Original Article

A Comparative Study on the Accuracy of an Odontometric and Radiographic Method for Determination of Sex in Western Uttar Pradesh Population

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ABSTRACT

Context: This comparative study was conducted in the field of forensic odontology for sex determination.

Aims: This study aimed to evaluate the reliability and accuracy of an odontometric method and a radiographic method for sex determination.

Settings and Design: The study was conducted in the department of oral medicine and radiology on 100 participants (52 males and 48 females) with an age range of 20–36 years.

Subjects and Methods: Both methods were applied on each participant, and the data were collected. After obtaining the data (casts and radiographs), they were coded, analyzed, decoded, interpreted, and statistically analyzed.

Statistical Analysis Used: The data were entered into MS Excel and then analyzed with SPSS version 19. Analysis was done in two parts. Part 1 dealt with descriptive statistics and Part 2 dealt with inferential statistics.

Results: In the present study, when both the parameters were compared, mesiobuccal–distolingual diagonal diameter showed the maximum accuracy of 92% followed by distobuccal–mesiolingual diagonal diameter with an accuracy of 91%, while area and perimeter of the maxillary sinus had an accuracy of 80%, and 76%, respectively.

Conclusions: Odontometric method is more reliable and accurate than radiographic method for determination of sex.

Key Words: *Forensic odontology, maxillary sinus, odontometric method, sex determination*

Introduction

Identification of humans is a mainstay of civilization and of paramount importance in a social setup. Medico-legally, the term identification means complete or partial determination of individuality of a person.[1] Sex determination is a very important aspect in the identification of an individual and, therefore, is the focus of many studies and is of huge interest to forensic experts and anthropologists. Sexual dimorphism is defined as the systematic difference in form between males and females of the same species. It aids by excluding half of the population and thereby narrowing down the search to identify the person.[1,2] Hence, sex determination forms a vital step in the process of identification and guides forensic experts and investigating teams to undertake more focused search and hasten the course of investigation.[3]

In forensic dentistry, various methods have been used for sex determination which include cheiloscopy, palatoscopy, buccolingual dimensions of teeth, mandibular canine index, buccal mucosa smears (Barr bodies), and frontal and maxillary sinus morphology.[4-6] Accuracy of sex determination by hard tissues is considered to be almost 100%. Among the hard tissues, teeth play a very prominent role as they are resistant to decomposition. Teeth remain intact even after death, as enamel is the hardest tissue of the body. Skeletonized remains that are found may be partial or incomplete, whereas out of all teeth, few may be recovered that can assist in investigation. In case of teeth, forensic odontometrics can be applied in all age groups (infants and adults).[3] Hence, teeth form a very useful tool in forensic identification.[3,7,8]

The use of skull radiographs to compare sinuses is a well-established method when it comes to forensics for identification of individuals or in cases of mass disasters.[9] It has been reported that in cases where the skull and other bones may be badly disfigured or when the whole skeleton is not available, maxillary sinuses remain intact; hence,

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width, length, and height of maxillary sinus can be used for identification or for gender determination.[6]

Maxillary sinus is an air-filled space present bilaterally in the skull. It is located in the maxillary bone, having thin walls, and can be in various sizes and shapes. The apex of the sinus extends into the zygomatic process, and the floor is formed by the alveolar process.[8] The maxillary sinus is the first to develop (10 weeks *in utero*) and largest of all the paranasal sinuses. Pneumatization of the sinus continues into the developing alveolar ridge, after birth, as the permanent teeth erupt. At 12–13 years of age, the sinus floor is level with the nasal floor. The pneumatization of the sinus ends when the sinus reaches 5 mm inferior to the nasal floor, at age 20, with the completion of the eruption of the third molars.[10]

Various studies on maxillary sinus for sex determination have been conducted using different methods: from the skull, radiographic techniques, and advanced imaging techniques such as computed tomography (CT) scan. Radiographs which are being used to view maxillary sinus and their evaluation are lateral cephalogram, posteroanterior view, and Water's projection. Three-dimensional (3D) view of the maxillary sinus can be obtained by CT scan. Dried skulls have also been used to study maxillary sinuses by direct measurements or through radiograph.

The intend of the study is to emphasize the importance of maxillary molar teeth (an odontometric method) and maxillary sinus area (a radiographic method) in sexual dimorphism in forensic odontology. Hence, it was undertaken to check its reliability and accuracy in sex determination.

Subjects and Methods

The present study was conducted on the population of western Uttar Pradesh, India, after obtaining approval from the ethics committee. The study included 100 participants, including 52 males and 48 females, with age ranging from 20 to 36 years. After explaining the entire procedure to the patients, a written consent was obtained. A thorough detailed oral examination was conducted, and the data were collected as per the pro forma. The individuals were selected on the basis of the inclusion and exclusion criteria.

Inclusion criteria

Both sexes were considered randomly, subjects above 20 years of age, and fully erupted right maxillary first molar.

Exclusion criteria

No carious or restored teeth or teeth with crowns and bridges; orthodontically treated, posterior tooth crowding; fractured/missing/rotated right maxillary first molar; maxillary sinusitis and other maxillary sinus pathologies; and facial bone fracture. Complete arch maxillary impressions were made on the study participants using alginate irreversible hydrocolloid impression material. On the prepared maxillary cast, diagonal intercuspal distance (mesiobuccal distolingual [MBDL] and distobuccal mesiolingual [DBML]) was recorded in the maxillary first molar tooth. The measurements were recorded using a digital vernier caliper. The caliper was held perpendicular to the long axis of the tooth while taking the readings. Pointed tips of the caliper were placed at the most prominent part of each cusp and the distance was calculated. Three readings were taken to avoid any bias while recording the readings [Figure 1].

The lateral cephalograms were obtained using standard techniques with Villa Sistemi Medicali: Rotograph plus machine (Villa Sistemi Medicali, Buccinasco, Italy) for extra-oral radiography set at 80 kVp, 10 mA, and 0.8 s. The image receptor (8 × 10' digital cassette) was a Kodak intensifying screen (Eastman Kodak Company, Rochester, New York, United States), and the X-ray film was developed with FCR Capsula automatic processing unit (FUJIFILM, Japan). After taking radiograph, it was digitally processed. Each X-ray was assessed for maxillary sinus area and perimeter with AutoCAD 2010 software (AUTODESK, California, United States). The area and perimeter of the maxillary sinus were evaluated, and each picture was saved in JPEG format. After obtaining the data (casts and radiographs), they were coded [Figure 2]. After analysis, the data were decoded, interpreted, and statistically analyzed.

Results

The data were entered into MS Excel, and the results were analyzed with SPSS software version 19 (IBM Corporation, Armonk, New York, United States) using descriptive statistics and inferential statistics. In the present study, the results showed gender-wise descriptive statistics of intercuspal diagonal distance parameter MBDL with a total mean of 1.04930 cm. The mean MBDL for males (1.14885 cm) is larger than that of females (0.94146 cm). In group centroids, if someone's discriminant function (DF) score is closer to −1.685, then those will be a female, whereas DF score closer to 1.555 is considered to be a male. The classification results of MBDL dimension of the actual group membership against the predicted group membership revealed that 92% of original grouped cases were correctly classified with significant *P* value ($P < 0.001$) [Table 1]. In the intercuspal diagonal parameter DBML, the total mean distance is 0.92316 cm. The mean DBML for males (0.98243 cm) is larger than that of females (0.85896 cm). In group centroids, if someone's DF score is closer to −1.192, then those will be a female, whereas DF score closer to 1.100 is considered to be a male. The classification results of DBML dimension of the actual group members against the predicted group members revealed that 91% of original grouped cases were correctly classified and *P* value was highly statistically significant ($P < 0.001$) [Table 2]. Hence, MBDL was found to be more reliable than DBML, and males showed high intercuspal diagonal distance of the right maxillary first molar as compared to females.

A significant sex difference was found in relation to maxillary sinus area and perimeter. The mean area for males (1.69043) was larger than females (1.40598). In group centroids, if someone's DF score is above −0.051, then the person belongs to female category, whereas if DF score is <−0.051, the person belongs to male category. The classification results of area of maxillary sinus (80%) of original grouped cases were correctly classified with a significant *P* value ($P < 0.001$) [Table 3]. The mean perimeter for males (5.24542) was larger than that of

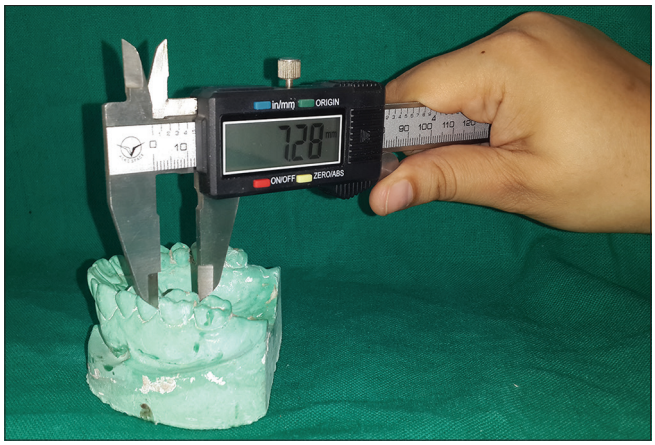

Figure 1: Intercuspal distance measurement with digital vernier caliper

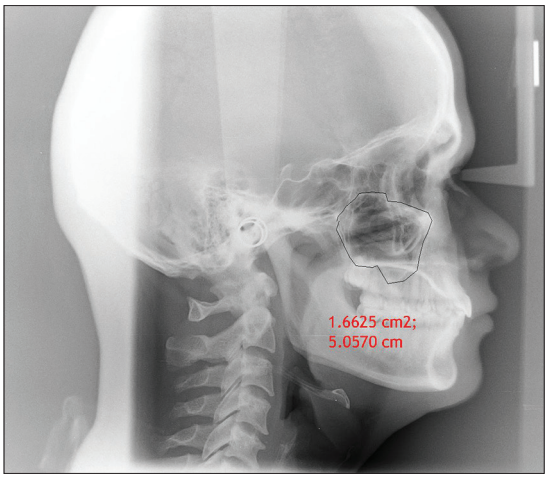

Figure 2: Area and perimeter of maxillary sinus on lateral cephalogram using AutoCAD 2010

females (4.53437). In group centroids, if someone's DF score is above −0.046, then the person belongs to female category, whereas if DF score is <−0.046, the person belongs to male category. The classification results of perimeter of maxillary sinus (76%) of original grouped cases were correctly classified and had a significant *P* value ($P < 0.001$) [Table 4]. Hence, males showed larger area and perimeter of maxillary sinus as compared to females.

Discussion

Identification of humans is based on four main biological attributes, namely, gender, age, stature, and ethnic or racial background, which are unique in an individual, and a person is identified by these characteristics. In forensic human identification, gender determination is usually the first step in the identification process.[11-13] After pelvis, the skull is the most easily sexed portion of the skeleton. Forensic odontologists and anthropologists have long been engaged in odontometrics which involves dental indices, buccolingual (BL) and mesiodistal (MD) measurements, diagonal dimensions, etc.[8,9,11] Teeth can be easily used for determining sex as the coronal morphology and dimensions of permanent teeth remain unchanged during the growth and developmental phases of the human body except for specific conditions such as nutritional abnormality and inherited disorders.[2] The study casts are used because of simpler and easier accessibility of various dimensions particularly for diagonal measurements.

One of the initial studies was conducted by Garn to calculate intercuspal distances in newly emerged maxillary premolars, in which cusp tips were well identified. Three dimensional (3D) measurements of occulsal surfaces of maxillary first molars wereobtained by Kanazawa using Moire photography.[3]

According to various studies, canines exhibit a great degree of sexual dimorphism followed by molars. Zorba *et al*. in 2011 while studying sexual dimorphism in teeth using odontometrics involving crown and cervical MD, BL, and diagonal diameters found molars to present a high degree of sexual dimorphism. They concluded that the lower first and second molars as well as the upper second molar are most dimorphic teeth. Similarly, Bishara *et al*. observed that first molars present high degree of sexual dimorphism. On the other hand, Prabhu and Acharya reported that the lower first molar is the most sexually dimorphic tooth even ahead of canines. Iscan and Kedici mentioned that upper first molars and lower second molars are among the most dimorphic teeth. However,

Table 1: Classification results of mesiobuccal-distolingual dimension

Classification results[a]	Sex code	Predicted group membership		Total
		Female	Male	
Original				
Count	Female	45	3	48
	Male	5	47	52
Percentage	Female	93.8	6.3	100.0
	Male	9.6	90.4	100.0

[a]92.0% of original grouped cases correctly classified

Table 2: Classification results of distobuccal-mesiolingual dimension

Classification results[a]	Sex code	Predicted group membership		Total
		Female	Male	
Original				
Count	Female	44	4	48
	Male	5	47	52
Percentage	Female	91.7	8.3	100.0
	Male	9.6	90.4	100.0

[a]91.0% of original grouped cases correctly classified

Table 3: Classification results of area of maxillary sinus

	Sex code	Classification results[a]		Total
		Predicted group membership		
		Female	Male	
Original				
Count	Female	43	5	48
	Male	15	37	52
Percentage	Female	89.6	10.4	100.0
	Male	28.8	71.2	100.0

%=Percentage. [a]80.0% of original grouped cases correctly classified

Table 4: Classification results of perimeter of maxillary sinus

Classification results[a]	Sex code	Predicted group membership		Total
		Female	Male	
Original				
Count	Female	33	15	48
	Male	9	43	52
Percentage	Female	68.8	31.3	100.0
	Male	17.3	82.7	100.0

%=Percentage. [a]76.0% of original grouped cases correctly classified

most of these studies are concerned with sexual dimorphism for MD and BL crown diameters based on cusp dimensions of maxillary molars. With regard to all these dental studies, the primary interest of forensic odontologists revolves around the concept of assessing the most reliable and accurate method for sex determination besides other traditional and alternative methods.[3,11,13]

Molars are the preferred teeth when it is with regard to forensic or an archaeological context as these teeth are most often present in fragmentary remains. Their presence is attributed to the fact that they have multiple roots and are held better in the jaw than the anterior single-rooted teeth. Much of a human molar's morphological complexity is localized on its occlusal surface. Interindividual variations and determination of the size and shape characteristics within and among populations are dependent on the establishment of cuspal arrangements of a tooth.[3,8,14]

In a study conducted by Karaman,[14] males showed significantly greater intercuspal measurements than females with the highest reliability in MBDL measurements. The classification accuracy was found to be 83.3% for the total sample, 78.3 for the upper jaw, and 85.0% for the lower jaw. Zorba *et al*.[6] concluded that the cervical diagonal diameters were more sexually dimorphic than coronal diagonal diameters, and the classification accuracy was found to be 93% for the total sample, 77.4% for the upper jaw, and 88.4% for the lower jaw. Anuthama *et al*.[2] observed that in all the observed mean dimensions, males showed larger dimensions as compared to females. Zorba *et al*.[15] found that cervical diagonal diameters are more accurate followed by crown diagonal diameters (75%–85.1%) and crown and cervical MD and BL diameters with the accuracy range from 65.5% to 88.4%. Angadi *et al*.[3] studied 600 dental casts (306 females and 294 males) of young adults (18–32 years), measured BL and MD dimensions of all permanent teeth, and applied logistic regression formulae on a test sample. The results showed that the canines were the most sexually dimorphic teeth followed by molars, with males having statistically larger measurements as compared to females. In a study conducted by Mujib *et al*.,[16] statistically higher values in males with classification accuracy of 69% in males and 73% in females and an overall accuracy of 71% were seen. MBDL measurements were found to be more reliable. Most dimorphic measurements included right molar cervical MBDL, left molar cervical MBDL, and right and left molar crown MBDL.

On the other hand, Townsend[17] showed that although MD and BL dimensions showed sexual dimorphism, no significant differences were noted between the sexes for intercuspal distances. Manchanda *et al*.[18] conducted a study for sex assessment using diagonal tooth measurements on North Indian population and concluded that the accuracy of determination of sex by MBDL crown dimension ranged from 55% to 75% in males and 47% to 84% in females. On the other hand, the accuracy of determination of sex by DBML crown dimension ranged from 55% to 80% in males and 65% to 80% in females. Hence, the overall accuracy of sex determination was found to be higher for DBML measurements.

Therefore, the results of the present study are in accordance with those of Karaman,[14] Zorba *et al*.,[6] Anuthama *et al*.,[2] Zorba *et al*.,[15] Angadi *et al*.,[3] and Mujib *et al*.[16]

The difference in odontometric measurements between males and females could be attributed to the control mechanisms for sexual dimorphism namely factors such as those that define the diameter of pulp chamber, dentine thickness, and enamel thickness. These become operative after mineralization of occlusal surface.[19,20] The timing of initial calcification is similar for both sexes, but that there is subsequently a longer duration and/or greater rate of growth of developing teeth in males as compared to females.[19] Eimerl and De Vore[21] postulated that Y chromosome intervenes most in the size of the teeth by controlling the thickness of dentine, whereas the X chromosome, which was considered once the chromosome responsible for the thickness of the dentin, actually comes into play concerning the thickness of the enamel. Hence, sexual dimorphism is attributed to the role played by genetic, cultural, and environmental factors.

In the present study, it was possible to predict the sex of an individual to an extent as high as 92% by odontometric method. It was also observed that there are variations in tooth size in various populations and races, which emphasizes the role of genetics in the same. An important point to be taken into consideration here is that any measurement by these methods, unaccompanied by age, race, and sex, must be treated with great reserve. However, these methods of sex determination have their limitations, as the sex of the individual to whom the fragment of the skull belongs can be determined correctly only if the fragment is recovered from the geographical area where the individual is native of that particular area.

Next to the pelvis, the skull is the most easily sexed portion of the skeleton.[2] In the skull, maxillary sinus is actively being used in studies for sex determination. Area and perimeter measurements of maxillary sinus can be standardized and are reproducible with newer technologies such as CT scan, ADOBE, AutoCAD, and Slidex image analysis software. When advanced imaging modalities such as CT scan are not available, then simple conventional radiographic techniques can be utilized; therefore, a routine extra-oral radiograph, lateral cephalogram, was used.

One of the foremost conducted studies include a 4-year research by Kim[22] in 1962 on Korean population with main

emphasis on frontal sinus, and maxillary sinus, using lateral cephalogram and posteroanterior view. He obtained standard values for Korean population from the collected data and also concluded that the size of sinuses was greater in males as compared to females.

Fernandes[7] performed volume, area, and shape analysis of maxillary sinus with the help of helical, multislice CT on 53 dried adult crania from persons of European and Zulu descents. He found that European sinuses were much larger in volume than Zulu sinuses, with male sinuses having a much larger volume than female sinuses. Ghaus and Faruqi Nafis[23] morphometrically analyzed maxillary sinuses in 37 human fetuses of different age groups (16–34 weeks of intrauterine life). Anteroposterior measurements were found to be more in males at 26–36 weeks, whereas transverse diameters in males were found to be larger at 21–25 weeks. It was concluded that maxillary sinuses remain relatively larger in males throughout life and different diameters of maxillary sinus have spurt of growth in different periods of intrauterine life.

Teke *et al*.[8] used CT scans for sex determination in 127 adults. The results showed that the ability of the maxillary sinus to identify gender was 69.4% in females and 69.2% in males. Similarly, Sahlstrand-Johnson *et al*.[24] found that maxillary sinus volume was significantly larger in males compared to females ($P = 0.004$). Uthman *et al*.[4] conducted a study to check the accuracy and reliability of maxillary sinus dimensions for sex determination using reconstructed helical CT images in 43 men and 45 women. It was concluded that height of maxillary sinus was the best discriminant parameter and reconstructed CT images can be used for sex determination.

Amin and Hassan[25] conducted a similar study on an Egyptian population using multidetector CT of the maxillary sinus. They concluded that cephalo-caudal measurements and size of the left maxillary sinuses are useful in gender determination in Egyptians.

Tambawala *et al*.[26] conducted a study using cone-beam CT (CBCT) and found that the overall values of the parameters were significantly greater in males as compared to females, with the right height (90.0%) and the left height (83.3%) being the best predictors.

However, Praveen *et al*.[27] analyzed maxillary sinus on lateral cephalogram using Slidex image analysis software. Dimensions of maxillary sinus showed no statistically significant difference in height and length of maxillary sinus among males and females. Similarly, Urooge and Patil[28] evaluated the size and volume of maxillary sinus in determining gender by CBCT. Insignificant differences were observed on both the right and left sides with respect to the maxillary sinus length, height, area, volume, and perimeter. The overall results showed that the ability of the maxillary sinus to identify gender was 68% in males and 74% in females, with an overall accuracy of 71%. Bangi *et al*.[29] also found that the accuracy rate of maxillary sinus to determine gender was 84% in males and 92% in females using CT.

Hence, the results of the present study are in accordance with those of Kim,[22] Fernandes,[7] Ghaus and Faruqi Nafis,[23] Teke *et al*.,[8] Uthman *et al*.,[4] Amin and Hassan,[25] and Tambawala *et al*.[26] However, the results are not in accordance with those of Praveen *et al*.,[27] Urooge and Patil,[28] and Bangi *et al*.[29] Therefore, sexual dimorphism can be attributed to varied growth rates in both sexes, resulting in larger skull/cranial measurements in males as compared to females.

Conclusion

In the present study, it was possible to predict the sex of an individual to an extent of 80% by radiographic method, with the area of maxillary sinus having an accuracy of 80% and perimeter of maxillary sinus having an accuracy of 76%. It was also observed that there are variations in sinus size in various populations and races, which emphasizes the role of genetics in the same. An important point to be taken into consideration here is that any measurement by these methods, unaccompanied by age, race, and sex, must be treated with great reserve. However, these methods of sex determination have their limitations as the sex of the individual to whom the fragment of the skull belongs can be determined correctly only if the fragment is recovered from the geographical area where the individual is native of that particular area.

The predicted value for sex determination varies with each population, for which studies have to be conducted on different populations from various geographic areas and calculate the predictive value, which can help in accurate sex determination. However, future studies are required with larger sample size in various study populations to validate the findings.

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Conflicts of interest

There are no conflicts of interest.

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