



Bulletin of the International Association for Paleodontology

Volume 18, Issue 2, 2024

Established: 2007

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We thank all the reviewers for their effort and time invested to improve the papers published in this journal.

Gender determination by radiomorphometric analysis of permanent mandibular canines using orthopantomograms: an observational study*

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Bull Int Assoc Paleodont. 2024;18(2):111-116.

Abstract

Introduction: Identification of unknown human remains is mainly done by establishing a biological profile in which sex determination is one of the key identifiers. The present study aims to analyze the sexual dimorphism exhibited by mandibular canines in the South Indian population. **Materials and Method:** A total of 250 orthopantomograms of adults aged 20 to 59 years were selected for the present observational study. The maximum mesiodistal diameter of the permanent mandibular canines was measured using Image J software. The maximum mesiodistal crown diameter at the height of the contour and the cervical line was considered. **Results:** An accuracy of 66.8% was obtained by the derived logistic regression formula. The maximum mesiodistal diameter at the HOC and cervix is higher in males compared to females. The index of Sexual Dimorphism calculations showed a higher value at the cervix than at the height of contour. **Conclusion:** Mesiodistal radiomorphometric measurements of mandibular canines can aid in gender determination in forensic odontology and paleodontology. The radiomorphometric measurements at the cervix show a better sexual dimorphism than the maximum crown diameter. Radiomorphometric measurements can be used as an aid in establishing the biological profile of unknown human remains.

Keywords: Canines; sex determination; orthopantomogram; odontometry, paleodontology

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Introduction

Teeth are considered one of the most suitable tissues for the identification of unknown human remains in forensic and archaeological investigations as they are able to withstand the test of time by tolerating mechanical, chemical, and thermal damage. Metric and non-metric features of teeth have been analyzed to identify differences amongst individuals of different races or genders (1,2). The sexual dimorphism in various metric parameters such as mesiodistal (3-5) or diagonal (6,7) diameter of the crown has been extensively studied in an attempt to find methods for sex determination in paleodontology. Mandibular canine index (MCI), representing the ratio of the mesiodistal width of canines to the intercanine distance has been suggested as a method for sex determination although contradicting results have been reported across multiple studies (8-10). Regressive alterations and pathologies affecting the crown part of the tooth make it difficult to obtain crown measurements for sex determination. Few archaeological studies in different population groups have shown that mesiodistal diameter at the cervix (MDC) gives better sexual dimorphism than the maximum mesiodistal diameter of the crown (MMDC). In this context, the present study aimed to determine the sexual dimorphism exhibited by the MMDC and MDC with the objective of comparing their utility as aids for sex determination in paleodontology.

Materials and Methods

A total of n=250 Orthophantomograms (OPG) of patients (119 males and 131 females) were randomly selected from the institutional radiology archives. Only good quality OPGs of patients of age ranging from 20 to 59 years having mandibular canines without any pathological changes were considered eligible for inclusion in the present study. OPGs of patients with systemic disorders, caries in canines, or a history of trauma to the teeth or jawbones were excluded. The OPGs were uploaded to Image J software, where the measurements were obtained using linear tools (Figure 1). The MDC of the crown at the cervix and the height of the contour were measured for mandibular canines bilaterally.

All the measurements were recorded and the data obtained was compiled on an MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States). The data was subjected to statistical analysis using Statistical Package for the Social Sciences

(SPSS v 26.0, IBM). The level of statistical significance was set at $p < 0.05$. Descriptive statistics were described in frequency and percentage. Means of odontometric values were compared by students t-test. The overall logistic regression analysis was done and a formula was derived for sex determination.

According to Gran et al's formula Index of Sexual dimorphism (ISD) is accessed at the crown (MDC) and at the cervix (MDCC) to know the degree of sexual differences between male and female mandibular canines (7). The formula used was $ISD = [X_M / X_f] - 1 \times 100$. Where X_m = Male mean, X_f = Female.

The bivariate correlation between age and mesiodistal diameter at the crown and at the cervix was checked using Pearson's correlation coefficient. The measurements were calculated by one observer. In order to assess the reliability of the measurements, intra-observer error was tested by using the measurements that were obtained from 50 randomly selected OPGs from the original sample after 1 month of time. Another observer measured the same randomly selected OPG in order to test the interobserver error.

Results

The mean age of both male and female patients is 35.34 years. Depending on the data obtained logistic regression formula for the Indian population was derived for gender determination i.e. $Sex = -7.188 + 0.027 \times MMDC \text{ in mm} + 0.987 \times MDC \text{ in mm}$. By using this formula, we observed an accuracy of 66.8% (Table 1). A comparison of mean odontometric measurements showed a significant difference between males and females. Maximum mesiodistal diameter at the crown and at the cervix is higher in males compared to females (Figure 2). The index of sexual dimorphism shows higher values at the cervix (8.678) compared to the crown mesiodistal diameter (5.940) (Table 2). Pearson's correlation coefficient showed a negative and low correlation i.e. as age increases there is a mild decrease in the mesiodistal diameter of the tooth (Table 3). Inter and intra-observer correlation by Cronbach's alpha showed excellent internal consistency (Alpha value was greater than 0.9).

Discussion

Teeth being the hardest and chemically stable structures, they are well protected in case of fire, bacterial decomposition, and deterioration. Studies have proved that among all the teeth, canines are less prone to pathological changes and exhibit maximum sexual dimorphism, and

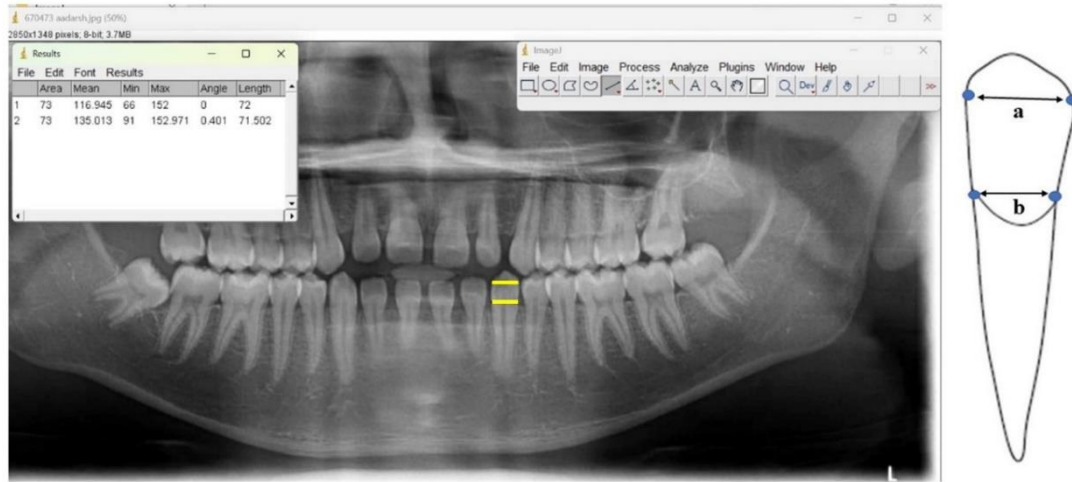


Figure 1. Linear odontometric measurements in ImageJ software. a – Mesiodistal diameter of the crown, b – Mesiodistal diameter of crown at cervix.

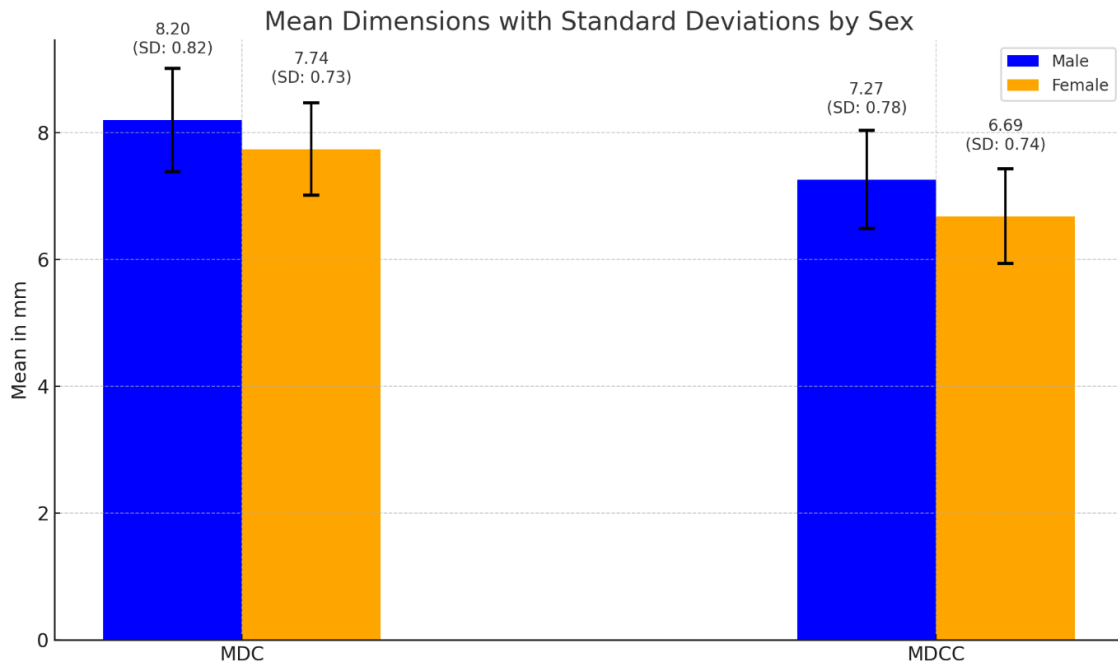


Figure 2. Bar graph representing the difference between males and females, canine measurements at crown (MMDC) and at cervix (MDC).

Table 1. Descriptive statistics of odontometric variable in Mandibular canines.

	SEX	N	Mean	Std. Deviation	Std. Error Mean	T value	p value of t test	ISD
MDC in mm	M	119	8.20451	.816771	.074873	4.717	.000**	5.940
	F	131	7.74442	.725532	.063390			
MDCC in mm	M	119	7.2655	.77818	.07134	6.022	.000**	8.678
	F	131	6.6853	.74459	.06505			

*P < 0.05, **P < 0.001, ISD: Index of sexual dimorphism, MDC: Mesiodistal diameter at crown, MDCC: Mesiodistal diameter at cervix. N: Total number of cases.

Table 2. Bivariate Correlation between the mesiodistal diameter at crown and at cervix of Mandibular canines with age.

		AGE	MDC in mm
MDC in mm	Pearson Correlation r value	-.272**	
	P value	.000	
	N	250	
MDCC in mm	Pearson Correlation r value	-.286**	.793**
	P value	.000	.000
	N	250	250

** - r value represents low correlation, weak relationship, N - total number of cases.

Table 3. The accuracy percentage of mandibular canines using both MDC and MDCC using Multivariate Logistic regression analysis.

Classification Table					
	Observed		Predicted		Percentage correct.
			Sex		
Step 1	Sex	F	M		
				94	37
		46	73		61.3
	Overall Percentage				66.8

these are the last teeth to be extracted with age. So, they are considered as “Key Tooth” for identification of an unknown person (9,11). There are many studies morphometrically analyzing the canine for gender determination. Most of the studies are mainly based on measurements taken on casts, clinically in the patient, extracted teeth, or from archaeological samples. Very few studies are there based on the radiomorphometric method (12,13).

Nadendla et al. (12) and Kapila Ret al. (11) in their studies observed significant sexual dimorphism by using all three methods i.e. measurements taken intraorally, on the plaster models, and on radiographs. Indian population-specific logistic regression formula derived from radiomorphometric analysis of mandibular canines showed an accuracy of 66.8%. In the present study, the mesiodistal diameter of the mandibular canines at the crown was significantly higher in males compared to females which was in accordance with many studies (4,5,10). In contrast, a study by Alanazi et al. in the Arabian population showed higher mesiodistal diameter in females compared to males but there was no wide difference between two values (3). According to them it can be due to population-specific or due to the presence of a single observer.

There are few archaeological population-specific studies undertaken that confirmed that the mesiodistal diameter of the tooth at the cervix

exhibits significant sexual dimorphism (1,2). Population-specific differences in sexual dimorphism can be attributed to genetic and environmental influences, including diet and cultural habits affecting tooth wear. For instance, the influence of Y chromosome on tooth size, combined with differences in enamel and dentin deposition between males and females, explains why cervical measurements provide greater sexual dimorphism than crown measurements. The cervix predominantly reflects dentin, which is more influenced by the Y chromosome, unlike the crown, where enamel also plays a role.

Similarly in the present study mandibular canines also shows significant differences between males and females in the Indian population. Studies by Monalisa et al. (13) on premolar teeth found that enamel area and average enamel thickness were significantly greater in females and coronal dentin area was greater in males. This suggests that the maximum mesiodistal diameter of the crown is predominantly influenced by the amount of dentin deposited rather than the proportion of enamel. In the present study, sexual dimorphism was higher at the cervix compared to crown mesiodistal diameter.

Suggesting that cervical measurements can be best used to assess the gender of an unknown person. The mesiodistal diameter at the crown is influenced by both enamel and dentin at the crown and at the cemento-enamel junction we can find predominantly dentine and little or no

enamel. So, the enamel does not have much influence on the mesiodistal diameter at the cervix, resulting in greater sexual dimorphism at the cervix compared to that of the crown. This can be explained by specific facts that males show longer bell stage during dentin deposition before amelogenesis. Similarly, during histogenesis X-chromosomes promote enamel formation, and Y-chromosome helps in both enamel and dentin formation. The size of the tooth is predominantly influenced by Y-chromosomes (13,14).

In the present study Pearson's correlation coefficient showed a negative and low correlation i.e as age increases there is a mild decrease in the mesiodistal diameter of the tooth and it was not statistically significant. The results were in accordance with study by Farzin et al. (15) where he observed a non-significant decrease in the mesiodistal diameter of maxillary canine with an increase in age. The mild decrease in the mesiodistal diameter of the crown can be due to proximal wear of the tooth with an increase in age.

Conclusion

The present study successfully fulfilled its aim of analyzing sexual dimorphism in the mesiodistal dimensions of mandibular canines at the crown and cervix in the South Indian population. The findings demonstrated that the mesiodistal diameter at the cervix exhibited greater sexual dimorphism than at the crown, highlighting its potential as a more reliable metric for gender determination in forensic and archaeological contexts. By developing a population-specific logistic regression formula with an accuracy of 66.8%, this study underscores the importance of cervical measurements as a significant aid in establishing the biological profile of unknown human remains. These findings are particularly relevant for forensic odontology and paleodontology, where determining sex is critical in the identification process. Future research expanding this methodology to include other teeth and diverse populations could further enhance the accuracy and applicability of such approaches in gender determination.

Declaration of Interest

None

Author Contributions

All authors have contributed significantly to the manuscript and meet the ICMJE criteria for authorship. MSM, KKG, and BNS were responsible for conceptualization, while SSC, MSM, and KKG contributed to data curation. Formal analysis was conducted by ASR, SSC, and MSM, and funding acquisition was secured by SSSKB and BNS. Investigation was carried out by SSC, MSM, and KKG, and methodology development involved BNS, MSM, and ASR. SSSKB and SSC oversaw project administration, and software support was provided by KKG and MSM. Resources were managed by BNS and ASR, with supervision provided by SSC and BNS. Validation of the results was done by MSM, KKG, and SSSKB, and visualization tasks were undertaken by KKG and ASR. SSC, MSM, and ASR prepared the original draft, while BNS, SSSKB, and KKG contributed to reviewing and editing. All authors have read and approved the final manuscript and agree to be accountable for its content.

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