the total skulls. The LPF were absent in the two skulls on the left side and three skulls on the right side of the total study sample (Table 5).

Figure 1: Measurement of various parameters of the hard palate: AB- palatine length, CD-Palatine breadth

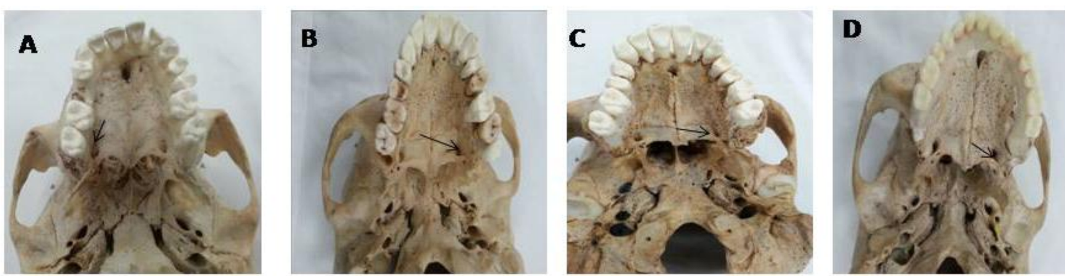

Figure 2: Illustrates showing position of greater palatine foramen, Arrow marked on picture A=Opposite 2nd molar, B= opposite 2nd and 3rd molar, C=opposite 3rd molar, D=Behind 3rd molar (Retromolar)

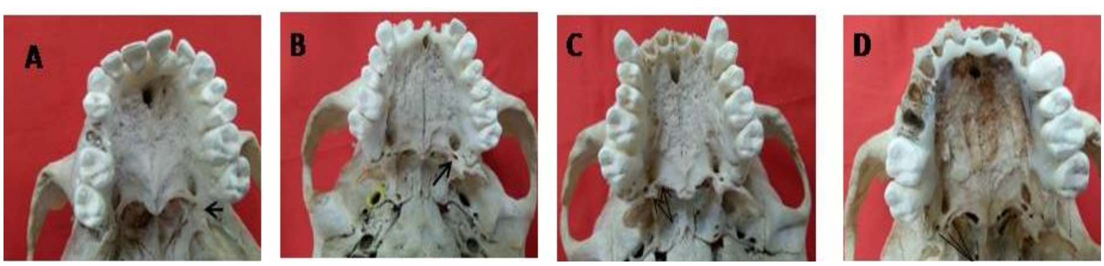

Figure 3: Illustrates the number of lasser palatine foramen. Arrow marked on picture.
A= Absent, B=Single=paired, D=Triple.

Table 1: The Palatine parameters and indices according to the sex of the skull

Parameter	Sex				P-Value
	Male (N = 50)		Female (N = 36)		
	Range (min-max)	Mean ± SD	Range(min-max)	Mean ± SD	
Palatine Length	45.1-60.22	52.5 ± 0.37	40.12-54.23	48.1 ± 0.36	<0.01
Palatine Breadth	31.01-45.32	36.51 ± 0.27	32.42-40.26	32.33 ± 0.20	<0.01
Palatine height	11.32-18.12	16.81 ± 2.7	10.3-17.62	14.2 ± 0.20	>0.01
Palatine Index	66.67-95.21	69.80± 6.84	59.26-100	73.64 ± 8.75	<0.01
Palatine height index	26.41-48.22	46.03± 1.33	26.13-37.4	34.66 ± 2.05	<0.01

P ≤ 0.01 is considered as significant value

Table 2: The frequency of types of hard palate according to palatine index in male and female skulls

Types	PI (%)	Male [N (%)]	Female [N (%)]	Total [N (%)]	P-Value
Leptostaphyline	≤79.9	31/50 (62%)	19/36 (52.77%)	50/86 (58.13%)	<0.01
Mesostaphyline	80-84.9	12/50 (24%)	11/36 (30.55%)	23/86 (26.74%)	
Brachystaphyline	≥85	07/50 (14%)	06/36 (16.66%)	13/86 (15.11%)	

P ≤ 0.01 is considered as significant value

Table 3: The frequency of types of hard palate according to palatine height index in male and female skulls

Types	PHI (%)	Male [N (%)]	Female [N (%)]	Total [N (%)]	P-Value
Chamestaphyline	≤27.9	20/50 (40%)	15/36 (41.66%)	35/86 (40.69%)	<0.01
Orthostaphyline	28-39.9	24/50 (48%)	14/36 (38.88%)	38/86 (44.18%)	
Hypsistaphyline	≥40	06/50 (12%)	07/36 (19.44%)	13/86 (15.11%)	

P ≤ 0.01 is considered as significant value

Table 4: The relation of greater palatine foramen in maxillary molars

Relation to maxillary molars	Right side N (%)	Left side N (%)	Total side N (%)
Opposite to second molar	3 (3.4%)	5 (5.81%)	8 (4.60%)
Between second and third molar	31 (36.05%)	30 (34.88%)	61 (35.46%)
opposite to third molar	51 (59.30%)	50 (58.13%)	101 (58.71%)
Retromolar (behind third molar)	1 (1.16%)	1 (1.16%)	2 (1.16%)

Table 5: The number of lesser palatine foramen (LPF) in hard palate of human skulls

Number of LPF	Numbers of skulls having LPF		
	Left side N (%)	Right side N (%)	Total side N (%)
0	2 (2.86)	3 (3.48)	5 (2.90%)
1	42 (48.83)	61 (70.93)	103 (59.88%)
2	39 (45.34)	19 (22.09)	58 (33.72%)
3	3 (3.48)	3 (3.48)	6 (3.48%)

Table 6: Comparison of present study with the other studies regarding relation of GPF to maxillary molars

S. No.	Relation of GPF to maxillary molars	Opposite to 2nd molar	Between 2nd & 3rd molar	Opposite to 3rd molar	Beyond 3rd molar (Retromolar)
1	Westmoreland and Blanton (1982)	9.7	33.6	50.7	6
2	Langenegger *et al* (1983)	1	3	62	34
3	Malamed and Triegger (1984)	-	39.9	50.6	-
4	Hassanali and Mwaniki (1988)	10.4	13.6	76	-
5	Wang *et al*.[28] (1988)	17	48	33.5	0
6	Ajmani (Indian skulls) (1994)	0	32.35	64.69	2.94
7	Aterkar *et al* (1995)	-	26.2	69.1	2.6
8	Jaffar and Hamadah (2003)	12	19	55	14
9	Sujatha *et al*. (2004)	0.88	13.15	85.95	-
10	Methathrathip *et al*. (2005)	7	14.1	71.9	7
11	Saralaya & Nayak (2007)	40	24.2	74.6	0.8
12	Chrcanovic & Custodio (2010)	-	6.19	54.87	38.94
13	Osunwoke (2010)	2	22.7	74.6	2
14	Kumar A *et al*. (2011)	5	9	85	1
15	Fu *et al*. (2011)	19.1	66.6	14.3	-
16	D'Souza S *et al*. (2012)	2.5	23.75	73.75	-
17	Vinay KV *et al*. (2012)	3.67	19	76	1.33
18	Piagkou *et al*. (2012)	16.82	-	75.7	7.48
19	Jotania *et al*. (2013)	4.17	17.5	78.33	-
20	Dave *et al*. (2013b)	1	3	87.5	8
21	Ikuta *et al* (2013)	3	53	39	5
22	Nimigean *et al*. (2013)	9	15	73	3
23	Renu (2013)	9	25.5	47.5	18
24	sharma and Garud (2013)	7.9	35.25	38.13	17.99
25	Anjankar VP *et al*. (2014)	6.98	16.27	73.26	3.49
26	Tomaszewska *et al*. (2014)	16.3	6.8	74.7	2.2
27	Sushobhana *et al*. (2015)	14	10	76	-
28	Sarilita and Roger (2015)	4	37.3	58.7	
29	Our study (2016)	4.6	35.46	58.71	1.16

4. Discussion

The hard palate should be considered as an important feature when sexing the entire human skeleton or the human skull alone [11]. The mean values of maximum palatal length and breadth in male skulls was significantly higher than those in female skulls. The mean palatal length and breadth are sexually dimorphic. This finding is similar to that of Bigoni *et al*, who noted significant sex differences in the region of the palate [12]. Similar findings were observed by other studies who also concluded that the size of the palate was the best sex determinant among five hard palate variables, and hard palate variables correctly classified sex in 70% of his sample from the North Indian population [13- 15].

The comparison of means of the palatine height indicated a lack of statistically significant differences (P > 0.01) between the male and female groups. The mean palatal height in male skull is ranging from 11.32-18.12 mm and in female it was 10.3-17.62 mm. When determined in previous studies, mean palatal height also showed a wide range of values (9.87 to 13.1 mm), with that in the present study being close to that reported by Hassanali and Mwaniki [10]. The exception is Dave *et al* (2013a), who reported lower values of palatal breadth, length and height [16].

Krogman (1946) enlisted palate among the characters of the skull which show maximum contrast between the sexes [17]. Rogers (2005) has ranked palate size/shape as sixth among the morphological features of the skulls used for sexing unknown skeletal remains [18]. Johnson *et al*., (1989) selected palatal length as one of the best variable for sex determination of caucasiod skulls [19]. Shalaby *et al* reported that external palate breadth has been found to the best sex determinant subsequent to statistical analysis of the five hard palate variables by Logistic regression [20]. Gangrade *et al* also reported External palate breadth alone correctly classified 66.7% of the sample [14].

In the present study, 58% of North Indian skulls had narrow palates (leptostaphyline), 15% had wide palates (brachystaphyline), and the remaining 27% had intermediate (mesostaphyline) palates, with statistical difference the two sexes. Similar findings were reported by Shalaby *et al*., he found that 64% of Egyptian skulls had narrow palates (leptostaphyline), 12% had wide palates (brachystaphyline), and the remaining 24% had intermediate (mesostaphyline) palates, with no significant difference between the two sexes [20]. In a study on Kenyan skulls by Hassanali and Mwaniki, 43% had narrow palates, 33% had wide palates, and 24% had intermediate palates [10]. D'Souza *et al* found in South Indian skulls that 37.5% of the palates were narrow, 40% were wide, and 22.5% were intermediate [21]. The knowledge of palatine index is important because high and narrow palate has been reportedly associated with many syndromes such as Apert syndrome, Turner's syndrome, Marfan syndrome, Franceschetti-Teacher-Collins syndrome [22].

Palatal height index showed the skulls in the present study had an intermediate palatal height (orthostaphyline), being observed in 44% of skulls (Table 4). This is consistent with the observations of [10] Hassanali and Mwaniki (1988) in Kenyan skulls (56.67%) and [16] Dave *et al* (2013a) in Indian skulls (54%), but differs from [21] D'Souza *et al*, who found a low palate (chamestaphyline) to be the most common (87.5%). Shalaby *et al* found that low palates were more in male skulls than in female skulls and the difference was significant [20]. In the total sample, 56% had intermediate arched palates (orthostaphyline), 36% had low palates (chamestaphyline), and 8% had highly arched palates (hypsistaphyline). When the results of our study were compared with the results of Saralaya and Nayak on Indian skulls, it was found that the percentage of low palates was nearly similar in both studies [30]. D'Souza *et al* found that 87.5% of skulls had low palates and 12.5% had intermediate ones [21].

Knowledge of palatine index and palatine height index will be helpful in comparing the Indian skulls with those from various other regions as well as skulls of different races [16]. Hard palate is preserved even in severe damages to skull for studying sexual dimorphism [15]. Taking into account the general morphometric features, male palates analyzed in this study were longer, narrower and deeper than the female ones, which generally complies with the findings of other authors. However there are works showing that it is the female palate that is actually wider and longer [11]. The reason for this discrepancy cannot be explained by racial differences alone. Bigoni *et al* observed that size-related sexual dimorphism shows significant inter-population variability [12].

The maxillary molars are the best landmarks for locating the GPF. The present study found the GPF to be opposite the upper maxillary third molar tooth in the majority of skulls (59%). The majority of the studies conducted to observe the location of the GPF (Table 6) found it to be opposite the third molar tooth. [24] Sujatha *et al* observed this location in 85.95% of Indian skulls, whereas [25] Wang *et al* reported the same location in only 33.5% of Chinese skulls. According to Moore (1980) it was medial to the third molar tooth [26]. Anjankar *et al* reported 73.26% GPF are located opposite the third maxillary molar [27]. Kumar *et al* noted that 85% GPF are located opposite third molar tooth [28]. Study by Wang *et al* in Chinese population found GPF between 2^{nd} and 3^{rd}

molar in 48.5% and opposite third molar in 33.5% cases [29].

Westmoreland & Blanton (1982) had cited it commonly opposite the third molar (50.7%) [30]. In the study done by Ajmani (1994), 48 % of foramina in Nigerians and 64% in Indian skulls were located opposite the third maxillary molar [31]. It also showed that the location of GPF was intermediate between the second and the third molars in 36% of the sample, behind the maxillary third molar in 1%, and opposite the upper second molar tooth in 5% (Table 4). In Egyptian, Shalaby *et al* reported; 9.7% skull it was opposite second molar, and in 6% it was distal to third molar [20]. According to Khatri *et al* (1986), the foramen was located opposite the third molar in 56%, behind third molar in 16%, opposite second molar in 14%, and between second and third molars in 14% [32]. Slavkin *et al* (1966) who stated that the GPF in infants and children was located distal to the posterior deciduous molar and then moved posteriorly as the next posterior tooth erupted. This transition is caused by appositional and sutural growth at the interface between the maxilla and palatine bones, as well as by the increasing anteroposterior dimension of the palate associated with eruption of the dentition [33].

The pooled data, presented in this study (Table 6) will allow clinicians to adequately prepare before performing procedures using in the vicinity of the GPF, regardless of the geographical region they are working in. Finally, this study presents evidence that GPF position may not be so prone to anatomical variability. The large discrepancies between certain studies originate rather from differences in measurement methodology.

There is a dearth of literature data suggesting that the number of LPF may have clinical meaning. Bilateral symmetry in the number of LPF was seen in most of the skulls. In the rest of the skulls the number varied from one to three or even may be absents. However, the absence of LPF, as it was found in our study may cause the lesser palatine nerve to exit through the GPF, and thus be prone to anesthesia when blocking the greater palatine nerve [11]. Multiple openings of LPF were also present in the majority of skulls examined in this study, agreeing with the findings of [34] Berge and Bergman (2001), [35] Jaffar and Hamadah (2003), [36] Jotania *et al* (2013), but in contrast with [10] Hassanali and Mwaniki (1988), [21] D'Souza *et al* (2012), [37] Piagkou *et al* (2012) and [27] Anjankar *et al* (2014) who reported a single LPF opening to be dominant. The importance of knowing that individuals may have more than a single LPF is that the lesser palatine nerves may be unintentionally blocked if the needle tip is located posterior to the greater palatine foramen, resulting in anaesthesia of the soft palate and inducing the gag reflex [10].

5. Conclusion

It is well known that the credibility and reliability of human identification processes is directly related to the amount of data available for the individual. Thus, assessment of all truly dimorphic bones in the human skeleton would be an ideal condition for determining sex. The present study provides the baseline data for the determination of sex of Indian individuals from a fragment of skull, that is, hard palate. Detailed anatomical study of hard palate is helpful in ethnic and racial classification of crania, anthropological studies, fabricating complete maxillary dentures for edentulous patients and performing certain surgical procedures in hard palate & soft palate. Knowledge of exact location of GPF can be useful for giving local block of greater palatine nerves. A thorough understanding of the anatomy will allow for careful planning and execution of anesthesiological and surgical procedures involving the maxillary nerve and its branches including greater palatine foramina.

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