

Gender determination using maxillary sinus parameters and distance of mental foramen from lower border of mandible: a cone beam computed tomography analysis in Nepalese subpopulation

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Editor: Dr. Altair A. Del Bel Cury

Received: April 20, 2024

Accepted: November 26, 2024

Aim: To assess the reliability of morphometric measurements performed on the maxillary sinus and the distance of mental foramen from the lower border of mandible for gender determination by cone beam computed tomography (CBCT).

Materials and Methods: A total of 390 CBCT images were included in this study. The length, width and height of the maxillary sinus and the distance from the superior and inferior border of the mental foramen to the lower border of mandible were assessed. All the measured parameter data was then subjected to discriminative statistical analysis and analyzed using unpaired t-test. P-value ≤ 0.05 was considered as significant. Logistic regression analysis was done to determine which measures were more predictive of sexual dimorphism. Discrimination values were determined by receiver operating characteristic curve analysis, thus generating area under the curve (AUC) values, which ranged from 50% (very weak) to 100% (very strong). **Results:** The overall values of the maxillary sinus dimensions were significantly greater ($p \leq 0.05$) in males as compared to females except right maxillary sinus length and left maxillary sinus width ($p = 0.162$). The distances from the superior and inferior border of mental foramen to lower border of mandible were significantly greater ($p \leq 0.05$) in males as compared to females. The accuracy of the maxillary sinus and the mental foramen for gender identification was found to be 65.5% and 73.8% respectively. **Conclusion:** CBCT measurement of the maxillary sinus and distance from the mental foramen to the lower border of the mandible can be used as a supplementary tool for gender determination in forensic anthropology.

Keywords: Maxillary sinus. Mental foramen. Sex characteristics. Cone-beam computed tomography. Forensic anthropology.



Introduction

Human identification holds significant importance in forensic medicine. Among various methods of human identification, gender determination plays a crucial role in identifying skeletal remains of missing individuals¹.

Fingerprints, DNA profiling, and dental evidence are essential techniques in human identification. Among osseous structures, the skull and pelvis best demonstrate sexual dimorphism².

The maxillary sinuses, situated bilaterally in the maxilla, are the largest paranasal sinuses. They typically begin development around the end of the second embryonic month and generally stabilize by the second decade of life³.

The mental foramen is also a stable landmark on the mandible. It can be easily recognized by the forensic odontologists on radiographs⁴.

CBCT provides clinicians with three-dimensional and multi-planar views, enhancing diagnostic precision and treatment planning while avoiding the financial costs and radiation exposure associated with conventional CT scans⁵. Additionally, CBCT enables quicker and more accurate measurements of the maxillary sinus and mental foramen compared to traditional radiography.

Due to the need for gender estimation when postmortem data from primary identifiers is unavailable, the desire to utilize a more advanced radiographic tool in the human identification process, and the limited studies in this field, especially using the cone beam computed tomography (CBCT) technique this study aimed to examine maxillary sinus and mental foramen variables measured via CBCT for sex determination in Nepalese subpopulation.

Materials and Methods

Before conducting the present research, ethical clearance was obtained from the Institutional Review Committee of Kathmandu University School of Medical Sciences, Dhulikhel Hospital, Kathmandu (No.41/20). The procedures followed the ethical standards of the responsible committee on human experimentation (institutional or regional) and the Helsinki Declaration of 1975, revised in 2013.

A retrospective study was carried out in the Dental Department of a tertiary care centre from February 2021 to June 2021.

The following inclusion criterias were adopted : age group more than 20 years, high-quality images with known patient's age, gender and origin, patients with at least 28 teeth and with no missing teeth or systemic disease were selected. Distorted, overlapped, unclear images, images with gross artifacts, images that did not show proper anatomic details of the area of interest, patients associated with periapical infections, periodontal pathologies and sinus pathologies, subjects with pathologic lesions in the jaws near site of interest were excluded from the study.

Convenience sampling technique was used to collect the data and sample size was calculated using the following formulae

$$n = [Z^2 \times p(1-p)] / e^2$$

$$= 385$$

Where, n= minimum required sample size

Z = 1.96 at 95% of Confidence Interval (CI)

p = proportion of population is taken as 50% for maximum sample size calculation

e = margin of error, 5%

A total of 600 CBCT radiographs were scanned, of which 390 were included. All radiographs had been taken using Dentium Rainbow CBCT machine (having specifications as scan Time: 20 seconds, peak Voltage: 100 kVp, tube Current: 12 mA, Field of View: 16cm x 18cm, voxel size: 300 μ m). All CBCTs were shot at 80kVp, 7.0mA and scan time 17 seconds in standard mode. Volume CT data was acquired. Multi-planar reconstruction was performed on a viewing workstation to obtain axial and coronal images. The axial and sagittal slices in the CBCT were aligned by default according to the orthogonal planes, with a slice thickness of 0.5 mm. The obtained images was viewed and analyzed in Rainbow™ Image Viewer Version 1.0.0.0. The images were viewed on the same computer screen using the same image viewer, under ambient light with all curtains closed by an oral radiologist with more than three years of experience in CBCT reporting.

The width of the maxillary sinus was measured as the longest distance from the medial wall to the lateral wall of the maxillary sinus in the axial view (Figure 1). The same length was measured as the longest distance from the anterior wall to the posterior wall in the axial view (Figure 1). The height was measured as the longest distance from the superior wall to the inferior wall or floor of the maxillary sinus on the coronal view (Figure 2).



Figure 1. Width and length of maxillary sinus in axial view

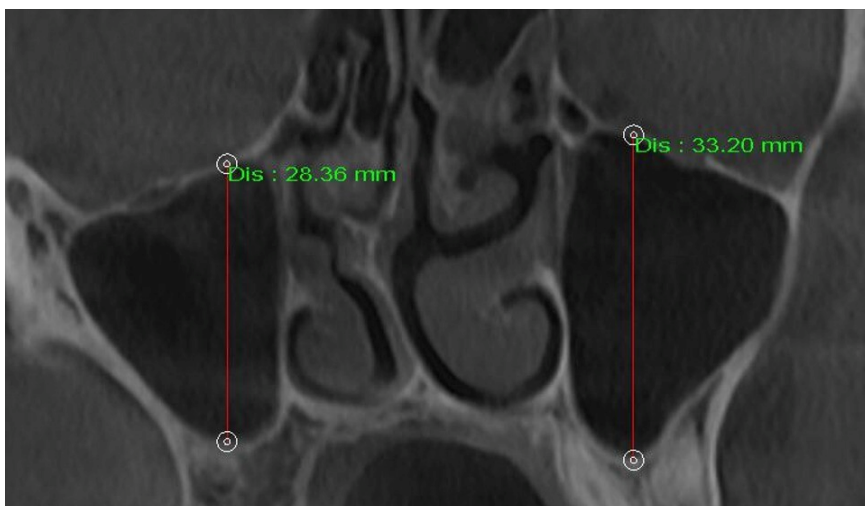


Figure 2. Height of maxillary sinus in coronal view



Figure 3. Measurements of mental foramen

The mental foramen was measured by drawing tangents along the lower border of the body of the mandible. A perpendicular line was drawn separately from the inferior (ILM) and superior (SLM) point of outline of the mental foramen to the tangent drawn along the lower border of the body of the mandible (maximum parabolic curvature) and the distance was measured on both sides. (Figure 3).

Statistical analyses was done using SPSS (version 20.0, Statistical Package for the Social Sciences, IBM, USA), with differences considered significant at the 95% level. Mean value of each linear measurement was then calculated. Statistical analysis was done by calculating the mean and standard deviation of both maxillary sinuses and mental foramen measurements which were calculated and compared. All the measured parameter data was then subjected to discriminative statistical analysis and analyzed using unpaired t-test. P-value ≤ 0.05 was considered as significant. Logistic

regression analysis was done to determine which measures were more predictive of sexual dimorphism. Discrimination values were determined by receiver operating characteristic curve analysis, thus generating area under the curve (AUC) values, which ranged from 50% (very weak) to 100% (very strong).

Results

In the present study, total of 390 CBCT scans were analysed. Of these, 46.2% (180) were females and 53.8% (210) were males. The mean patient age was found to be 34.14 years with a standard deviation of 14.71 years (range 20-79 years).

The mean of different variables of right maxillary sinus (width, length and height) for males were 25.58 mm, 36.54 mm and 33.93 mm respectively and for females were 22.84 mm, 35.14 mm and 30.79 mm respectively (Table 1). According to the Student's *t*-test, there was a statistically significant difference between males and females in the right maxillary sinus width and right maxillary sinus height (Table 1). The mean of different variables of left maxillary sinus (width, length and height) for males were 24.38 mm, 36.47 mm and 34.66 mm respectively and for females were 22.56 mm, 34.43 mm and 31.39 mm respectively (Table 1). According to the Student's *t*-test, there was a statistically significant difference between males and females in the left maxillary sinus length and left maxillary sinus height (Table 1).

Table 1. Comparison of parameters (width,length,height) of right and left Maxillary Sinus between males and females

Parameter	Gender	Mean±SD(mm)	T	p value
Right maxillary sinus width	Male	25.58±4.67	2.673	.009*
	Female	22.84±4.65		
Right maxillary sinus Length	Male	36.54±4.68	1.411	.162
	Female	35.14±4.31		
Right maxillary sinus Height	Male	33.93±5.96	2.515	.014*
	Female	30.79±5.45		
Left maxillary sinus width	Male	24.38±4.83	1.663	0.10
	Female	22.56±5.06		
Left maxillary sinus Length	Male	36.47±3.31	2.549	.013*
	Female	34.43±3.83		
Left maxillary sinus Height	Male	34.66±6.36	2.503	.014*
	Female	31.39±5.56		

Based on the logistic regression analysis (Table 2), the gender predictability was the highest for Right maxillary sinus length and the lowest for Right maxillary sinus height. With the help of maxillary sinus, the gender determination was established correctly with accuracy of 65.5%.

Table 2. Accuracy level for each parameter in determining gender.

Parameter	% Correctly Classified
Right maxillary sinus width	60.7 %
Right maxillary sinus Length	64.3%
Right maxillary sinus Height	58.3%
Left maxillary sinus width	60.7 %
Left maxillary sinus Length	60.7%
Left maxillary sinus Height	60.7%

Based on the regression coefficients, a formula was developed to predict the probability of the gender based on height, length and width of maxillary sinus.

$$\text{Predicted probability (P)} = 1/e^{-(\beta_0 + \beta_1 \times \text{height} + \beta_2 \times \text{length} + \beta_3 \times \text{width})}$$

Where β_0 is the intercept, and $\beta_1, \beta_2, \beta_3$ are the coefficients for each of the predictor variables.

Right maxillary sinus:

$$\text{Predicted probability (P)} = 1/1 + e^{-[4.489 + (-0.09 \times \text{right width}) + (0.000 \times \text{right length}) + (-0.062 \times \text{right height})]}$$

Left maxillary sinus:

$$\text{Predicted probability (P)} = 1/1 + e^{-[6.278 + (-0.001 \times \text{left width}) + (-0.112 \times \text{left length}) + (-0.06 \times \text{left height})]}$$

The mean of right and left SLM for males were 17.14 mm and 17.27 mm respectively and for females were 16.001 mm and 15.42 mm respectively. The mean of right and left ILM for males were 13.54 mm and 13.29 mm respectively and for females were 12.57 mm and 12.35 mm respectively. According to the Student's *t*-test, there was a statistically significant difference between males and females in both Right and left SLM and ILM (Table 3).

Table 3. Comparison of different parameters of right and left Mental Foramen between males and females.

Parameter	Gender	Mean±SD(mm)	t	p value
RightSLM	Male	17.14±2.002	2.68	0.009*
	Female	16.001±1.88		
Right ILM	Male	13.54±1.84	2.32	0.023*
	Female	12.57±1.92		
Left SLM	Male	17.27±2.29	4.34	0.000*
	Female	15.42±1.6		
Left ILM	Male	13.29±2.37	2.18	0.031*
	Female	12.35±1.55		

SLM- Distance from superior border of mental foramen to inferior border of mandible.

ILM- Distance from inferior border of mental foramen to inferior border of mandible.

Based on the logistic regression analysis (Table 4), the gender predictability was the highest for left SLM, followed by left ILM and right ILM and the lowest for right SLM.

And with the help of location of mental foramen, gender could be correctly predicted with accuracy of 73.8%.

Table 4. Accuracy level for each parameter in determining gender.

Parameter	% Correctly Classified
Right SLM	63.1 %
Right ILM	66.7 %
Left SLM	75%
Left ILM	71.4%

SLM- Distance from superior border of mental foramen to inferior border of mandible.

ILM- Distance from inferior border of mental foramen to inferior border of mandible.

Based on the regression coefficients, a formula was developed to predict the probability of the gender based on height, length and width of maxillary sinus.

$$\text{Predicted probability (P)} = 1/e^{-(\beta_0 + \beta_1 \times \text{SLM} + \beta_2 \times \text{ILM})}$$

Where β_0 is the intercept, and β_1 and β_2 are the coefficients for each of the predictor variables.

Right Mental Foramen:

$$\text{Predicted probability(P)} = 1/1 + e^{-[5.131 + (-0.262 \times \text{right SLM}) + (-0.037 \times \text{right ILM})]}$$

Left Mental Foramen:

$$\text{Predicted probability(P)} = 1/1 + e^{-[9.118 + (-0.666 \times \text{left SLM}) + (0.155 \times \text{right ILM})]}$$

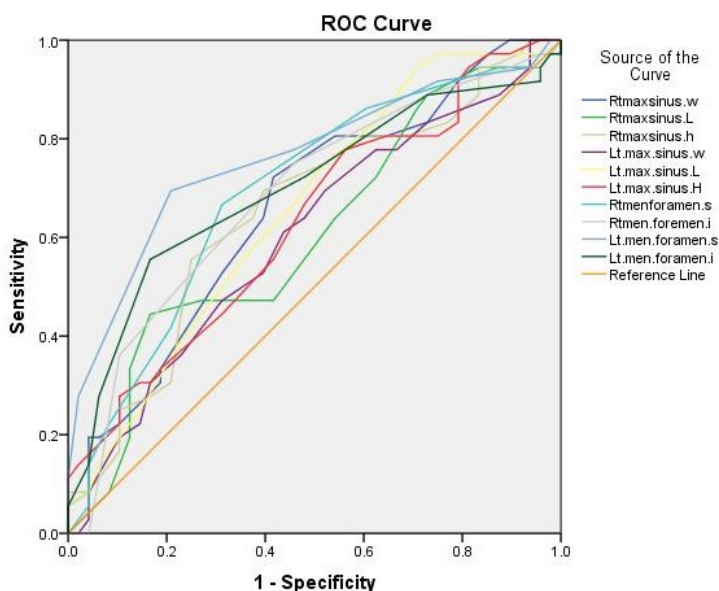


Figure 4. ROC curve for gender determination for different parameters.

A receiver operating characteristic curve (ROC) was created which showed area under the curve for different parameters (Figure 4) and cut off value was determined (Table 5). If the values were greater than or equal to the cut-off values, the sex was estimated to be male.

Table 5. Area under the curve for different variables and optimum cut off value.

Test Result Variable(s)	Area under the curve	Optimum Cut-off Value (mm)
Right maxillary sinus width	0.661	23.5
Right maxillary sinus Length	0.607	38.5
Right maxillary sinus Height	0.654	33.5
Left maxillary sinus width	0.603	23.5
Left maxillary sinus Length	0.655	36.5
Left maxillary sinus Height	0.629	33.5
Right SLM	0.692	16.5
Right ILM	0.684	12.5
Left SLM	0.762	16.5
Left ILM	0.700	13.5

Discussion

Gender determination from human skeleton is an important forensic procedure. In the present study, the dimensions of maxillary sinus were found to be greater in males compared to females as consistent with many studies⁶⁻¹¹. Contrary to our findings, Barros et al.¹² (2022) and Gulec et al.¹³ (2020) in their study of volumetric analysis of the maxillary sinus did not find significant statistical differences between the genders.

Deshpande et al.⁷(2022) in their study reported statistically significant difference between males and females in the maxillary sinus height (right and left side) and Left Sinus Length. Such statistically significant difference could not be found in the width and Right Sinus Length of the maxillary sinus for males and females⁷.

Waluyo et al.⁹ (2020) showed significant differences in the maxillary sinus height, length and width between Indonesian men and women⁹. Whereas, in the present study statistically significant difference were found between males and females in the right maxillary sinus width, right maxillary sinus height, left maxillary sinus length and left maxillary sinus height.

A similar study from Iran by Akhlaghi et al.¹⁴ (2017) reported statistically significant difference between males and females with respect to maximum height and maximum width of sinuses of right and left sides. They also demonstrated that the female group had statistically significant lower values for both the left and right MS in context to the length, height and width dimensions¹⁴. However, in the present study no statistically significant difference was found between males and females concerning the width of maxillary sinuses of left side.

In the present study the correctly predicted gender was 65.5% using maxillary sinus parameter and it was highest for right maxillary sinus length. Whereas Deshpande et al.⁷ (2022) reported that the gender predictability was the highest for height, followed by length, and the lowest for width. They found gender identification correctly with an accuracy of 71.3% in males and females. Teixeira et al.¹⁵ (2020) reported the overall accuracy rate of gender determination to be 73.6%. They reported right maxillary sinus Height (66.9%) and left maxillary sinus length (64.0%) were the best individual discriminators. Paknahad et al.⁶ (2017) and Mathew and Jacob¹⁶ (2020) also showed that the maxillary sinus height was the best pronounced variable in the differentiation of gender groups.

The mental foramen, located on the mandible, is a consistent anatomical landmark among many others in the human skull¹⁷. Despite alveolar bone loss above the mental foramen, the distance from the foramen to mandible's inferior border remains relatively consistent or stable over time, making it a reliable landmark on the mandible¹⁸.

In the present study, SLM and ILM values in males on both sides were higher compared to the females. These findings align with many previous researches^{17,19-21}. Conversely, a study by Shams et al.²² (2019) conducted on the Iranian population revealed no discernible sexual dimorphism in the vertical positioning of the mental foramen.

ILM were almost similar in gender predictability with respect to sides. Therefore, the distance from any of the sides of ILM can be used as a representative for gender discrimination and is in agreement with Vodanović et al.²³ (2006), who found that the mean value of ILM of both the sides is equal to each other; any side can be used to determine sexual dimorphism²³.

SLM values shows higher predictability using left side. This results in partial agreement with the study of Agthong et al.²⁴ (2005), who have found differences in several measurements, suggestive that both gender and side should be considered when applying the anatomical variation data to an individual subject²⁴.

The variation observed in the reported accuracy rates of the previous studies were probably because of diverse ethnic and racial groups, various methodological and statistical analysis applied, different radiographic techniques, and different sample size.

As observed in this study, we found it difficult to identify the superior border of the mental foramen which is generally in continuation with the body of the mandible, could be also one of the key attributes to the variation in the results seen above.

Our study also had a few limitations. Being a retrospective study, factors such as environmental factors, ethnic and racial groups, the history of maxillary sinus pathologies, etc., which could have caused variation in the maxillary sinus could not be known.

In conclusion, the results from the present study showed that the length, width and height, perimeter, and area of the maxillary sinuses were greater in men compared to women. Thus, CBCT measurements of maxillary sinus can be used as a supplementary tool for gender determination in forensic anthropology, especially in cases where other traditional methods are not conclusive.

Moreover, the distance from mental foramen to the lower border either side of the mandible shows clear sexual dimorphism, thus can be used as an effective tool for gender discrimination.

Data availability

Datasets related to this article will be available upon request to the corresponding author.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Approval

The Ethical approval was obtained from the the Institutional Review Committee of Kathmandu University school of Medical Sciences, Dhulikhel hospital, Kathmandu (No.41/20)

Author Contribution

Harleen Bali: Conceptualization, Investigation, Methodology, Project administration, Writing- original draft, Writing-review and editing. **Manisha Neupane:** Conceptualization, Writing-review and editing. **Nitin Khanduri:** Visualization, Supervision, Writing-review and editing. **Swagat Kumar Mahanta:** Formal analysis, Result validation, Writing-review and editing. **Chandan Upadhaya:** Conceptualization, Visualization, Writing-review and editing. **Gaurav Pratap Singh:** supervision, Writing-Review and editing. All authors actively participated in the discussion of the manuscript's finding, revised and approved the final version of the manuscript.

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