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Linear vs Diagonal Odontometry in identification of an individual

[1]Dr. Vinita Murgod, Reader, Dept of Oral and Maxillofacial Pathology, Saraswati Dhanwantari Dental College and Hospital, Parbhani, Maharashtra, India

[2]Dr. Vinodkumar MP, Reader, Dept of Oral and Maxillofacial Pathology, Saraswati Dhanwantari Dental College and Hospital, Parbhani, Maharashtra, India

[3]Dr. Vina Vaswani, Professor and Head, Department of Forensic Medicine & Toxicology, Yenepoya Medical College, Yenepoya (Deemed to be University], Karnataka

Corresponding Author: Dr. Vinita Murgod, Reader, Dept of Oral and Maxillofacial Pathology, Saraswati Dhanwantari Dental College and Hospital, Parbhani, Maharashtra, India

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Abstract

Background: Linear odontometry is customarily used in gender determination which can pose difficulties in cases of tooth decay, attrition since they mainly involve the proximal surfaces.

Objectives: The present cross-sectional observation study, estimated the efficacy of alternative measurements i.e. diagonal measurements and cervical measurements in gender determination in comparison to routine odontometry.

Material and Methods: 200 dental cast models (upper and lower] of 100 individuals (50 male and 50 female] from Maharashtra state were included.

Two Linear measurements 1] Mesio-distal (MD) 2] Bucco-lingual (BL) at the height of contour

Four Diagonal measurements 1] Mesiolingual to Distobuccal 2]Mesiobuccal to Distolingual at height of contour and at cervical region of the first molars were done using vernier callipers.

Results: Descriptive statistics showed that all dimensions are larger in males compared to females. Univariate discriminant function analysis showed that, for maxillary molars, MD width gave highest gender dimorphism of 64%, followed by BL with 62%. In the mandibular teeth, MD gave an accuracy of 75% followed by MB-DL with 73%. Multivariate logistic regression analysis showed that overall diagonal and linear measurements gave highest dimorphism of 81% with 80% correctly identified as females and 82% as males. The mandibular MD, BL, MB-DL gave an accuracy of 79% with 78% corrected identified females and 80% correctly identified as males. Mandibular ML-DB and CDB-CML together gave an accuracy of 77%, and Mandibular MD with 75%.

Conclusion: Thus, the study proves that diagonal measurements give almost equivalent or better results than linear measurements in gender determination.

Keywords: Odontometry, gender identity, Dental Models, Female, Male, Regression analysis

Introduction

Gender determination is important in identification and recreation of biological profile of the individual because it reduces the probable matches to ante-mortem data to 50%. [1] [2] [3] [4] Very often a need for application of newer methods and unusual techniques is necessitated. [5]

Teeth are feasible specimens for gender discrimination, as they can resist taphonomic decay and also resist the mechanical, thermal and chemical changes. [2] [6] [1] [7] [8] [9] Odontometry has proven to be valuable in gender discrimination. [10]. As seen in majority of the previous studies, it is customary to use mesiodistal and buccolingual crown measurements i.e. linear measurements for gender identification [11] Odontometry of teeth with caries or attrition or incomplete eruption where linear measurements won't be possible. Thus alternative measurements like diagonal measurements or linear measurements at the cervical line might be required. [6] [7]The present study was conducted with an aim to evaluate and compare linear and diagonal odontometry of maxillary and mandibular molars in gender discrimination.

Material and methods

Sample: Our study sample consisted of 100 individuals of Maharashtra in the age group of 18-35 years with average age of 22yrs. Most participants were students studying at Dental School in Maharashtra and few of them were staff members working in the same school.

The study protocol was approved by the Institutional Ethical Committee of Saraswati Dhanwantari Dental College and Hospital, Parbhani. After taking an informed verbal consent from the participants, impressions of their maxillary and mandibular dentitions were made using alginate material followed by their disinfection and then the casts were poured in dental stone.

Inclusion criteria: Subjects aged 18-35 years were selected since the dentitions will be relatively intact and they have a lesser possibility of physiologic and pathologic wear of teeth.

Exclusion criteria: If the first molars are fractured or missing or malformed, such individuals were excluded.

Measurements

Digital vernier calliper calibrated to 0.01 mm (Digimatic Vernier Caliper – 0-150 mm) was used for making the measurements. In total 4 teeth, i.e. 2 maxillary (first) and 2 mandibular (first) molars were measured in each individual's casts. A total of 24 measurements were made in each individual's casts.

Linear measurements

Linear measurements i.e. Mesio-distal (MD) and Bucco-lingual (BL) measurements were made by placing beaks of the vernier calliper perpendicular to the long axis of the tooth. The maximum distance between the contact points on mesial and distal surface was considered for MD diameter (Figure 1) and buccal and lingual surface for BL diameter (Figure 1).

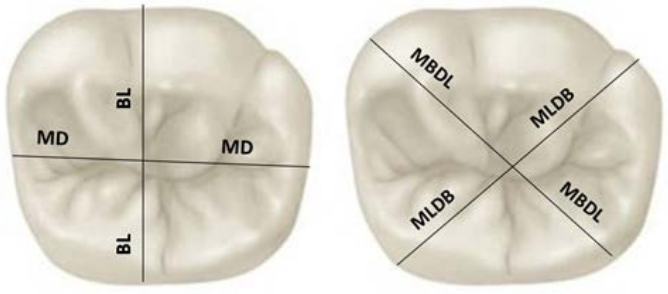

Figure 1: Schematic Representation of linear and diagonal measurements

Diagonal measurements

Four Diagonal measurements were made, two at the height of contour and two at the cervical region of the

tooth. Maximum distance between the mesiobuccal corner and distolingual corner of the crown (MB-DL) (Figure 1) and maximum distance between the mesiolingual corner and distobuccal corner of the crown i.e. ML-DB (Figure 1), were measured at the height of contour of the tooth. The maximum distance between the mesiobuccal corner and distolingual corner of the crown at the cervical line i.e. CMB-CDL (Figure 2) and maximum distance between the mesiolingual corner and distobuccal corner of the crown at the cervical line i.e. CML-CDB (Figure 2) were measured at the cervical area of the tooth.

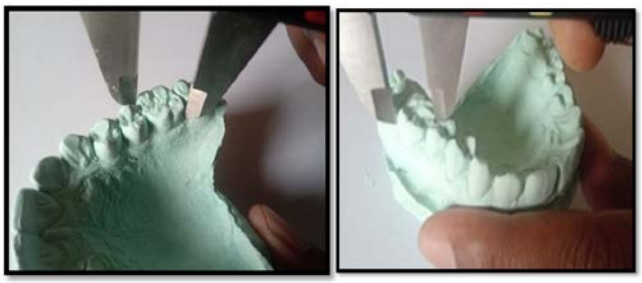

Figure 2: Cervical Diagonal measurements CMB -CDL and CML- DB of crown at cervix

The Principal investigator was blinded to the gender of the examined casts by the third investigator. Prior to conducting the main study, the Principal investigator recorded the dimensions of randomly selected 10 study casts and repeated the measurements for these ten casts after a period of one week, to check for variability if any, in order to limit intraobserver error. All the measurements on each cast were made by the Principal investigator only in order to avoid interobserver error.

Statistical analysis

Kappa Statistics was applied to check for intraexaminer variability. Descriptive statistics of individual tooth combined, left and right molars in both the genders were performed. Unpaired T test was performed to see whether the differences noted in means of males and females are significant. We also calculated the gender dimorphism index using the formula given by Garn et al (12) Univariate and Multivariate Discriminant function analysis, Univariate and Mulitivariate Logistic Regression analysis were performed.

Statistical analysis and Results

Intra-examiner variations

The intraexaminer variabilities were calculated using Kappa statistics which showed values ranging between 0.81 – 0.90, thus showing that there was negligible intraexaminer variation.

Descriptive Statistics

The descriptive statistics and t-values for the linear, diagonal and cervical diagonal dimensions along with the combined statistics for maxillary and mandibular molars as depicted in Table 1 showed that all the dimensions are larger in males compared to females. The Pearson's correlation coefficient along with index for gender dimorphism is also shown.

Table 1: Descriptive statistics for all values, Pearson's correlation & Gender Dimorphism Index

Females N=50			Males N=50		t-value	Unpaired t-test P value	CI		Pearson'sCorrelation			%Gender Dimorp hism
	Mean	S.D.					Lower Bound	Upper Bound	Correlation coefficient	P value	Interpretation	
MD16	10.0140	0.55738	10.3256	0.50134	-2.939	0.004	-0.52199	-0.10121	0.285**	0.004	Significant	3.11%
BL16	10.2510	0.64477	10.5564	0.63748	-2.382	0.019	0.55986	0.05094	0.234*	0.019	Significant	2.98%
MB-DL16	12.0220	0.64282	12.4856	0.66602	-3.542	0.001	-0.72338	-0.20382	0.337**	0.001	Significant	2.29%
CMB-CDL16	12.4930	0.73411	12.7810	0.67951	-2.036	0.044	- 0.56874	- 0.00726	0.201*	0.044	Significant	2.3%
ML-DB16	10.7564	0.70282	10.8390	0.39355	-0.725	0.470	-0.30866	0.14346	0.073	0.470	NS	0.77%
CDB-CML16	11.2696	0.78194	11.3670	0.43493	-0.770	0.443	- 0.34851	0.15371	0.078	0.443	NS	0.86%
MD26	9.9598	0.49709	10.2694	0.44615	-3.278	0.001	-0.49706	-0.12214	0.314**	0.001	Significant	3.10%

BL26	10.1620	0.67678	10.4824	0.47007	-2.749	0.007	0.55166	0.08914	0.268**	0.007	Significant	3.15%
MB-DL26	12.1570	0.70343	12.5070	0.65367	-2.577	0.011	-0.61949	-0.08051	0.252*	0.011	Significant	2.78%
CMB-CDL26	12.4832	0.77292	12.8368	0.64521	-2.483	0.015	- 0.63616	- 0.07104	0.243*	0.015	Significant	2.86%
ML-DB26	10.5834	0.61846	10.6458	0.52672	-0.543	0.588	-0.30866	0.14346	0.073	0.470	NS	0.77%
CDB-CML26	11.1276	0.70329	11.1416	0.42743	-0.120	0.905	- 0.24497	0.21697	0.012	0.905	NS	0.13%
MD36	10.4432	0.51239	10.2694	0.44615	-6.103	0.000	-0.83618	-0.42582	0.525**	0.000	Significant	6.04%
BL36	9.6828	0.62275	10.4824	0.47007	-0.747	0.457	0.31810	.14410	0.075	0.457	NS	0.9%
MB-DL36	11.3482	0.57386	12.5070	0.65367	-4.589	0.000	-0.73570	-0.29150	0.421**	0.000	Significant	4.53%
CMB-CDL36	12.0670	0.52455	12.8368	0.64521	-3.932	0.000	- 0.58953	- 0.19407	0.369**	0.000	Significant	3.25%
ML-DB36	11.1824	0.49467	10.6458	0.52672	-4.305	0.000	-0.60543	-0.22337	0.399**	0.000	Significant	3.71%
CDB-CML36	11.5936	0.62899	11.1416	0.42743	-3.017	0.003	- 0.58754	- 0.12126	0.291**	0.003	Significant	3.06%
MD46	10.4122	0.50832	10.3256	0.50134	-5.486	0.000	-0.78108	-0.36612	0.485**	0.000	Significant	5.51%
BL46	9.4584	0.57794	10.5564	0.63748	-1.642	0.104	0.46380	.04380	0.164	0.104	NS	2.22%
MB-DL46	11.3584	0.63996	12.4856	0.66602	-4.613	0.000	-0.78805	-0.31395	0.422**	0.000	Significant	4.85%
CMB-CDL46	12.0240	0.54011	12.7810	0.67951	-3.242	0.002	-0.57551	-0.13849	0.311**	0.002	Significant	2.97%
ML-DB46	10.9948	0.47583	10.8390	0.39355	-5.354	0.000	-0.60543	-0.22337	0.399**	0.000	Significant	3.71%
CDB-CML46	11.4940	0.50366	11.3670	0.43493	-3.513	0.001	- 0.49421	- 0.13739	0.334**	0.001	Significant	2.74%
MD16,26	9.9869	0.47731	10.2975	0.38290	-3.589	0.001	-0.48233	-0.13887	0.341**	0.001	Significant	3.11%
BL16,26	10.2065	0.60850	10.5194	0.50949	-2.788	0.006	0.53563	0.09017	0.271**	0.006	Significant	3.07%
MB-DL16,26	12.0895	0.63763	12.4963	0.61522	-3.246	0.002	-0.65547	-0.15813	0.312**	0.002	Significant	3.36%
CMB-DL16,26	12.4881	0.70793	12.8089	0.61316	-2.422	0.017	-0.58364	-0.05796	0.238*	0.017	Significant	2.57%
ML-DB16,26	10.6699	0.61264	10.7424	0.38794	-0.707	0.481	-0.27601	0.13101	0.071	0.481	NS	0.68%
CDB-CML16,26	11.1986	0.67917	11.2543	0.36117	-0.512	0.610	- 0.27158	0.16018	0.052	0.610	NS	0.50%
MD36,46	10.4277	0.46623	11.0300	0.48502	-6.330	0.000	-0.79111	-0.41349	0.539**	0.000	Significant	5.78%
BL36,46	9.5706	0.56981	9.7191	0.57442	-1.298	0.197	0.37557	.07857	0.130	0.197	NS	1.55%
MB-DL36,46	11.3533	0.57328	11.8856	0.51446	4.887	0.000	-0.74847	-0.31613	0.443**	0.000	Significant	4.69%
CMB-CDL36,46	12.0455	0.50335	12.4199	0.49167	-3.762	0.000	- 0.57187	- 0.17693	0.355**	0.000	Significant	3.11%
ML-DB36,46	11.0886	0.45069	11.5384	0.41668	- 5.182	0.000	-0.27601	0.13101	0.071	0.481	NS	0.68%
CDB-CML36,46	11.5438	0.51881	11.8789	0.42157	-3.545	0.001	- 0.49421	- 0.13739	0.334**	0.001	Significant	2.74%

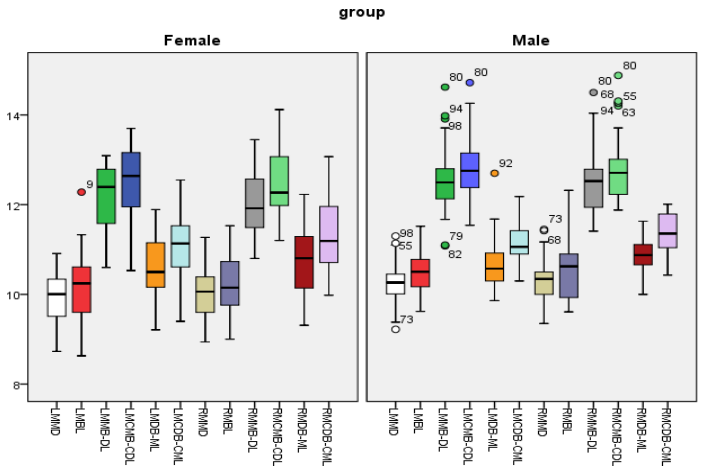

Figure 3: Box plot graph between male and female molar measurements both maxillary and mandibular for individual parameters.

There is a difference in individual parameters in both maxillary and mandibular molars in male and female gender. As can be noted in the plot graph the mean measurements of left mandibular MD and right mandibular cervical MB-DL show good variability.

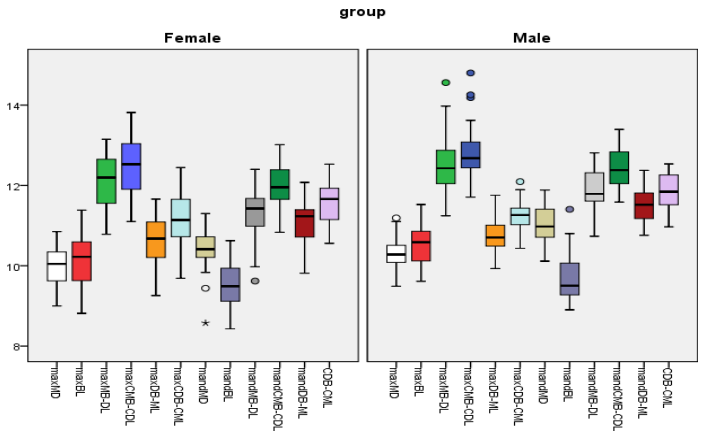

Figure 3: The Box plot graph between male and female molar measurements parameters maxillary combined and mandibular combined parameters.

The results were similar to the individual parameters for combined measurements too as noted in the Figure 3

Univariate Discriminant Function Analysis

Table 2: Univariate Discriminant Function Analysis

	WL	CFC	GC	FCFC		Accuracy Percentage		
				Female	Male	Female	Male	Total
Max MD	0.884	2.31	-0.36	53.34	55.00	66	62	64
		-23.44	0.36	-267.06	-283.89			
Max BL	0.927	1.78	-0.28	32.41	33.40	58	66	62
		-18.47	0.28	-166.08	-176.38			
Max MB-DL	0.903	1.60	-0.33	30.80	31.84	56	58	57
		-19.62	0.33	-186.86	-199.60			
Max CMB- CDL	0.944	1.51	-0.24	28.48	29.21	50	52	51
		-19.10	0.24	-178.49	-187.74			
Max ML-DB	0.995	1.95	-0.07	40.58	40.86	52	48	50
		-20.88	0.07	-217.21	-220.16			
Max CDB-CML	0.997	1.84	-0.05	37.85	38.04	52	52	52
		-20.64	0.05	-212.64	-214.75			
Mand MD	0.71	2.10	-0.63	46.08	48.74	76	74	75
		-22.55	0.63	-240.93	-269.49			
Mand BL	0.983	1.75	-0.13	29.24	29.69	56	44	50
		-16.86	0.13	-140.61	-144.99			
Mand MB-DL	0.804	1.84	-0.49	38.27	40.07	72	74	73
		-21.33	0.49	-217.94	-238.79			
Mand CMB- CDL	0.874	2.01	-0.38	48.66	50.17	62	60	61
		-24.59	0.38	-293.75	-312.25			
Mand ML-DB	0.785	2.30	-0.52	58.87	61.25	66	68	67
		-26.07	0.52	-327.06	-354.07			
Mand CDB-CML	0.886	2.12	-0.35	51.66	53.16	58	60	59
		-24.78	0.35	-298.89	-316.45			

The results of univariate discriminant function analysis and regression analysis were run separately for upper and lower molars and have been presented in Tables 2 and 3, respectively. The univariate discriminant function analysis results showed that, for the maxillary molars, the MD width gave highest gender dimorphism of 64%, followed by BL with 62%. MB-DL gave an accuracy of 57%. CMB-CDL, ML-DB and CDBCML gave almost 50% of accuracy. In the mandibular teeth, MD gave an accuracy of 75% followed by MB-DL with 73%, ML- DB with 67%, CMB-CDL with 61% and CDBCML with 59%. Thus the mesiodistal width of mandibular teeth gave higher accuracy. The least dimorphic percentage of 50% was seen Max ML-DB and mandibular BL.

The equations for predicting the probability of genders can be given using the results as follows:

For example the equation for the maxillary MD is: -23.44x2.31x X = Y (Where -23.44 and 2.31 are CFC values and X is maxillary mesiodistal width of the tooth under consideration). If Y is larger than 0.36 (i.e. GC) than it is probably male & if vice versa a female.

Univariate logistic regression analysis

On running the data for Univariate logistic regression analysis, as shown in table 3, we noted that the mandibular MD gave the best dimorphism with almost equal potential was mandibular MB-DL. The next parameter with high dimorphic potential was mandibular ML-DB. The mandibular CMB- CDL, CDB-CML and Maxillary MD and BL lied almost in similar range. Maxillary ML-DB gave the least potential.

Table 3: Univariate Logistic Regression

	B	S.E.	Wald	p-value	Odds Ratio	R Square		Accuracy in Percentage		
						Cox &Snell	Nagelkerke	Female	Male	Total
Max MD	1.69	0.52	10.35	0.001*	5.40	0.12	0.16	66	60	63
	-17.11	5.33	10.32	0.001*	0					
Max BL	1.00	0.38	6.94	0.008*	2.71	0.07	0.10	58	66	62
	-10.33	3.93	6.91	0.009*	0					
Max MB- DL	1.08	0.36	8.76	0.003*	2.94	0.10	0.13	56	58	57
	-13.25	4.48	8.74	0.003*	0					
Max CMB-CDL	0.75	0.33	5.33	0.02*	2.12	0.06	0.08	50	52	51
	-9.48	4.11	5.32	0.02*	0					
Max ML- DB	0.28	0.40	0.51	0.48(NS)	1.33	0.005	0.007	52	48	50
	-3.01	4.24	0.50	0.48(NS)	0.05					
Max CDB-CML	0.19	0.37	0.27	0.61(NS)	1.21	0.003	0.004	52	52	52
	-2.16	4.19	0.27	0.61(NS)	0.12					
M and MD	2.94	0.63	21.77	<0.001*	18.82	0.3	0.40	76	74	75
	-31.48	6.74	21.80	<0.001*	0					
M and BL	0.46	0.36	1.67	0.197	1.59	0.02	0.02	56	44	50
	-4.46	3.46	1.66	0.198	0.01					
M and MB-DL	1.92	0.48	15.70	<0.001*	6.79	0.2	0.27	74	74	74
	-22.28	5.63	15.68	<0.001*	0					
M and CMB- CDL	1.52	0.45	11.29	0.001*	4.56	0.13	0.17	62	62	62
	-18.55	5.52	11.29	0.001*	0					
M and ML-DB	2.51	0.61	16.89	<0.001*	12.31	0.22	0.29	66	68	67
	-28.41	6.92	16.87	<0.001*	0					
CDBCML	1.49	0.46	10.34	0.001*	4.45	0.11	0.15	60	60	60
	-17.50	5.45	10.30	0.001*	0					

Multivariate discriminant function analysis

The multivariate discriminant function analysis was run on the our data as shown in **Table 4.** Among the Maxillary linear measurements, MD gave an accuracy of 64% with 66% correctly identified as females and 62% correctly identified males. Among the maxillary diagonal, Maxillary MB-DL and CDBCML gave an accuracy of 65%. Among the Mandibular linear, MD gave an accuracy of 75% which is the highest among all the variables considered in the study. Among the mandibular diagonal measurements, ML-DB gave an accuracy of 67%. Among the Maxillary all, the maxillary MD, MB-DL, CML-CDB, together gave and accuracy of 65%. In the mandibular all, the mandibular MD alone could give an accuracy of 75%. Among all the variables of maxillary and mandibular measurements, mandibular MD, alone gave an accuracy of 75%.

Table 4: Multivariate Discriminant Function Analysis

	Variable selected	WL	CFC	GC	FCFC		Accuracy Percentage		
					Female	Male	Female	Male	Total
Max linear	Max MD	0.88	2.31	-0.36	53.34	55.00	66	62	64
			-23.44	0.36	-267.06	-283.89			
Max diagonal	Max MB-DL	0.84	2.36	-0.43	14.29	16.32	72	58	65
	Max CDB-CML		-1.80	0.43	25.65	24.10			
			-8.85		-230.70	-238.31			
M and linear	M and MD	0.71	2.10	-0.63	46.08	48.74	76	74	75
			-22.55	0.63	-240.93	-269.49			
M and diagonal	M and ML-DB	0.79	2.30	-0.52	58.87	61.25	66	68	67
			-26.07	0.52	-327.06	-354.07			
Max All	Max MD	0.80	1.79	-0.49	41.75	43.50	68	62	65
	Max MB-DL		1.30	0.49	-3.87	-2.60			
	Max CDB-CML		-1.86		19.11	17.29			
			-13.21		-292.73	-305.67			
M and All	M and MD	0.71	2.10	-0.63	46.08	48.74	76	74	75
			-22.55	0.63	-240.93	-269.49			
Max + M and All	M and MD	0.71	2.10	-0.63	46.08	48.74	76	74	75
			-22.55	0.63	-240.93	-269.49			

Multivariate logistic regression analysis.

Table 5 shows the multivariate logistic regression analysis. The overall diagonal and linear measurements of the selected teeth for analysis gave the highest dimorphism of 81% with 80% correctly identified as females and 82% as males. The mandibular MD, BL, MB-DL gave an accuracy of 79% with 78% corrected identified females and 80% correctly identified as males. The mandibular ML-DB and CDB-CML together gave an accuracy of 77%, followed by Mandibular MD with 75%.

Table 5: Multivariate Logistic Regression

	Variable selected	B	S.E.	Wald	p-value	Exp (B)	R Square		Accuracy Percentage		
							Cox & Snell	Nagel kerke	Female	Male	Total
Max Linear	Max MD	1.69	0.52	10.35	0.001*	5.40	0.12	0.16	66	60	63
		-17.11	5.33	10.32	0.001*	0.00					
Max Diagonal	Max MB-DL	3.91	1.20	10.59	0.001*	49.77	0.18	0.24	66	66	66
	Max CMB-CDL	-1.68	0.95	3.12	0.08(NS)	0.19					
	Max ML-DB	-1.78	0.71	6.32	0.01*	0.17					
		-7.77	5.10	2.32	0.12(NS)	0.00					
M and Linear	M and MD	2.94	0.63	21.77	<0.001*	18.82	0.30	0.40	76	74	75
		-31.48	6.74	21.80	<0.001*	0.00					
M and Diagonal	M and ML-DB	4.20	1.22	11.86	0.001*	66.63	0.24	0.32	76	78	77
	CDB-CML	-1.69	1.00	2.86	0.09(NS)	0.19					
		-27.74	7.17	14.97	<0.001*	0.00					
Max All	Max MD	1.99	0.89	5.01	0.03*	7.34	0.23	0.30	72	70	71
	Max MB-DL	3.35	1.25	7.25	0.007*	28.63					
	Max CMB-CDL	-1.98	0.99	3.99	0.04*	0.14					
	Max ML-DB	-2.19	0.78	7.96	0.005*	0.11					
		-12.90	5.78	4.99	0.03*	0.00					
M and All	M and MD	2.22	0.74	8.99	0.003*	9.25	0.34	0.45	78	80	79
	M and BL	-1.24	0.63	3.85	0.05*	0.29					
	M and MB-DL	1.68	0.81	4.28	0.04*	5.38					
		-31.47	7.44	17.90	<0.001*	0.00					
Max+ M and All	Max MB-DL	1.99	1.24	2.59	0.11(NS)	7.34	0.36	0.48	80	82	81
	Max CMB-CDL	-1.79	1.12	2.56	0.11(NS)	0.17					
	M and MD	2.22	0.76	8.58	0.003*	9.19					
	M and BL	-1.30	0.67	3.78	0.05(NS)	0.27					
	M and MB-DL	1.63	0.88	3.42	0.06(NS)	5.12					
		-32.10	7.92	16.41	<0.001*	0.00					

*p<0.05 Statistically Significant, p>0.05 Non Significant, N

Discussion

Human identification is fraught with ambiguity especially in cases where the bodies are in mutilated state or are skeletal remains. In many cases, even the bones are damaged or incomplete due to various reasons. In such circumstances, teeth are very helpful in identification of the individuals. Teeth are well preserved within the jaws and the overlying soft tissues, and also since they are highly mineralised, the possibility of damage to them is minimal. [13] [14] Gender determination is considered to be one of the key steps in identification process since it reduces the possible matches to almost half. [1] [2] Metric method involves measuring the various dimensions of the tooth in identification and the non-metric method involves examination of the presence or absence of specific dental trait. [2] Metric method is considered to be more reliable since it is comparatively less subjective. [15] Linear measurements i.e. the mesiodistal width and the buccolingual width have been extensively employed in the identification procedures. [11] But in many cases, especially in context of the molars, linear measurements would not be possible due to presence of caries, attrition, incomplete eruption, malocclusions and restorations covering the occlusal and proximal surfaces. In these circumstances, alternative measurements need to be sought in the identification procedure such as diagonal and

cervical measurements could be used, which are less affected by regressive alterations affecting the teeth. [16] [17] Very few studies have been seen in literature, in which the diagonal and cervical measurements of teeth are used in the identification. The present study was conducted to evaluate the application of diagonal and cervical measurements in comparison to the traditional linear measurements in a sample from Maharashtra. The present odontometric study was conducted in the Department of Oral Pathology and Microbiology, Saraswati Dhanwantari Dental College and Hospital, Parbhani – Maharashtra, after the approval from the institutional review board and ethical committee. 100 individuals belonging to Maharashtra state population participated in the study after giving a written/verbal informed consent. Only subjects aged between 18- 35 years of age were selected for the study, since the regressive alterations like caries, attrition, recession etc., are known to affect the teeth in older individuals. The impressions of maxillary and mandibular arches were made using alginate material followed by their disinfection and then the casts were poured in dental stone. The casts were observed grossly to see if the morphology of the required teeth is clearly seen in the casts. 100 casts showing complete morphology of the 1st molars were selected, out of which 50 belonged to the male subjects and 50 were of female subjects. Only the Principal investigator recorded all the measurements to avoid inter-observer error. The Principal investigator was blinded to the gender of the examined casts by the second investigator, in order to avoid bias in recording the measurements. The measurements were made using digimatic Vernier calliper calibrated to 0.01mm. Prior to conducting the main study, the training and calibration was done. The Principal investigator recorded the dimensions of randomly selected 10 study casts and repeated the measurements for these ten casts after a period of one week, to check for variability if any, in order to limit intraobserver error. Kappa statistics gave a value of 0.81 – 1.00 showing that the measurements were almost in perfect agreement and that there is no intraobserver error. The Principal investigator recorded the measurements of only 6-8 casts/day spread over the whole day in order to avoid errors. The posterior teeth are more likely to be preserved in mutilated cases, hence we chose the maxillary and mandibular 1st molars were selected which are also known to have high dimorphic potential.

The measurements recorded in the study were as follows

1. Linear measurements

a. The maximum Mesiodistal diameter of the crown

b. The maximum buccolingual diameter of the crown

2. Diagonal measurements

a. Maximum distance between the mesiobuccal corner and distolingual corner of crown

b. Maximum distance between the distobuccal corner and mesiolingual corner of crown

c. Maximum distance between the mesiobuccal corner and distolingual corner of crown at the cervical line

d. Maximum distance between the distobuccal corner and mesiolingual corner of crown at the cervical line

The data obtained was analysed using the SPSS software version19. The following statistics were applied to the data obtained:

1. Descriptive statistics
2. Unpaired t test
3. Pearson’s correlation coefficient
4. Index of gender dimorphism
5. Univariate Discriminant function analysis
6. Multivariate Discriminant function analysis
7. Univariate Logistic Regression analysis
8. Multivariate Logistic Regression analysis

In the present study, it was noted that both linear and diagonal dimensions irrespective of the arch or quadrant were larger in males compared to females in accordance to the previous studies [11] [18] [19] [17] [20] [21]. This finding reconfirms the conclusions of the above quoted studies that the difference noted might be due to larger jaw size in males as compared to females, the potential of Y chromosome to cause higher mitotic activity in odontogenesis, longer amelogenesis activity and thicker dentin in males etc. [11] [18] [19] [20] [21] In few previous studies, reverse dimorphism has been noted. [18] [22] We did not note any such finding in any of our parameters.

The descriptive statistics showed that, out of the six variables under consideration in our study, 3 variables i.e. MD, MB-DL, CMB-CDL showed statistically significant [$p<0.05$ or $p<0.01$] difference in both the maxillary and mandibular first molars irrespective of the quadrant or arch. 3 variables on the other hand, showed statistically significant difference in only BL dimensions of Maxillary teeth, ML-DB and CML-CDB dimensions of the mandibular teeth.

On considering the individual parameters, we noted a loss of symmetry in all the molars that is a difference in the dimensions of the left and right molars of the same arch.

In both the genders, we noted that the mean MD of left maxillary 1st molars was seen to be lesser than that of the right molars; this was in concurrence with Periera et al [21] study conducted in Maharashtra population and Dash et al [23] study conducted in Odisha population and also in Prabhu et al study conducted in Dharwad [18]. But the results were in contrast to study by Agarwal et al [24] done in probably Saudi population and Sonika et al [25] in Haryana population and Mehta et al [26] done in Rajasthan population. Also the mean MD of left mandibular molars was more than that of the right mandibular molar similar to the study conducted by Agarwal et al [24] and Dash et al [23] and Prabhu et al [18] and in contrast to Mehta et al [26]. Similarly mean BL dimension of left maxillary 1st molars was seen to be lesser than that of the right molars similar to Periera et al [21] and Dash et al [23] in contrast to Mehta et al [26]. The vice versa was noted for the mandibular molars in our study which was in contrast to the study by Agnihotri et al [27] and Dash et al [23]. The differences noted in various studies might be due to the variation in population under study. The difference noted in the males and females was statistically significant with p value of <0.05.

Zorba et al [28] reported that the BL dimensions have higher dimorphic potential compared to MD dimensions whereas MD dimensions were found to be more reliable in gender prediction in our study in concurrence to the study by Acharya and Mainali [11].

Even the diagonal dimensions i.e. MB-DL dimension, CMB-CDL, ML-DB, CML-CDB showed similar findings.

The Pearson's correlation coefficient shows the correlation of a particular dimension to gender. It showed that the MD width in all the molars showed strong correlation to gender. The best correlation was noted with mandibular combined with a coefficient of 0.539, among all the variables and teeth under consideration.

The gender dimorphism index showed that the gender dimorphism was highest for MD of mandibular left molars (6.04%) followed by MD mandibular molars combined (5.78%) and mandibular right 1st molar [5.51%] among all the variables under consideration. The mandibular molars combined gave higher gender dimorphism compared to maxillary molars. Similar results were noted in the study by Agrawal et al [31] and Kazzazi et al [46]

The dimorphic potential for BL maxillary combined was more than the mandibular combined, similar to Kazzazi et al. [46]

The MB-DL dimensions of all the molars showed strong correlation to gender in all the parameters under study except the maxillary left MB-DL. In our study we noted that the dimorphic potential of MB-DL of the mandibular molars (4.69%) was greater than that for the maxillary molars (3.36%) in concurrence to Manchanda et al in contrast to Zorba et al, emphasizing the population specific nature of the dimensions.

The CMB-CDL dimensions on the other hand showed weak correlation to gender. The dimorphism percentage again being higher for the lower molars (3.11%) compared to upper (2.57 %) in concurrence to study by Manchanda et al [29] and in contrast Zorba et al [28].

The CML-CDB dimensions of all the molars showed weak correlation to gender. The dimorphism percentage for upper and lower molars combined was very low with 0.50 % and 2.90% respectively. In contrast Zorba et al study done in Greeks, who found high percentage of gender accuracy with 8.46% and 7.44%. This again emphasizes on the fact the gender determination is population specific.

Various odontometric studies have shown the importance of application of logistic regression analysis and discriminant function analysis in predicting gender of the individuals. [30] We subjected our data collected from the present study to these two statistical tests.

The contribution of a variable in correctly identifying the gender can be assessed using the Discriminant Function analysis. The best dimensions were selected and 7 different functions were generated to predict gender by multivariate discriminant function analysis.

The univariate discriminant function analysis showed that the mandibular MD and mandibular MB-DL showed highest accuracy of 75% and 73% respectively, which was confirmed with the univariate logistic regression analysis which gave an accuracy of 75% and 74% respectively.

The equation for determination of gender with individual parameter could be derived from the univariate discriminant function analysis as follows:

CFC constant x CFC coefficient x parameter value = X

If X is less than the value of the group centroid [GC], probability of female and if more than GC it is probably a male.

The Univariate logistic regression analysis showed that the prediction of female with reference to male, with the odds of a person being male or female. The odds ratio was highest for mandibular MD [18.82] followed by mandibular ML-DB [12.31] and Mandibular MB-DL. Both the tests showed that the mandibular molars gave higher gender dimorphic potential compared to the males. The cervical diagonal measurements in mandibular teeth gave an accuracy of 60- 62%.

On running the data through Multivariate discriminant function analysis, it was found the mandibular first molars give higher accuracy compared to the maxillary molars. Also we noted that linear and diagonal measurements gave almost equal accuracy in case of maxillary molars. But in case of the mandibular molars, the linear measurement especially the MD gave the highest accuracy i.e. 75%. Among the mandibular diagonal measurements, ML-DB gave an accuracy of 67%.

Logistic regression analysis has been tried and tested in previous studies [7] [30] and has been shown to give higher accuracy compared to discriminant function analysis, which proved true even in our study.

According to the Multivariate logistic regression analysis, the mandibular and maxillary combined measurements, which includes the Maxillary diagonal measurements i.e. MB-DL and CMB-CDL along with mandibular linear measurements i.e. MD and BL and diagonal measurements MB-DL gave the best accuracy ranging to 81%. The statistical analysis showed that even

mandibular molar measurements gave high percentage of accuracy. According to the Nagelkerke test, the values equal to 0.4 and above are significant. Thus, even the Mandibular MD, Mandibular all and Maxillary and mandibular all contribute substantially in gender determination.

Conclusion

The present study results suggest that both the linear and diagonal dimensions of the molars contribute in gender determination. Significant differences in dimensions are noted between the genders with larger dimensions noted in males compared to females. In our study, we noted that the mandibular first molars predict the gender with good accuracy. Hence, even if only the mandible or the mandibular molars are recuperated or available, it could be adequate in gender determination of the deceased. The linear dimensions especially the MD alone gave an accuracy of 75% in case of mandibular molars. We noted that the Diagonal measurements combined with the cervical measurements increases the accuracy in gender determination.

We noted in our study that on considering multiple dimensions of many teeth the accuracy in gender determination is augmented.

To conclude, linear, diagonal and cervical measurements together give the best accuracy in gender determination. In circumstances, where linear dimensions are not possible, taking both the diagonal and cervical measurements enhances the accuracy rate in gender determination.

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