Original Article

Regression Equations for Determining Mesiodistal Crown Diameters of Canines and Premolars

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Abstract: In this study, regression equations (prediction equations) were established for the purpose of accurately predicting the widths of the crowns of unerupted canines (C) and premolars (P_1 and P_2) on the basis of the measured mesiodistal diameter (MDD) and vestibulooral diameter (VOD) of the crowns of the erupted central and lateral incisors (I_1, I_2) and first permanent molars (M_l) . On the plaster casts of 120 subjects (60 boys and 60 girls), MDD and VOD of the crowns of I_1, I_2, C, both P_1 and P_2, and M_l on both sides in both jaws were measured twice, with a time distance between measurements. Gradual regression equations were derived on the basis of the measurement results, by which the sums of the widths of crowns of C, P_1, and P_2 can be predicted using three to five predictors. The coefficients of multiple correlations regarding the sex and the jaw varied from 0.79 to 0.85. (*Angle Orthod* 2003;73:314–318.)

Key Words: Regression equation; Mesiodistal crown diameters; Canine; Premolars

INTRODUCTION

The determination of the mesiodistal diameters (MDD) of crowns of unerupted canines and premolars (C, P_1, and P_2) has great importance in determining the choice of therapy during the mixed dentition. There are three basic methods of predicting MDD of the C, P_1, and P_2—application of middle values,[1–3] correlation-statistical methods,[4–15] and combination of X-ray and correlation-statistical methods.[16–19]

Because of their simplicity, correlation-statistical methods are most frequently applied. However, several authors have pointed out that the predicted values are too high.[20–29]

The aim of this study was to establish regression equations, ie, prediction equations, which would give the greatest correlation coefficient for the sum of MDD of the C, P_1, and P_2 for both jaws by using three to five predictors, measured MDD, and vestibulooral diameters (VOD) of crowns of the permanent central and lateral incisors (I_1, I_2) and the first permanent molars (M_l).

MATERIALS AND METHODS

A total of 120 plaster casts (60 boys and 60 girls) were chosen from the plaster cast archives of the orthodontic clinics in the city of Zagreb. All casts met the following criteria: permanent dentition in both jaws (age ranged from 14 to 18 years); teeth without anomalies in number, form, size, and structure; intact mesiodistal and vestibulooral surfaces of the crowns of the teeth I_1, I_2, C, P_1, P_2, and M_1; and children without syndrome diseases.

The MDD and VOD of I_1, I_2, C, P_1, P_2, and M_1 were measured on the plaster casts in all four segments. The measurements were made according to the method of Seipel[30] using electronic digital caliper, 150 mm HS/R3/lA, from Knuth GmbH + Co., Werkzeugmaschinen KG, with an accuracy of 0.01 mm. To gain an easier approach to interdental spaces, the measuring surfaces of the digital caliper were narrowed. Before the measurement, the caliper was set at the Faculty of Machine Engineering and Ship Building of the University in Zagreb.

To determine the consistency in the measurements of MDD and VOD of the I_1, I_2, C, P_1, P_2, and M_1 crowns, the measurements were conducted twice within a 10-day period (test-retest reliability). The repeated measurement was entered twice to prevent the results of the previous measurement from influencing the second measurement.

The variables for the analyses of regression equations were obtained by determining the arithmetic mean of two measurements. The variables were divided into groups of predictor variables (MDD and VOD of I_1, I_2, and M_l) and criteria variables (sum of MDD of C, P_1, and P_2) in all four segments. The consistency in measurement was determined by Pearson's correlation coefficients. The discrepancies in

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TABLE 1. Mesiodistal and Vestibulooral Diameters of Crowns of Incisors and the Analysis of the Variant with Independent Sex Variable[a]

	Girls		Boys			
Variables	AM	SD	AM	SD	*F* Ratio	*P*
MDD 11	8.52	0.47	8.69	0.57	2.91	.0909
VOD 11	6.99	0.44	7.14	0.57	2.63	.1078
MDD 12	6.62	0.52	6.68	0.67	0.36	.5500
VOD 12	6.20	0.60	6.40	0.61	3.26	.0734
MDD 21	8.52	0.47	8.70	0.54	4.36	.0390**
VOD 21	6.98	0.45	7.20	0.54	5.87	.0170**
MDD 22	6.61	0.50	6.69	0.68	0.47	.4924
VOD 22	6.22	0.49	6.46	0.57	6.52	.0119**
MDD 31	5.28	0.39	5.42	0.38	3.91	.0505
VOD 31	5.99	0.70	6.10	0.50	0.70	.4034
MDD 32	5.81	0.02	0.25	0.43	6.54	.0118**
VOD 32	6.17	0.40	6.26	0.55	1.26	.2644
MDD 41	5.26	0.33	5.38	0.37	3.90	.0509
VOD 41	5.90	0.37	6.05	0.50	3.40	.0679
MDD 42	5.82	0.31	6.00	0.42	7.66	.0066**
VOD 42	6.18	0.38	6.27	0.49	1.18	.2786

[a] AM indicates arithmetic mean; SD, standard deviation; MDD, mesiodistal diameter; and VOD, vestibulooral diameter.
* $P < .01$, ** $P < .05$.

MDD and VOD of teeth between boys and girls were verified by the *t*-test procedure, the aim being the need to calculate a separate optimal linear combination for each sex.

Because the research showed exceptionally high measures of connections between the different tooth size measures on the left and right sides of the jaw, the justification of determining the linear regression for only one side of the jaw was verified by Pearson's correlation coefficient.

β-ponders for three to five predictors, MDD and VOD of I_1, I_2, and M_l, in all segments were determined by the linear regression analysis, in gradual regression analysis for the prediction of the sum of MDD, C, P_1, and P_2 with the highest coefficient of multiple correlations. The criterion for excluding the predictors from the gradual regression analysis was determined in advance to be 10%.

RESULTS

Because the aim of this study was to determine optimal linear combinations of predictors (I_1, I_2, and M_l) for predicting the criteria C, P_1, and P_2, it was important to determine in advance whether the dimension of teeth of boys and girls vary (Tables 1 through 4). It can be seen from the tables that there is a statistically significant sex discrepancy, which necessitates division of the subjects according to sex when determining optimal linear combinations of predictors.

Correlation coefficients between homologous teeth of the left and right side of the same jaw were exceptionally positive and varied from 0.72 to 0.97 (girls, maxilla 0.72–0.95; boys, maxilla 0.88–0.97; girls, mandible 0.78–0.93; boys, mandible 0.88–0.96).

TABLE 2. Mesiodistal and Vestibulooral Diameters of Crowns of Canines and the Analysis of the Variant with Independent Sex Variable[a]

	Girls		Boys			
Variables	AM	SD	AM	SD	*F* Ratio	*P*
MDD 13	7.66	0.29	8.00	0.49	20.89	.0000*
VOD 13	7.85	0.48	8.30	0.70	16.16	.0001*
MDD 23	7.62	0.28	7.96	0.47	23.22	.0000*
VOD 23	7.84	0.48	8.29	0.70	16.71	.0001*
MDD 33	6.60	0.32	7.00	0.43	31.67	.0000*
VOD 33	7.14	0.50	7.45	0.69	7.72	.0063**
MDD 43	6.57	0.30	0.32	0.43	33.45	.0000*
VOD 43	7.15	0.50	7.42	0.05	6.43	.0125**

[a] AM indicates arithmetic mean; SD, standard deviation; MDD, mesiodistal diameter; and VOD, vestibulooral diameter.
* $P < .01$, ** $P < .05$.

TABLE 3. Mesiodistal and Vestibulooral Diameters of Crowns of Premolars and the Analysis of the Variant with Independent Sex Variable[a]

	Girls		Boys			
Variables	AM	SD	AM	SD	*F* Ratio	*P*
MDD 14	6.90	0.39	7.06	0.48	3.92	.0499
VOD 14	9.18	0.49	9.44	0.78	4.81	.0301**
MDD 15	6.61	0.41	6.85	0.53	8.20	.0050**
VOD 15	9.24	0.52	9.60	0.75	9.85	.0021*
MDD 24	6.90	0.40	7.11	0.47	6.90	.0097**
VOD 24	9.14	0.51	9.46	0.75	7.46	.0073**
MDD 25	6.58	0.42	6.78	0.47	5.91	.0165**
VOD 25	9.27	0.49	9.65	0.73	10.79	.0013*
MDD 34	7.03	0.37	7.22	0.49	5.42	.0217**
VOD 34	7.59	0.44	8.01	0.57	21.07	.0000*
MDD 35	7.12	0.46	7.34	0.52	6.42	.0126**
VOD 35	8.34	0.44	8.73	0.62	16.87	.0000*
MDD 44	7.00	0.36	7.16	0.49	3.90	.0508
VOD 44	7.61	0.47	8.00	0.62	15.70	.0001*
MDD 45	7.13	0.62	7.31	0.04	3.21	.0755
VOD 45	8.31	0.40	8.70	0.71	13.56	.0003*

[a] AM indicates arithmetic mean; SD, standard deviation; MDD, mesiodistal diameter; and VOD, vestibulooral diameter.
* $P < .01$, ** $P < .05$.

TABLE 4. Mesiodistal and Vestibulooral Diameters of Crowns of Molars and the Analysis of the Variant with Independent Sex Variable[a]

	Girls		Boys			
Variables	AM	SD	AM	SD	*F* Ratio	*P*
MDD 16	10.08	0.45	10.53	0.65	19.54	.0000*
VOD 16	11.08	0.58	11.54	0.72	14.50	.0002*
MDD 26	10.00	0.53	10.40	0.62	14.10	.0003*
VOD 26	11.01	0.64	11.50	0.64	18.00	.0000*
MDD 36	10.67	0.77	11.14	0.75	11.76	.0008*
VOD 36	10.36	0.53	10.81	0.56	20.47	.0000*
MDD 46	10.69	0.04	11.17	0.67	16.84	.0001*
VOD 46	10.30	0.49	10.79	0.61	23.46	.0000*

[a] AM indicates arithmetic mean; SD, standard deviation; MDD, mesiodistal diameter; and VOD, vestibulooral diameter.
* $P < .01$, ** $P < .05$.

TABLE 5. Results of Gradual Regression Analysis for the Sum of Predictable Mesiodistal Diameters of Crowns of C, P_1, and P_2 for Both Sexes[a]

	Gradual Regression Analysis	
	Girls	Boys
Maxilla	.79 $F = 17.45$ $P = .0000$ SEE = .61	.84 $F = 15.53$ $P = .0000$ SEE = .54
Mandible	.78 $F = 28.30$ $P = .0000$ SEE = .63	.85 $F = 36.24$ $P = .0000$ SEE = .53

[a] SEE indicates standard error of the estimate.

TABLE 6. Gradual Regression Equation for the Prediction of the Sum of Mesiodistal Diameters of Crowns of C, P_1, and P_2 in the Upper Jaw for the Girls[a–c]

Predictors	Beta	β Ponder	*t*	*P*
MDD 32	1.415	0.498	4.343	.0001
MDD 36	0.386	0.326	2.371	.0213
VOD 31	0.398	0.306	2.338	.0231
VOD 32	−0.725	−0.313	−2.753	.0080
VOD 26	0.277	0.193	1.813	.0754

[a] MDD indicates mesiodistal diameter; VOD, vestibulooral diameter.

[b] Constant = 7.80.

[c] +C, P_1, P_2+ = 1.415(MDD 32) + 0.386(MDD 36) + 0.398(VOD 31) − 0.725(VOD 32) + 0.277(VOD 26) + 7.80.

The coefficients of canonic correlation between the observed six teeth of the right and left sides of both jaws were also determined.

The first pair of canonic correlations was greater than 0.97 in all cases. These findings justify the use of linear equations for both sides of the jaw regardless of the side for which they were determined. In this study, we opted for the left side.

The correlations between the first and second measurement of MDD and VOD lie in the interval from 0.85 to 0.99. Because the reliability between the first and the second measurement on all variables was extremely high, we decided to determine the average of the first and second measurements.

Table 5 illustrates the coefficients of multiple correlations resulting from gradual regression analysis by a backward method for both subsamples.

Tables 6 through 9 show the results of gradual regression analysis for the prediction of sums of MDD of C, P_1, and P_2 with regard to the jaw and sex.

Regression equations for the prediction of sums of MDD of C, P_1, and P_2 for girls, each jaw separately, are established from Tables 6 and 7.

Regression equations for the prediction of the sums of MDD of C, P_1, and P_2 for boys, each jaw separately, are established from Tables 8 and 9.

TABLE 7. Gradual Regression Equation for the Prediction of the Sum of Mesiodistal Diameters of Crowns of C, P_1, and P_2 in the Lower Jaw for the Girls[a–c]

Predictors	Beta	β Ponder	*t*	*P*
MDD 32	0.916	0.327	3.161	.0025
MDD 36	0.430	0.369	3.605	.0007
VOD 26	0.414	0.293	3.209	.0022

[a] MDD indicates mesiodistal diameter; VOD, vestibulooral diameter.

[b] Constant = 6.28.

[c] −C, P_1, P_2− = 0.916(MDD 32) + 0.430(MDD 36) + 0.414(VOD 26) + 6.28.

TABLE 8. Gradual Regression Equation for the Prediction of the Sum of Mesiodistal Diameters of Crowns of C, P_1, and P_2 in the Upper Jaw for the Boys[a–c]

Predictors	Beta	β Ponder	*t*	*P*
MDD 32	1.003	0.341	3.669	.0006
MDD 22	0.444	0.240	2.282	.0264
MDD 26	0.490	0.241	2.308	.0248
VOD 26	0.385	0.196	1.767	.0828

[a] MDD indicates mesiodistal diameter; VOD, vestibulooral diameter.

[b] Constant = 3.34.

[c] +C, P_1, P_2+ = 1.003(MDD 32) + 0.444C,P_1,P_2+(MDD 22) + 0.490(MDD 26) + 0.385(VOD 26) + 3.34.

TABLE 9. Gradual Regression Equation for the Prediction of the Sum of Mesiodistal Diameters of Crowns of C, P_1, and P_2 in the Lower Jaw for the Boys[a–c]

Predictors	Beta	β Ponder	*t*	*P*
MDD 32	1.019	0.337	3.415	.0012
MDD 36	0.430	0.251	2.935	.0049
VOD 32	0.497	0.213	2.710	.0090
MDD 22	0.611	0.322	3.775	.0004

[a] MDD indicates mesiodistal diameter; VOD, vestibulooral diameter.

[b] Constant = 3.45.

[c] −C, P_1, P_2− = 1.019(MDD 32) + 0.430(MDD 36) + 0.497(VOD 32) + 0.611(MDD 22) + 3.45.

In gradual regression analysis, only three to five predictors were maintained. Betas and β-ponders are given in those tables, as well as the constant for determining MDD of C, P_1, and P_2.

DISCUSSION

The aim of this study was to establish regression equations with which, by the use of the predictors MDD and VOD, I_1, I_2, and M_1, the sums of MDD of C, P_1, and P_2 in both jaws would be predicted, and these predicted values would be the most authentic representation of the measured values.

Out of all the proposed methods so far for the prediction of the sums of MDD of C, P_1, and P_2, Moyer's method is

most frequently applied.[1–19] Proffit and Ackerman[31] find Moyer's method satisfactory, whereas many others have indicated that the predicated values were too high when this method is used with a different population.[13,15,23] Moyer's predicted values are too high for the Croatian population as well.[20–22]

Another method that is frequently used is the Tanaka and Johnston[8] method. This method also has been reported by several authors to be imprecise.[24,25,28] The predicted values are, as with Moyer's, too high.

X-ray correlation methods proposed by several authors have turned out to be very reliable.[16–19,32–35] However, when the reliability of correlation methods and X-ray methods were compared, many authors found that the latter was much more precise.[24,28,33,34,36]

In this study, using three to five predictors (MDD and VOD of I_1, I_2, and M_1), correlation coefficients with the sums of MDD of C, P_1, and P_2 amounted to: for the boys, 0.84 in the maxilla and 0.85 in the mandible; and for the girls, 0.79 in the maxilla and 0.78 in the mandible.

A more comprehensive research in future studies will surely check the stability of ponder, predicting mesiodistal diameters of the C, P_1, and P_2 crowns.

For the requirements of this work, we cross-validated in the following way: randomly chosen testees of both sexes were divided into halves. For each half, ponders were calculated for the group of predictor variables obtained in the gradual regression analysis. The ponder obtained in the first subsample was applied to the testees' variables from the second subsample and vice versa.

What we got were very high coefficients of correlation (between 0.93 and 0.96) among the criteria variables calculated in that way. Sums of MDD of C, P_1, and P_2 in both jaws predicted by this method were more precise in boys. Staley et al[34] have made similar observations. According to Staley et al,[34] the prediction of the width of the crowns of teeth is more reliable on the left than on the right side of the jaw. According to our research, the choice of the side is not important. Bachmann[15] and Gross and Hasund[13] used three predictors in their regression equations for predicting the sums of MDD of C, P_1, and P_2. Bachmann[15] obtained correlation coefficients from 0.83 in the maxilla to 0.85 in the mandible without dividing the sample according to sex, and Gross and Hasund,[13] depending on the side of the jaw, got correlation coefficients from 0.72 to 0.85.

The VOD of the M_l crown is used as a predictor in this study. Their use showed greater correlation with C, P_1, and P_2 than the use of MDD as indicated by Gross and Hasund[13] and Ingerwal and Lennartsson.[32] They used the VOD of the M_1 in their prediction methods. According to Potter,[37] the VOD of the teeth in the maxilla are more strongly controlled than the genetic system of MDD.

According to Staley et al,[34] combinations of three predictors, two of which are determined by measuring MDD of crowns on radiographs and the third by measuring MDD of crowns on the plaster cast, give the greatest correlation coefficient (0.89–0.93). The study elaborates regression equations separately for each sex. The MDD and VOD of almost all teeth were statistically significantly higher in boys. Other authors have also pointed at sex dimorphism of dimensions of MDD of C, P_1, and P_2.[29,38,39] All of them find that the methods of determining the sums of MDD of C, P_1, and P_2 have to be different according to sex.

CONCLUSION

On the basis of the established aim of this research and analysis of the results, it is concluded that with correlation coefficients from 0.84 to 0.85 in boys and 0.78 to 0.79 in girls, the sums of MDD of C, P_1, and P_2 can be predicted by regression equation with the use of three to five predictors.

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