

Gender Determination Using Diagonal Measurements of Maxillary Molar and Canine Teeth in Davangere Population

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ABSTRACT

Background: Mesiodistal and buccolingual measurements of the teeth have been the traditional means of determining gender which sometimes are difficult to measure.

Aims and Objectives: To assess the degree of sexual dimorphism in upper permanent canines and first molars using diagonal diameters and to evaluate the applicability of diagonal measurements in sex determination.

Materials and Methods: Mesiobuccal-distolingual (MBDL) and distobuccal-mesiolingual (DBML) measurements of the crown and cervix of maxillary canine and maxillary molar were taken using digital vernier callipers in 100 upper dental casts obtained from 50 males and 50 females of the age group of 17-25 y.

Results: With step wise discriminant function analysis, results were statistically significant with males showing higher diagonal measurement values. The classification accuracy for males was 69% and in females was 73% with overall accuracy of 71%. Results showed that canines exhibited highest accuracy with cervical measurements being more dimorphic. MBDL measurements were found to be more reliable. Most dimorphic measurements included right molar cervical MBDL, left molar cervical MBDL followed by right and left molar crown MBDL.

Conclusion: In cases of tooth rotations, crowding, certain fillings and attritions where traditional mesio-distal and bucco-lingual measurements are not applicable, diagonal measurements could be of help in predicting gender.

Keywords: Distobuccal-mesiolingual, Mesiobuccal-distolingual, Sexual dimorphism

INTRODUCTION

Gender determination has been the focus of many forensic studies and is of significance in mass fatality cases where bodies are damaged beyond recognition. Further, in incidents where only jawbone fragments with teeth are found, gender determination is possible only with the help of teeth. Teeth being resistant to post-mortem destruction and being chemically stable are an excellent material for odontologic and forensic investigations [1]. Therefore, teeth can be used as a tool of reconstructive identification particularly in cases of major catastrophes [2].

Determining gender using dental features is mainly achieved by comparing the tooth dimensions in males and females using traditional mesiodistal and buccolingual crown diameters of teeth. But these dimensions get affected by attrition, interproximal wear facets, cervical abrasions, crowding, and presence of dental calculus in cervical third. Further, these dimensions are difficult to measure when the teeth are still held in socket [2,3]. As a result, alternative measurements including the crown and cervical diagonal diameters were developed. According to Hillson et al., most of the archaeological and fossil remains of human teeth exhibit heavy attrition of usual crown diameters but alternative diagonal measurements are not affected until later stages of wear. Exclusion of contact points remains one of the major advantages of diagonal diameters of molars. The diagonal diameters proposed by Hillson et al., included Mesiobuccal-distolingual crown diameter, Mesiolingual-distobuccal crown diameter, Mesiobuccal-distolingual cervical diameter and Mesiolingual-distobuccal cervical diameters [4].

Canines being least affected by periodontal disease are last to be extracted. Canines have been recovered from dental remains even in hurricanes and air disasters and are found to withstand extreme conditions [5]. Boaz et al., has mentioned sexual dimorphism of canine with larger crowns in males, because of longer period of amelogenesis [6].

Maxillary first molars are among the early permanent teeth to erupt at an age of 6-7 y. Accuracy of gender determination in mature individuals is possible if the postcranial skeleton is intact. But in case of younger children, gender estimation from skeleton is difficult. In those cases, odontometric features of teeth that erupted at an early age can be of immense use in gender determination according to a study on the Haryana population by Sonika V [1].

Therefore, aim of the present study is to determine the accuracy with which gender can be differentiated using odontometric diagonal measurements in Davangere population. The objective of the study is to assess the degree of sexual dimorphism in upper permanent canines and first molars using diagonal diameters and to evaluate applicability of diagonal measurements in sex determination.



[Table/Fig-1]: Figure of ten cast samples taken together



[Table/Fig-2]: Recording diagonal measurements of molar using digital vernier callipers

Teeth	First observation		Second Observation		't' value	'P' value
	Mean	Standard deviation	Mean	Standard deviation		
RtCanCrMBDL	6.95	0.48	7.02	0.47	1.83	0.07
RtCanCrDBML	7.18	0.47	7.22	0.50	1.53	0.13
RtCanCerMBDL	7.56	0.51	7.53	0.50	0.46	0.65
RtCanCerDBML	7.36	0.53	7.31	0.56	0.73	0.47
RtMolCrMBDL	12.18	0.63	12.17	0.62	0.28	0.78
RtMolCrDBML	10.51	0.64	10.50	0.66	0.40	0.69
RtMolCerMBDL	12.33	0.64	12.32	0.62	0.41	0.68
RtMolCerDBML	10.64	0.65	10.65	0.64	0.45	0.66
LtCanCrMBDL	6.90	0.53	6.91	0.49	0.43	0.67
LtCanCrDBML	7.14	0.48	7.13	0.48	0.41	0.68
LtCanCerMBDL	7.51	0.50	7.49	0.46	1.22	0.23
LtCanCerDBML	7.28	0.52	7.29	0.50	0.18	0.86
LtMolCrMBDL	12.12	0.62	12.14	0.60	1.09	0.28
LtMolCrDBML	10.63	0.58	10.64	0.60	0.24	0.81
LtMolCerMBDL	12.25	0.64	12.26	0.63	0.84	0.40
LtMolCerDBML	10.79	0.59	10.77	0.62	1.14	0.26

[Table/Fig-3]: Paired t-test evaluating intra-observer variation in crown and cervical diagonal measurements of canines and molars (of both right and left sides). (None of the t-values are significant at the p<0.05 level)

MATERIALS AND METHODS

Study sample included 100 upper dental casts [Table/Fig-1] obtained by alginate impression after informed consent, from 50 males and 50 females of the age group of 17-25 y in a population of Davangere, in Karnataka. Diagonal measurements of crown and cervix of upper canines and first molars were taken.

Using the study dental casts, mesiobuccal-distolingual and distobuccal-mesiolingual measurements were taken separately. All the measurements were taken from both right and left sides using a 6" digital vernier calliper of 0.01mm resolution.

When placing the calliper parallel to the occlusal surface [Table/Fig-2], the following points were taken as guide during the measurements as defined by Hillson et al., [4].

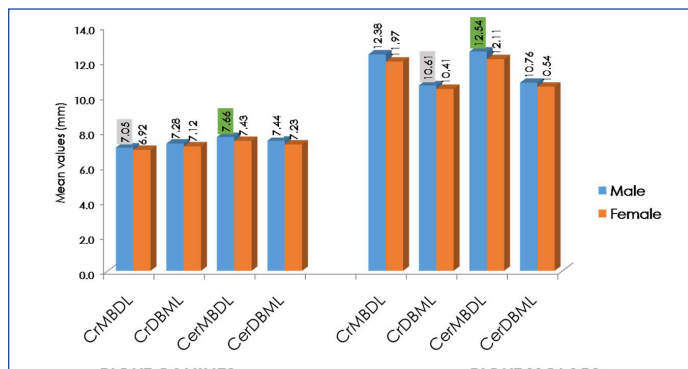
MBDL: the largest distance between the mesiobuccal corner and the distolingual corner of the crown

DBML: the largest distance between the distobuccal corner and the mesiolingual corner of the crown

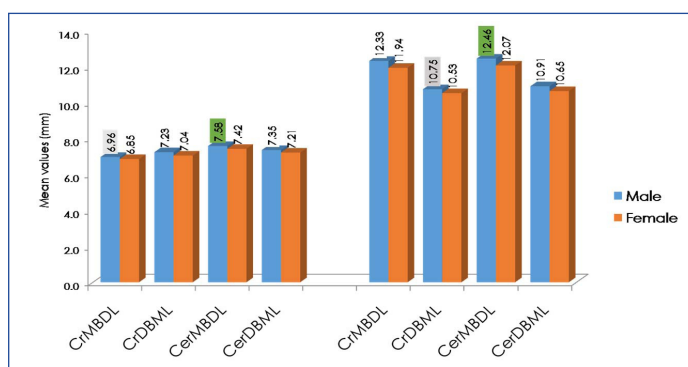
Mesiobuccal–distolingual cervical diameter (cervical MBDL) is defined as the maximum distance from the mesiobuccal corner of cemento–enamel junction point to the distolingual corner.

Mesiolingual–distobuccal cervical diameter (cervical MLDB) is defined as the maximum distance from the mesiolingual corner of cemento–enamel junction point to the distobuccal corner.

Two crown and two cervical diagonal measurements of upper canines and first molars were taken. Each dimension was measured twice



[Table/Fig-4]: Percentage of sexual dimorphism of right side canines and molars



[Table/Fig-5]: Percentage of sexual dimorphism of left side canines and molars

at a different time interval by the same observer. Selection criteria included fully erupted permanent maxillary canines and maxillary first molars of 17-25 y age group subjects. Extractions, fillings, crowns or orthodontic apparatuses, orthodontic anomalies and teeth with dental caries involving the point angles (in canines) and cusp tips (in molars) that could affect the odontometric measurements were excluded from the study.

Results were subjected to discriminant function analysis (using SPSS software statistics). Step wise discriminant function analysis allows a researcher to test whether a set of independent variables can be used to discriminate group membership by generating a valid equation. Wilks' lambda is the criterion for tooth variable selection. It is used to add or remove variables from the analysis according to their discriminatory power. It denotes how useful a given variable is in the step wise analysis and determines the order in which variables enter the analysis.

RESULTS

Four diagonal measurements on each tooth (including two cervical and two crown), altogether 16 measurements on both sides, were obtained in each of the individuals. Each measurement was measured twice at two different intervals by the same examiner to check for intra observer error. There was no statistically significant difference between the first and second measurements made as shown in [Table/Fig-3].

All the 16 measurements taken revealed greater values in males than in females and the differences were statistically significant. Highly significant dimorphic measurements included right molar cervical MBDL followed by right molar crown MBDL, left molar crown MBDL and left molar cervical MBDL. All the values on right side of jaw were greater than the left side except for molar crown and cervical DBML values [Table/Fig-4&5]. Overall classification accuracy of results was 71% with males exhibiting 69% and females exhibiting 73%, with accuracy rate being higher in females [Table/Fig-6]. Accuracy rate was higher in canines, as shown in [Table/Fig-7] and MBDL measurements were found to be more reliable. Cervical measurements revealed to be more dimorphic as seen in [Table/Fig-8].

Accuracy of classification results			
Variable	Predicted group membership		Total average (%)
	Male (%)	Female (%)	
RtCanCrMBDL	59	53	56
RtCanCrDBML	63	58	60
RtCanCerMBDL	61	62	62
RtCanCerDBML	58	58	58
RtMolCrMBDL	63	75	69
RtMolCrDBML	65	75	70
RtMolCerMBDL	63	71	67
RtMolCerDBML	58	69	64
LtCanCrMBDL	49	52	51
LtCanCrDBML	60	56	58
LtCanCerMBDL	54	60	57
LtCanCerDBML	63	60	61
LtMolCrMBDL	63	69	66
LtMolCrDBML	60	66	63
LtMolCerMBDL	60	66	63
LtMolCerDBML	60	69	65
Overall	69	73	71

[Table/Fig-6]: Accuracy of classification results in determining gender

Accuracy of classification results			
Function	Predicted group membership		Total average (%)
	Male (%)	Female (%)	
Canines	67	66	67
Molars	65	66	65

[Table/Fig-7]: Accuracy of determination of gender using upper canines and molars

Accuracy of classification results			
Function	Predicted group membership		Total average (%)
	Male (%)	Female (%)	
Crown	72	64	68
Cervical	69	68	69

[Table/Fig-8]: Accuracy of determination of gender using crown and cervical measurements

Stepwise discriminant function analysis

Discriminant function analysis [Table/Fig-9 &10] was carried out to find which of the variables affected the functions the most. This analysis allows the examiner to test whether a set of independent variables can be used to discriminate group membership and provides the equation for such discrimination.

Discriminant function score (Z) for gender assessment = $-17.665 - 0.32(\text{RtCanCrMBDL}) + 0.509(\text{RtCanCrDBML}) + 0.796(\text{RtCanCerMBDL}) + 0.038(\text{RtCanCerDBML}) + 0.109(\text{RtMolCrMBDL}) - 0.904(\text{RtMolCrDBML}) + 0.695(\text{RtMolCerMBDL}) + 0.664(\text{RtMolCerDBML}) - 0.399(\text{LtCanCrMBDL}) + 0.669(\text{LtCanCrDBML}) - 0.217(\text{LtCanCerMBDL}) - 0.869(\text{LtCanCerDBML}) + 0.411(\text{LtMolCrMBDL}) - 0.162(\text{LtMolCrDBML}) - 0.180(\text{LtMolCerMBDL}) - 0.094(\text{LtMolCerDBML})$.

If the discriminant score is below sectioning point, individual is classified as female and if the score is above sectioning point, individual is classified as male.

DISCUSSION

Teeth being the most durable tissue in the body, have been the focus of interest for various forensic odontogenic studies [3].

A variety of factors contribute to the magnitude of dimorphism in the teeth. Environmental influence due to variation in food resources of

Stepwise discriminant analysis of means of diagonal measurements of canines and molars for gender identification					
Variable entered	Wilks' Lambda	Exact F statistic	df1	df2	Sig.
RtCanCrMBDL	0.987	1.153	1	90	0.286
RtCanCrDBML	0.967	3.055	1	90	0.084
RtCanCerMBDL	0.935	6.292	1	90	0.014
RtCanCerDBML	0.962	3.564	1	90	0.062
RtMolCrMBDL	0.896	10.444	1	90	0.002
RtMolCrDBML	0.979	1.956	1	90	0.165
RtMolCerMBDL	0.877	12.618	1	90	0.001
RtMolCerDBML	0.967	3.035	1	90	0.085
LtCanCrMBDL	0.989	0.97	1	90	0.327
LtCanCrDBML	0.969	2.896	1	90	0.092
LtCanCerMBDL	0.983	1.513	1	90	0.222
LtCanCerDBML	0.982	1.687	1	90	0.197
LtMolCrMBDL	0.905	9.425	1	90	0.003
LtMolCrDBML	0.968	3.011	1	90	0.086
LtMolCerMBDL	0.913	8.617	1	90	0.004
LtMolCerDBML	0.955	4.232	1	90	0.043

[Table/Fig-9]: Stepwise discriminant function analysis of mesiobuccal-distolingual and mesio-lingual-distobuccal crown and cervical dimensions of upper canines and molars. F value for a variable indicates its statistical significance in the discrimination between groups. Wilk's lambda is the criterion for tooth variable selection

different populations can be the major cause. Further, there can also be complex interaction between genetic and environmental factors resulting in variation in the magnitude of dimorphism in the teeth. Garn et al., has proposed that teeth through the course of evolution behave in many ways ranging from reduction of the entire dentition to reduction of one group of teeth in relation to other [7].

According to Kalia S, difference in the balance of hormonal production between the sexes consequent to the differentiation of either male or female gonads during the sixth or seventh week of embryogenesis attributed to the difference in sizes of teeth rather than any direct effect of sex chromosomes themselves [8].

In forensics, mesio distal and bucco lingual width measurements have been routinely used for gender determination. These measurements provide accurate results and should be the preferred method if width measurements are possible. But conditions like tooth rotations, crowding, orthodontic anomalies, occlusal attrition, Mesio-Occlusal, Disto-Occlusal, Mesio Occluso distal fillings may prevent one from taking accurate width measurements. In those situations, diagonal measurements would be of help in determining gender and also these diagonal axes do not include the contact points of the crown, and are therefore not affected by approximal attrition until the facets become large enough to include them [4]. But caution is needed in taking diagonal measurements as measurements will go wrong if the callipers is not placed correctly [9].

According to the results of the present study, the diagonal measurements were significantly greater in males than females. The results were in accordance with various other studies revealing clear dimorphic differences between male and female teeth [6,10].

According to a study by Hashim HA, Murshid ZA evaluating 720 teeth in a Saudi population, canines were the only teeth to exhibit dimorphism [11]. In a study carried out by Karaman in Turkish population, diagonal measurements of canines revealed greatest accuracy rate with MBDL measurements being more reliable, which is consistent with the present study [9].

Accuracy rate of gender determination was found to be higher in females than males according to Karaman which is also in accordance with the current study [9]. According to Bishara et al., first molars exhibited significant sexual dimorphism with respect to

Variable	Unstandardised coefficient ^a	Structured matrices ^b	Standardised coefficients ^c	Group centroids		Sectioning Point
				Males	Females	
RtCanCrMBDL	-0.688	0.2	-0.329	0.525	-0.503	0.00
RtCanCrDBML	1.091	0.721	0.509			
RtCanCerMBDL	1.598	0.656	0.796			
RtCanCerDBML	0.073	0.623	0.038			
RtMolCrMBDL	0.181	0.596	0.109			
RtMolCrDBML	-1.425	0.509	-0.904			
RtMolCerMBDL	1.155	0.418	0.695			
RtMolCerDBML	1.032	0.383	0.664			
LtCanCrMBDL	-0.748	0.355	-0.399			
LtCanCrDBML	1.421	0.354	0.669			
LtCanCerMBDL	-0.437	0.352	-0.217			
LtCanCerDBML	-1.682	0.345	-0.869			
LtMolCrMBDL	0.696	0.284	0.411			
LtMolCrDBML	-0.28	0.264	-0.162			
LtMolCerMBDL	-0.296	0.25	-0.18			
LtMolCerDBML	-0.16	0.218	-0.094			
Constant	-17.665					

[Table/Fig-10]: Canonical discriminant function coefficients for diagonal diameters groups

a. Unstandardised discriminant function evaluated as group means;
b. Pooled within groups correlations between discriminating variables and standardised canonical discriminant functions
c. Discriminant score less than sectioning point is categorised as female & more than sectioning point is considered as male

buccolingual dimensions [12]. Also, according to Karaman, if the accuracy rate of width measurements of certain teeth is high, then the accuracy rate of diagonal measurements of such teeth is also high [9].

According to Hilson et al., alternative diagonal measurements were as reliable as normal width measurements and remain a promising method for sex determination. Diagonal measurements would be better measures for worn out teeth in archeological and fossil dental remains [4].

Cervical diagonal diameters of molars were found to be more sexually dimorphic than crown diagonal diameters in a study performed over modern greek population similar to that of the present study. Cervical measurements are not affected until most of the tooth is lost and thereby offer greater advantage in archeological specimen identification [4]. Analysis of the data generated reveals that diagonal measurements can be an useful aid in gender determination especially in situations where width measurements are not applicable [3]. But taking diagonal measurements has got certain limitations as the measurements are most difficult to obtain and require more attention [9]. Measurements might go wrong if the callipers is not positioned properly parallel to tooth axis.

The method applied in the present study is simple, inexpensive and can therefore be applied in forensic odontology for establishing gender identity of an individual.

In future, alternative diagonal measurements should find wider usage along with conventional width measurements and in near future, digital imaging techniques might be available to measure different aspects of tooth size and shape which are not strongly affected by wear.

CONCLUSION

The evolving field of forensic odontology in India depends a lot on simple and economical methods to identify persons with their dental remains and fragmented jaws. In those conditions, a dentist may be called upon to render expertise in forensic science.

In general, Mesiodistal and Buccolingual measurements are more reliable than diagonal measurements. Diagonal values are preferred over the width measurements in attrition, malpositions such as tooth rotation, crowding, and orthodontic anomalies which cause difficulties in taking width measurements. So along with width measurements, diagonal measurements of teeth can be used in determining the gender.

To conclude, crown and cervical diagonal diameters of canines and molars can be used as an aid for sex determination in support of width measurements. Thereby, they can aid in identifying a person from fragmented jaws and dental archaeological remains. This study needs further evaluation in other populations as sexual dimorphism is a population specific phenomenon.

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