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Are the Lower Incisors the Best Predictors for the Unerupted Canine and Premolars Sums? An Analysis of a Peruvian Sample

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ABSTRACT

The lower permanent incisor tooth width sum has been proposed as the best predictor for the tooth width sums of the unerupted canine and premolars (SPCP) for populations from different ethnic origins. Only two previous studies have refuted it. The purpose of the present study was to determine which sum or combination of sums of permanent tooth widths presented the best prediction capability for the SPCP in a Peruvian sample, to calculate a specific linear regression equation for this population, and to evaluate the clinical significance. A total of 150 children with complete permanent dentitions were selected. Fifty more children were used as a validation sample for the application of a multiple linear regression equation (MLRE). They did not present clinically visible dental caries or proximal restorations and no active or previous orthodontic treatment. Their dental casts were measured to 0.1 mm with a sliding caliper with a Vernier scale. Three-way analysis of variance, Pearson Correlation Test, Fisher *Z* values and a MLRE were used for the statistical analysis. The combination of the sums of permanent upper and lower central incisors and upper first molars was the best predictor for the SPCP in this sample. A MLRE was calculated including sex and arch as additional predictor variables. The MLRE determination coefficient was 60% with a standard error of 0.8 mm. This new MLRE underestimates (less than 1 mm discrepancy) the actual SPCP in only 7% of the cases on the basis of a validation sample.

KEY WORDS: Mixed dentition analysis, Multiple regression, Mesiodistal tooth size.

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INTRODUCTION Return to TOC

Mixed dentition analysis is the prediction of the tooth size of nonerupted permanent canine and premolars to determine the discrepancy between the available and required space in each dental arch. Some basic principles for a mixed dentition analysis are: (1) a known minimum systemic error, (2) ease of use by any person with basic training, (3) fast, (4) no special equipment required, (5) can be carried out directly in the mouth, and (6) can be used in both dental arches.[1]

Mixed dentition analysis methods can be grouped into three categories, ie, those which use regression equations, those which use radiographs, and those which use a combination of both. Among the different mixed dentition analysis methods reported in the literature, the regression equations based on the already erupted permanent teeth in early mixed dentition are the most broadly used, especially the Moyers probability tables[1,2] and the Tanaka and Johnston equations.[3]

Carey[4] reported the existence of a significant linear association between the mesiodistal tooth width sum of the lower permanent incisors and the sum of the lower or upper permanent canine and premolars (SPCP) in 1949. Since then, several simple linear regression equations have been proposed for populations of different ethnic origins.[3,5–14]

Only two recent studies[15,16] reported that the lower permanent incisor mesiodistal tooth width sum is not the best predictor. Advances in statistical software have permitted complex calculations of multiple regression models that could simultaneously evaluate several explanatory variables. Nourallah et al[15] reported that the sum of the lower central incisors and upper first molars had the highest prediction value (determination coefficient between 52% and 56%) for SPCP. A year later, Legovic et al[16] developed multiple linear regression equations (MLRE) with higher prediction values (determination coefficient between 62% and 72%) when they also considered the buccolingual tooth size. Finally, Hashim and Al-Shalan[17] have recently reported the inclusion of the sex factor as an additional predictor variable for the estimation of the canine and premolars sum on the basis of the sexual dimorphism in tooth size that predominated in their sample, but they did not state the determination coefficients for their MLRE. However, Legovic et al[16] and Hashim and Al-Shalan[17] did not validate their findings in a new sample.

Therefore, the present study was conducted with the following purposes: (1) to determine in a Peruvian sample which sum or combination of sums of permanent tooth widths presented the best prediction capability for the permanent canine and premolars sums, (2) to calculate and validate a multiple linear regression equation that included sex and arch as predictor factors for this population, and (3) to evaluate the clinical significance of the new prediction equation.

MATERIALS AND METHODS Return to TOC

A representative public school with a population of 1389 adolescent children (ages 12–16 years) from Lima, Peru, was selected for this study. From the pool of 1389 students, 673 consented to participate in the study by means of informed consent letters obtained from the subjects' parents. Students were called in groups from their respective classrooms to a specially equipped room where clinical examinations were conducted. A total of 321 subjects fulfilled the selection criteria, ie, Peruvian ancestors from at least one previous generation, both last names of Hispanic-American origin, no previous orthodontic treatment, and complete permanent dentition without clinically visible dental caries, restorations or attrition in proximal surfaces or any dental anomalies.

From these 321 subjects, a random sample of 150 students (75 male and 75 female) was selected. A validation sample of another 50 students (25 male and 25 female) was also randomly selected from the same population to calculate the amount of underestimation of the SPCP using the MLRE. Dental impressions were taken and immediately poured with dental plaster to avoid any distortion. Mesiodistal tooth widths were measured subsequently from dental casts according to the technique proposed by Moorrees et al,[18] using a sliding caliper with a Vernier scale (Dentaurum, Pforzheim, Germany) with an accuracy of 0.1 mm.

The intraexaminer calibration procedure consisted of the primary investigator (Dr Bernabé) measuring five pairs of models two times, separated by 24 hours. The interexaminer calibration was done against an experienced orthodontist (Dr Flores-Mir), who also measured the five pairs of models two times, separated by 24 hours. Concordance between the three groups of measurements was high (intraclass correlation coefficient, 0.987 and 0.981 for intra- and interexaminer calibration) and statistically different from zero in both cases ($P < .001$). Using the one sample *t*-test the intra- and interexaminer measurement errors were −0.08 mm ($CI_{95\%}$[−0.24; 0.08]; $P = .316$) and 0.11 mm ($CI_{95\%}$[−0.09; 0.31]; $P = .256$), respectively.

For the main study, the primary investigator analyzed up to 10 pairs of models each day to avoid eye fatigue.[15,19,20] Each tooth was measured twice, from the right first molar to the left first molar in each arch; if the difference between both measurements was less than 0.2 mm, then the first measurement was registered.[19,20] If the second measurement differed more than 0.2 mm from the first measurement, then the tooth was remeasured,[14,19–22] and only the new measurement was then registered.[19,20]

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Eight groups divided according to the mesiodistal tooth width SPCP were gathered according to arch side, arch, and sex. All groups fulfilled normality (Shapiro-Wilks test, $P > .134$) and homogeneity of variances (Levene test, $P = .993$) criteria; thereafter, parametric tests were used. A three-way univariate analysis of variance (ANOVA) test (according to arch side, arch, and sex) found a statistically significant difference among sex ($P < .001$) and arch ($P < .001$) but not for arch side ($P = .338$). Therefore, only four groups (upper and lower arch from female and male) were used for the calculation of the regression equation. Values for each arch side were maintained without averaging both measurements per arch.

The linear association between different tooth-type combinations and the SPCP for the four groups established was evaluated by Pearson correlation coefficient (Table 1), once normality criterion was corroborated in all the groups (Shapiro-Wilks test, $P > .240$). The force of the association increased as the number of pairs of teeth increased following this pattern, ie, if only a pair has to be chosen as predictor, it should be the upper first molars; if two pairs have to be chosen, lower central incisors should be added; and if three pairs have to be chosen, the upper central incisors should be added. The inclusion of more pairs did not produce notable increases in the correlation values.

The comparison by pairs of the correlation coefficients among the three groups with higher correlation values according the number of teeth included in the tooth-type combination (groups 3, 8, and 13, respectively) was done using Fisher *Z* values. No statistically significant differences among the three groups were found, even if analyzed as total correlations or grouped by sex ($P > .092$ and $P > .082$, respectively).

On the basis of group 13 (sum of permanent upper first molar, upper and lower central incisors), a new MLRE ($Y = 3.763 + 0.37 \times X_0 + 1.057 \times X_1 + 0.366 \times X_2$, where X_0 is the sum of permanent upper and lower central incisors and upper first molars, X_1 is 0 for the mandible and 1 for the maxilla, and X_2 is 0 for female and 1 for male) was calculated including sex and arch as additional independent variables. The SPCP estimated by the MLRE was more precise than the one obtained by just using the mean SPCP (ANOVA, $P < .001$). Also, all the coefficients were statistically different from zero (*t*-test, $P < .001$).

An evaluation of the suppositions of independence (colinearity), normality, and homoscedasticity of the MLRE was completed through analysis of the residuals, which was calculated as the difference between the real and estimated SPCP. Furthermore, residuals were transformed to the *Z* score (Studentized) for identified atypical cases and then represented graphically against the distribution of the values estimated by the MLRE (Figure 1). This analysis demonstrated that homogeneous variance (homoscedasticity) and normality existed among the residuals, as well as absence of nonlinear pattern. Therefore, the equation was considered linear. Two cases were identified as potential problematic, but no substantial improvement was noted neither in explanatory capability ($r^2 = 0.604$) nor in accuracy (SEE = 0.791 mm) of the MLRE after both cases were deleted from the database. Therefore, both cases were maintained in the analysis.

Validation of the proposed MLRE was done through the evaluation of its prediction capability for the SPCP in the validation sample (25 male and 25 female). For this, SPCP were estimated by using the proposed MLRE and then compared with the actual SPCP. Table 2 exhibits frequencies distribution for the overall difference between actual and predicted SPCP separated by sex and arch. In 34% of the validation sample (68 from 200 SPCP because in each subject the four hemiarches were measured) the sum predicted by the MLRE under- or overestimate the real SPCP. The MLRE under- and overestimate by more than 1 mm the real SPCP in 7% (14) and 27% (54) from the cases evaluated, respectively.

DISCUSSION Return to TOC

Of all the different mixed dentition analysis methods reported in the literature (regression equations, radiographic methods, or combination of both), the regression equations based on measurements from the already erupted permanent teeth in early mixed dentition are the most broadly used. Therefore, the present study was conducted to corroborate their principles in a Peruvian sample.

Significant differences for the SPCP according to arch and sex were found, which was consistent with previous findings.[6,7,9,11,13,15] As expected, on the basis of other studies,[6,7,11,22] no differences for the SPCP between arch sides were found.

To determine the best tooth-type combination for predicting SPCP, 15 different groups were configured only on the basis of permanent teeth already erupted in the early mixed dentition. Lower first permanent molars were not included in the calculations because they may be still covered by gingival tissue in the distal groove, making measurements difficult.[15] Upper lateral incisors also were not included because of their size and form variability.[1,15,23]

Because the low Pearson correlation coefficient of any selected pair, more pairs were added to get higher correlation values. Even then, the correlation coefficients were, at most, only moderate but still higher than the ones reported in the literature for only lower incisors.[3,6,10,11,15,24]

Although comparisons between pairs of correlation coefficients did not find any significant differences, the group 13 (upper and lower central incisors and upper first molars) was selected as the best predictor group because its higher correlation with the SPCP than groups 3 and 8 and because the evaluation of four pairs of tooth types (including lower lateral incisors), and not three, did not have any potential significant increment in the values of the correlation coefficients. Only Nourallah et al[15] and Legovic et al[16] had previously reported that lower incisors are not the best predictor for the SPCP, and the present results are in agreement with them. On the other hand, van de Merwe et al[7] reported that in their population, the sum of the four lower incisors was the best predictor after comparing linear associations with other tooth-type combinations. Searching for the best predictor for the SPCP on the basis of correlation coefficients must always be done before starting the regression analysis independently from the results. Variations that exist between and within populations support the implementation of this strategy.[25,26]

Legovic et al[16] reported a MLRE that also considered the buccolingual tooth size. The buccolingual tooth widths were not considered in this study because their measurement would augment significantly the measurement time needed for the clinical use of the mixed dentition analysis and because maximum buccolingual tooth width can not be measured accurately on dental casts.[27–29] Because maximum buccolingual tooth width is often located subgingivally, it can not always be measured properly on plaster casts, which could bias the results.[30–32]

On the basis of group 13, a new MLRE was calculated including sex and arch as additional independent variables. Only Hashim and Al-Shalan[17] earlier reported the use of sex as an extra predictor variable though they did not explain their results thoroughly.

The influence from each of the three independent variables entered to the MLRE on SPCP could be analyzed by checking standardized regression coefficients (Table 3). Upper and lower central incisors and upper first molar sum was the variable with the highest standardized coefficient, followed immediately by arch and sex of the students (variable with the lowest standardized coefficient). Furthermore, the contribution of each explanatory variable on variability of the SPCP was evaluated through unstandardized regression coefficients. If the upper and lower central incisors and upper first molar sum increased 1 mm, then the SPCP also increased 0.37 mm. If predictions for both arches in the same child are made, the upper estimations will be higher for about 1 mm than lower. If a prediction is done for the same dental arches in two children with different sexes, the SPCP estimated will be 0.3 mm larger in the male child.

The proposed MLRE has a multiple correlation of 0.78; it means, that the three predictor variables explain approximately 60% of the variability which exists in SPCP (determination coefficient of 0.601). This value is among the highest in the literature when only mesiodistal tooth width measurements from dental casts were used.[3,6,10,11,15,24]

The prediction capability of one linear regression equation can be evaluated by two interrelated methods. The first is entirely on the basis of probabilities and consists in determining the standard error of estimation of the MLRE proposed (0.805 mm). In statistical terms, approximately 68% and 95% of the scholar population evaluated had differences between the actual SPCP and the predicted ones below or above 0.8 and 1.6 mm, respectively. Because a difference between both sums less or equal to 1 mm has been established previously as a clinical cutoff point for previous reports,[9,10,14,22] and according to this method of evaluation, approximately 20% from the cases evaluated had differences between both sums less or higher than 1 mm, under- and overestimating 10% in both cases.

The second method consisted in the prediction of SPCP through the MLRE in a validation sample. Using an extra sample results in a more precise validation of the MLRE because it is on the basis of actual measurements and not on probabilities. When the proposed MLRE was applied to the validation sample selected randomly from the same population, underestimation of the actual SPCP of more than 1 mm occurred only in 14 (7%) from the 200 SPCP obtained. Therefore, this MLRE could be considered a good clinical diagnostic alternative on the basis of its prediction capability for this sample. It is also important to note that in 54 (27%) from the 200 SPCP, the MLRE overestimated that the true SPCP is more than 1 mm (with a maximum of 2.5 mm), but this problem is considered of less clinical importance on the basis of the fact that orthodontists are more concerned about the prediction for the lack of than the excess of space in a specific dental arch.

A primordial issue with a mixed dentition analysis is the accuracy that can be obtained using the prediction equation. Therefore, further studies that include more explanatory variables for the SPCP should be conducted with the goal of explaining the overall variability present in the SPCP. These studies should be also on the basis of the actual knowledge of tooth size heritability and genetics. Finally, even Peruvian clinicians should use this MLRE carefully. An assumption that the patient fulfills the selection criteria of the present population should be made. Further studies with larger and representative samples are required to confirm these findings.

CONCLUSIONS Return to TOC

The combination of upper and lower central incisors and upper first molars was the best predictor for the SPCP in this sample of Peruvian schoolchildren; the MRLE proposed presented a explanatory capability from the variability in the SPCP of 60% and a standard error of estimation of 0.8 mm; and in 90% of the cases evaluated the estimation of the SPCP was smaller than 1 mm compared with the actual values in a validation sample.

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TABLE 1. Pearson Correlation Coefficients for Different Teeth Groups According to Arch and Sex[a]

Group	Tooth Combinations[b]	Sum of Upper Canine and Premolars			Sum of Lower Canine and Premolars		
		Female (r)	Male (r)	Total (r)	Female (r)	Male (r)	Total (r)
1	*11, 21*	0.62	0.46	0.53	0.61	0.51	0.54
2	*41, 31*	0.51	0.50	0.50	0.44	0.54	0.47
3	*16, 26*	0.62	0.55	0.61	0.65	0.64	0.67
4	*42, 32*	0.52	0.60	0.55	0.54	0.62	0.57
5	*11, 21, 41, 31*	0.64	0.54	0.59	0.61	0.60	0.59
6	*42, 41, 31, 32*	0.58	0.60	0.58	0.55	0.63	0.58
7	*11, 21, 16, 26*	0.73	0.59	0.67	0.74	0.68	0.71
8	*41, 31, 16, 26*	0.69	0.64	0.68	0.67	0.72	0.71
9	*42, 32, 16, 26*	0.66	0.65	0.67	0.69	0.72	0.72
10	*42, 32, 11, 21*	0.64	0.57	0.60	0.65	0.62	0.62
11	*42, 41, 31, 32, 11, 21*	0.65	0.60	0.62	0.63	0.65	0.63
12	*42, 42, 31, 32, 16, 26*	0.69	0.67	0.68	0.68	0.73	0.71
13	*41, 31, 11, 21, 16, 26*	0.73	0.63	0.69	0.72	0.71	0.72
14	*42, 32, 11, 21, 16, 26*	0.72	0.64	0.68	0.73	0.71	0.72
15	*42, 41, 31, 32, 11, 21, 16, 26*	0.72	0.66	0.69	0.71	0.72	0.72

[a] Statistical significance ($P < .001$) for all the Pearson correlation coefficients (r).
[b] FDI tooth numbering system is used.

TABLE 2. Difference (mm) Between the Predicted SPCP Through the MLRE and the Actual SPCP in the Validation Sample[a]

Sex	Dental Arch	Difference Between Predicted and Actual SPCP Values					Total
		>−1.01 mm	−1.00 to −0.51 mm	−0.50 to 0.50 mm	0.51 to 1.00 mm	>1.01 mm	
Female	Lower	7 (14%)	15 (30%)	17 (34%)	3 (6%)	8 (16%)	50 (100%)
	Upper	15 (30%)	4 (8%)	25 (50%)	3 (6%)	3 (6%)	50 (100%)
Male	Lower	14 (28%)	12 (24%)	15 (30%)	7 (14%)	2 (4%)	50 (100%)
	Upper	18 (36%)	11 (22%)	16 (32%)	4 (8%)	1 (2%)	50 (100%)

[a] Numbers between parentheses represent the percentage of cases in each group.

TABLE 3. MLRE for Predicting the Sum of Cuspid and Bicuspids[a,b]

	Regression Coefficient			95% CI	
Variable	Beta	Beta Standard-ized	Sig	Lower Bound	Upper Bound
Constant	3.763	—	<.001	2.288	5.239
Group 13 (X_0)	0.370	0.621	<.001	0.329	0.389
Arch (X_1)	1.057	0.415	<.001	0.928	1.186
Sex (X_2)	0.366	0.144	<.001	0.236	0.496

[a] MLRE: $Y = 0.370 \times X_0 + 1.057 \times X_1 + 0.366 \times X_2 + 3.763$.
[b] MLRE indicates multiple linear regression equation; CI, confidence intervals; and Sig, statistical significance.

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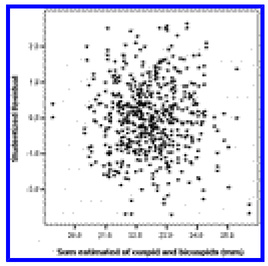

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FIGURE 1. Residual dispersion vs the sum estimated of cuspid and bicuspids. Studentized residuals were obtained by transforming to *Z* score the differences between actual and estimated sum of cuspid and bicuspids

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