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Development of a prediction equation for the mixed dentition in a Pakistani sample

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Introduction: Regression equations are widely used for mixed dentition analysis. However, estimations from these equations can vary in different population groups. The aim of this study was to produce simple linear equations and tables for Pakistani children. Methods: Two hundred subjects of Pakistani descent who met our criteria (ages, 13-15 years; 100 boys, 100 girls) were selected from local schools. The mesiodistal widths of all mandibular permanent incisors, canines, and premolars were measured and analyzed by using paired t tests. The results were also compared with predicted values from the Moyers and the Tanaka and Johnston methods. Correlation and linear regression analyses were performed between the predicted and actual tooth sizes for Pakistani children, and standard regression equations were developed. Results: No significant differences were observed for measured canine and premolar antimeres and sex. Significant and high positive correlations were found between the mandibular incisors and the combined mesiodistal widths of the canines and premolars for the maxillary (r = 0.65; P < 0.001) and mandibular (r = 0.59; P < 0.001) segments. Conclusions: The equations and charts commonly used for North American children (75th percentile) did not accurately predict for our sample. The regression equations and tables developed in this study can be used for orthodontic treatment planning for children in Pakistan. (Am J Orthod Dentofacial Orthop 2011;140:626-32)
Evidence of racial tooth size variability suggests that prediction techniques based on 1 racial sample might not be universal. A recent study by Sakrani showed marked variability in the mesiodistal dimensions of Pakistani subjects when compared with other population groups, and advised caution regarding the use of the mixed dentition prediction methods of Moyers and Tanaka and Johnston for Pakistani children. To date, no data have been published regarding the study and development of mixed dentition analyses with nonradio- graphic means in Pakistani subjects. Therefore, in this study, we aimed to (1) measure the mesiodistal crown diameters of the mandibular incisors, canines, and premolars and study their relationships; (2) see any sex dimorphism of the above; (3) construct prediction tables and equations for Pakistani children; and (4) check the reliability of both the Moyers and the Tanaka and Johnston methods in the local setting. This will help in orthodontic diagnosis and treatment planning for our children.

**MATERIAL AND METHODS**

The subjects for this cross-sectional study were selected from 5 schools after approval from the hospital ethical review committee and the school board in Karachi, Pakistan. Additionally, consent was obtained from the subjects and their parents for dental examinations and for possible selection for subsequent dental impressions. Students were called in groups from their classrooms to a specially equipped room where the clinical examinations and screenings were conducted. After we examined children in the age range of 13 to 15 years, we selected a sample of 200 (100 boys, 100 girls) who met our study criteria. Inclusion criteria were Pakistani descent; all permanent teeth present in each arch (fully erupted with the exception of the second and third molars); Class I molar and canine relationships; and minor malocclusions such as minimal incisor crowding or spacing.

The exclusion criteria were subjects with congenital craniofacial anomalies or previous orthodontic treatment, and teeth with fractures, malformations, proximal caries, proximal restorations, or attrition. Alginate impressions of the subjects were obtained at Aga Khan University Hospital and local schools, and poured in orthodontic plaster. A number was assigned to each cast.

Two investigators (A.K., G.E.) measured the unsoaped plaster study models manually and independently. The mesiodistal widths of all mandibular permanent incisors, canines, and premolars were measured with pointed vernier calipers, read to the nearest 0.1 mm. The beaks of the calipers were machine sharpened to a fine taper to improve accessibility to the proximal surfaces of the teeth, especially for the mesiodistal dimensions. All measurements were made perpendicular to the long axis of the tooth, with the beaks entering the interproximal area from either the buccal or the occlusal side. The preferred method was from the buccal side, unless the tooth appeared to be severely rotated. Interexaminer and intraexaminer reliability was predetermined at 0.2 mm as suggested by Bishara et al. The 2 measurements obtained by the investigators were compared; if less than a 0.2-mm variation was found, the values were averaged. If there was more than 0.2 mm, the teeth were re-measured, and the closest 3 measurements were averaged.

### Statistical analysis

Descriptive statistics, including means, standard deviations, and ranges, were calculated for age, teeth (canines, premolars, and mandibular incisors), and groups of teeth (canines, premolars, and mandibular incisors) according to sex and between the maxillary and mandibular arches. Student t tests were used to determine whether there were significant differences between the right and left sides in each arch for the boys and girls, as well as between the sexes by using the independent samples t test. Correlation coefficients and regression equations were formulated to see any relationship between the summed widths of the 4 mandibular incisors

| Table I. Descriptive statistics for CPM and LI |
|---|---|---|---|---|---|---|---|---|
| Tooth | Sex | Mean | Range | SD | Mean | Range | SD |
| | | Mandibular arch (mm) | Maxillary arch (mm) | | | | |
| PM 1 Both | 7.01 | 2.45 | 0.418 | 6.99 | 2.35 | 0.418 |
| M | 7.01 | 2.05 | 0.430 | 6.99 | 2.35 | 0.432 |
| F | 7.01 | 2.40 | 0.408 | 6.99 | 1.90 | 0.388 |
| PM 2 Both | 7.18 | 1.95 | 0.411 | 6.76 | 2.18 | 0.398 |
| M | 7.18 | 1.95 | 0.421 | 6.78 | 1.80 | 0.390 |
| F | 7.18 | 2.03 | 0.403 | 6.73 | 2.18 | 0.407 |
| C Both | 6.73 | 2.08 | 0.385 | 7.72 | 2.38 | 0.402 |
| M | 6.86 | 2.08 | 0.371 | 7.80 | 2.38 | 0.411 |
| F | 6.60 | 1.80 | 0.355 | 7.63 | 1.90 | 0.393 |
| LLI Both | 5.95 | 1.80 | 0.331 | 5.90 | 1.80 | 0.364 |
| M | 6.00 | 1.73 | 0.286 | 5.90 | 1.80 | 0.364 |
| F | 5.90 | 1.80 | 0.345 | 5.35 | 1.73 | 0.309 |
| LCI Both | 5.38 | 1.73 | 0.329 | 5.42 | 1.73 | 0.309 |
| M | 5.35 | 1.70 | 0.345 | 5.20 | 1.60 | 0.329 |
| F | 5.35 | 1.70 | 0.345 | 5.20 | 1.60 | 0.329 |
| CPM Both | 20.93 | 5.75 | 1.04 | 21.47 | 6.08 | 1.01 |
| M | 21.06 | 5.25 | 1.05 | 21.58 | 5.80 | 1.05 |
| F | 20.80 | 5.37 | 1.02 | 21.37 | 4.50 | 0.96 |
| LLI Both | 22.69 | 6.70 | 1.25 | 22.86 | 6.10 | 1.12 |
| M | 22.51 | 6.70 | 1.35 | 22.86 | 6.10 | 1.12 |
| F | 22.51 | 6.70 | 1.35 | 22.86 | 6.10 | 1.12 |

PM1, first premolar; PM2, second premolar; C, canine; LLI, lower lateral incisor; LCI, lower central incisor; CPM, canine and premolars; LI, lower incisors; M, male; F, female.
and the canines and premolars of each dental arch. Statistical calculations and analyses, including standard errors of the estimate and coefficients of determination, were carried out by using the SPSS for Windows statistical computer package (version 10.0.1; SPSS, Chicago, Ill).

RESULTS

A total of 200 plaster study models were obtained from our male and female subjects with mean chronologic ages of 14.2 years (SD, 1.3) and 13.9 years (SD, 0.8), respectively. On comparing individual teeth in the buccal segment with their opposing units, the mandibular second premolars and the maxillary canines showed increased mesiodistal dimensions (Table I). Similarly, the sums of the maxillary canines and premolars showed higher mean differences when compared with the sums of the mandibular canines and premolars for the male and female subjects, and for all subjects.

No significant mesiodistal width difference was observed between the left and right sides for teeth measured individually as well as in combined segments of canine and first and second premolars (P > 0.05) for boys, girls, or the sexes combined (Table II). Based on these findings, either the right or the left measurements can be used to represent the mesiodistal width of the canine and premolar segment. However, in this study, the values were averaged for statistical analysis.

The values for boys and girls were computed separately to permit evaluation of sexual dimorphism, as shown in Table III. Individually, the mandibular and maxillary canines and the mandibular lateral incisors showed significantly greater mesiodistal widths in the boys than in the girls (data not shown). In spite of these individual differences, the combined dimensions of the canine, and first and second premolars of the sexes showed insignificant differences (P < 0.05).

These dimensions were then subjected to regression analysis to evaluate the relationship between the combined mesiodistal dimensions of the mandibular incisors and the canine-premolar segments.

The regression relationship between the sum of the mesiodistal dimensions of the mandibular incisors and those of the canine and premolars was initially evaluated from scatter plots, as shown in Figures 1 and 2.
Because the maxillary and mandibular arches were evaluated independently, their combined relationships were evaluated in 2 discrete scatter plots. A correlation between the 2 variables was suggested by the linear trend seen in each scatter plot. The correlation was represented by the regression equation derived from the equation of the slope, \( Y = a + bX \) of each scatter plot, where \( Y \) is the mesiodistal width of the canines and the first and second premolars in 1 buccal segment in millimeters (dependent variable), \( X \) is the measured width of the 4 mandibular permanent incisors in millimeters (independent variable), \( a \) is the slope of the regression line, and \( b \) is the y intercept.

The equations for estimating the combined width of the unerupted canine and premolars are (1) maxillary, \( Y = 10.52 + 0.48X \); and (2) mandibular, \( Y = 8.56 + 0.54X \). The prediction table generated from these equations is given in Table IV.

A paired \( t \) test was used to check for the reliability of Moyers prediction (75th percentile) tables\(^6\) and Tanaka and Johnston’s prediction equation\(^7\) when compared with the actual sums of the widths of the canines and premolars in both arches. Significant differences \( (P < 0.05) \) were seen for both prediction methods when applied to our Pakistani sample, thus questioning their reliability in our population.

**DISCUSSION**

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

Different racial and ethnic groups have variations in the mesiodistal widths of permanent teeth\(^{11-16}\). Our sample showed lower mean values for the summed mesiodistal widths of the canines and premolars along with the mandibular incisors when compared with population groups from South Africa\(^{15}\), Thailand\(^{18}\).  

**Fig 1.** Linear relationship of the mesiodistal dimensions of the mandibular canine and premolars segment, and the incisors. CPM, Canine and premolars.
Hong Kong Chinese, and black Americans. These studies also reported sexual dimorphism in tooth width measurements, including one from a Pakistani sample, where significantly larger tooth sizes were measured for male subjects but with the limitation of fewer male vs female subjects (66 vs 234, respectively). We found no significant difference between the sexes when the sums of the canines and premolars were compared in spite of significantly larger canines and mandibular lateral incisors in the boys. This can be attributed to a different genetic makeup and a larger sample of adolescents matched for sex that represents the population group. The absence of statistically significant sexual dimorphism in this study permitted grouping of the data regardless of sex.

This variation in width among ethnic groups is also illustrated by observed differences in regression coefficients (Table V). The correlation coefficients for the Pakistani population between the segment of the canine and premolars of each arch and the mandibular incisors were smaller than for Hong Kong Chinese, black Americans, and Senegalese subjects, but slightly higher than for Thai subjects for the maxillary segment. When we compared the same with the study of Tanaka and Johnston, the mandibular incisors had a slightly lower correlation, \( r = 0.59 \), for the maxillary segment of canine and premolars (Tanaka and Johnston, \( r = 0.63 \)) and a comparable coefficient, \( r = 0.65 \), for the mandibular segment of canine and premolars (Tanaka and Johnston, \( r = 0.65 \)). Correlation coefficients in our study were all above 0.5, so these regression parameters can be put into good clinical orthodontic use by the construction of prediction equations for a Pakistani sample.

Relative comparisons of the regression parameters from the different studies showed similar \( b \) values (0.48 and 0.47, respectively) in the maxilla between our study and a study of Thai subjects when the sexes were combined. A value of 0.5 for the \( b \) constant, the slope of the line, facilitates practical application of the prediction equations. Constant \( a \) values of 8.5 for mandibular teeth and 10.52 for maxillary teeth in our sample appeared to overlap with those of others.

The \( r^2 \) values are indicators of the predictive accuracy of the regression equations. This study showed comparable \( r^2 \) values for both arches with the Thai subjects, but smaller values than for Hong Kong Chinese, black Americans, Senegalese, and Saudi Arabian samples.

The standard error of the estimate indicates errors in the use of prediction equations. For this study, the standard errors of the estimate combined for maxillary and
mandibular predictions of the canine and premolars segments resulted in lower values than the findings of other investigators except for Hong Kong Chinese.\textsuperscript{21}

Moyers’ mixed dentition analysis\textsuperscript{6} is based on the correlation of tooth sizes between the sum of the mandibular permanent incisors and unerupted canines and premolars. Moyers recommended using the 75th percentile level of probability in his tables. In agreement with previous studies concluding that Moyers’ regression equations are not an accurate method for the prediction of the size of unerupted permanent teeth in different populations,\textsuperscript{15,17,18} we showed in this study that Moyers’ tables cannot be used at the recommended 75% probability, since significant differences were observed for the actual widths of the canine and premolars segment and those predicted by Moyers’ probability tables.

The use of the 75th percentile level allows overprediction and offers extra protection in patients with more crowding than spacing. The experienced clinician might choose to use the 50th percentile level because it is a more precise estimate, and the error would be equally distributed on both sides. In addition to this, some authors recommend underprediction because it results in a more conservative clinical approach, and unnecessary extractions can be avoided.\textsuperscript{24} The proposed new probability tables for Pakistani subjects are based on the 50th percentile level and considered more accurate and relevant to this specific population. They can therefore be applied to determine the sum of the mesiodistal dimensions of unerupted permanent canines and premolars when the 4 mandibular permanent incisors are fully erupted.

These prediction tables, based on data from a Pakistani sample, should be accurate when applied to local children, despite the ethnic diversity in our sample. The prediction table is convenient to use and does not require memorizing equations. Further investigations with larger samples, including more ethnic groups, are required to collect more representative odontometric data for Pakistan. Pakistani clinicians should use this linear regression equation carefully. A determination that the patient fulfills the selection criteria of our subjects should be made. We recommend that validating studies (based on similar samples) must be conducted to confirm the applicability and precision of the new regression equations. Additionally, the accuracy of these equations should be tested in various ethnic groups in Pakistan to further generalize their applicability.

**CONCLUSIONS**

1. No difference in the mesiodistal widths of canines and premolars between the left and right sides was observed.
2. No difference between the summed mesiodistal widths of canines and premolars was observed between the sexes.
3. The prediction equations of Tanaka and Johnston\textsuperscript{7} and the charts of Moyers\textsuperscript{5} (75%) did not accurately
predict the mesiodistal diameters of unerupted canines and premolars in a sample of Pakistani children.

4. There is a linear relationship between the sum of the mandibular incisor widths and those of the canines and premolars. The regression equations proposed in this study are a good prediction method to determine widths of the maxillary and mandibular permanent canine and premolars: mandibular, $Y = 0.856 + 0.54X$, and maxillary, $Y = 1.052 + 0.48X$.

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