ORIGINAL ARTICLE

Dental sex dimorphism: Using odontometrics and digital jaw radiography

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Abstract

Context: Estimating the gender from the human skeletal remains can guide the forensic investigator in revealing the missing person's identity. **Aims:** (1) To determine the utility of the various parameters taken on the orthopantomographs (mandible) and of odontometrics on tooth remains to estimate the gender. (2) To determine the most dimorphic parameter taken on the radiograph as well as tooth (odontometrics) in the study taken. **Study and Design:** (1) A retrospective study was planned on 200 subjects (100 males and 100 females) in the age group of 18–30 years and the following parameters (maximum ramus height, bigonion width, and bicondylar breadth) were measured on the orthopantomograph. (2) A prospective clinical study was planned on 200 subjects (100 males and 100 females) in the age group of 18–30 years, to measure the mesio-distal width of permanent maxillary central incisors and canines directly in the patient's mouth, using Digital Vernier calipers. **Statistical Analysis Used:** The mean, range, and standard deviation were calculated for each variable in the study. The *Z*-score test was done to find out the magnitude of sexual dimorphism for each parameter in each part of the study. **Results:** Maximum ramus height proved to be the most dimorphic parameter depicting the utility of mandible for the estimation of gender of the deceased. Permanent maxillary central incisor proved to be more dimorphic than the maxillary canines, depicting it to be population specific. **Conclusion:** Measurements taken on the mandible proved to be useful in the estimation of gender of the deceased. In cases of fragmentary or missing mandible, odontometrics can be used. Hence, teeth proved to be an adjunct tool in the determination of gender of the deceased.

Key words: Forensic odontology, gender estimation, mandibular measurements, mesio-distal dimension, odontometry, orthopantomograms, sexual dimorphism, tooth measurements

Introduction

Forensic dentistry is an applied branch of dental anthropology and forensic medicine which deals with the examination and assessment of the dental evidence to identify the victims of crime, accidents, or calamities. [1,2]

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The estimation of gender is one of the most important steps during the postmortem reconstruction of the biological profile of the skeletal remains that are obtained from the site of the event. This allows the forensic investigator to exclude approximately half of the population which allows for a more concentrated approach to recover the missing person's files. This step carries a potential for the recovery of the ante-mortem records for comparison and establishing the identity of the individual.[3,4]

When the entire skeleton is available, the gender can be identified with 100% accuracy. Whereas, in cases of mass disasters when the body is mutilated beyond the scope of visual identification, the skull and the teeth often prove to be a valuable source for the identification process.[1,2]

In cases when intact skull is not found, mandible may play an important role in the estimation of gender because it is considered to be dimorphic, largest, and strongest bone of the body. Mandibular dimorphism varies with the race, age, and the activity of masticatory muscles of the subject.[5,6]

Dentofacial radiography is easily accessible which gives valuable information about the identity of the subject. If ante-mortem radiographs are available, then a comparison can be made with the postmortem radiographs for the identification of the deceased. Any ante-mortem radiograph of the subject may provide useful information about the horizontal as well as vertical measurements of the mandible.[5]

The teeth are resilient structure which can resist high temperatures and bacterial decomposition. The measurements taken from the teeth (odontometrics) can be useful as an adjunct in gender estimation when other skeletal parameters are unavailable due to fragmentation or loss.[3,4,6]

The present study is undertaken for the comparison of the two methods used for the gender estimation. The study also takes into account the amount of the accuracy for a particular method in the situations when the other method is not feasible to carry out.

Aims and objectives

The present study was designed to fulfill the following aims and objectives:

1. To measure, compare, and assess the various measurements, i.e., maximum ramus height, bi-gonial width, and the intercondylar width on the mandible as observed on digital orthopantomographs
2. The accuracy with which these measurements can be employed for the estimation of gender in a population
3. To measure, compare, and assess the mesio-distal (M-D) dimension of permanent maxillary incisors and canines as observed clinically with the help of Digital Vernier calipers
4. To assess the usefulness of these parameters taken on the teeth in the estimation of gender in a population.

Materials and Methods

The present study was carried out for 1 year.

Methodology employed for the measurements on the permanent maxillary incisors and canines (odontometrics)

A prospective clinical study was planned and the sample consisted of 200 subjects, of which 100 were males and 100 were females within the age group of 18–30 years. The participants of the study were undergraduate and postgraduate students from dental and medical college situated in North Karnataka region in India, who were purposely selected and blinding was not carried out for the clinical study.

The inclusion criteria for the subjects included the following features:

1. Complete set of fully erupted teeth
2. Healthy periodontium of the teeth
3. Teeth free of any pathology or wear
4. Properly aligned teeth with minimal crowding.

These criteria were taken into consideration to maximize the information gathered from the odontometric data.

Informed written consent was obtained from the subjects after which the maximum M-D dimensions of each tooth was measured directly on the patient with the help of Digital Vernier calipers calibrated to 0.01 mm. The method used in the clinical study was noninvasive; hence, the Ethical Committee granted the permission to continue the study.

Moorrees *et al*. have defined the M-D dimensions of tooth as the greatest distance between contact points on the proximal surfaces of the crown, which are measured by placing the beaks of the calipers occlusally along the long axis of the tooth.[7] For the teeth which were rotated or malaligned, measurements were taken between the points in the approximate proximal surfaces of the crown where it was considered that contact with the adjacent teeth would normally occur.[8]

The above-mentioned definition was followed carefully till the point where the beaks of the caliper would maximally extend.

The measurements were taken by a single examiner to eliminate the possible inter-observer error. To eliminate the intra-observer error, each reading was taken two times, and the average of these values was tabulated. The data collected were entered into a Microsoft Excel spreadsheet, and it was subjected to statistical analysis to quantify and assess the sexual dimorphism.

Methodology employed for the measurements on the mandible taken from orthopantomographs

A retrospective study was planned with a sample size of 200 subjects using the orthopantomographs of 100 male and 100 female subjects in the age range of 18–30 years. The orthopantomographs were obtained from the computer records of the patients who had visited the HKES's S.N. Dental College for restorative or orthodontic treatment purposes.

The inclusion criteria for the study were:

1. Clear radiographs with a full set of dentition
2. Radiographs showing a normal transverse and vertical relationship.

The exclusion criteria for the study were:

1. The presence of any bone pathology, deformity or fracture of any of the jaws including the temporomandibular joint.

Radiographs used in the study were taken by Kodak 8000 Digital Panoramic and Cephalometric System.

All the measurements taken on the mandible were recorded with the help of the Kodak Dental Software (master view 3.0 software) by mouse-driven method that is by moving the mouse and drawing lines between the chosen landmarks on the orthopantomograph.

The following parameters were considered in the study:

1. Maximum ramus height: It is measured from the highest point on the condyle to the most protruding point on the inferior border of the mandible. Ramus height was measured on both the sides on each orthopantomograph.[9]
2. Bigonial width: It is the distance between both the gonia (Go), i.e. the distance between the right and the left gonion. Gonion is the most inferior, posterior, and lateral point on the external angle of the mandible[10]
3. Bicondylar breadth: It is the distance measured between condylion laterale (cdl) on one side to cdl to the other side. Cdl is the most lateral point on the mandibular condyle.

Measurements on the radiograph were recorded by a single examiner to eliminate the inter-observer bias. To eliminate the intra-observer error, each reading was taken two times, and the average of the two values was taken. The data collected were entered into a Microsoft Excel spreadsheet and was subject to statistical analysis to quantify and assess the sexual dimorphism.

Statistical analysis

The study was aimed towards validation of the results obtained in the previous studies. The mean, range and standard deviation were calculated for each parameter. We performed the Z-score test for the statistical evaluation of the data as the sample size for each group was more than 30.

Stepwise discriminant functions were calculated to develop functions that could separate the sexes with a variable measurement composition. At each step, a variable was selected which gave the greatest univariate discrimination, and this criterion was reevaluated for all the remaining variables. Furthermore, their accuracy in the estimation of gender was calculated.

The magnitude of sex difference was also compared by calculating the percentage of sexual dimorphism, with the help of a formula given by Garn *et al*.[11]

The dimorphic ranking was then tabulated with the first rank allotted to the parameter showing the highest sexual dimorphism in each group. All the statistical analyses were performed using SPSS 17.0 software package (IBM statistics) (ssps.co.in).

Results

i. Observer variations: The paired *t*-test showed no significant inter-observer and intra-observer variation ($P < 0.05$).
ii. Univariate comparisons: The mean and standard deviation for each of the variables were calculated [Tables 1-3]. In all the observed mean dimensions, the male values exceeded the female values. The *Z*-score values for all the variables showed that there was statistically significant difference ($Z \geq 1.96$ for $P = 0.05$) between male and female dimensions.
Among the measurements taken from the radiograph of the mandible on the radiograph, the maximum ramus height showed the greatest sexual dimorphism followed by the bicondylar breadth and bigonion width [Table 1].
Among the measurements (M-D width) taken on the incisors and canines, the incisors showed a significant sexual dimorphism [Table 3].
The Z-score test was also used to compare between the right and left side incisors and canines. The right upper central incisor was the most dimorphic tooth and the canines on both sides were least dimorphic [Table 2].
iii. The percentage of dimorphism for each tooth was calculated using the following formula given by Garn *et al*.[11]
Percentage of dimorphism = ([Xm/Xf] −1) × 100, where Xm = mean male tooth dimension; Xf = mean female tooth dimension [Table 2 and 3].

Table 1: Mean and standard deviation for radiographic study on the mandible

Variables	Male		Female		*Z*
	Mean	SD	Mean	SD	
Maximum ramus height	69.04	2.82	60.28	3.03	21.15
Intercondylar breadth	181.48	8.92	167.39	8.27	11.58
Bigonion width	171.61	10.21	159.80	8.04	9.08

SD: Standard deviation

iv. Stepwise discriminant analysis: Table 4, 5 show the variables taken into the radiographic study on the mandible and the odontometrics on the incisors and canines, which contributed to the stepwise discriminant analysis. Wilk's lambda shows the usefulness of a given variable to enter into the stepwise analysis and also determines the order in which the variables enter into the analysis. The F-statistic denotes the variation existing between the gender and the significance level of the variance. Furthermore, the demarking points and the accuracies were calculated for each variable entering into the analysis in the descending order [Table 6, 7].

Discussion

Gender estimation is one of the most important steps to identify the deceased individual, especially in cases of mass disasters, natural calamities, road traffic accidents, fire accidents, etc., where only the skeletal remains are left behind.

In the present study, we chose two methods for the gender estimation namely radiographic method odontometric method.

The mandible bone was chosen for the estimation of gender for two reasons: Firstly, due to the paucity of standards in utilizing this element, and secondly, this bone is recovered largely intact as compared to other bones.[12]

Three parameters included in the study were, the maximum ramus height, bicondylar breadth, and bigonion width.

Measurements were taken on orthopantomogram in which there is no superimposition of the image seen on lateral cephalogram. However, orthopantomographic images are associated with magnification and geometric distortion. Laster *et al*.[13] and Van Elslande *et al*.[14] have stated that the horizontal measurements taken in shifted skull positions had a greater discrepancy as compared to the vertical dimensions. Kambylafkas *et al*.[14] examined the ability of panoramic radiographs to assess the side to side differences in condyle and ramus height. They concluded that the panoramic radiographs are reliable to measure these parameters and an asymmetry of >6% is an indication for true asymmetry.

All the three variables included into the present study had a statistically significant difference between the two genders. The most dimorphic parameter was the maximum ramus height followed by bicondylar breadth and bigonion width.

Humphrey *et al*.[15] stated that the mandible remodels during its growth and the greatest morphological changes are associated with mandibular condyle and ramus. Furthermore, the mandibular dimorphism is affected by the relative development of the masticatory muscles attached to the mandibular ramus, condyle, and coronoid process.[12]

Indira *et al*.[5] conducted a panoramic study on mandibular ramus and found that minimum ramus breadth, maximum ramus breadth, and projective height of the ramus were the most dimorphic parameters.

Table 2: Mean and standard deviation for odontometric data

Variables	Male		Female		*Z*	Percentage of dimorphism
	Mean	SD	Mean	SD		
Incisors 21	8.27	0.51	8.11	0.49	2.27	1.97
Incisors 11	8.34	0.50	8.07	0.47	3.84	3.35
Canine 23	7.45	0.47	7.29	0.51	2.24	2.19
Canine 13	7.45	0.52	7.29	0.54	2.20	2.19

SD: Standard deviation

Table 3: Mean and standard deviation for odontometric data

Variables	Male		Female		*Z*	Percentage of dimorphism
	Mean	SD	Mean	SD		
Incisors	8.30	0.49	8.09	0.46	3.14	2.59
Canine	7.45	0.46	7.29	0.51	2.33	2.19

SD: Standard deviation

Table 4: Stepwise discriminant analysis of the variables chosen in the mandible

Variables used	Wilk's lambda statistic	Exact *F* statistic	*P*
Maximum ramus height	0.89	14.57	<0.001
Bicondylar breadth	0.83	11.03	<0.001
Bigonion width	0.76	10.15	<0.001

Table 5: Stepwise discriminant analysis for the odontometric data

Variables used	Wilk's lambda statistic	Exact *F* statistic	*P*
Incisor (M-D width)	0.71	7.93	<0.01
Canine (M-D width)	0.68	7.83	<0.01

M-D: Mesio-distal

Table 6: Expected accuracy along with demarking points (in mm) for sex differentiation

Variables	Demarking points	Expected accuracy (%)
Maximum ramus height	Females <64.66> males	78
Bicondylar width	Females <174.43> males	76
Bigonion width	Females <165.7> males	75

Overall accuracy: 79.12%

Table 7: Expected accuracy along with demarking points (in mm) for sex differentiation

Variables	Demarking points	Expected accuracy (%)
Incisors (11, 12, 21, and 22)	Females <8.19> males	73
Canines (13 and 23)	Females <7.37> males	72

Overall accuracy: 78.3%

Franklin *et al*.[12] conducted an anthropometric research on the mandibles of indigenous South Africans and found ramus height to be highly dimorphic parameter followed by bigonion breadth and bicondylar width.

Al-Shamout *et al*.[16] conducted a panoramic study on dentate Jordanian subjects found that the mandibular ramus height was the most dimorphic parameter followed by bigonion width.

Saini *et al*.[9] conducted a study on dry adult mandibles of North Indian population in which they found the coronoid height as the most dimorphic parameter which was followed by condylar height and ramus height.

The results of the present study were consistent with the findings of the previous studies, showing the mandibular ramus as the highest magnitude of sexual dimorphism.

Odontometric parameters recorded from the teeth can be used as an adjunct for the estimation of gender when it cannot be estimated using craniofacial features.

Odontometric parameters when included as a procedure for the estimation of gender, the efficiency of estimation increased from 55.8% (on the basis of craniofacial features alone) to 86% (combining craniofacial and odontometric features).

Ditch and Rose[17] were the first to prove that teeth diameters can be successfully used in the estimation of gender in poorly preserved and fragmentary skeletal remains in archaeology.

It is considered that odontometric features of teeth differ depending on the population and it cannot be directly compared with other populations. Such a comparison can lead to false conclusions.[18]

Because of the formation of the crowns of the permanent teeth at an early stage, their dimensions remain the same during further growth and development. This excludes the conditions such as disorders in terms of functionality, pathology, and nutrition.

Alvesalo Lassi[19] stated that the sex chromosomes affect the teeth during the development which results in dimorphism in teeth in males and females.

Garn *et al*.[20] stated ted that a large variation in the magnitude of sexual dimorphism can be attributed to both genetic factors and environmental factors.

In the present study, we have chosen M-D diameter of permanent right and left maxillary central incisors and canines of the North Karnataka population.

The results in our study revealed a greater magnitude of sexual dimorphism for maxillary central incisors as compared to the maxillary canines and the percentage of sexual dimorphism ranged from 2.19% to 2.59%.

Results of our study were consistent with the study conducted by Anuthama *et al*[2]., on south Indian population in which percentage of sexual dimorphism ranged from 3.23% to 5.56%.

The results of our study did not correlate with the studies conducted by Acharya and Mainali[21] in Nepalese population, Pereira *et al*.[1] in Portuguese population, and Angadi *et al*.[4] on Southwestern India and on a Southeast Indian state, in which, canines were the most dimorphic teeth noted.

Stepwise discriminant function analysis was also performed on the data collected from the radiographic analysis on the mandible and from the odontometrics done on the incisors and canines.

This analysis has been a widely accepted method for the estimation of gender from the human skeletal remains. It helps in the calculation of the function when the variables are combined, and it also defines the contribution to each of the variables in the estimation of the gender.[1]

In the present study, all the three parameters from a radiographic study on the mandible when entered into the discriminate function analysis, yielded an overall accuracy of 79.12%. It proved that mandible could be used to estimate the gender of an individual with an expected accuracy ranging from 75% to 78%. The mandibular ramus height showed the best function as a parameter in the estimation of gender with an accuracy of 78%. The accuracy of the functions recorded in this study correlated with the studies of Indira *et al*.[5] with an accuracy of 76% and Saini *et al*.[9] with an accuracy of 80.2%.

When the odontometric data from the incisors and canines were put under the stepwise discriminate analysis, it yielded an overall accuracy of 78.3% which is similar to the accuracy (76%) obtained by Prabhu and Acharya.[3]

To conclude, the present study described the sexual dimorphism using univariate analysis and discriminate function analysis on orthopantomogram of the mandible and the odontometric data on the incisors and canines, to assess the importance of these variables in the estimation of gender in the deceased.

Mandibular ramus height proved to be the most dimorphic parameter in our study, thus correlating with the results from other studies.

In cases of fragmentary or missing mandible, odontometrics can be used because teeth are the most resilient structures

in the body and can withstand high temperatures and bacterial decomposition. Maxillary central incisor was the most dimorphic tooth in our study, which is population dependent. Odontometrics can act an adjunct to the craniofacial features in the process of the estimation of gender of the deceased.

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Conflicts of interest
There are no conflicts of interest.

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