Identification of gender using radiomorphometric measurements of canine by discriminant function analysis

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ABSTRACT

Purpose: Human teeth are the most stable and durable tissues in the body. Teeth can be identified even after complete decomposition, thus making them invaluable for identification of sex and age from fragmentary adult skeleton. This study aimed to compare the morphological and radiological measurements of canine and investigate its accuracy in sex determination.

Materials and Methods: This study involved 60 males and 60 females between the age group of 20 and 30 years. Mesiodistal (MD) widths of mandibular left canines and mandibular inter-canine distance (ICD) were measured and compared both clinically and on digital intraoral periapical and occlusal radiographs. Discriminant function analysis was carried out for gender determination. Discriminant equation and cutoff point were used in determining the gender and the percentage accuracy. Kappa statistics were carried out to assess intra-observer agreement.

Results: A definite statistically significant difference in the MD width and ICD was found between males and females. Clinical and radiological measurements were almost equally efficacious in gender determination with an accuracy of 55–75% in both males and females. When all the variables were used, the accuracy of gender determination increased substantially to 94%. k-values suggested a high intra-observer agreement.

Conclusion: It can be concluded that both the clinical and radiographic measurements of MD width of canine and ICD are quick and easy methods for determining sex and in identification of an unknown individual with a substantial accuracy.

Key words: Anthropometry, forensic dentistry, odontometry, radiometry

Gender determination of skeletal remains is an important part of forensic, archaeological, and many medico-legal examinations. In forensic contexts, correct sex identification limits the pool of missing persons to just one half of the population. The techniques used in sex determination have been primarily focused on the pelvis where reproductive difference is best seen and in the cranium where the size and morphology are varied and best represented.[1] The accuracy of sexing using diverse parameters of the body such as craniofacial morphology and measurements on the pubis ranges from 96% to 100%.2,3 Long bones,4,5 ribs,6,7 vertebrae,8 and clavicle9 were also studied for sexual dimorphism.

Radiography can assist in giving accurate dimensions for which certain formulae can be applied to determine gender.[10] The skull, pelvis, and femora are the most useful for radiological determination of gender. The length and the height of the head, the circumference of the head, the circumference of the occipital condyles, and the foramen magnum have been used to determine gender in unidentifiable human remains.[11–16] However, the tendency of these bones to be fragmented may preclude accurate sex estimation. The teeth are considered useful adjuncts in such scenarios since they are frequently recovered intact from skeletonized remains and have the ability to estimate sex correctly with accuracy rates that range between 76% and 92.5%.[17,18]
Various studies have tested the reliability of canine dimensions morphologically in gender establishment, but very few studies have investigated the accuracy of morphological dimensions of canine radiologically in gender determination. Radiometric analysis of canine was previously studied for age determination and was found to have a reliable accuracy. The present study was undertaken to compare the morphological and radiological measurements in digital radiographs by radiometric analysis and test the reliability of mandibular canine in gender determination using discriminant function analysis.

MATERIALS AND METHODS

The study was conducted in the Department of Oral Medicine and Radiology, Kamineni Institute of Dental Sciences, India. Ethical clearance was obtained from Institutional Ethical Committee. Population of Nalgonda (district) where the study is being carried out is around 3.4 million. At 95% confidence level and confidence interval <10, a sample size >96 was suggested by the statistician. Hence, a sample of 120 was selected for the study, with 60 male and 60 female patients between the age group of 20 and 30 years. Subjects with healthy state of gingiva and periodontium, normal molar–canine relationship, caries-free teeth, absence of spacing in the anterior teeth, and normal overjet and overbite were included in the study after a written informed consent. Subjects with partial anodontia, supernumerary teeth, hypoplastic teeth, teeth showing physiologic or pathologic wear, and patients with parafunctional habits were excluded from the study. Mesiodistal (MD) width of the left mandibular canine and mandibular inter-canine distance (ICD) were measured clinically for all subjects [Figures 1 and 2] using digital vernier calipers with a resolution of 0.01 mm. Intraoral periapical (IOPA) of the left mandibular canine and mandibular cross-sectional occlusal projection were taken using digital photostimulable phosphor plates. MD widths of the left mandibular canine were measured on digital IOPA and occlusal radiographs, and ICD between the mandibular canines was measured on occlusal radiographs using DBSWIN software (Durr Dental India Pvt Ltd, Patparganj Industrial Area, Delhi, India) with a least count of 0.1 mm [Figures 3 and 4]. Canine index (CI) was calculated both clinically and radiographically as a ratio of MD width and ICD. Statistical analysis was done using SPSS 20 software (IBM manufacturers, New Orchard Road, Armonk, New York, United States). Univariate analysis was done for all the canine measurements by calculating mean and standard deviation. Student’s t-test was used to distinguish between the male and female mean values for each variable. Then, discriminant function analysis was performed by calculating Wilk’s lambda, eigenvalue, canonical correlation, and percentage of correct gender determination was quoted in assessing the relative validity of discriminant functions. Low values of Wilk’s lambda, high values of eigenvalues, high value of canonical correlation, and high value of percentage of correct gender determination are associated with excellent discriminant function. Discriminant functions were calculated with each single variable and also with all the variables combined together. Intra-observer agreement was assessed using cross-tabulation and k-value by kappa statistics.

RESULTS

On the basis of univariate analysis and Student’s t-test, it was found that all the canine measurements except for CI values differ significantly among males and females both clinically and radiographically at 5.0% level of significance ($P \leq 0.05$). There is no significant difference between clinical and radiological measurements [Table 1].

The discriminant function equation for the determination of sex and their respective cut-off value was derived using discriminant function analysis [Table 2]. If the calculated discriminant score using the equation ($s$) is <0 (cut-off point),
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the case is classified as “female” and if the score is ≥0, the case is classified as “male.”

Discriminant functions were calculated with each single variable and with all variables together [Table 3]. When individual functions were compared, the best function in the present study was obtained by MD width of canine measurement on digital IOPA with lowest Wilk’s lambda (0.574), the highest eigenvalue (0.742), the highest canonical correlation (0.653), and the highest percentage of correct classification (76.65%). The next best functions were obtained by MD width of canine on occlusal radiograph, clinical measurement of MD width of canine, ICD on occlusal radiograph, and clinical measurement of ICD in the descending order. On the other hand, the functions produced by clinical and radiological CI values showed higher Wilk’s lambda, lower eigenvalues, lower canonical correlation, and the lowest percentage of correct classification suggesting far less discriminative capacity in determining gender. When all the variables were used, the common function has got the least Wilk’s lambda (0.326), the highest eigenvalue (2.069), the highest canonical correlation (0.821), and the highest percentage of correct classification (94.2%). k-values of all the canine values are >0.6 suggesting a high intra-observer agreement [Tables 3 and 4].

DISCUSSION

Sexual dimorphism represents a group of morphologic characteristics that differentiate a male from a female. Sexual dimorphism has been of great interest for many years. Odontometry is a useful adjunct in sex determination. Males possess larger tooth crowns than females in contemporary human populations. This may be due to a longer period of amelogenesis for both deciduous and permanent dentitions in males.[21] Of all the teeth in the human dentition, the canines are the least frequently extracted teeth (possibly, because of the relatively decreased incidence of caries and periodontal disease). In addition, canines are reported to withstand extreme conditions and have been recovered from human remains even in air disasters and hurricanes.[22] Canines are also known to show the greatest degree of sexual dimorphism across numerous populations.[21‑24] It was for these reasons that Rao et al.[25] examined the utility of canines alone in sex

Table 1: Group statistics of canine measurements

| Discriminant function | Mean±SD | P   |
|-----------------------|---------|-----|
| Females               | Males   |     |
| MDc                   | 6.2336±0.47 | 6.7781±0.52 | <0.001 |
| MDi                   | 6.3496±0.54 | 7.2508±0.51 | <0.001 |
| MDi                   | 6.4048±0.54 | 6.882±0.48 | <0.001 |
| ICDc                  | 23.82±2.1  | 25.98±1.74 | <0.001 |
| ICDO                  | 23.96±2.11 | 26.28±1.91 | <0.001 |
| Clc                   | 0.2630±0.02 | 0.2614±0.01 | 0.6   |
| Clo                   | 0.2765±0.02 | 0.2625±0.01 | 0.5   |

SD=Standard deviation, MD=Mesiodistal, IOPA=Intraoral periapical, ICD=Inter-canine distance, Cl=Canine index, MDc=Clinical MD width of canine, MDi=MD width of canine in IOPA, MDo=MD width of canine in occlusal, ICDc=Clinical ICD, ICDO=ICD in occlusal, Clc=Clinical CI, Clo=CI in occlusal

Table 2: Discriminant function equation and cut-off points for determining sex

| Discriminant function | Discriminant equation | Cut-off point |
|-----------------------|-----------------------|--------------|
| MDc                   | D=−13.088+2.012*MDc   | 1/2×(−0.548+0.548)=0 |
| MDi                   | D=−12.895+1.869*MDi   | 1/2×(−0.854+0.854)=0 |
| MDi                   | D=−13.183+1.955*MDi   | 1/2×(−0.271+0.271)=0 |
| ICDc                  | D=−12.870+0.517*ICDc  | 1/2×(−0.558+0.558)=0 |
| ICDi                  | D=−12.449+0.495*ICDi  | 1/2×(−0.572+0.572)=0 |
| Clc                   | D=−12.043+45.927*Clc  | 1/2×(−0.038+0.038)=0 |
| Clo                   | D=−13.714+50.883*Clo  | 1/2×(−0.357+0.357)=0 |
| All variables         | D=−12.047+11.005*MDc + | 1/2×(−1.426+1.426)=0 |
|                       | 3.288*MDi + (−14.069)*MDo + |                      |
|                       | (−2.790)*ICDc +3.152*ICDo + |                      |
|                       | (−273.959)*Clc + (278.611)*Clo |

MD=Mesiodistal, IOPA=Intraoral periapical, ICD=Inter-canine distance, Cl=Canine index, MDc=Clinical MD width of canine, MDi=MD width of canine in IOPA, MDo=MD width of canine in occlusal, ICDc=Clinical ICD, ICDO=ICD in occlusal, Clc=Clinical CI, Clo=CI in occlusal
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Table 3: Variable-wise calculation of discriminant functions

| Discriminant function | Wilk’s Lambda Score | Eigen value | Canonical correlation | Females correctly classified (%) | Males correctly classified (%) | Total correctly classified (%) | k |
|-----------------------|---------------------|-------------|-----------------------|--------------------------------|-------------------------------|-------------------------------|---|
| MDo                   | 0.666               | 0.305       | 0.483                 | 70                             | 76.7                          | 73.35                         | 0.852 |
| MDi                   | 0.574               | 0.742       | 0.653                 | 80                             | 73.30                         | 76.65                         | 0.863 |
| MDo                   | 0.651               | 0.575       | 0.564                 | 70                             | 76.7                          | 73.35                         | 0.855 |
| ICDc                  | 0.759               | 0.317       | 0.491                 | 75                             | 63.30                         | 69.15                         | 0.767 |
| ICDo                  | 0.750               | 0.333       | 0.500                 | 68.30                          | 71.70                         | 70                            | 0.798 |
| Ctc                   | 0.999               | 0.001       | 0.038                 | 31.70                          | 76.70                         | 54.20                         | 0.657 |
| Cto                   | 0.885               | 0.129       | 0.339                 | 58.30                          | 71.70                         | 65                            | 0.735 |
| All variables         | 0.326               | 2.069       | 0.821                 | 91.70                          | 96.70                         | 94.20                         | 0.943 |

ICDc=Inter-canine distance, MD=Mesiodistal, IOPA=Intraoral periapical, CI=Canine index, MDo=Clinical MD width of canine, MDi=MD width of canine in IOPA, MDo=MD width of canine in occlusal, ICDc=Clinical ICD, ICDo=ICD in occlusal, Ctc=Clinical Ctc, Cto=Cto in occlusal

Table 4: Interpretation of k-value

| Value of K          | Strength of agreement |
|---------------------|-----------------------|
| <0.20               | Poor                  |
| 0.21-0.40           | Fair                  |
| 0.41-0.60           | Moderate              |
| 0.61-0.80           | Good                  |
| 0.81-1.00           | Very good             |

a relative value, it is obtained as the ratio of two absolute measurements (MD dimension of canines and ICD), it does not reflect sex differences that exist in absolute measurements, and these sex differences might have got cancelled because of the division between these absolute measurements.

The uniqueness of this study is the use of radiographs for the measurement of MD width of canine and ICD. The results suggested it to be a very reliable method for these measurements. The correlation coefficient was very high for the mandibular cross-sectional occlusal radiograph measurements as they are almost same as that of the clinical measurements. Here, we have used digital radiography and lead aprons to minimize the amount of radiation exposure. There are several advantages of using digital occlusal radiography. It is very less time-consuming procedure, image can be stored as digital data for future reference, and it can give all the measurements such as MD width of canine, ICD, and CI with a reliable accuracy. Hence, future studies can be carried out on larger sample with the mandibular cross-sectional radiograph alone, replacing the use of plaster models.

De Angelis et al. in their study suggested a sexual dimorphism in the volume of the canine apart from previously investigated linear measurements. Manchanda et al. evaluated North Indian population using the crown diagonal diameters in sex determination by means of discriminant functional analysis. Although the results are in agreement with most of the previous studies, the present study has its own limitations. Smaller sample size and single examiner might have resulted in few errors or bias in the dimensions and results. The present study measured only linear dimensions because of the simplicity, reliability, and inexpensivity. More accuracy could have been obtained by the application of Moire’s topography and Fourier’s analysis that, however, require sophisticated equipment and the use of complex mathematical equations, respectively. Future studies have to include larger sample size, multiple observers to check intra-observer variation, and inter-observer agreement.
CONCLUSION

Left mandibular canine showed significant sexual dimorphism in both clinical and radiographic measurements, and the radiographic measurements are in high correlation with clinical measurements. Sex of a person can be identified using dimensions of MD width of canine and ICD on mandibular cross-sectional occlusal radiographs with an acceptable accuracy. Discriminant function analysis using various functions of canine together yielded a high percentage of accuracy in gender determination (>90%). Anyway, it is better to confirm the results by using other methods of determining sex because sex determination using the pelvis and skull bones shows an accuracy of 95% and above.[2,3]

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Acási Gy, Nemeskéri H. History of human life span and mortality. Am J Phys Anthropol 1970;36:300-2.
2. Williams BA, Rogers T. Evaluating the accuracy and precision of cranial morphological traits for sex determination. J Forensic Sci 2006;51:729-35.
3. Luo YC. Sex determination from the pubis by discriminant function analysis. Forensic Sci Int 1995;74:89-98.
4. Steyn M, Iscan MY. Sex determination from the femur and tibia in South African whites. Forensic Sci Int 1997;90:111-9.
5. Iscan MY, Loth SR, King CA, Shihai D, Yoshino M. Sexual dimorphism in the humerus: A comparative analysis of Chinese, Japanese and Thais. Forensic Sci Int 1998;98:17-29.
6. Iscan MY. Osteometric analysis of sexual dimorphism in the sphenial end of the rib. J Forensic Sci 1985;30:1090-9.
7. Wiredu EK, Kumoji R, Seshadri R, Brittwum RB. Osteometric analysis of sexual dimorphism in the sphenial end of the rib in a West African population. J Forensic Sci 1999;44:921-5.
8. MacLaughlin SM, Oldale KN. Vertebral body diameters and sex prediction. Am Hum Biol 1992;19:285-92.
9. Králik M, Urbanová P, Wagenknechtová M. Sex assessment using clavicle measurements: Inter- and intra-population comparisons. Forensic Sci Int 2014;234:181 e1-15.
10. Di Vella G, Campobasso CP, Dragone M, Introna F J. Skeletal sex determination by scapular measurements. Boll Soc Ital Biol Sper 1994;70:299-305.
11. Verma S, Mahima VG, Patil K. Radiomorphometric analysis of frontal sinus for sex determination. J Forensic Sci 2014;6:177-82.
12. Güney Y, Altinkök M, Cagdirci S, Kirangil B. Gender determination with skull measurements. J Forensic Med 1997;13:13-9.
13. Güney Y, Altinkök M. The value of the size of foramen magnum in sex determination. J Clin Forensic Med 2000;7:147-9.
14. Cameriere R, Ferrante L, Mirrella D, Rollo FU, Cingolani M. Frontal sinuses for identification: Quality of classifications, possible error and potential corrections. J Forensic Sci 2005;50:770-3.
15. Rogers TL. Determining the sex of human remains through cranial morphology. J Forensic Sci 2005;50:493-500.
16. Gruber P, Henneberg M, Böni T, Rühli FJ. Variability of human mandible height and body mass index. Anat Rec (Hoboken) 2009;292:1713-9.
17. Ates M, Karaman F, Iscan MY, Erdem TL. Sexual differences in Turkish dentition. Leg Med (Tokyo). 2006;8:288-92.
18. Acharya AB, Mainali S. Univariate sex dimorphism in the Nepalese dentition and the use of discriminant functions in gender assessment. Forensic Sci Int 2007;173:47-56.
19. Kapila R, Nagesh KS, R Iyengar A, Mehkri S. Sexual dimorphism in human mandibular canines: A radiomorphometric study in South Indian population. J Dent Res Dent Clin Dent Prospects 2011;5:51-4.
20. Tardivo D, Sastre J, Catherine JH, Leonetti G, Adalian P, Foti B. Age determination of adult individuals by three-dimensional modelling of canines. Int J Legal Med 2014;128:161-9.
21. Moss ML, Moss-Salentijn L. Analysis of developmental processes possibly related to human dental sexual dimorphism in permanent and deciduous canines. Am J Phys Anthropol 1977;46:407-13.
22. Kaushal S, Patnaik VV, Agnihotri G. Mandibular canines in sex determination. J Anat Soc India 2003;52:119-24.
23. Garn SM, Lewis AB, Swindler DR, Kerewsky RS. Genetic control of sexual dimorphism in tooth size. J Dent Res 1967;46:963-72.
24. Potter RH, Alcazaren AB, Berbosa FM, Tomaneng J. Dimensional characteristics of the Filipino dentition. Am J Phys Anthropol 1998;115:33-42.
25. Rao NG, Rao NN, Pai ML, Kotian MS. Mandibular canine index – A clue for establishing sex identity. Forensic Sci Int 1989;42:249-54.
26. Giles E. Sex determination by discriminant function analysis of the mandible. Am J Phys Anthropol 1964;22:129-35.
27. Steyn M, Iscan MY. Sexual dimorphism in the crania and mandibles of South African whites. Forensic Sci Int 1998;98:9-16.
28. Hu KS, Koh KS, Han SH, Shinn KJ, Kim HJ. Sex determination using nonmetric characteristics of the mandible in Koreans. J Forensic Sci 2006;51:1376-82.
29. Boaz K, Gupta C. Dimorphism in human maxillary and mandibular canines in establishment of gender. J Forensic Dent Sci 2009;1:42-4.
30. Paramkusam G, Nadendla LK, Devulapalli RV, Pokala A. Morphometric analysis of canine in gender determination: Revisited in India. Indian J Dent Res 2014;25:425-9.
31. Reddy VM, Saxena S, Bansal P. Mandibular canine index as a sex determinant: A study on the population of Western Uttar Pradesh. J Oral Maxillofac Pathol 2008;12:56-9.
32. Sreedhara, Sumalatha MN, Ramesh G, Nagarajappa R, Murari A, Agrawal A. Dimorphic mandibular canines in gender determination in Moradabad population of Western Uttar Pradesh. J Forensic Dent Sci 2015;7:32-6.
33. De Angelis D, Gibelli D, Gaudio D, Cipriani Noce F, Guercini N, Varvara G, et al. Sexual dimorphism of canine volume: A pilot study. Leg Med (Tokyo) 2015;17:163-6.
34. Manchanda AS, Narang RS, Kahlon SS, Singh B. Diagonal tooth measurements in sex assessment: A study on North Indian population. J Forensic Dent Sci 2015;7:126-31.