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Morphology of the human hard palate: a study on dry skulls

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Abstract

To determine morphological variations of the hard palate in dry human skulls, 85 skulls of unknown age and sex from nine medical schools in Khyber Pakhtunkhwa, Pakistan were examined. The transverse diameter, number, shape and position of the greater (GPF) and lesser (LPF) palatine foramina; canine to canine inter-socket distance; distance between greater palatine foramen medial margins; on each side, the distances between greater palatine foramen and base of the pterygoid hamulus, median maxillary suture and posterior border of the hard palate; palatal length, breadth and height; maximum width and height of the incisive foramen; and the angle between the median maxillary suture and a line between the orale and greater palatine foramen were determined. Palatine index and palatal height index were also calculated. An oval greater palatine foramen was present in all skulls, while a mainly oval lesser palatine foramen was present in 95.8% on the right and 97.2% on the left. Single and multiple lesser palatine foramina were observed on the right/left sides: single 44.1%/50.7%; double 41.2%/34.8%; triple 10.2%/11.6%. The greater palatine foramen was located above the third molar in 74.7% (right)/87.8% (left), between the second and third molars in 25.3%/9.5%, and above the second molar in 2.7% (left). A single oval-shaped incisive foramen was observed in 87.1%. The median maxillary suture angle was 13.74±1.58° on the right and 13.14±1.68° on the left. In conclusion, no significant differences were observed in any distances on the right and left side related to greater palatine foramen; however a significant difference ($p < 0.05$) was observed between the right and left sides for median maxillary suture angle.

Key words

Greater palatine foramen, lesser palatine foramen, incisive foramen, hard palate, Khyber Pakhtunkhwa.

Key to abbreviations

GPF = greater palatine foramen
LPF = lesser palatine foramen
IF = incisive foramen
H = hamulus
MMS = median maxillary suture
MOG = median maxillary suture-orale-greater palatine foramen angle
PI = palatine index
PHI = palatal height index

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Introduction

Anesthetizing the maxillary teeth during various dental and surgical procedures (e.g. cleft palate, upper tooth extraction and maxillary dental implants) requires precise knowledge of the morphological variations of the hard palate. It is, therefore, important for dentists and maxillofacial surgeons to have a sound understanding of the location and morphology of the greater (GPF) and lesser palatine foramina (LPF) to avoid injury to their contents (Das et al., 2006).

Morphological and osteological variations of the hard palate are of clinical significance because of its role in passive articulation in speech (Williams et al., 1989). The hard palate consists of the palatine processes of the maxillae anteriorly and horizontal plates of the palatine bones posteriorly, united by a cruciform suture (Standring, 2005). In adults, the incisive foramen (IF) represents the union between the primary and permanent palate: it may be altered in cleft palate (Jotania et al., 2013). Sleep apnea may be associated with hard and soft palate alterations (Victor, 1999), and is characterized by difficulty in breathing when asleep (Tangugsorn et al., 1995).

The GPF is located mainly above the second or third molar or between them and is close to the lateral border of the transverse palatine suture (Selden, 1985). Most anatomy texts refer to the GPF location being above the second molar (Blanton and Jeske, 2003). Lesser palatine foramina vary in number, but are usually two on each side (D'Souza et al., 2012). The greater and lesser palatine neurovascular bundles pass through the GPF and LPF respectively, while the nasopalatine neurovascular bundle passes through the IF. Greater palatine nerves and vessels supply the mucosa of the hard palate, while the lesser palatine neurovascular bundle supplies the soft palate. The anterior palatal mucosa between the canines is supplied by the nasopalatine neurovascular bundle (Moore et al., 2013).

Deformities involving the hard palate, such as cleft lip and cleft palate, have an incidence of 1.91 per 1000 births (one per 523 births) in Pakistan: although cleft lip is more common than cleft palate a combined deformity is present in 34% of cases. Boys are more commonly affected by cleft lip and combined cleft lip and palate, whereas girls have predominately cleft palate (Elahi et al., 2004).

Although studies have been conducted on the morphology of the hard palate in human skulls, to the best of our knowledge no such research has been conducted in Pakistan. Therefore, the main objective of the present study was to determine the morphological variations of the hard palate in a Khyber Pakhtunkhwa population in Pakistan, which would be beneficial for maxillofacial surgeons and dentists, as well as anthropologists, in locating the GPF and LPF and thus avoid damaging their contents. Similarly, measuring palatal length, width and breadth in skulls from a Khyber Pakhtunkhwa Pakistani adult population would also be beneficial to plastic surgeons in identifying right-left side differences, if any, when undertaking surgery for cleft lip and cleft palate.

Materials and methods

Human skulls (n=85) of unknown age and sex from 9 medical schools in Khyber Pakhtunkhwa, Pakistan were examined. Neither ethical approval nor any consent were required. The parameters determined were adapted from Sarilita and Soames (2015) and were: transverse diameter, number, shape and position of the GPF and LPF; canine to canine inter-socket distance; distance between the GPF medial margins, and from GPF to the base of the pterygoid hamulus (H), median maxillary suture (MMS) and posterior border of the hard palate; palatal length, breadth and height (distance between deepest point of palatal surface and line of palatal breadth); maximum width and height of the incisive foramen; the angle between the MMS and a line between the orale (midpoint between the inner margins of the sockets of the medial upper incisive teeth) and GPF (MOG angle: Figure 1). Distances were measured using a protractor, a glass scale, a metal compass and a standard digital caliper micrometer (eSecure®, Dunfermline Fife, Scotland). Two indices, the palatine index (PI), which compares palatal breadth and length, and the palatal height index (PHI), which compares palatal height and breadth, were also calculated using the formulae taken from Premkumar (2011):

$$PI = [(\text{palatal breadth}/\text{palatal length}) \times 100] \text{ and}$$

$$PHI = [(\text{palatal height}/\text{palatal breadth}) \times 100].$$

The palatine index was classified as leptostaphyline (<79.9), mesostaphyline (80-84.9) or brachystaphyline (>85), while the palatal height index was classified as chamestaphyiline (<27.9), orthostaphyiline (28-39.9) or hypsistaphyline (>40).

For statistical analysis, data were analyzed using Minitab version 17 (Minitab® Inc., Champaign, Illinois). Numerical data are presented as mean and standard devi-

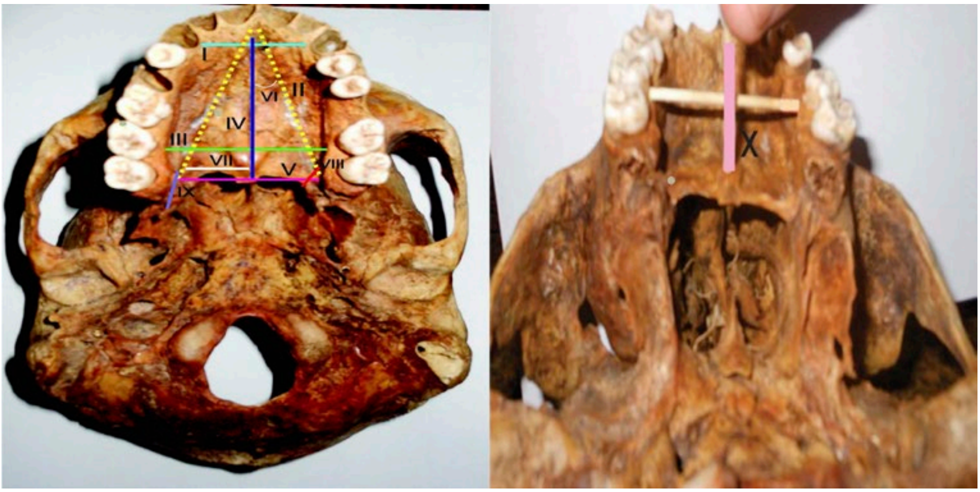

Figure 1. Parameters measured in the present study. I = canine to canine inter-socket distance; II = incisive fossa (IF) to greater palatine foramen (GPF) distance; III = palatal breadth; IV = IF to median maxillary suture (MMS) distance (palatal length); V = distance between the medial margins of the GPF; VI = MOG angle; VII = GPF to median maxillary suture (MMS) distance; VIII = GPF to the posterior border of the hard palate (PH) distance; IX = GPF to pterygoid hamulus distance; X = palatal height.

ation, while categorical data are expressed as frequency and percentages. Measurements from the right and left side were compared using paired sample t test. P-value of less than 0.05 was considered significant.

Results

The GPF was mainly oval and present in all skulls, while the LPF, also mainly oval, was present in 95.8% on the right side and 97.2% on the left side (Figure 2). Single and multiple LPFs were observed on the right and left sides respectively: single 44.1% and 50.7%, double 41.2% and 34.8%, and triple 10.2% and 11.6%, respectively; the remaining cases had more than three foramina (respectively, 4.5% and 2.9%).

Figure 2. Specimens with no lesser palatine foramen (LPF) on either sides.

Table 1. Mean and standard deviation (SD) of greater palatine foramen (GPF) transverse diameter; distance between the GPF and medial pterygoid hamulus, median maxillary suture, posterior border of hard palate and incisive foramen, and MOG angle (between orale, incisive foramen and GPF) on both right and left sides.

Variable	Right		Left		p-value
	Mean	SD	Mean	SD	
Transverse diameter of GPF (mm)	2.12	0.59	2.55	3.78	NS
Distance between GPF and medial pterygoid hamulus (mm)	8.24	1.66	7.91	1.58	NS
Distance between GPF and median maxillary suture (mm)	14.40	1.32	14.39	1.31	NS
Distance between GPF posterior border of hard palate (mm)	4.05	1.26	3.96	1.35	NS
Distance between GPF and incisive foramen (mm)	39.03	3.27	39.40	3.09	NS
Angle between orale, incisive fossa and GPF (°)	13.74	1.58	13.14	1.68	<0.05

Table 2. Frequency, percentage, mean and standard deviation (SD) of distance between medial margin of right and left greater palatine foramen (GPF); canine to canine inter-socket distance; palatal length, breadth and height; palatine index; palatine height index; incisive foramen maximum width and height. N = number of skulls in which each parameter was measured.

Variable	N	n / 85 (%)	Mean	SD
Distance between medial margin of right and left GPF (mm)	73	85.88	28.34	2.24
Canine to canine inter-socket distance (mm)	69	81.18	24.85	2.59
Palatal length (mm)	68	80.00	51.89	4.11
Palatal breadth (mm)	74	87.06	38.04	3.18
Palatal height (mm)	59	69.41	14.16	3.07
Palatine index	68	80.00	73.43	7.60
Palatine height Index	59	69.41	37.94	9.53
Incisive foramen maximum width (mm)	73	85.88	3.03	1.04
Incisive foramen maximum height (mm)	73	85.88	3.39	1.11

The GPF was located above the third molar in 74.7% on the right and 87.8% on the left, between the second and third molar in 25.3% (right) and 9.5% (left), and above the second molar in 2.7% on the left side only. A single oval-shaped incisive foramen was observed in 87.1% of skulls. Right MOG angle was 13.74±1.6°, while on the left it was 13.14±1.7°. The various distances measured are presented in Tables 1 and 2, from which it can be seen that only MOG angle differed significantly between the right and left side (Table 1).

Where possible, for each skull the palatine (PI) and palatine height indices (PHI) were calculated. In the present study, the leptostaphyline type of palate was observed in the majority of skulls (55/85 = 65%), while the mesostaphyline and brachystaphyline types were observed in only 8/85 (9%) and 5/85 (6%) skulls respectively:

Table 3. Comparison of palatal morphology between present and previous studies.

Study	Palatal breadth (Mean)	Palatal length (Mean)	Palatal height (Mean)	PI (%)			PI (mm)	PHI (%)			PHI (Mean)	GPF-GPF (Mean)	GPF-MMS (Mean)	
				L	M	B		C	O	H			Right	Left
Present Study	38.04	51.89	14.16	65	9	6	73.43	8	33	28	37.94	28.34	14.40	14.39
Sarilita & Soames (2015)	37.97	52.2	11.54	84.1	7.9	7.9	73	32	59	10	30.5	27.6	14.02	13.57
Dave et al (2013a)	33.83	43.54	9.87	63	24	13					29.23			
D'Souza et al (2012)				37.5	22.5	40		87.5	12.5	0			14.6	14.4
Hassanali & Mwaniki (1988)	40.2	49.2	12.2	43.2	23.7	33.1	82.01	40	56.67	3.33	30.30			
Jaffar and Hamadah (2003)	39.29	50.82		-	-	-	77.6							
Jotania et al (2013)	37.75	49.74		70	15	15							14.8	14.83
Chrcanovic et al (2010)													14.68	14.44
Dave et al (2013b)													M=16.7 F=16.2	M=16.6 F=16.4
Urbano et al (2010)												32.74	16.63	16.39

PHI; Palatine height index, PI; palatine Index, L; Leptostaphyline, M; Mesostaphyline, B; Brachystaphyline, C; Chamestaphyline, O; Orthostaphyline, H; Hypsistaphyline, M; Male, F; Female.

PI could not be determined in 17/85 (20%) skulls due to significant damage to the hard palate. For palatine height index, the orthostaphyiline type was observed in the majority of skulls (28/85 = 33%), with the hypsistaphyline and chamestaphyline types observed in 24/85 (28%) and 7/85 (8%) respectively; in 26/85 (31%) of skulls PHI could not be determined due to significant damage to the hard palate.

Discussion

In the present study which is based on a brown Caucasian population, an oval-shaped GPF was observed in all skulls. This is in contrast to Lopes et al. (2011) who reported oval-shaped GPFs in 57% of their population. In the present study the GPF was a single opening on both sides: Sarilita and Soames (2015) observed one skull with two GPFs.

In the present study, a LPF was observed in 68 (80%) skulls on the right and 70 (82%) on the left: it was mainly oval. The number of LPFs varied on each side, being single in 30 (44%) on the right and 35 (51%) on the left, double in 28 (41%) and 24 (35%), and triple in 7 (10%) and 8 (12%) skulls: an LPF was absent in 3 (4%) skulls on the right and 2 (3%) on the left. These observations differ from Piagkou et al. (2012) (single LPF in 53%, double in 31% and quintuplet in 2%, and Jotania et al. (2013) (absent LPF 1%, single, 48%, double, 38%, triple 11% and quadruple 2%).

The location of the right GPF was above the third molar in 56 (75%) and between the second and third molars in 19 (25%), while on the left it was above the third molar in 65 (88%), between the second and third molar in 7 (9%) and above the second molar in 2 (3%) of skulls. This is in contrast to D'Souza et al. (2012) who observed that the GPF was located above the third molar on the right in 75% and on the left in 73%, between the second and third molar in 23% and 25%, and above the third molar in 3% on both sides.

A single oval-shaped incisive foramen was present in 74 (87%) skulls, with the mean (and associated standard deviation) of the MOG angle being 13.7±1.6°on the right and 13.1±1.7° on the left, smaller than the 16.45 ± 1.6° reported by Sarilita and Soames (2015).

Mean palatal length, breadth and height in the present study were greater than reported by Dave et al. (2013a). The dominant types of palatine and palatine height indices were leptostaphyline (narrow palate) and orthostaphyline (intermediate palatal height), consistent with the observations of Hassanali et al. (1984) and Dave et al. (2013a), but different from D'Souza et al. (2012) who observed the chamestaphyline type as the most common palatine height index.

The distance between the GPF and MMS is similar to the observations of Vinay et al. (2012), i.e. 14.8 mm and 0.16 mm on the right and 14.8 mm and 0.15 mm on the left. Similarly, the transverse diameter of the GPF is similar to Jaffar and Hamadah (2003) and Langenegger et al. (1983), i.e. 2.77 ± 0.63 mm on the right and 2.5 ± 0.5 mm on the left.

However, the distance between the medial margins of the GPFs, the canine to canine inter-socket distance and the maximum width of the incisive foramen were comparable to those of Sarilita and Soames (2015), i.e. 27.6 ± 2.8 mm, 23.5 ± 2.2 and 4.08 ± 0.99 mm respectively. The distance between the medial margins of the GPFs was less than reported by Urbano et al. (2010) and Tomaszewska et al. (2014), i.e. 32.74 mm and 29.1 ± 2.6 mm respectively. The distance between GPF and medial pterygoid hamulus (8.24 ± 1.66 on the right and 7.91 ± 1.58 on the left), was also less than observed by Nimigean et al. (2013: 12 mm), while the distances between the GPF and posterior border of the hard palate and between the incisive foramen were greater than reported by Chrcanovic and Custodoi (2010).

In conclusion, no significant differences were observed in any parameter related to GPF between the right and left side: however, a significant difference between sides was observed for MOG angle ($p<0.05$). For successful greater palatine nerve block, MOG angle provides a guide for practitioners as unsuccessful nerve block can lead to strabismus, ptosis, diplopia and nerve injuries (Das et al., 2006). A trend was observed between the right and left side GPF-IF ($p=0.067$) and GPF-H ($p=0.076$) distances, suggesting the existence of a morphological variation of the hard palate in the Khyber Pakhtunkhwa (Pakistan) population. Such differences could be important for determining the ancestry of archaeological specimens, as well as for maxillofacial surgeons and dentists when undertaking cleft lip and cleft palate surgery in an adult patient population.

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Conflict of Interest

None

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