ORIGINAL ARTICLE

Morphometric Analysis and Variations of the Hard Palate in Human Dry Skulls: A Cross-Sectional Study from the Punjab Region, Pakistan

Yasmeen Bashir[1*], Hammad Ayyaz[2], Tayyaba Mahmud[3], Sadia Hassan[4], Lubna Shahpar[1]

ABSTRACT

Objective: This study aims to measure and analyze the morphometric parameters of the hard palate in human dry skulls, including length, width, height, palatine, and height indices, and categorize the anatomical variations observed in the hard palate in the Punjab region.

Study Design: Cross-sectional study.

Place and Duration of Study: This study was conducted on dry human skull specimens from November 2024 to January 2025 at the Department of Anatomy, Services Institute of Medical Sciences (SIMS), Lahore, Pakistan.

Methods: Sixty well-preserved, non-pathological adult dry human skulls of were used to measure length, breadth, height, and indices for the specific types of palate with the help of a digital vernier caliper. Data was collected and assessed using SPSS 25.0 for mean and standard deviation.

Results: The hard palate's mean length, breadth, and height were 40.56±3.48mm, 36.51±2.73mm, and 16.45±3.38mm, respectively. In the present study, the palatine Index indicates that 72% of the palates were wide (Brachystaphyline), followed by 18% and 10% intermediate (Mesostaphyline), and narrow (Leptostaphyline), respectively. According to the palatine height index, 75% of the palates were deep (Hypsistaphyline), 20% intermediate (Orthostaphyline), and 5% were low arched (Chamestaphyline). In 79% of the skulls, the lesser palatine foramen was present on both sides, absent in 12%, whereas in 15% of the skulls, there were two on the left side.

Conclusion: Morphometric evaluation of the hard palate enhances our understanding of its anatomical variations and underscores their critical role in clinical and forensic applications.

Keywords: *Cleft Palate, Forensic, Lesser Palatine Foramina, Palate Hard.*

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[1]*Department of Anatomy*
Services Institute of Medical Sciences (SIMS), Lahore, Pakistan
[2]*Department of Surgery*
National Defense Hospital, Lahore, Pakistan
[3]*Department of Anatomy*
CMH Lahore Medical and Dental College, Lahore, Pakistan
[4]*Department of Anatomy*
Gujranwala Medical College, Gujranwala, Pakistan

Correspondence:
Dr. Yasmeen Bashir
Associate Professor, Anatomy
Services Institute of Medical Sciences (SIMS), Lahore, Pakistan
E-mail: yasmeen.javed75@gmail.com

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Introduction

Precise knowledge of osteological morphometry, characteristics, and types of hard palate is necessary for forensic dentistry, maxillofacial surgery, orthodontic treatments, and designing of instruments. The hard palate is a vital anatomical structure within the oral cavity, forming its roof while also serving as the floor of the nasal cavity. It comprises the maxilla and palatine bones, which are joined by cruciate sutures.[1] A thorough understanding of its typical structure and dimensions is essential for procedures such as nasopharyngoscopy, nasogastric intubation, precise surgical manipulations, and the development of medical instruments.[2] Understanding the

morphometric variations of the hard palate is crucial for various fields, including anatomy, dentistry, maxillofacial surgery, and forensic science.[3] These variations are also clinically significant because of their role in passive speech articulation.[4] The hard palates of children and adults have different structures. In the clinical dental sciences, the morphometric characteristics of the palate are also very significant. When it comes to orthodontic treatment planning and the early detection of oral disease, the palate's length, depth, and width have all been crucial factors.[5,6] The skull, especially the hard palate, is one of the most useful sex-determination parameters after the pelvis; it is usually well preserved, secured, and retrieved compared to other bones after extreme damage.[7] Human identification procedures are continuously being improved by forensic science, the palate morphology and other detailed Images of the oral cavity can be compared to the database already in existence to generate profiles for the precise identification process.[8]

The palatine index (PI) and palatine height index (PHI) serve as useful tools in assessing patients undergoing prosthodontic treatment, orthodontic planning, and forensic anthropology for skull identification.[9] The greater and lesser palatine foramina, located at the posterior end of the hard palate near the third molars, allow the passage of the greater and lesser palatine nerves and vessels. Due to the importance of structures passing through them and their location, knowledge about their anatomy is important in surgeries of the posterior maxilla, maxillary sinus, reconstruction of cleft palate, and various procedures of the third molar tooth.[10] This research aims to conduct a comprehensive morphometric analysis of the hard palate using human dry skulls to elucidate anatomical variations and their potential clinical implications.

Methods

This anatomical cross-sectional study was conducted at the Department of Anatomy, Services Institute of Medical Sciences (SIMS), Lahore, Pakistan on adult dry human skull specimens of unknown sex available in the department from November 2024 to January 2025 after approval from the Ethical Review Board of the Institution under Ref No. IRB/2024/1466/SIMS, dated: 2nd November 2024. Sixty well-preserved, non-pathological dry human skulls with intact base of the skull, including anterior and middle cranial fossa, and associated structures, will be included, and skulls with broken palates were excluded from the study.

The parameters were measured by two observers independently with predetermined procedures to prevent inter-observer and intra-observer error. The palatal length, breadth and height were measured with the help of digital Vernier calipers. The Palatine Index (PI) for the type of palate, i.e., narrow (Leptostaphyline), intermediate (Mesostaphyline), and wide (Brachystaphyline), was calculated by the formula, i.e, Palatine width/ Palatine length X100. The PI was Classified based on the methodology employed in earlier research.[11-13] Palatal Height index indicates the characteristic arching of the palates.[14] The hard palate is low (Chamestaphyline), intermediate (Orthostaphyline) and deep (Hypsistaphyline). This is measured by: PHI=Palatal height/Palatal breadth×100.

Data will be analyzed using the Statistical Package for Social Sciences (SPSS) version 25.0. All Quantitative variables will be presented as mean and standard deviation. Frequency and percentages were given for qualitative parameters.

Results

Sixty nonpathological adult dry skulls were considered for measurements, including palatal length, which is the distance from the midpoint of the line joining the sockets of upper central incisors to the nasal spine posteriorly. The mean palatal length is 40.56±3.48 mm, while the mean palatal breadth and height were 36.51±2.73mm and 16.45±3.38mm, respectively (Fig.1A, Table-1). The mean Palatine Index and the mean Palatine Height Index were 90.69±10.46 and 45.19±8.97, respectively. (Table-1).

In 72% of the skulls the palate is wide, in 18% it is intermediate and 10% having narrow palate. (Table-2). According to the palatal Height Index indicating the arching pattern of the palate, 75% of the palates are deep, 20% intermediate and 5% are shallow. (Table-3).

Lesser palatine foramina are the openings present

Table-1: Morphometric parameters and indices of the hard palate

Parameters	Count (n)	Mean ± Standard Deviation (SD) in (mm)	Std. Error Mean
Palatal Length	60	40.56mm ±3.48mm	0.4502
Palatal Breadth	60	36.51mm ±2.73mm	0.3533
Palatal Height	60	16.45mm ±3.38mm	0.4370
Palatal Index	60	90.69mm ±10.46mm	1.3511
Palatal Height Index	60	45.19mm ±8.97mm	1.1583

Table-2: The Types of the hard palate according to the palatine index (PI)

Types of Palate	Count (60)	Range	Percentage
Narrow (Leptostaphyline)	6.0	<80%	10%
Intermediate (Mesostaphyline)	11.0	80-85%	18%
Wide (Brachystaphyline)	43.0	>85%	72%

Table-3: The classification of the hard palate according to the palatine height index (PHI)

Types of Palate	Count (60)	Range	Percentage
Low (chamestaphyline)	3.0	<27.9%	5%
Intermediate (Orthostaphyline)	12.0	28-39.9%	20%
Deep (Hypsistaphyline)	45.0	>40	75%

Table-4: The number of Lesser palatine foramen

Right Lesser Palatine Foramen			Left Lesser Palatine Foramen		
2, >2	3	5%	2, >2	9	15%
1	48	80%	1	46	77%
Absent	9	15%	Absent	5	8%

on the posterolateral aspect of the hard palate, present on the base of the pyramidal process of the palatine bones, and allow lesser palatine nerves and vessels to pass through them.[15] In more than 78 % of skulls, it is present on both sides, in 80% of the skulls, it is present on the right side, and 77% on the left. It is absent in 15% of the right and 8% of the left side. The number also varies in different skulls, in 15% of the skulls we observed 2 LPF on the left side and in 5% 2LPF on the right side (Fig.1B, Table-4).

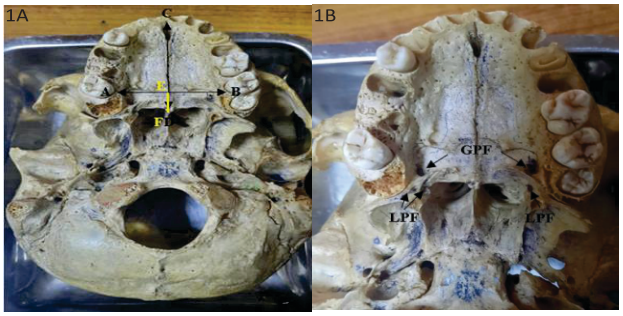

Fig.1A: Showing breadth (AB), length (CD) & height (EF) of the hard palate

Fig.1B: Showing greater and lesser palatine foramen, LPF is present on both sides with two on the right & one on the left side

Discussion

In the present study, which is based on central Punjab, the morphometric variations of the hard palate provide critical insights into its anatomical and clinical implications. The study on 60 well-preserved adult dry skulls identified significant variations in palatal dimensions, indices, and foraminal structures, emphasizing the importance of detailed anatomical knowledge for clinical and forensic applications.

In this study, the mean palatal length was 40.56 ± 3.48 mm, comparable with a study conducted on the South Indian population, where the length of the palate was 40.42 mm.15, but it is less than the data presented in other studies. The mean palatal breadth in our study is 36.51± 2.73mm, which was equivalent to the previous study from India (36.26 ± 2.55mm).[16] but less than the study conducted in Egypt (38.68mm).[17] Mean palatal height was 16.45±3.38 mm, which was more than the studies conducted earlier in Budapest and India .[8,9,14] The Palatine Index (PI), averaged 90.69 ± 10.46,

indicating that 72% of the palates were classified as wide (Brachystaphyline, PI > 85%). Conversely, 18% of the samples were intermediate (Mesostaphyline, PI 80-85%), and only 10% were narrow (Leptostaphyline, PI < 80%). These findings contradict regional morphometric trends observed in Indian and Saudi populations.[2,9,18] The study conducted on Napalese population showed the same results that 84.85% of the palates were Brachystaphyline type.[19] The study conducted in Khyber Pakhtunkhwa showed that narrow palate was more common in the observed data. 4 There is no such study and data available in Punjab; this emphasizes the need for population-specific considerations in prosthodontic and orthodontic planning.

The palatal height, another crucial parameter, had a mean of 16.45 ± 3.38 mm, with the Palatine Height Index (PHI) averaging 45.19 ± 8.97. Based on PHI, 75% of the palates were classified as deep (Hypsistaphyline, PHI > 40), while 20% were intermediate (Orthostaphyline, PHI 28–39.9), and only 5% were low (Chamestaphyline, PHI < 27.9). The data of the present study is comparable with the previous study on the Nepalese population.[19] The predominance of deep palates highlights potential challenges in prosthodontic treatment, as these structures may require specialized appliances and adjustments in this region to ensure stability and function.

The study also analyzed the presence/absence and number of lesser palatine foramina. Among the specimens, 80% had one lesser palatine foramen on the right side, 15% exhibited two or more, and 5% lacked any foramina. On the left side, 77% had one foramen, 15% had two or more, and 8% had none. This data is in agreement with the earlier studies.[9,20,21] This asymmetry of the foramina is clinically significant, particularly for maxillary nerve blocks, cleft palate surgeries, and procedures involving the posterior maxilla, where accurate localization of foramina is essential to minimize iatrogenic complications.

In conclusion, the detailed morphometric evaluation of the hard palate enhances our understanding of its anatomical variations and underscores their critical role in clinical and forensic applications.

Conclusion

Although this study provides valuable morphometric data, its limitations, including the sex, regional, and ethnic diversity, restrict its generalizability. Future studies using advanced imaging modalities, such as cone-beam computed tomography, and involving broader population samples are recommended to validate and expand these findings.

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Author Contributions

YB: Conception and design of the work, writing original draft (methodology, investigation), revising, editing, and supervising for intellectual content

HA: Data acquisition, curation, and statistical analysis, validation of data, interpretation and write-up of results

TA: Data acquisition, curation, and statistical analysis, validation of data, interpretation and write-up of results

ST: Writing original draft (methodology, investigation), revising, editing, and supervising for intellectual content

LS: Conception and design of the work, validation of data, interpretation, and write-up of results