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Use of Diagonal Teeth Measurements in Predicting Gender in a Turkish Population*

ABSTRACT: Mesiodistal and buccolingual measurements, commonly used as a means of sex determination from teeth, can sometimes cause difficulties. The aim of this study is to test whether diagonal measurements can make it possible to take more accurate measurements. The results of diagonal measurements of dental casts taken from 30 males and 30 females have been evaluated by discriminant function statistics. Intra- and interobserver error tests did not indicate any statistically significant differences between the findings of two observers. Seven of the 14 measurements on the maxilla and 10 of the 14 measurements on the mandible have been found to be significantly greater in males. According to the results of the stepwise discriminant function statistics, the most contributory measurements to the function were upper first incisor mesiobuccal–distolingual (MBDL) and distobuccal–mesiolingual, lower second incisor MBDL, and lower canine MBDL. The highest reliability was obtained in MBDL measurements. It was realized that diagonal measurements of teeth, especially of canines, revealed clear dimorphic differences. Classification accuracy was found to be 83.3% for total sample, 78.3 for upper jaw, and 85.0% for the lower jaw. Accuracy rate was higher in the lower teeth. Commonly seen orthodontic anomalies, such as tooth rotations, crowding, attritions, deep dentin–enamel junction defects, and certain types of fillings, could make it difficult to correctly take width measurements or could cause other mistakes to occur. This explains the reason why this research has been considered to be of some use in diagonal measurements, which is an accurate method, particularly when employed for the front teeth.

KEYWORDS: forensic science, forensic odontology, dental sizes, sex determination

The aim of this study was to investigate the practicability of diagonal measurements used instead of width measurements when it is difficult to take correct measurements of mesiodistal (MD) and buccolingual (BL) dimensions of teeth. The second goal of this study was to find the accuracy rate of sex determination by using only the diagonal measurements. The diagonal measurements were evaluated to distinguish sex by odontometric analyses in a Turkish population. These measurements were then tested for reliability.

Sexual variations in human skeleton and dentition have been a great concern for both odontologists and anthropologists. Several methods have been used for sex determination from skeletal remains. Generally, sex is determined by primary anatomic structures. Various bone structures of human body show sexual dimorphisms. Correct evaluation of such dimorphisms depends on the available bones and their condition. If a whole mandible exists, sex determination can be made by measurements of distance between the tip of the coronoid process and the angle of the chin corner (1). Sex is also determined from the pulpal tissue of teeth (2). This DNA technique always gives the most accurate results; however, it may not be used in every case because of several reasons (3). Thus, sex determination by anthropological measurements of available bones is a more common method (4).

In the case of a complete jaw bone, it is possible to determine sex by measuring teeth sizes (5–8). Teeth sizes show some differences in both sexes and populations (9). Generally, the MD and BL measurements of teeth are used in sex determination studies.

Kieser has researched into sex determination by odontometric measurements and found significant differences between male and female teeth by using MD and BL dimensions (10). Crown diameters and combinations of root lengths are also used for measurements in sex determination (11). It is possible to find a higher rate of discriminatory capability between sexes by using these measurements regardless of the differences existing among populations (12). One of the other common methods for sex determination is the mandibular canine index. In this method, sex is determined by using the ratio of maximum crown width in MD dimension of lower canines and lower intercanines arch width (13–16).

The most commonly used odontometric dimensions in sex determination studies are MD and BL measurements (17–20). However, the measurements taken on these dimensions sometimes cause problems. If tooth rotations and/or anterior crowding exist, it may be difficult to take correct measurements. Additionally, tooth attritions, mesio-occlusal (MO), disto-occlusal (DO), mesial–distal–occlusal (MOD) restored fillings and deep dentin–enamel junction defects can cause mistakes in measuring actual dimensions.

Materials and Methods

Sixty upper and lower jaw dental models, belonging to 30 males and 30 females, have been used in this study. These samples were chosen from among the students of a high school situated in Istanbul (Yedikule High School). Following oral examinations, 30 male and 30 female students who were between 16 and 19 years of age were chosen. The inclusion criteria were as follows: fully erupted teeth, no fillings or extractions, no crowns or orthodontic apparatuses, and no orthodontic anomalies that could affect odontometric measurements. Upon their approval of the procedure, the students' upper and lower jaw impressions were taken with alginate material, which was followed by the preparation of their

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models by dental stone. Using these models, mesiobuccal–distolingual (MDBL) and distobuccal–mesiolingual (DBML) measurements of seven teeth on each jaw were taken separately. The third upper and lower molars were excluded. All the measurements were taken from the same side, which was usually the right side in these cases. The measurements were taken with a digital caliper. When placing the caliper parallel to the occlusal surface, the following points were accepted as a guide during the measurements:

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.

To perform the intra- and interobserver error test, upper and lower jaw impressions were taken from 30 people (15 males and 15 females) other than the original research group of 60 individuals. This was followed by the preparation of 30 new dental casts. Two observers independent of each other took the measurements of these 30 people at two different times/on two separate occasions.

The SPSS program was made use of in statistically analyzing the data obtained from this study.

Results

Twenty-eight measurements were taken on the 14 teeth of each individual included in this study: seven teeth from the upper jaw and seven from the lower. A total of 1,680 measurements on the teeth of 60 individuals were accomplished and analyzed by means of the SPSS program. Descriptive analyses were used and some interesting results were obtained by this means.

Table 1 shows descriptive statistics and univariate F ratios for the upper and lower dental dimensions of all the males and females included in this study. Seven of the 14 measurements performed on the maxilla and 10 of the 14 measurements performed on the mandible of the males revealed greater values than those performed on the females. The difference was statistically significant ($p < 0.05$). Similar results were obtained from five MBDL measurements performed on both the maxilla and mandible, and two DBML measurements performed on the maxilla and five on the mandible. These results show that lower teeth are more dimorphic, and MBDL measurements are more reliable.

The next step of the study was the intra- and interobserver error test. On two separate occasions, two observers took measurements on 30 test casts belonging to the control group. Their differences were analyzed using *t*-test with the base sample, within observer 1 and observer 2, and between observer 1 and observer 2. There was no statistically significant difference between the findings of the two observers. Table 2 shows the results of the intra- and interobserver error test.

The differences between the sexes were analyzed by discriminant function statistics. The question of which of the measurements affected the functions most was answered by employing the stepwise method.

Table 3 shows the contributions of diagonal measurements of all the teeth over the functions calculated by means of the stepwise method, and their order of entering the analyses. Upon analysis of the diagonal measurements, upper first incisor MBDL and DBML, lower second incisor MBDL, and canine MBDL measurements were entered into the function. An 87% of accuracy rate was found for males, and 80% for females, the average of which was 83.3% (Table 5). As a result, by using the four diagonal measurements of U1 MBDL, U2 DBML, L2 MBDL, LC MBDL, and the stepwise method, it was possible to determine sex from teeth with an average accuracy rate of 83.3%.

In Table 4, all the necessary coefficients and sectioning points are given for all functions to be used in sex determination. The values below include the kinds of teeth mentioned respectively: F1—all teeth; F2—upper teeth; F3—lower teeth; F4—incisors; F5—canines; F6—premolars; F7—molars. The structure matrix shows the relation between functions and variables. For instance; in F1, the structure matrix is 0.509 for U1 MBDL and 0.245 for U1 DBML. This means that U1 MBDL is more related to this function. While group centroid shows the average discriminant scores of the sexes, the sectioning point indicates the score of separation. Unstandardized coefficient is used in the calculation of discriminant function score. To calculate this, the dimensions of teeth are first multiplied with their coefficients, and the results are then added to the constant. The addition is finally compared with the sectioning point. If the result is below the

TABLE 1—*Descriptive statistics of diagonal dental dimensions in Turkish males (N = 30) and females (N = 30) and univariate F ratios.**

	MBDL					DBML				
	Male		Female			Male		Female		
	Mean	SD	Mean	SD	F	Mean	SD	Mean	SD	F
Upper teeth										
I1	8.54	0.545	8.05	0.401	15.6^c	8.13	0.812	7.82	0.379	3.61
I2	6.76	0.549	6.45	0.761	3.25	6.62	0.567	6.23	0.380	9.63^b
C	7.71	0.780	7.25	0.293	3.95^b	7.71	0.669	7.22	0.317	13.09^c
P1	8.14	0.904	7.60	0.452	8.56^c	8.26	0.984	8.06	0.395	1.04
P2	8.15	0.752	7.84	0.487	3.70	8.32	0.773	7.95	0.714	3.66
M1	12.67	0.801	11.84	1.149	10.49^b	11.06	0.782	10.68	0.831	3.39
M2	11.85	0.895	11.32	0.739	6.33^a	10.53	0.884	10.53	0.734	0.000
Lower teeth										
I1	5.59	0.684	5.22	0.406	6.69^a	5.78	0.644	5.33	0.430	10.33^b
I2	5.71	0.577	5.69	0.669	0.018	6.13	0.878	5.69	0.624	5.17^a
C	7.35	0.665	6.66	0.427	22.97^c	6.80	0.635	6.25	0.455	14.93^c
P1	7.73	0.675	7.22	0.482	11.50^c	7.20	0.771	6.99	0.437	1.68
P2	8.23	0.608	7.90	0.629	4.35^a	7.90	0.581	7.62	0.450	4.51^a
M1	12.21	0.615	11.76	0.413	10.69^b	11.79	0.682	11.47	0.515	4.32^a
M2	11.79	0.953	11.49	0.733	1.94	11.75	0.838	11.59	0.985	0.45

*Statistically significant at $^a p < 0.05$, $^b p < 0.01$, $^c p < 0.001$; df = 1.58.
MBDL, mesiobuccal–distolingual; DBML, distobuccal–mesiolingual.

TABLE 2—*t Values of intra- and interobserver error tests (N = 60 for base sample, N = 30 for test samples).*

	Base and Observer 1	Base and Observer 2	Intraobserver 1	Intraobserver 2	Interobservers
U1 MBDL	−0.12	0.11	−0.09	−0.08	0.20
U1 DBML	−0.06	0.12	−0.10	−0.09	0.16
U2 MBDL	0.06	0.26	−0.07	−0.06	0.18
U2 DBML	−0.09	0.15	−0.13	−0.10	0.21
UC MBDL	−0.62	−0.42	−0.09	−0.08	0.17
UC DBML	−0.51	−0.30	−0.09	−0.07	0.17
UP1 MBDL	−0.35	−0.11	−0.09	−0.07	0.21
UP1 DBML	0.16	0.37	−0.06	−0.06	0.17
UP2 MBDL	−0.04	0.17	−0.07	−0.06	0.18
UP2 DBML	−0.17	0.03	−0.07	−0.05	0.17
UM1 MBDL	−0.19	−0.04	−0.04	−0.02	0.13
UM1 DBML	−0.74	−0.57	−0.07	−0.06	0.14
UM2 MBDL	−0.24	−0.07	−0.05	−0.04	0.14
UM2 DBML	−0.37	−0.21	−0.08	−0.05	0.14
L1 MBDL	−0.37	−0.12	−0.09	−0.09	0.21
L1 DBML	−0.16	0.14	−0.10	−0.08	0.25
L2 MBDL	−0.51	−0.27	−0.09	−0.07	0.20
L2 DBML	0.12	0.34	−0.08	−0.06	0.19
LC MBDL	−0.46	−0.25	−0.08	−0.09	0.17
LC DBML	−0.22	0.00	−0.09	−0.07	0.18
LP1 MBDL	0.01	0.22	−0.09	−0.06	0.17
LP1 DBML	−0.42	−0.13	−0.08	−0.06	0.23
LP2 MBDL	−0.01	0.22	−0.07	−0.08	0.17
LP2 DBML	−0.10	0.19	−0.12	−0.07	0.24
LM1 MBDL	0.12	0.42	−0.09	−0.08	0.24
LM1 DBML	−0.47	−0.25	−0.11	−0.07	0.18
LM2 MBDL	−0.18	−0.06	−0.06	−0.04	0.10
LM2 DBML	−0.13	−0.01	−0.06	−0.03	0.10

None of the *t* values are significant at the $p < 0.05$ level.
MBDL, mesiobuccal–distolingual; DBML, distobuccal–mesiolingual.

sectioning point, the person is female, and if over the sectioning point, the person is male. For instance, the dental dimensions entered to the function for F4 are 8.54 and 5.71. According to this formula,

$$8.54 \times 2.684 = 22.9213$$
$$5.71 \times -1.249 = -7.1317$$
$$22.9213 + -7.1317 = 15.7896$$
$$15.7896 + -15.162(\text{constant}) = 0.6276$$
$$0.6276 > 0(\text{sectioning point}) = \text{Male}$$

With the help of the stepwise method, the diagonal measurements of the upper and lower jaws were analyzed separately. By making use of the same method, the molars, premolars, the canines, and incisors were analyzed separately. Table 5 shows the results of the analyses of diagonal measurements taken in these groups and accuracy rates.

In this study, the accuracy rate was found to be 78.3% for the upper jaw and 85% for the lower jaw. These results show that the lower teeth are more dimorphic in the Turkish nation, and the diagonal measurements can support the width measurements. Accuracy rates differed from 63.3% to 86.7% in males and from 70% to 90% in females.

When this widely used and reliable formula is applied to an unknown sample group of the same population, accuracy of sex determination will be similar to that of the base sample. In the original group, the accuracy rates of 73.3% for upper jaw and 90.0% for lower jaw show that the lower teeth have been found to be more dimorphic. In the test groups, accuracy rates differed from 60.0% to 93.3% in males and from 66.7% to 100% in females. The highest accuracy rates were obtained in F3, in the lower teeth and in the teeth of females. These results are in agreement with the base sample results (Table 6). The diagonal measurements of the lower first incisor, lower second premolar, and first molar teeth gave more accurate results in both MBDL and DBML dimensions, and so did lower second incisors in DBML and lower first premolars in MBDL. The differences between the accuracy rates of one dimension and the other were statistically significant ($p < 0.05$). When the results of DBML and MBDL dimensions of males were compared with those of females, the upper teeth of the former group, excluding the canines, did not significantly differ from those of the latter. However, the results of DBML dimension showed that there was a statistically significant difference between the upper second incisors of the former group and those of the latter. Likewise, the results of DBML dimension revealed that there was a statistically significant correlation between the upper first incisor, second premolar, and first and second molar teeth of the males and those of the females. While the differences between the upper canines of males and females were statistically significant in both dimensions, the difference between the upper second premolars of one group and the other was not. The highest degree of significance was

TABLE 3—*Stepwise discriminant function analyses of all dimensions.*

Steps	Variables Entered	Wilks' Lambda Statistic	Exact *F* Statistic	df 2
1	LC MBDL	0.716	22.974	1.58
2	L2 MBDL	0.632	16.607	2.57
3	U1 MBDL	0.532	16.425	3.56
4	U1 DBML	0.490	14.289	4.55

MBDL, mesiobuccal–distolingual; DBML, distobuccal–mesiolingual.

TABLE 4—*Canonical discriminant function coefficients for tooth groups.*

	Unstandardized Coefficients	Structure Matrix	Standardized Coefficients	Group Centroids		Sectioning Point
				Male	Female	
F1: all teeth						
U1 MBDL	2.572	0.509	1.232	1.002	– 1.002	0
U1 DBML	– 1.281	0.245	– 0.812			
L2 MBDL	– 1.207	0.017	– 0.754			
LC MBDL	1.695	0.617	0.948			
(Constant)	– 16.136					
F2: upper teeth						
U1 MBDL	3.217	0.638	1.540	0.799	– 0.799	0
U1 DBML	– 2.195	0.307	– 1.392			
UC DBML	1.450	0.585	0.759			
(Constant)	– 20.033					
F3: lower teeth						
LC MBDL	1.419	0.693	1.116	0.892	– 0.892	0
L2 MBDL	– 1.302	0.019	– 0.814			
L1 DBML	1.996	0.465	0.778			
LM2 MBDL	– 0.698	0.202	– 0.594			
(Constant)	– 6.328					
F4: incisors						
U1 MBDL	2.684	0.795	1.285	0.642	– 0.642	0
L2 MBDL	– 1.249	0.027	– 0.781			
(Constant)	– 15.162					
F5: canines						
LC MBDL	1.788	1.000	1.000	0.619	– 0.619	0
(Constant)	– 12.538					
F6: premolars						
LP1 MBDL	2.707	0.818	1.590	0.535	– 0.535	0
LP1 DBML	– 1.535	0.313	– 0.962			
(Constant)	– 9.349					
F7: molars						
LM1 MBDL	2.542	0.752	1.333	0.561	– 0.561	0
UM2 DBML	– 1.080	0.004	– 0.878			
(Constant)	– 19.103					

MBDL, mesiobuccal–distolingual, DBML, distobuccal–mesiolingual.

TABLE 5—*Classification results of the original and cross-validated* samples.*

	Sex				
	Male		Female		Total Average
Functions	*N*	%	*N*	%	(%)
F1: all teeth					
Original	26/30	86.7	24/30	80.0	83.3
Cross validated	26/30	86.7	24/30	80.0	83.3
F2: upper teeth					
Original	25/30	83.3	22/30	73.3	78.3
Cross validated	23/30	76.7	22/30	73.3	75.0
F3: lower teeth					
Original	24/30	80.0	27/30	90.0	85.0
Cross validated	21/30	70.0	27/30	90.0	80.0
F4: incisors					
Original	24/30	80.0	22/30	73.3	76.7
Cross validated	24/30	80.0	21/30	70.0	75.0
F5: canines					
Original	19/30	63.3	22/30	73.3	68.3
Cross validated	19/30	63.3	22/30	73.3	75.0
F6: premolars					
Original	20/30	66.7	23/30	76.7	71.1
Cross validated	20/30	66.7	23/30	76.7	71.1
F7: molars					
Original	22/30	73.3	22/30	73.3	73.3
Cross validated	22/30	73.3	21/30	70.0	71.1

*Cross validation is done only for those cases in the analysis. In cross-validation, each case is classified by the functions derived from all cases other than that case.

found in the lower canines. In taking diagonal measurements, MBDL dimension gave more accurate results.

Discussion

According to the results obtained from diagonal measurements taken during the course of this study, male teeth have been found to be larger than female teeth. The difference was statistically significant. These results are in accordance with various studies previously carried out using odontometric measurements. These studies report clear dimorphic differences between male and female teeth (21–23). The results of another study performed on the Swedish population show that the dimorphic differences in canines and in MBDL dimensions may also be valid for the Turkish population (24). This is in confirmation with the above-mentioned studies.

Among the other 14 teeth investigated during the course of this study, the highest rate of accuracy was observed in canines. This result shows that the canines can be used for determining sex by means of odontometric analyses, as stated in other similar studies (25,26). Additionally, the statistically significant dimorphisms of canines were not only found in width measurements, but also in diagonal measurements. This shows that when width measurements fail to be employed as a reliable method, diagonal measurements of canines can be used instead. The accuracy rates of first and second incisors in diagonal measurements were not so high as the canines, but were statistically significant and reliable

TABLE 6—*Accuracy errors made by intraobservers (observer 1 and test, observer 2 and test) and interobservers (observers 1 and 2) in determining sex from diagonal dimensions taken at different times by each observer.*

	Male		Female				Male		Female		
	N	%	*N*	%	Average (%)		*N*	%	*N*	%	Average (%)
Observer 1						Observer 2					
F1	14/15	93.3	12/15	80.0	86.6		14/15	93.3	12/15	80.0	86.6
F2	13/15	86.7	11/15	73.3	80.0		12/15	80.0	11/15	73.3	76.6
F3	12/15	80.0	15/15	100	90.0		12/15	80.0	15/15	100	90.0
F4	12/15	80.0	10/15	66.7	73.3		12/15	80.0	10/15	66.7	73.3
F5	11/15	73.3	11/15	73.3	73.3		11/15	73.3	11/15	73.3	73.3
F6	9/15	60.0	12/15	80.0	70.0		10/15	66.7	12/15	80.0	73.3
F7	9/15	60.0	11/15	73.3	66.6		9/15	60.0	11/15	73.3	66.6
Observer 1 Test						Observer 2 Test					
F1	14/15	93.3	12/15	80.0	86.6		14/15	93.3	12/15	80.0	86.6
F2	13/15	86.7	11/15	73.3	80.0		13/15	86.7	11/15	73.3	80.0
F3	12/15	80.0	15/15	100	90.0		12/15	80.0	15/15	100	90.0
F4	12/15	80.0	10/15	66.7	73.3		12/15	80.0	10/15	66.7	73.3
F5	11/15	73.3	11/15	73.3	73.3		11/15	73.3	11/15	73.3	73.3
F6	10/15	66.7	12/15	80.0	73.3		10/15	66.7	12/15	80.0	73.3
F7	9/15	60.0	11/15	73.3	66.6		9/15	60.0	11/15	73.3	66.7

in case difficulties arose when taking width measurements. The same method can be applied to the premolars, excluding the upper second, and to the first molars. However, when used in measuring upper second premolars and the upper and lower second molars, the method is not reliable.

According to the results obtained from this study, the accuracy rate of sex determination was higher in females than in males. Compared with that of the upper ones, the accuracy rate of the lower teeth was higher. This shows that lower teeth are more dimorphic than the upper ones. The most important dimorphism was found in canines, in the lower of which the rate of accuracy was the highest. Lower canines were observed to include all the variations of a certain sex.

In general, MD and BL measurements give more accurate results, and should be preferred if it is possible to take width measurements. However, such malpositions as tooth rotation, crowding and orthodontical anomalies may cause difficulties in taking width measurements. Furthermore, occlusal attritions, MO, DO, and MOD types of fillings may change the original dimensions of teeth and may cause mistakes to occur or may prevent taking precise MD measurements. Lower incisor crowding and deep dentin–enamel junction defects may also cause problems in BL measurements. Diagonal measurements should be tried only if these difficulties in taking width measurements arise. Taking diagonal measurements is always more difficult and requires more attention. If the compass is not placed correctly, measurements will most probably be wrong.

It is a fact that 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. Similarly, if the accuracy rate of width measurements of certain teeth is low, then the accuracy rate of diagonal measurements of such teeth is also low. This shows that, along with width measurements, diagonal measurements can also be used in sex determination. When it is difficult to measure the front teeth groups or sometimes premolars, diagonal measurements may be a reliable method. In this study, however, when it came to the molars, where anomalies are seldom found, the method was not found to be reliable.

In conclusion, the author would like to suggest that diagonal measurements may, in certain cases, be used in support of width measurements.

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