Original Article

Sex Determination by Maxillary Sinus Dimensions using Cone-Beam Computed Tomography and Discriminant Function: An Analytical Study

Ramhari S. Sathawane, Vidyarjan A. Sukhadeve, Rakhi M. Chandak, Ashish B. Lanjekar, Gunjan V. Moon

From the Department of Oral Medicine and Radiology, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, Maharashtra, India

Abstract

Background: Sex determination of unknown persons plays an important role in forensic medicine. Zygomatic bone and maxilla remain intact although the skull and other bones may be badly disfigured in victims who are incinerated. Cone-beam computed tomography (CBCT) is an excellent radiographic modality for accurate measurement of the maxillary sinus (MS) dimensions.

Aim: To determine sex by MS measurements using CBCT scans and discriminant function.

Objectives: To measure and compare the MS dimensions in males and females.

Materials and Methods: Sixty CBCT scans showing bilateral MSs of 30 males and 30 females were retrieved and evaluated. The parameters such as width, length, and height were measured and recorded. The data were analyzed using unpaired *t*-test and discriminant function analysis to assess sexual dimorphism.

Results: Statistically significant differences are observed between males and females in respect to the MS height and length on both the right and left MSs, whereas statistically significant difference is observed in respect to width only on the right MS. The accuracy rate of sex determination was 73% in males and 69% in females, with overall accuracy of 71%. The most pronounced parameter in differentiation of sex is the MS height. The discriminant equations are derived for both right and left MSs.

Conclusion: MS dimensions can be used as an aid in forensic anthropology for the determination of sex. MS height is found to be the most predictive parameter in sex determination. The prediction from the derived discriminant equations is found accurate ≥80% for both sexes and both right and left MSs.

Key Words: *Cone-beam computed tomography scans, forensic medicine, maxillary sinus dimensions, sex determination, sexual dimorphism*

Received: 24 March, 2020.
Revised: 11 May, 2020.
Accepted: 28 May, 2020.
Published: 29 June, 2020.

Introduction

Gender identification is an unique procedure in forensic medicine as sex assessment constitutes an important step in constructing a postmortem profile.[1] Recently, judicial demand for gender identification has increased because of an increase in criminal cases involving young people, irregular immigration, and modern crimes. Conventional radiology has got some limitations in its applications to forensic medicine in the field of gender identification. Visual inspection and precise measurement of the bone dimensions often exceed radiologic contribution, particularly where the identification of skeletal remains is required. Still, radiography is one of the commonly used modalities in forensic medicine for the identification of human, particularly where the body is decomposed, fragmented, or burned. The skull, pelvis, and femora are the most useful body parts for the radiographic determination of gender, whereas the skull is the most useful body part for comparison radiography.[2]

It is thus imperative to use bones that are often recovered intact such as maxilla for sex estimation. It has been reported that zygomatic bones and maxilla remain intact although the skull vault and other bones may be badly damaged in victims who are incinerated.[3]

Maxillary bones contain air spaces/cavity called as maxillary sinuses (MSs) which can be of various sizes and shapes. They start appearing at the end of the second embryonic month and attain their mature sizes at the age of about 20 years, when the permanent teeth are fully developed and tend to stabilize

Access this article online

Quick Response Code:

Website: www.ijofo.org

DOI: 10.4103/ijfo.ijfo_8_20

Address for correspondence:
Dr. Vidyarjan A. Sukhadeve, E-mail: vidyarjan99@gmail.com

How to cite this article: Sathawane RS, Sukhadeve VA, Chandak RM, Lanjekar AB, Moon GV. Sex determination by maxillary sinus dimensions using cone-beam computed tomography and discriminant function: An analytical study. Int J Forensic Odontol 2020;5:19-22.

after the second decade of life. Radiographic images provide adequate measurements of the MSs for use in morphometric forensic analysis that cannot be approached by other means.[4]

Various radiographic imaging techniques such as conventional radiography and computed tomography (CT) have been used in forensic anthropology to evaluate the paranasal sinuses' dimensions for determining sex of an individual including measurements on dry skulls.[5-10] Magnetic resonance imaging and CT are the gold standard methods to depict the true anatomy of the Highmore's antrum. However, their use is restricted by their high dose and cost. These limitations are overcome with the introduction of cone-beam CT (CBCT).[11-13]

Hence, the present study is conducted to determine sex by the MS measurements using CBCT scans and discriminant function.

Materials and Methods

The study sample included retrospective CBCT scans of the bilateral MSs of 60 subjects (30 males and 30 females) in the age group of 20–50 years. The sample size was determined considering 76% level of accuracy with 20% relative precision and 95% confidence level as reported by Paknahad *et al*.[5] as follows:

$$n = \frac{Z^2 (1-\alpha) \times p (1-p)}{d^2}$$

where,

Z^2 $(1-\alpha)$ = standard normal score for 5% level of significance = 1.96

P = percentage level of accuracy = 76% =0.76

d = relative precision = (0.20 × 0.76)

Therefore,

$$n = \frac{(1.96)^2 \times 0.76 \times 0.24}{(0.20 \times 0.76)^2} = 30$$

Therefore, 30 males and 30 females were included in this study.

These CBCT images were acquired with Sirona Orthophos SL, Germany CBCT Unit, with Xelis software, in the Department of Oral Medicine and Radiology of Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur. Retrospective CBCT scans without imaging errors/distortions, showing disease-free MSs and having all maxillary permanent teeth, selected by convenience sampling method, are included in the study.

The three longest straight distances (height, width, and length or depth) were measured for the right and left MSs on the axial and coronal sections as follows:

1. The width of the MS was measured as the longest distance perpendicular from the medial wall of the sinus to the most lateral wall of the lateral process of the MS in the axial view [Figure 1]
2. The length (depth) was measured as the longest distance from the most anterior point to the most posterior point of the medial wall in the axial view [Figure 2]
3. The height was measured from the inner surface of the anterior border of the MS as the longest distance from the lowest point of the sinus floor to the highest point of the sinus roof in the coronal view [Figure 3].

The measurements were recorded as:

Right MS length (RMSL), left MS length (LMSL), right MS width (RMSW), left MS width (LMSW), right MS height (RMSH), and left MS height (LMSH).

To assess the correctness of measurements, of 60 CBCT scans, 30 scans were randomly selected from the study scans, and MS measurements were again taken after 15 days by the same observer in the presence of another observer. It was found that there was no difference in the recorded measurements.

Data were analyzed in a statistical software "STATA" version 10.1, 2011 (StataCorp LP, Texas, USA). Descriptive statistics was used to summarize quantitative variables by mean and standard deviation and qualitative variables by frequency and percentages. Inferential statistics included test of significance and P values. Mean difference is compared by unpaired t-test. Comparison between the right and left MS was done using paired t-test, and $P \leq 0.05$ is considered statistically significant. Discriminant analysis (DA) is used to predict the sex from MSs.

Results

Table 1 shows the mean, standard deviation, and P value of all predictor variables for male and females. According to the Student's t-test, there was statistically significant difference between males and females in the right length, left length, right height, left height, and right width. However, no significant difference was found between males and females concerning the left width of the MS.

A discriminant function analysis was then performed to assess whether the measurements of the MSs could be used for sex determination. Multiple logistic regressions were performed to generate an equation that could reliably classify the observations according to sex.

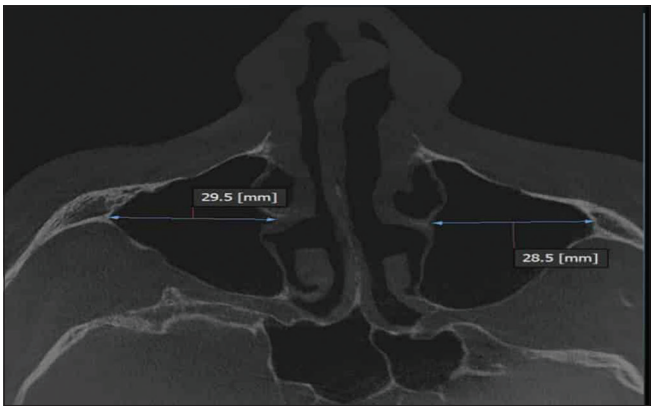

Figure 1: Width of the maxillary sinus in the axial view

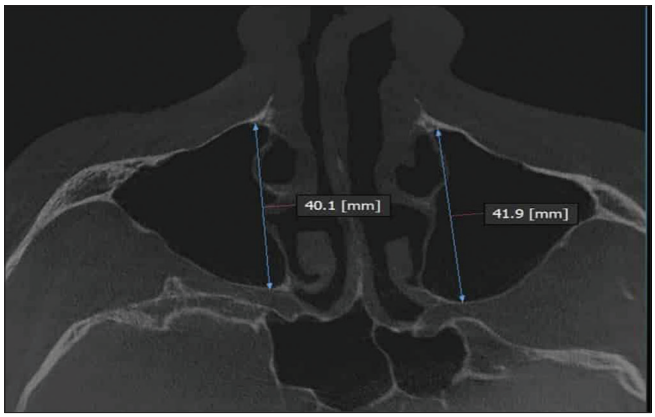

Figure 2: Length of the maxillary sinus in the axial view

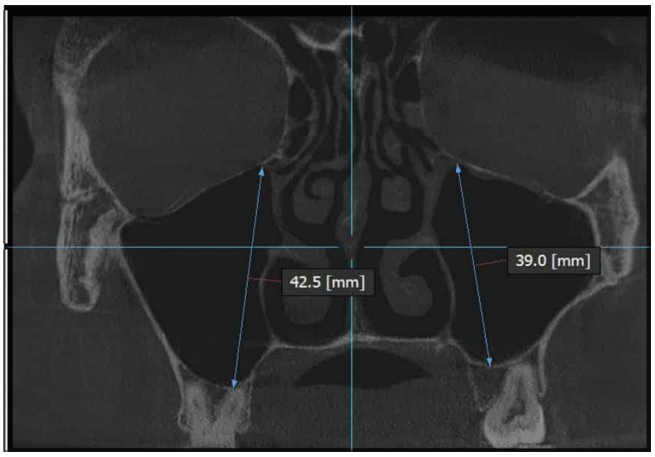

Figure 3: Height of the maxillary sinus in the coronal view

Based on DA, the most pronounced variable in the differentiation of sex groups was the MS height. The sex predictability was the highest for height, followed by length, and the lowest for width. Sex assessment was established correctly with an accuracy of 73% for males and 69% for females, with a mean accuracy of 71% [Table 2].

Following equations for sex determination from measurements by the multiple logistics regression are derived as follows:

Right MS: Sex (D) = −22.54+ (0.47 × RMSL) + (-0.47 × RMSW) + (0.52 × RMSH)

Left MS: Sex (D) = −20.54+ (0.41 × LMSL) + (−0.51 × LMSW) + (0.57 × LMSH).

D score >0 indicates male and <0 indicates female. Predictions from derived equations were found accurate for ≥80% for both sexes (male and female) and both sides (right and left).

Table 1: Descriptive analysis of maxillary sinus measurements in males and females

Parameters	Sex	Mean (mm)±SD	*P*
RMSL	Male	39.61±3.29	0.0001*
	Female	36.02±2.62	
LMSL	Male	38.58±3.42	0.0004*
	Female	35.64±2.53	
RMSW	Male	28.87±2.85	0.0088*
	Female	26.77±3.13	
LMSW	Male	28.02±3.03	0.49**
	Female	27.42±3.64	
RMSH	Male	37.57±4.66	0.0001*
	Female	31.52±2.61	
LMSH	Male	36.79±3.79	0.0001*
	Female	31.92±2.28	

*Highly significant, **Not significant. RMSL: Right maxillary sinus length, LMSL: Left maxillary sinus length, RMSW: Right maxillary sinus width, LMSW: Left maxillary sinus width, RMSH: Right maxillary sinus height, LMSH: Left maxillary sinus height, SD: Standard deviation

Discussion

Determination of sex from the remains of the human skeleton is an important forensic procedure. It has been reported that the sex can be determined with an accuracy of 100% if entire skeleton is available. A total of 98% accuracy can be achieved from both the pelvis and the skull.[14-17]

Many previous studies clearly showed that the MS exhibited anatomic variability between sexes. It was also noted that genetic diseases, postinfections, and environmental factors can affect the sizes of MS.[18-20] Considering this, the scans of subjects with disease conditions were excluded from the study. The current study was designed to determine the reliability and accuracy of MS dimensions measurement as a method for sex identification using CBCT on 60 subjects (30 males and 30 females). In the present study, a significant difference was found in the height and length of MSs. There was no significant difference between sexes in the MS width. It was found that the most pronounced variable in the differentiation of sex groups was the MS height. The sex predictability was the highest for height, followed by length, and the lowest for width. Sex assessment was established correctly with an accuracy of 73% for males and 69% for females, with a mean accuracy of 71%. The discriminant equations were derived for both right and left MSs which can be used for the determination of sex.

Soman[20] conducted a study on 30 patients which showed statistically significant lower sinus parameter values in females than males, with the sinus height being a relatively better predictor for sexual dimorphism. These findings are in accordance with the findings of present study.

Tambawala *et al*.[4] observed that the females had statistically significant lower values for both the left and right MS in context to the length, height, and width dimensions as compared to males.

Teke *et al*.[15] found the accuracy of 69.4% in females and 69.2% in males for sex determination. The accuracy in the present study is found comparatively greater than this study.

Sharma *et al*.[18] conducted a study showed an accuracy of 68.9% for females and 65.16% for males, with overall accuracy of 67.03%. The accuracy in the present study is found comparatively greater than this study.

Table 2: Results of discriminant analysis

Parameters	Sex	DA	
		Accuracy (%)	Errors
RMSL	Male	73.33	26.67
	Female	60	40
LMSL	Male	76.67	23.33
	Female	70	30
RMSW	Male	70	30
	Female	60	40
LMSW	Male	70	30
	Female	53.33	46.67
RMSH	Male	70	30
	Female	86.67	13.33
LMSH	Male	76.67	23.33
	Female	76.67	23.33

*Accuracy for males=73%, for females=69%, total=71%. DA: Discriminant analysis, RMSL: Right maxillary sinus length, LMSL: Left maxillary sinus length, RMSW: Right maxillary sinus width, LMSW: Left maxillary sinus width, RMSH: Right maxillary sinus height, LMSH: Left maxillary sinus height

Conclusion

CBCT is a significant advance in dentomaxillofacial radiography, and it is becoming increasingly available in the dental practice for forensic purposes. Sex determination is an important step in the identification of individuals. From the present study, the following conclusions are drawn:

1. MS dimensions of males exceeded that of females, thus exhibiting sexual dimorphism between sexes
2. The overall accuracy rate of MS measurements for sex determination was 71% in a central Indian population
3. MS height is the strongest predictor for sex determination followed by MS length
4. The discriminant equations for sex determination are derived for the right and left MSs
5. The prediction from derived discriminant equations is found accurate ≥80% for both sexes and both sides of the MSs.

Recommendations of the Study

It is recommended for using the proposed discriminant equations derived for the right and left MSs in the present study for sex determination of Central Indian population.

Limitations of the Study

- As the CBCT machines are available mostly in major cities of India, there are less referral and access for CBCT scans for general population
- It is recommended to conduct further studies on large sample size.

Financial Support and Sponsorship

Nil.

Conflicts of Interest

There are no conflicts of interest.

References

1. Saccucci M, Cipriani F, Carderi S, Di Carlo G, D'Attilio M, Rodolfino D, *et al*. Gender assessment through three-dimensional analysis of maxillary sinuses by means of cone beam computed tomography. Eur Rev Med Pharmacol Sci 2015;19:185-93.
2. Sidhu R, Chandra S, Devi P, Taneja N, Sah K, Kaur N. Forensic importance of maxillary sinus in gender determination: A morphometric analysis from Western Uttar Pradesh, India. Europ J General Dent 2014;3:53-6.
3. Ravali CT. Gender determination of maxillary sinus using CBCT. Int J Appl Dental Sci 2017;3:221-4.
4. Tambawala SS, Karjodkar FR, Sansare K, Prakash N, Dora AC. Sexual dimorphism of foramen magnum using Cone Beam Computed Tomography. J Forensic Leg Med 2016;44:29-34.
5. Paknahad M, Shahidi S, Zarei Z. Sexual dimorphism of maxillary sinus dimensions using cone-beam computed tomography. J Forensic Sci 2017;62:395-8.
6. Vidya CS, Shamasundar NM, Manjunatha B, Raichurkar K. Evaluation of size and volume of maxillary sinus to determine gender by 3D computerized tomography scan method using dry skulls of South Indian origin. Int J Curr Res Rev 2013;5:97-100.
7. Ali AR, Al-Nakib LH. The value of lateral cephalometric image in sex identification. J Baghdad Coll Dent 2013;25:54-8.
8. Kim GR. A morphological study of the paranasal sinuses in Koreans. Yonsei Med J 1962;3:11-7.
9. Amin MF, Hassan EI. Sex identification in Egyptian population using Multidetector Computed Tomography of the maxillary sinus. J Forensic Leg Med 2012;19:65-9.
10. Sahlstrand-Johnson P, Jannert M, Strömbeck A, Abul-Kasim K. Computed tomography measurements of different dimensions of maxillary and frontal sinuses. BMC Med Imaging 2011;11:8.
11. Lenza MG, Lenza MM, Dalstra M, Melsen B, Cattaneo PM. An analysis of different approaches to the assessment of upper airway morphology: A CBCT study. Orthod Craniofac Res 2010;13:96-105.
12. Ahmed AG, Gataa IS, Fateh SM, Mohammed GN. CT scan images analysis of maxillary sinus dimensions as a forensic tool for sexual and racial detection in a sample of Kurdish population. Europ Sci J 2015;11.
13. Ariji Y, Ariji E, Yoshiura K, Kanda S. Computed tomographic indices for maxillary sinus size in comparison with the sinus volume. Dentomaxillofac Radiol 1996;25:19-24.
14. Naeem A, Nadia K, Saluja SA, Taseer B, Akhtar H. Evaluation of gender by measuring the size of maxillary sinus using computed tomographic scan in Indian Population. J Int Oral Health 2015;7:88-92.
15. Teke HY, Duran S, Canturk N, Canturk G. Determination of gender by measuring the size of the maxillary sinuses in computerized tomography scans. Surg Radiol Anat 2007;29:9-13.
16. ELbaz DA, El-Shall O, El Kolaly H. Sexual dimorphism by analysis of maxillary sinus dimensions in a sample of Egyptian population using cone beam computed tomography. Al-Azhar Dent J Girls 2019;6:385-90.
17. Sheikh NN, Ashwinirani SR, Suragimath G, Kumar KS. Evaluation of gender based on the size of maxillary sinus and frontal sinus using paranasal sinus view radiographs in Maharashtra population, India. J Oral Res Rev 2018;10:57-61.
18. Sharma SK, Jehan M, Kumar A. Measurements of maxillary sinus volume and dimensions by computed tomography scan for gender determination. J Anatomical Soc India 2014;63:36-42.
19. Urooge A, Patil BA. Sexual dimorphism of maxillary sinus: A morphometric analysis using cone beam computed tomography. J Clin Diagn Res 2017;11:ZC67-70.
20. Soman C. CBCT evaluation of gender dimorphism using maxillary sinus in a small subpopulation in Riyadh. Global J Res Analysis 2019;8:1-3.