Morphometric analysis for gender determination using maxillary sinus on panoramic radiographs- a retrospective study

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ABSTRACT

Human identification in forensic investigations relies on the assessment of biological parameters such as age, sex, and stature. When conventional identification methods are limited, forensic dentistry plays a crucial role. Sex determination is a primary step in skeletal identification, and craniofacial structures—particularly the maxillary sinus—exhibit marked sexual dimorphism. Panoramic radiography provides a practical and non-invasive method for evaluating these structures. To analyze the dimensions of right and left maxillary sinuses on panoramic radiographs of adult subjects and assess their usefulness in gender determination.

A retrospective cross-sectional study conducted at the Department of Oral Medicine and Radiology, People's Dental Academy, Bhopal, Madhya Pradesh, India.

Digital panoramic radiographs of 800 individuals aged 20–60 years with complete permanent dentition were evaluated. Maxillary sinus height and width on both sides were measured using calibrated PLANMECA ROMEXIS 2.9.2.R software. Radiographs with sinus pathology, positioning errors, or history of maxillary surgery were excluded.

Data analysis was performed using SPSS version 22. Mean and standard deviation were calculated, and comparisons between genders were made using the Independent Student's t-test. A p value <0.05 was considered statistically significant.

All maxillary sinus dimensions were significantly greater in males compared to females on both sides (p <0.001). Height and width measurements of the right and left maxillary sinuses demonstrated consistent sexual dimorphism.

Maxillary sinus dimensions measured on panoramic radiographs show significant sexual dimorphism and can serve as a reliable adjunct in gender determination for forensic identification

Keywords: Forensic dentistry; Gender determination; Maxillary sinus; Panoramic radiography; Sexual dimorphism

INTRODUCTION

Sex determination is a fundamental component of biological profiling in forensic investigations, as it significantly narrows the pool of potential identities and facilitates subsequent estimation of age and stature.[1] The human skeleton has traditionally served as the primary source for sex estimation because of its pronounced sexual dimorphism.[1] However, in cases involving mutilated, decomposed, or fragmented remains, commonly used skeletal indicators such as the pelvis and skull may be unavailable or compromised.[2] This limitation underscores the need to explore alternative anatomical structures capable of demonstrating measurable and reliable sexual dimorphism.[2]

The maxillary sinus has emerged as one such structure of forensic importance. Age-related changes in maxillary sinus volume have been documented, indicating that its dimensions vary systematically over time and may assist in biological profiling.[3] Due to its protected anatomical location within the maxilla and relative resistance to postmortem destruction, the maxillary sinus has been proposed as a valuable structure in forensic identification.[4] Subsequent investigations have demonstrated significant sexual dimorphism in maxillary sinus morphology and dimensions, reinforcing its utility in gender determination.[5],[6],[7]

With advancements in dental imaging, radiographic evaluation of the maxillary sinus has gained increasing relevance in

Dr. Palak Dawrani , Dr.Hina Handa , Dr.Christopher Vinay Shinde, Dr. Shubha Sharma

forensic sciences. Panoramic radiography (orthopantomogram, OPG) provides bilateral visualization of the maxillary sinuses in a single image and is widely available in routine dental practice.[8],[9] The availability of ante -mortem panoramic records further enhances its value in comparative forensic identification.[10] Several studies have demonstrated the effectiveness of panoramic radiographs as a forensic aid in age and gender estimation.[11],[12],[13] These investigations have reported statistically significant differences in maxillary sinus dimensions between males and females when assessed using panoramic radiographs, supporting their applicability in sex determination..

Beyond two-dimensional imaging, computed tomography (CT) has been utilized to measure maxillary sinus size and volume with greater precision, demonstrating improved diagnostic accuracy in forensic gender determination.[14] Cone -beam computed tomography (CBCT) has further enhanced morphometric evaluation by providing high -resolution three-dimensional imaging of sinus anatomy.[15] Three-dimensional analytical approaches have strengthened the reliability of sex estimation based on maxillary sinus characteristics.[16] Recent CT-based morphometric studies conducted in different populations have reaffirmed the diagnostic significance of volumetric assessment of the maxillary sinus.[17] Similarly, CBCT-based investigations have demonstrated consistent sexual dimorphism in sinus morphology, further supporting its forensic applicability.[18],[19]

More recently, advanced computational methodologies incorporating artificial intelligence architectures have been introduced for automated classification of sex and age using maxillary sinus parameters, reflecting the evolving integration of technology in forensic identification.[20]
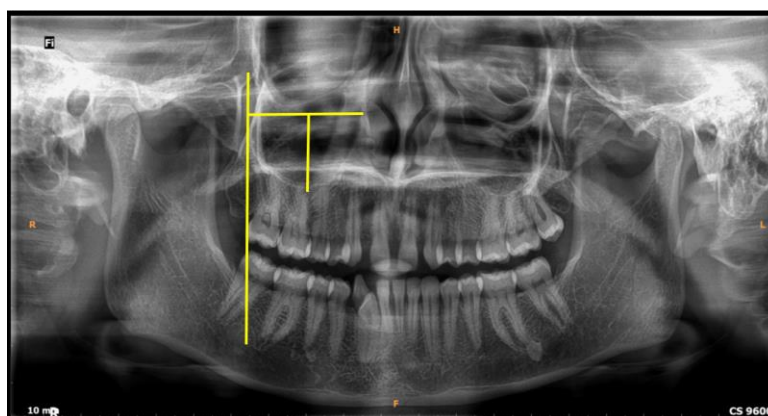
Despite the superior dimensional accuracy offered by CT and CBCT, their routine forensic application may be limited by higher costs, restricted accessibility, and radiation considerations.[14],[15] In contrast, panoramic radiography remains cost-effective, widely accessible, and suitable for large-scale and retrospective studies.[11]–[13] When standardized imaging protocols and digital measurement techniques are employed, OPG-based morphometric analysis of the maxillary sinus provides reproducible and clinically meaningful results.[13]

Therefore, the present study aims to assess sexual dimorphism of the maxillary sinus using morphometric measurements obtained from orthopantomograms, with the objective of evaluating its reliability and applicability as a non -invasive, accessible, and practical tool for forensic sex determination.

MATERIALS AND METHODS

A retrospective radiographic study was conducted in the Department of Oral Medicine and Radiology, People's Dental Academy, Bhopal, Madhya Pradesh, India. A total of 800 digital panoramic radiographs of individuals aged 20 –60 years were evaluated. Radiographs of subjects with complete permanent dentition, fully developed bilateral maxillary sinuses, and acceptable image quality were included. Images showing sinus pathology, developmental anomalies, history of sinus lift or trans-maxillary surgery, positioning errors, missing teeth, or skeletal abnormalities were excluded.

All radiographs were acquired using a digital panoramic unit and analysed using PLANMECA ROMEXIS software version 2.9.2.R (Planmeca Proline XC; Planmeca USA, Inc., licensed to Planmeca India). For calibration, Linear measurements were obtained using the "straight line" tool. Vertical reference lines were drawn along the distal borders of each maxillary sinus, and horizontal lines perpendicular to these were used to determine sinus width. Sinus height was measured by extending a vertical line from the midpoint of the width to the sinus floor. (figure 1-image of one of the panoramic radiographs used,showing how the width and the height of maxillary sinuses were measured.)
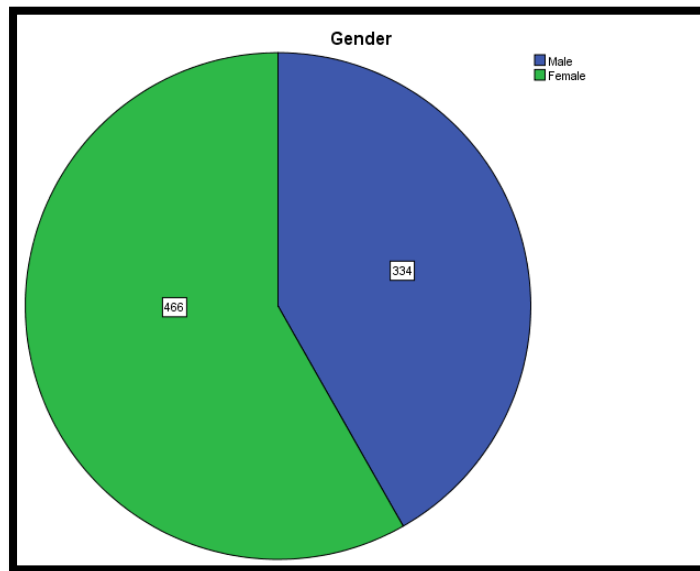

(Figure 1-image of one of the panoramic radiographs used,showing how the width and the height of maxillary sinuses were measured.)

Measurements of right and left maxillary sinus height and width were recorded along with the gender of each subject.

Dr. Palak Dawrani , Dr.Hina Handa , Dr.Christopher Vinay Shinde, Dr. Shubha Sharma

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software, version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation. Data distribution was assessed and parametric tests were applied. Gender-based comparisons of maxillary sinus dimensions were performed using the Independent Student's t-test. A two-tailed p value <0.05 was considered statistically significant, and p <0.001 was considered highly significant, with a confidence level set at 95%. All selected radiographs fulfilled the inclusion criteria, and no loss to observation was recorded.

RESULTS

Analysis of 800 digital panoramic radiographs revealed a higher proportion of females (58.3%) compared to males (41.8%). (FIGURE.2 Descriptive statistics of gender distribution).

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The mean age of females was marginally higher than that of males. (FIGURE 3 Age distribution among genders).
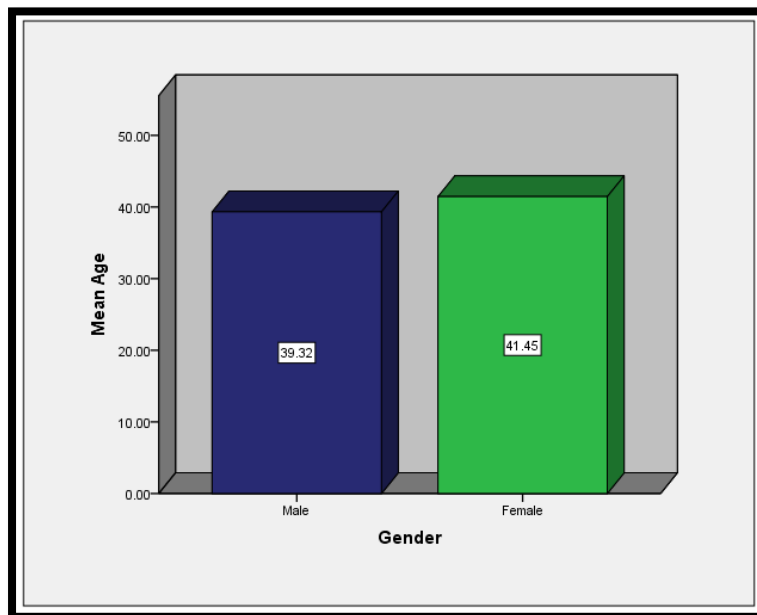

FIGURE 3 Age distribution among genders

This demographic distribution indicates adequate representation of both genders across the adult age range.

Dr. Palak Dawrani , Dr.Hina Handa , Dr.Christopher Vinay Shinde, Dr. Shubha Sharma

All measured maxillary sinus parameters—height and width on both right and left sides—were consistently greater in males than in females.(Table 1 Mean height and width of maxillary sinus among gender distribution)

Table 1: Mean height and width of maxillary sinus among gender distribution

	Gender			
	Male		Female	
	Mean	SD	Mean	SD
Left Sinus Height	31.39	1.56	24.09	.79
Left Sinus Width	48.06	1.03	41.83	1.22
Right Sinus Height	30.88	1.22	24.68	1.16
Right Sinus Width	48.12	.93	41.35	1.24

The left maxillary sinus height and width were significantly higher in males compared to females ($p < 0.001$), indicating pronounced sexual dimorphism in left maxillary sinus dimensions. (Table 2: Comparison of the left sinus height among gender) , (Table 3: Comparison of the left sinus width among gender).

Table 2: Comparison of the left sinus height among gender

		Left Sinus Height		T value	P value
		Mean	SD		
Gender	Male	31.39	1.56	86.7	<0.001**
	Female	24.09	.79		

Dr. Palak Dawrani , Dr.Hina Handa , Dr.Christopher Vinay Shinde, Dr. Shubha Sharma

Table 3: Comparison of the left sinus width among gender

		Left Sinus Width		T value	P value
		Mean	SD		
Gender	Male	48.06	1.03	75.9	<0.001**
	Female	41.83	1.22		

Similarly, right maxillary sinus height and width measurements were significantly greater in males than in females (p < 0.001). (Table 4: Comparison of the Right sinus height among gender), (Table 5: Comparison of the Right sinus width among gender).

Table 4: Comparison of the Right sinus height among gender

		Right Sinus Height		T value	P value
		Mean	SD		
Gender	Male	30.88	1.22	72.9	<0.001**
	Female	24.68	1.16		

Table 5: Comparison of the Right sinus width among gender

		Right Sinus Width		T value	P value
		Mean	SD		
Gender	Male	48.12	.93	84.1	<0.001
	Female	41.35	1.24		

The presence of statistically highly significant differences on both sides suggests bilateral symmetry in sexual dimorphism of the maxillary sinus. The consistent and highly significant gender-based differences in maxillary sinus dimensions observed in this study support the reliability of maxillary sinus measurements obtained from panoramic radiographs as a useful adjunct

Dr. Palak Dawrani , Dr.Hina Handa , Dr.Christopher Vinay Shinde, Dr. Shubha Sharma

in gender determination. These findings reinforce the applicability of panoramic radiography in forensic identification, particularly in situations where other skeletal indicators may be unavailable or compromised.

DISCUSSION

Sex determination remains a pivotal step in forensic identification, as it significantly reduces the pool of potential matches and enhances the accuracy of subsequent biological profiling.[1] The human skeleton, particularly the pelvis and skull, has traditionally been considered the most reliable indicator of sex due to marked sexual dimorphism.[1,2] However, in circumstances involving fragmentation, advanced decomposition, or destruction of remains, these conventional skeletal markers may not be available, necessitating the exploration of alternative anatomical structures.[2]

The present study evaluated the reliability of maxillary sinus morphometry on panoramic radiographs for sex determination. The maxillary sinus, owing to its deep anatomical location within the maxilla, is relatively well protected from external trauma and postmortem destruction, thereby serving as a stable structure for forensic identification.[3] Ariji et al.[3] demonstrated that the maxillary sinus exhibits age-related volumetric changes, highlighting its dynamic anatomical nature and contribution to biological profiling. Furthermore, Fernandes[4] emphasized the forensic relevance of the maxillary sinus, particularly in circumstances where conventional skeletal markers are unavailable or severely compromised. Together, these observations support the rationale for utilizing maxillary sinus morphometry as a dependable adjunct in forensic sex determination.

Consistent with earlier literature, the findings of the present study support the presence of sexual dimorphism in maxillary sinus dimensions. Previous morphometric analyses have demonstrated statistically significant differences between males and females, attributing these variations to genetic, hormonal, and developmental influences.[5,6,7] Males generally exhibit larger sinus dimensions compared to females, likely reflecting overall craniofacial growth patterns and skeletal robustness.[5,6] These observations reinforce the potential of sinus morphometry as a dependable parameter in gender estimation.

Panoramic radiography has gained attention as a practical tool in forensic investigations due to its widespread availability and routine use in dental practice.[8,9] The presence of ante-mortem OPG records enhances its value in comparative identification.[10] Studies by Bhuyan et al.[11] and Iswani et al.[12] demonstrated the applicability of panoramic radiographs in age and gender estimation, while Divyadharsini and Maheswari[13] reported significant differences in adult maxillary sinus dimensions between sexes using panoramic imaging. The findings of the present study are in agreement with these investigations, supporting the diagnostic utility of OPG-based morphometric analysis in sex determination.

Although panoramic radiographs are subject to magnification and distortion, the use of standardized imaging protocols and digital measurement techniques can enhance reproducibility and minimize observer variability.[13] In contrast, computed tomography (CT) provides more precise volumetric measurements and has been shown to improve the accuracy of sex estimation through assessment of sinus size and volume.[14] Similarly, cone-beam computed tomography (CBCT) offers high-resolution three-dimensional imaging, enabling detailed morphometric evaluation of sinus anatomy.[15] Three-dimensional analytical methods have further strengthened the reliability of sex determination using sinus parameters.[16]

Recent CT-based studies conducted in diverse populations have reaffirmed the significance of maxillary sinus morphometry in gender determination.[17] Furthermore, CBCT-based investigations have consistently demonstrated sexual dimorphism in sinus morphology, highlighting its applicability across different ethnic groups.[18,19] These findings suggest that sinus-based morphometric assessment possesses cross-population relevance, although population-specific standards remain essential for improved accuracy.

Emerging advancements in artificial intelligence (AI) have introduced automated classification systems capable of predicting sex and age based on maxillary sinus characteristics.[20] Such computational approaches demonstrate promising accuracy and may reduce operator-dependent variability. The integration of AI with radiographic imaging represents a significant advancement in forensic identification, particularly for large-scale and retrospective analyses.[20]

Despite the superior accuracy of CT and CBCT, their routine forensic use may be limited by higher cost, accessibility constraints, and radiation exposure concerns.[14,15] In contrast, panoramic radiography remains cost-effective, widely accessible, and suitable for large population-based studies.[11–13] Therefore, OPG-based morphometric evaluation of the maxillary sinus continues to hold substantial practical relevance, particularly in resource-limited settings.

Within the limitations inherent to two-dimensional imaging, the findings of the present study support the reliability of maxillary sinus measurements on panoramic radiographs as an adjunctive tool for sex determination. While advanced three-dimensional modalities provide enhanced precision, OPG remains a pragmatic and clinically feasible alternative for forensic investigations.

Overall, the results corroborate previous literature and reaffirm that morphometric assessment of the maxillary sinus can serve as a valuable supplementary parameter in forensic sex determination. Future research incorporating larger, population-specific datasets and advanced computational techniques may further refine its diagnostic accuracy and broaden its forensic applicability.

Dr. Palak Dawrani , Dr.Hina Handa , Dr.Christopher Vinay Shinde, Dr. Shubha Sharma

Summary of the Study

The present retrospective study assessed the role of morphometric analysis of the maxillary sinus on panoramic radiographs for gender determination in adults. Digital panoramic radiographs of 800 individuals obtained from the Department of Oral Medicine and Radiology, People's Dental Academy, Bhopal (M.P.), India, were evaluated. Standardized digital software and reference markers were used to measure the height and width of the right and left maxillary sinuses under controlled conditions.

The study included dentate individuals aged over 20 years to ensure complete sinus development and minimize age-related variability. Statistical analysis demonstrated significant sexual dimorphism, with males exhibiting greater maxillary sinus height and width than females on both sides. No significant bilateral differences were observed within the same gender, indicating symmetry of sinus dimensions. Satisfactory intra-observer reliability confirmed the reproducibility of the measurement technique.

The findings support the forensic relevance of the maxillary sinus as a reliable anatomical structure for gender determination, particularly in situations where conventional skeletal indicators are damaged or unavailable. The results were consistent with previously reported studies using panoramic radiography and computed tomography, reinforcing the validity of sinus morphometry as a supplementary forensic tool.

CONCLUSION

Within the limitations of this retrospective study, morphometric analysis of the maxillary sinus on panoramic radiographs was found to be a simple, reliable, and cost-effective method for gender determination in adults. Maxillary sinus height and width can be effectively used as supplementary parameters in forensic identification, particularly in fragmented remains and mass disaster scenarios. When combined with other forensic and dental indicators, this method can enhance the accuracy of human identification. Future studies involving larger, diverse populations and incorporating three-dimensional imaging and artificial intelligence–based analysis are recommended to further strengthen the applicability and predictive accuracy of maxillary sinus morphometry.

LIMITATIONS OF THE STUDY

Despite its findings, the present study has certain limitations. The retrospective design restricted control over variables such as ethnicity, nutritional status, and environmental influences, which may affect craniofacial morphology. The reliance on two-dimensional panoramic radiographs introduces inherent limitations related to image distortion and magnification, which may influence measurement accuracy. Additionally, only linear measurements were assessed, whereas volumetric analysis may provide higher discriminatory accuracy.

The study sample, although adequate, was derived from a single institution and population group, which may limit the generalizability of the results. Advanced imaging modalities such as CT and CBCT, while offering greater precision, were not employed due to their limited availability and higher cost in routine forensic practice.

REFERENCES

[1] Krogman WM, İşcan MY. The human skeleton in forensic medicine. 2nd ed. Springfield: Charles C Thomas; 1986. p. 189–243.

[2] Kranioti EF. Forensic anthropology: Sexual dimorphism in skeletal remains. Forensic Sci Res. 2015;1(1):1–7.

[3] Ariji Y, Kuroki T, Moriguchi S, Ariji E, Kanda S. Age changes in maxillary sinus volume. Dentomaxillofac Radiol. 1994;23(3):163–8.

Dr. Palak Dawrani , Dr.Hina Handa , Dr.Christopher Vinay Shinde, Dr. Shubha Sharma

[4] Fernandes CL. Maxillary sinus in forensic identification. Am J Forensic Med Pathol. 2004;25(4):302–13.

[5] Paknahad M, Shahidi S, Zarei Z. Sexual dimorphism of maxillary sinus. J Forensic Sci. 2017;62(2):395–8.

[6] Belaldavar C, Kotrashetti VS, Hallikerimath S. Maxillary sinus morphometry. J Oral Maxillofac Pathol. 2014;18(1):86–90.

[7] Sharma SK, Kaur N, Chander S. Maxillary sinus and gender. J Forensic Dent Sci. 2020;12(1):15–20.

[8] Kiran CS, Ramaswamy P, Kumar PR. Gender determination using OPG. J Oral Maxillofac Radiol. 2019;7(1):1–6.

[9] Nikam SS, Gadgil RM. Maxillary sinus and sex determination. J Dent (Tehran). 2015;12(8):586–92.

[10] de Queiroz CL, Terada ASS, Dezem TU, Araújo LG, Galo R, Oliveira-Santos C, et al. Sex determination of adult human maxillary sinuses on panoramic radiographs. Acta Stomatol Croat. 2016;50(3):215–21.

[11] Bhuyan R, Mohanty S, Bhuyan SK, Pati A, Priyadarshini S, Das P. Panoramic radiograph as a forensic aid in age and gender estimation: A preliminary retrospective study. J Oral Maxillofac Pathol. 2018;22:266–270.

[12] Iswani R, Wulandari R, Lisfrizal H. Differences in the width of male and women maxillary sinus seen from panoramic radiography in Minang tribe students. J Dentomaxillofac Sci. 2021;6(1):35–38.

[13] Divyadharsini V, Maheswari TU. Assessment of adult maxillary sinus dimension in panoramic radiographs for sex determination. J Popul Ther Clin Pharmacol. 2023;30(10):180–186.

[14] Prabhat M, Rai S, Kaur M, Prabhat K, Bhatnagar P, Panjwani S. CT based forensic gender determination by measuring maxillary sinus size and volume. J Forensic Dent Sci. 2016;8(1):40–46. doi:10.4103/0975 1475.176950

[15] Paknahad M, Shahidi S, Zarei Z. Sexual dimorphism of maxillary sinus dimensions using cone beam computed tomography. J Forensic Sci. 2017;62(2):395–8.

[16] Jeon EY, Ahn HN, Park JT. Sex determination through 3D analysis of the maxillary sinus. Iran J Public Health. 2022;51(6):1435–41.

[17] Ominde BS, Ikubor JE, Iju WJ, Ebeye A, Igbigbi PS. Morphometry of the maxillary sinus and its role in sex determination in Delta State Nigeria: retrospective CT study. J Indian Acad Forensic Med. 2023;45(1):21–7.

[18] Fathima T, Pillai DSP. CBCT evaluation of maxillary sinus morphology for forensic gender determination: South Indian study. J Craniofac Surg. 2024;35(3):e214–20.

[19] Tahreem F, Pillai DS. CBCT evaluation of maxillary sinus in forensic gender determination. J Chem Health Risks. 2024;14(1):1145–1149.

[20] Anees W, Silva R, Khan A, et al. Maxillary sinus classification for sex and age using 23 artificial intelligence architectures. Sci Rep. 2026. doi:10.1038/s41598-026-36112-1.