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. (Angle Orthod 2005;75: 202–207.)

Key Words: Mixed dentition analysis; Multiple regression; Mesiodistal tooth size

INTRODUCTION

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 tables1,2 and the Tanaka and Johnston equations.3

Carey4 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 studies15,16 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 al15 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 al16 developed multiple linear regression equations (MLRE) with higher pre-
prediction values (determination coefficient between 62% and 72%) when they also considered the buccolingual tooth size. Finally, Hashim and Al-Shalan15 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 al16 and Hashim and Al-Shalan17 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 with three groups of measurements was high (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 $-0.08 \text{ mm (CI}_{95\%}[-0.24; 0.08]; P = .316]$ and $0.11 \text{ mm (CI}_{95\%}[-0.09; 0.31]; P = .256}$, 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 $0.2 \text{ mm}$, then the first measurement was registered.19,20 If the second measurement differed more than $0.2 \text{ mm}$ from the first measurement, then the tooth was remeasured,14,19–22 and only the new measurement was then registered.19,20

RESULTS

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 \( X_0 \) 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 (collinearity), normality, and homoscedasticity of the MLRE was completed through analysis of the residuals, which was calculated as the difference between the real and estimated values estimated by 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

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.\(^6,7,9,13,15\) 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

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**TABLE 1.** Pearson Correlation Coefficients for Different Teeth Groups According to Arch and Sex

<table>
<thead>
<tr>
<th>Group</th>
<th>Tooth Combinations(^a)</th>
<th>Sum of Upper Canine and Premolars</th>
<th>Sum of Lower Canine and Premolars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female (r)</td>
<td>Male (r)</td>
</tr>
<tr>
<td>1</td>
<td>11, 21</td>
<td>0.62</td>
<td>0.46</td>
</tr>
<tr>
<td>2</td>
<td>41, 31</td>
<td>0.51</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>16, 26</td>
<td>0.62</td>
<td>0.55</td>
</tr>
<tr>
<td>4</td>
<td>42, 32</td>
<td>0.52</td>
<td>0.60</td>
</tr>
<tr>
<td>5</td>
<td>11, 21, 41, 31</td>
<td>0.64</td>
<td>0.54</td>
</tr>
<tr>
<td>6</td>
<td>42, 41, 31, 32</td>
<td>0.58</td>
<td>0.60</td>
</tr>
<tr>
<td>7</td>
<td>11, 21, 16, 26</td>
<td>0.73</td>
<td>0.59</td>
</tr>
<tr>
<td>8</td>
<td>41, 31, 16, 26</td>
<td>0.69</td>
<td>0.64</td>
</tr>
<tr>
<td>9</td>
<td>42, 32, 16, 26</td>
<td>0.66</td>
<td>0.65</td>
</tr>
<tr>
<td>10</td>
<td>42, 32, 11, 21</td>
<td>0.64</td>
<td>0.57</td>
</tr>
<tr>
<td>11</td>
<td>42, 41, 31, 32, 11, 21</td>
<td>0.65</td>
<td>0.60</td>
</tr>
<tr>
<td>12</td>
<td>42, 42, 31, 32, 16, 26</td>
<td>0.69</td>
<td>0.67</td>
</tr>
<tr>
<td>13</td>
<td>41, 31, 11, 21, 16, 26</td>
<td>0.73</td>
<td>0.63</td>
</tr>
<tr>
<td>14</td>
<td>42, 32, 11, 21, 16, 26</td>
<td>0.72</td>
<td>0.64</td>
</tr>
<tr>
<td>15</td>
<td>42, 41, 31, 32, 11, 21, 16, 26</td>
<td>0.72</td>
<td>0.66</td>
</tr>
</tbody>
</table>

\( ^a \) Statistical significance (\( P < .001 \)) for all the Pearson correlation coefficients (r).

\( ^b \) FDI tooth numbering system is used.
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.

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

<table>
<thead>
<tr>
<th>Sex</th>
<th>Dental Arch</th>
<th>Difference Between Predicted and Actual SPCP Values</th>
<th>(-1.01) to (-0.51) mm</th>
<th>(-0.50) to 0.50 mm</th>
<th>0.51 to 1.00 mm</th>
<th>1.00 to 1.01 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Lower</td>
<td>7 (14%)</td>
<td>15 (30%)</td>
<td>17 (34%)</td>
<td>3 (6%)</td>
<td>8 (16%)</td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td>15 (30%)</td>
<td>4 (8%)</td>
<td>25 (50%)</td>
<td>3 (6%)</td>
<td>3 (6%)</td>
</tr>
<tr>
<td>Male</td>
<td>Lower</td>
<td>14 (28%)</td>
<td>12 (24%)</td>
<td>15 (30%)</td>
<td>7 (14%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td>18 (36%)</td>
<td>11 (22%)</td>
<td>16 (32%)</td>
<td>4 (8%)</td>
<td>1 (2%)</td>
</tr>
</tbody>
</table>

* Numbers between parentheses represent the percentage of cases in each group.

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 in-
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 MLRE proposed presented an 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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REFERENCES