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Morphometric Analysis of Hard Palate Using Cone Beam Computed Tomography for Sex Estimation

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ABSTRACT

Background: Sex determination from skeletal remains is crucial in forensic anthropology. The hard palate, being resistant to postmortem degradation, presents a potential indicator for sex estimation. This study aimed to analyze the hard palate's dimensions and structure in the South Indian population to assess its efficacy in sex determination.

Materials and Methods: The study examined 58 subjects (29 males, 29 females) using cone beam computed tomography (CBCT). Measurements included maxilla-alveolar breadth, maxilla-alveolar length, palatal depth, maxilla-alveolar index, and palatal size. The data were analyzed using descriptive statistics and independent sample t-tests, with significance set at p≤0.05.

KEY WORDS

Cone Beam Computed Tomography, Hard Palate, Sexual Dimorphism, Forensics.

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Results: Significant sexual dimorphism was observed in maxilla-alveolar breadth (male: 61.46±3.55 mm, female: 67.98±4.00 mm, p<0.001), maxilla-alveolar length (male: 48.60±3.98 mm, female: 46.13±3.93mm, p = 0.02), and size of the palate (male: 29.89±3.27 mm, female: 26.80±3.50 mm, p<0.001). The depth of the palate and maxilla-alveolar index showed no statistically significant differences between sexes. The intraclass correlation coefficient demonstrated high reliability for the measurements.

Conclusion: CBCT analysis of the hard palate revealed that maxilla-alveolar breadth, length, and palatal size are reliable indicators for sex determination in the South Indian population. This non-invasive method offers potential applications in forensic anthropology and medical diagnostics, though larger-scale studies are recommended for validation across different populations.

Introduction

The acquisition and analysis of skull fragments for sex determination is an essential facet of forensic anthropology. It is among the most significant aspects of the biological profile in certain forensic instances. The determination of the gender of an individual through their skull bones is not frequently straightforward, and the relevance of the findings could differ based on several circumstances. For instance, trauma, faulty preservation, animal scavenging, or the specifics of the incident may have provoked damage to or loss of several of the skeleton's areas that are implemented for figuring out the sex of an individual. The literature addresses this issue of qualitative sex differentiation through the use of various bones. [1,2] There is a certain extent of sexual dimorphism that exists in almost every component of the human skeleton. The hard palate is one of the 14 indicators that Krogman and Iscan reported with an accuracy of ninety percent, which can help in assessing the sex of an individual [3].

Palatal structures, alongside dental tissues, are impervious to postmortem degradation for several days, which validates the valuable role of forensic dentistry in human identification [4]. On top of that, the oral cavity hedges the palatal and dental structures, rendering them safe from temperature and severe trauma. For the previous reason, morphometric palatal features for individual identification and sex estimation impart an intriguing identification tool in cases involving severe tissue damage.

Highly detailed three-dimensional visualizations of the skull's anatomical components are produced by cone beam computed tomography (CBCT), a contemporary medical imaging approach. It is a significant alternative for future forensics since it has transformed treatment planning and diagnosis in various domains by allowing practitioners to view complex structures and abnormalities precisely and non-invasively [5].

Numerous investigations have focused on the linear dimensions of the hard palate using dry skulls from various geographical populations, which has led to misinterpretations and several flawed techniques [6–8]. Only one study has been found in the literature analyzing the morphometric character of the hard palate using a similar technique in the Arabian population [9]. Known for its reproducible and standard calibration, evaluating these hard palate linear measures using this modality can decrease errors and enhance the reliability of digital forensics. Therefore, this study is aimed at assessing the anatomy of the hard palate using CBCT to ascertain the dimensions and structural variations of the hard palate.

Material and Methods

The 58 subjects in this descriptive retrospective study comprised 29 men and 29 women from the Indian South region. The study samples were monocentric, homogeneous in origin, and chosen using a straightforward purposive sampling technique, including individuals aged 18 to 65. The institutional ethics committee granted ethical approval on 20/05/2023 with approval number 44/2023 with the following inclusion and exclusion criteria:

Inclusion criteria

- Optimally diagnostic quality CBCT images
- CBCT scans that indubitably display the structure of the skull base

Exclusion criteria

- Image with the presence of any developmental anomaly/central pathology involving the base of the skull
- Image with any evidence of previous surgery, fracture, or healed fracture of the base of the skull
- Nondiagnostic CBCT images, including partial images or the presence of artefacts at the base of the skull.

Radiographs satisfying the inclusion criteria were subjected to analysis for the following landmarks in axial and coronal dimensions in Planmeca Romexis 5.3 (3D software, Planmeca Oy, Helsinki, Finland), retrospectively sourced from the archives of the institution's data set.

1. Maxilla-Alveolar length: Prosthion (a point on the alveolar arch midway between the medial and upper incisor teeth) and Alveolon (the point where the mid-sagittal plane of the palate is intersected by a line connecting the posterior borders of the alveolar crests) will be taken as landmarks for length in the coronal plane. [Figure 1A]
2. Maxilla-Alveolar Breadth: The maximum breadth recorded on the lateral surfaces is at the level of the second maxillary molars across the maxilla's alveolar limits in the axial plane. [Figure 1B]
3. Depth of the palate: from the deepest point of the palate until the imaginary line from prosthion to alveolon in the coronal plane [Figure 1A]

We will also calculate and analyze the following parameters after collecting the above-mentioned data:

1. Maxilla-alveolar Index: {Maxilla-alveolar breadth / Maxilla alveolar length} x 100[10]
2. Size of the palate:{Maxilla-alveolar breadth x Maxilla alveolar length} / 100 [11]

The same observer, a certified oral and maxillofacial radiologist well-versed in CBCT, conducted two repetitions of each of these evaluations at a 15-day interval. To compensate for intra-examiner variability, an average of these measurements was adopted.

Statistical Analysis

Following data tabulation and statistical analysis, a comparison of the sex groups was carried out. An independent computation of the mean, SD, p, and t values was performed. The gathered data were subsequently put through the Kolmogorov-Smirnov test and descriptive statistics to determine normality. Given the normal distribution of the data, an independent sample two-tailed t-test was conducted. A p-value of less than or equal to 0.05 was considered statistically significant. The statistical analysis was carried out using SPSS version 23.0.

Results

The mean age of the population was 34.5, with a minimum of 18 years, and the maximum age recorded was 65. Table 1 shows the descriptive data that were used to estimate the mean, standard deviation, maximum, and minimum data based on sex.

As demonstrated in Table 1, a two-tailed t-test for independent samples revealed that the difference between the sexes in terms of the dependent variables -maxillo-alveolar length, maxilla-alveolar breadth, and size of the palate- was statistically significant with p-values less than 0.05. In contrast, the depth of the palate and the maxilla-alveolar index did not differ statistically between the sexes. The intraclass correlation coefficient (ICC) was 0.86 for maxillo-alveolar breadth, 0.91 for maxillo-alveolar length, and 0.84 for depth of the hard palate.

The logistic regression analysis presents results for three predictor variables (maxilla-alveolar breadth,

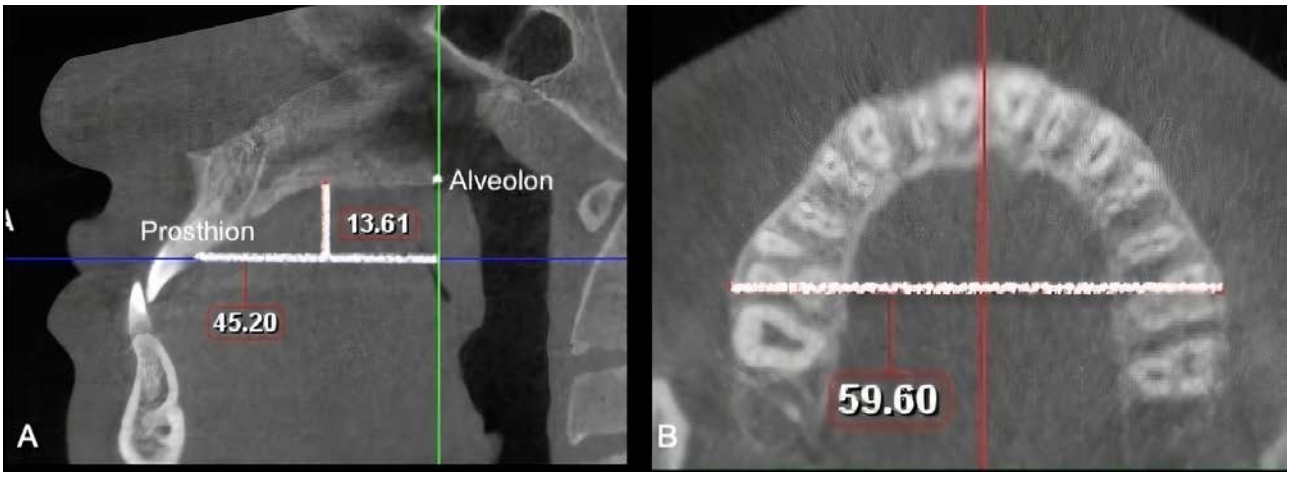

Figure 1: ***A.*** *CBCT image showing the Maxilla-alveolar length and Depth of the palate;* ***B.*** *CBCT image showing the maxilla-alveolar breadth*

maxilla-alveolar length, and size of the palate) and one outcome variable (odds ratio). None of the predictor variables show statistically significant effects on the outcome variable at the conventional alpha level of 0.05, as indicated by their respective p-values being greater than 0.05. Specifically, the coefficients for maxilla-alveolar breadth, maxilla-alveolar length, and size of the palate are 2.159 (p = 0.122), 1.853 (p = 0.100), and -3.402 (p = 0.139), respectively, with corresponding standard errors, Z-scores, and confidence intervals. The intercept, representing the log odds of the outcome variable when all predictor variables are zero, is not statistically significant (p = 0.087). These findings suggest that, within the context of this analysis, the included predictor variables do not significantly influence the outcome variable. [Table 2]

Discussion

The bony structure in the upper portion of the mouth, known as the hard palate, is essential for many aspects of human functionality and the state of health. It is a key component of speech and articulation because it operates as a surface on which the tongue strikes in order to generate specific sounds [12]. Additionally, the hard

Table 1: Descriptive Statistics based on sex with mean, standard deviation, maximum, and minimum values along with inferential analysis where p<0.05 is considered significant.

Parameters	Sex	Mean (mm)	Maximum (mm)	Minimum (mm)	t	p-value
Maxilla-alveolar Breadth	Male	61.46±3.55	68.4	52.8	-3.50	***<0.001***
	Female	67.98±4.00	67.6	61.6		
Maxilla-alveolar Length	Male	48.60±3.98	64.4	40.8	-2.37	***0.02***
	Female	46.13±3.93	64.8	34.8		
Depth of the Palate	Male	16.01±2.84	21.6	10.0	-1.64	0.10
	Female	14.51±3.99	20.8	3.6		
Maxilla-alveolar Index	Male	127.22±12.09	168.7	109.2	-0.46	0.79
	Female	126.39±12.00	164.3	100.9		
Size of the Palate	Male	29.89±3.27	23.0	36.0	-3.48	***<0.001***
	Female	26.80±3.50	19.9	37.0		

Table 2: The logistic regression results show values for maxilla-alveolar breadth, maxilla-alveolar length, and size of the palate.

Variable	Regression Coefficient	Standard Error	Z	Wald's P value	Odd's Ratio	Confidence Interval	
						Lower	Upper
Intercept	-116.586	68.168	-1.710	0.087	2.33x10-15	-250.193	17.022
Maxilla-alveolar breadth	2.16	1.39	1.546	0.122	6.379	-0.578	4.896
Maxilla-alveolar length	1.85	1.125	1.647	0.100	1.546	-0.352	4.058
Size of the Palate	-3.40	2.298	-1.481	0.139	-1.481	-7.905	1.102

palate plays a part in the digestive process by facilitating food mastication and preliminary digestive breakdown. Each of them produces substantial shifts in the hard palate's growth and development, contributing to unique variations. Given that changes in the hard palate may impact oral health and orthodontic therapies, its anatomical features may also be clinically significant [13].

For the purpose of ascertaining the gender of skeletal remains, one may additionally employ the hard palate. Owing to its pristine position and anatomy, it has attracted great interest. According to a study that implemented three-dimensional geometric morphometric methods, gender differences in the hard palate can be used to determine the gender of skeletal remains, as they are statistically significant [14]. In this study, men had a higher proportion of accuracy in identifying sex based on their hard palate. According to Alves et al., a U-shaped palate is male, but a V-shaped palate is female [15]. Additionally, at 18 to 20 years old, gender disparities in the thickness of the bony palate were discovered in a pilot investigation employing computed tomography [16].

The techniques used for assessing a person's sex from their cranium either use specific measurements of various components of the skull or hinge on visually discernible descriptive aspects of the skull. Experts can apply the observational approach with accuracy, but lay individuals can't employ it without training and experience, and it becomes inaccurate when misapplied. Currently, we are using imaging modalities for more precise analysis due to their standard calibration. The accuracy of cone beam computed tomography's (CBCT) sex determination varies depending on the specific anatomical features and regions being analyzed. In forensic anthropology, CBCT scans are sometimes used to examine the craniomaxillofacial region, which can provide valuable information for sex determination [5]. Many authors have analyzed the morphometry of the hard palate through dry skull studies [6,8,15].

Numerous investigations have been undertaken regarding sex prediction using metric and non-metric hard palate analyses in various populations. For instance, an analysis of dry skulls from South India quantified the hard palate with a vernier calliper on 24 male and 18 female skulls. The study discovered that its findings aligned with another survey of the hard palate in dry skulls from Central India [14]. The following research evaluated the dry skulls of 312 adult individuals of both sexes and concluded that the pyriform aperture and hard palate, both of which encompass metric and non-metric features, have significance for sex prediction [15]. Additionally, palatal dimensions reveal sexual dimorphism and can be employed as sex predictors under a morphometric study examining the hard palate and its significance to dentistry and forensic sciences [17]. These studies illustrate how the hard palate can potentially be used to predict sex in a range of demographics.

Maxilla-alveolar Length and Breadth

Skeletal remains can be analyzed for sex using the length of the maxilla alveolar and the breadth of the hard palate. According to Sumati et al. [18], in specific racial groupings, men had longer hard palates and wider maxilla-alveolar breadths on average than women, which is also consistent with the research carried out by Song et al. and Burris et al. [19,20]. The same, however, cannot be said with certainty about mixed-race or unidentified-race groups because of their unambiguous overlap. Similar outcomes were also noted in the present study, with noteworthy findings indicating that sexual dimorphism is present in maxilla-alveolar breadth and length.

Maxilla-alveolar index

The maxilla-alveolar index can be projected using the linear measures of maxilla-alveolar length and breadth, providing it with a collective perspective. An osteological study by Sumati et al. in North Indian communities revealed that the index was greater in females than in males [18,21]. Comparably, radiological studies in the Iraqi population by Abdul Ameer and Fatah discovered that Iraqi females had a greater maxilla-alveolar index, which does not correspond to the case in the present study [22]. The current investigation revealed higher values in males than in females, which was in contrast to the findings of other studies. However, the maxilla-alveolar index was shown to be an unfavorable feature for sex estimation, as none of the research cited had any significance with regard to it.

Size of the Palate

Research has presented evidence that the size of the palate, which was determined using the same linear

measurements, is a sexually dimorphic characteristic [18,23-25]. In 1949, Wood conducted research on a wide range of American populations, including white Americans, Black Americans, Inuit people, Native Americans, and Mongolians [23]. Meanwhile, Larnach and Macintosh examined the coastal New South Wales and Queensland regions, respectively. All three researchers demonstrated that men have a much larger palate [24,25]. Implementing metric measurements, Sumati et al. revealed that males had larger palates, with a size categorization accuracy of 70% based on measurements taken from a community of North Indians [18]. The current study's result, which reveals concurrently significant outcomes, is supported by all of the studies mentioned above.

Depth of the Palate

The depth of the palate was another linearly dependent variable examined in this study. A study on the palatal vault of primary dentition by Tsai et al. found that the mean palatal depth was 10.77 mm in males and 10.67 mm in females, with no statistically significant disparities between the sexes [26]. According to another study, males often have a deeper palate than females of the same age, which also indicates that the depth of the palate grows with age [6]. Males had greater values than females in the present analysis. Similar to these studies, the present study showed a significant positive correlation.

Any investigation based on the dimensions of the hard palate depends substantially on the community being studied because a wide range of determinants influence the size and shape of the palatal bone in different communities at large. To ensure that the findings of a study conducted in one demographic cannot be extrapolated to another, it is recommended that comparable research be carried out on a more extensive database and that these constraints be considered when interpreting the study's findings.

One limitation of the current study is its tiny sample size. We recommend investigating their role in sex estimation through larger-scale research.

Another limitation is the use of a particular kind of CBCT device with a predetermined FOV (field of vision) and voxel size. Changing study settings or employing different equipment may have an impact on the image's resolution, producing results that may vary.

Conclusion

To comprehend the hard palate's structural changes, dimensions, and their correspondence to the presence of sexual dimorphism, this study used quantifiable measures of the hard palate and concluded that parameters such as maxilla-alveolar length, maxilla-alveolar breadth, and size of the palate are dependable and statistically significant sexual indicators. Utilizing cutting-edge imaging methods, especially CBCT, offers a more comprehensive knowledge of the diversity of the hard palate.

The imaging modality not only has relevance in therapeutics, diagnostics, and craniofacial morphology but can also be helpful for precise population profiling and sex determination in forensic anthropology. Overall, this work lays the groundwork for future investigations and applications in the fields of craniofacial science and forensic medicine by highlighting the importance of morphometric analysis of the hard palate in both clinical and forensic contexts. **R**

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Conflict of Interest

None

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None

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