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# Mixed dentition space analysis in a Jordanian population: comparison of two methods

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**Summary.** *Aims.* To test the reliability of the Moyers charts and the Tanaka and Johnston equations in Jordanians and to derive coefficients of correlation between the combined mesiodistal widths of the four permanent mandibular incisors and the combined widths of the canine and premolars of the maxillary and mandibular quadrants.

*Methods.* The dental models of the dentition of 130 male and 96 female Jordanian subjects (age range is 14–16 years) with complete permanent dentition were randomly selected. The mesiodistal width of the four permanent mandibular incisors, maxillary and mandibular canines, and premolar teeth were measured using a vernier gauge caliper to the nearest 0·1 mm. The actual teeth measurements were then compared with the predicted values derived from the Tanaka and Johnston equations and Moyers probability tables. Correlation and linear regression analyses were performed between the predicted and actual tooth size for Jordanian children and standard regression equations were developed.

*Results.* Except for the maxillary arch in male subjects, Tanaka and Johnston regression equations underestimated the mesiodistal widths of permanent canines and premolars. On the other hand, there were no statistically significant differences between actual mesiodistal widths of canines and premolars and the predicted widths from Moyers charts at the 65% and 75% level for the lower and upper arches in male subjects and at the 85% level for the upper and lower arches in female subjects. For the newly developed regression equations, the correlation coefficients between the sum of the mandibular four incisors and the sum of the canine and premolars were 0·60 (for lower) and 0·51 (for upper) in male subjects and 0·59 and 0·64, respectively, in female subjects.

*Conclusions.* (1) Tanaka and Johnston prediction method was not accurate when applied to a Jordanian population. (2) Moyers method for prediction can be used for Jordanian children at different probability levels for male and female subjects.

## Introduction

Space management during mixed dentition period involves evaluating the space requirements for unerupted permanent teeth, usually the canines and premolars. Several methods have been developed for estimating the mesiodistal widths of unerupted teeth [1–4].

Early attempts to predict the mesiodistal widths of unerupted teeth were made by Black (1897) based on tables of average mesiodistal widths [5]. Unfortunately, these approximates were found clinically to be unreliable because of great individual variability. This was followed by further attempts by different investigators to estimate the mesiodistal widths of unerupted permanent teeth and three methods of tooth size prediction have been proposed: (i) direct measurements of unerupted tooth size on the radiographs [4,6], (ii) calculations from prediction equations and tables [2,3,7], and (iii) a combination of radiographic measurements and prediction tables [1,4,8]. The Hixon and Oldfather prediction approach is considered the most accurate [9,10]. The ease and accuracy of the analysis, however, is greatly affected by the quality of the radiographs available for use.

A reasonably good correlation between the mesiodistal width of the erupted lower permanent incisors and the unerupted canines and premolars exists [11]. Based on this, some investigators attempted prediction of unerupted permanent canines and premolars mesiodistal widths from the sum of four permanent mandibular

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incisors [2,3]. Tanaka and Johnston [3] suggested the following regression equations: (i) for each of the maxillary left and right permanent canine and first and second premolars widths: $Y = 11 + 0{\cdot}5\ (X)$; (ii) for each of the mandibular left and right permanent canine and first and second premolars widths: $Y = 10{\cdot}5 + 0{\cdot}5\ (X)$, where $Y$ is the estimate of unerupted permanent canine and premolars widths for each side and $X$ is the sum of the four permanent mandibular incisor widths.

The accuracy of Moyers proportionality tables and Tanaka and Johnston equations are fairly good when applied to children from northern European descents from which the data were originally obtained. Because racial difference in mesiodistal tooth width is said to exist [8,12–15], it is logical to doubt their applicability in Jordanians.

The aims of this study were to test the reliability of the Moyers charts and the Tanaka and Johnston equations in Jordanians, and to derive coefficients of correlation between the combined mesiodistal widths of the four permanent mandibular incisors and the combined widths of the canine and premolars of the maxillary and mandibular quadrants.

## Methods

The dental models of the dentition of 226 Jordanian subjects (130 boys and 96 girls, age range 14–16 years) who presented with complete eruption of the permanent teeth were randomly selected from orthodontic records of schoolchildren who were part of an earlier orthodontic survey at the discipline of orthodontics to investigate the prevalence of malocclusion among north Jordanians. The criteria for selection were based on the following:

a Patients had to be native Jordanians.
b The dental models had to be of high quality.
c The teeth measured had to be free of malformations, restorations, fractures, or caries as determined by radiographic examination.
d Class I molar relationship.
e No or mild malocclusion.

Mandibular permanent central and lateral incisors, maxillary and mandibular canines, and premolar teeth were measured. The mesiodistal width of the tooth was obtained by measuring the greatest distance between contact points on proximal surfaces. A vernier gauge caliper (Munchner model, Germany) was used to read to the nearest 0·1 mm and held parallel to the occlusal surface. For each subject the average of left and right mesiodistal diameter was used.

### *Reliability*

To test the reliability of the measurements, double determinations on a total of 20 randomly selected dental models (10 subjects) were performed. The measurements were made by the same examiner (EAA) at an interval of 1 week. The reproducibility of the double determinations of the mesiodistal widths of permanent mandibular central and lateral incisors, maxillary and mandibular canines, and premolar teeth was expressed using the Dahlberg method of errors [16]:

$$S = \sqrt{\left(\sum \frac{(X_1 - X_2)^2}{2N}\right)},$$

where $X_1$ = the original measurement value, $X_2$ = the repeated-measurement value, and $N$ = the total number of double determinations. The error values of mesiodistal teeth widths ranged from 0·1 mm to 0·25 mm. The values were considered clinically acceptable.

### *Statistical analysis*

Descriptive statistics, including means, standard deviations, and minimum and maximum values were calculated for the actual tooth size and the predicted tooth size using the Moyers and the Tanaka and Johnston methods. Student's *t*-tests were carried out to determine whether significant difference existed: (i) between the sums of the mesiodistal diameter of permanent: (a) incisors, (b) canine and first and second premolars canine and first and second premolars in male and female subjects, and (ii) between the regression values using Moyers tables and the Tanaka and Johnston equation with the actual canine and premolars width measurements. Correlation and linear regression analysis were performed between the predicted and actual tooth size for the Tanaka and Johnston prediction method. The constants 'a' and 'b' in the standard regression equation ($Y = a + b\ (X)$) and the standard errors of the estimates (SEE) were calculated for the sexes combined and for female and male subjects separately.

## Results

Means, standard deviations, range, and standard error of the means for the sum of four lower mandibular incisors, sum of the lower canine and premolars, and the sum of the maxillary canine and premolars for the sexes combined and for female and male subjects

**Table 1.** Descriptive statistics (mm) of the predicted and actual mesiodistal diameters of maxillary canine and first and second premolars.

| Sex | Tooth group | Mean | SD | Range | Standard error of the mean |
|---|---|---|---|---|---|
| Combined | Sum of incisors | 24·04 | 1·28 | 21·0–28·0 | 0·08 |
| | Sum of lower canine and premolars | 22·94 | 1·23 | 20·3–26·5 | 0·08 |
| | Sum of upper canine and premolars | 23·28 | 1·20 | 20·8–26·8 | 0·07 |
| Female | Sum of incisors | 23·96 | 1·28 | 21·0–28·0 | 0·11 |
| | Sum of lower canine and premolars | 22·64 | 1·14 | 20·3–26·0 | 0·10* |
| | Sum of upper canine and premolars | 23·02 | 1·06 | 20·8–26·5 | 0·09* |
| Male | Sum of incisors | 24·14 | 1·29 | 21·0–27·0 | 0·13 |
| | Sum of lower canine and premolars | 23·35 | 1·23 | 20·8–26·5 | 0·12* |
| | Sum of upper canine and premolars | 23·64 | 1·28 | 21·0–26·8 | 0·13* |

SD, standard deviation.
*Sex difference significant at $P < 0·001$.

**Table 2.** The difference (in mm) between the regression values of actual sum of permanent canines and first and second premolars of Jordanian subjects and those predicted from Tanaka and Johnston equations for the same subjects.

| Group | Difference between regression values (mm) | SD | 95% Confidence interval |
|---|---|---|---|
| Combined (226) | | | |
| Upper | 0·27** | 0·98 | 0·14–0·40 |
| Lower | 0·42** | 1·00 | 0·29–0·55 |
| Male (130) | | | |
| Upper | 0·04 | 0·92 | −0·12–0·20 |
| Lower | 0·16* | 0·92 | 0·00–0·32 |
| Female (96) | | | |
| Upper | 0·57** | 0·99 | 0·37–0·77 |
| Lower | 0·78** | 1·00 | 0·58–0·98 |

SD, standard deviation.
*$P < 0·05$.
**$P < 0·0001$.

separately are presented in Table 1. Gender differences were observed in the sum of canine and premolars in both arches ($P < 0·001$).

The difference (in mm) between the regression values of actual sum of permanent canine and first and second premolars of Jordanian subjects and those predicted from Tanaka and Johnston equations for same subjects for upper and lower arches is presented in Table 2. Except for the maxillary arch in the male subjects, Tanaka and Johnston regression equations underestimated the mesiodistal widths of permanent canines and premolars. Therefore, regression equations in the form of $Y = a + b\ (X)$ were formulated for upper and lower arches in male and female subjects and for both sexes combined. Table 3 shows correlation coefficients $r$ between mandibular incisors and sum of the upper canine and premolars and the sum of the lower canine and premolars, regression values of a and b in the standard linear regression equation ($Y = a + b\ (X)$), the standard error of estimate, and the 95% confidence interval for the sexes combined, and also for the female and male subjects separately.

The correlation coefficients between the sum of mandibular incisors and the sum of canine and premolars were 0·60 (for lower) and 0·51 (for upper) in male subjects, and 0·59 and 0·64, respectively, in female subjects. When both sexes were combined, the coefficients were 0·59 for the lower and 0·57 for the upper arches. Standard error of estimate ranged from 0·92 to 0·99 mm with the errors smaller in male subjects.

The 95% confidence interval values ranged from 0·30 to 0·79. The values of coefficient b ranged from 0·43 to 0·64 and were all significant at $P < 0·001$.

Tables 4 and 5 show the differences between the actual canine and premolar widths and the predicted widths of canine and premolar for upper and lower arches derived from Moyers charts at different probability levels. There were no statistically significant differences between actual mesiodistal widths of canines and premolars and the predicted widths from Moyers charts at the 65% and 75% level for the lower and upper arches in male subjects and at the 85% level for both upper and lower arches in female subjects.

## Discussion

Different racial and ethnic groups present variations in the mesiodistal widths of permanent teeth [8,13–15,17,18]. It was reported previously that mesiodistal widths of Jordanian permanent teeth are larger than those of Caucasians, Chinese, Iraqis, and Yemenites [13]. This is demonstrated in this study by the statistically significant differences seen between the means of actual mesiodistal widths of permanent

**Table 3.** Regression parameters for prediction of sum of unerupted upper and lower permanent canine and premolars widths for Jordanian male and female subjects.

| Sex | Tooth group | Coefficient of correlation (*r*) | Regression coefficient | | 95% Confidence interval | SEE | *P* value |
|---|---|---|---|---|---|---|---|
| | | | a | b | | | |
| Combined | Sum of lower canine and premolars | 0·59 | 9·41 | 0·56 | 0·46–0·67 | 0·99 | 0·000 |
| | Sum of upper canine and premolars | 0·57 | 10·55 | 0·53 | 0·43–0·63 | 0·99 | 0·000 |
| Male | Sum of lower canine and premolars | 0·60 | 9·80 | 0·54 | 0·41–0·66 | 0·92 | 0·000 |
| | Sum of upper canine and premolars | 0·51 | 12·80 | 0·43 | 0·30–0·55 | 0·92 | 0·000 |
| Female | Sum of lower canine and premolars | 0·59 | 9·79 | 0·56 | 0·40–0·72 | 1·00 | 0·000 |
| | Sum of upper canine and premolars | 0·64 | 8·31 | 0·64 | 0·48–0·79 | 0·98 | 0·000 |

SEE, standard error of estimate.

**Table 4.** The difference (in mm) between the mean values of actual sum of maxillary permanent canine and first and second premolars of Jordanian subjects and those predicted from Moyers charts for the same subjects.

| Percentile probability (%) | Combined | | | Males | | | Females | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean difference (mm) | SD | 95% CI | Mean difference (mm) | SD | 95% CI | Mean difference (mm) | SD | 95% CI |
| 5 | 2·30** | 1·41 | 2·12–2·48 | 2·10** | 1·24 | 1·89–2·32 | 2·57** | 1·57 | 2·25–2·89 |
| 15 | 1·73** | 1·41 | 1·55–1·92 | 1·55** | 1·25 | 1·33–1·76 | 1·99** | 1·57 | 1·67–2·31 |
| 25 | 1·40** | 0·98 | 1·27–1·53 | 1·18** | 0·93 | 1·02–1·34 | 1·70** | 0·99 | 1·50–1·90 |
| 35 | 1·13** | 1·41 | 0·95–1·32 | 0·95** | 1·25 | 0·73–1·16 | 1·39** | 1·57 | 1·07–1·71 |
| 50 | 0·78** | 0·98 | 0·65–0·91 | 0·55** | 0·93 | 0·39–0·72 | 1·08** | 0·98 | 0·88–1·28 |
| 65 | 0·43** | 1·41 | 0·24–0·61 | 0·21 | 1·33 | −0·06–0·48 | 0·73** | 1·47 | 0·43–1·02 |
| 75 | 0·13* | 0·98 | 0·00–0·26 | −0·09 | 0·93 | −0·25–0·07 | 0·43** | 0·97 | 0·23–0·63 |
| 85 | −0·20* | 1·41 | −0·39–−0·02 | −0·40** | 1·24 | −0·61–−0·18 | 0·07 | 1·57 | −0·25–0·38 |
| 95 | −0·77** | 0·99 | −0·90–−0·64 | −0·99** | 0·93 | −1·15–−0·83 | −0·47** | 0·98 | −0·66–−0·27 |

CI, confidence interval.
SD, standard deviation.
*$P < 0·05$.
**$P < 0·001$.

**Table 5.** The difference (in mm) between the mean values of the actual sum of permanent mandibular canine and first and second premolars of Jordanian subjects and those predicted from Moyers charts for the same subjects.

| Percentile probability (%) | Combined | | | Males | | | Females | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean difference (mm) | SD | 95% CI | Mean difference (mm) | SD | 95% CI | Mean difference (mm) | SD | 95% CI |
| 5 | 2·52** | 1·48 | 2·33–2·71 | 2·30** | 1·32 | 2·07–2·53 | 2·82** | 1·64 | 2·49–3·15 |
| 15 | 1·92** | 1·48 | 1·72–2·11 | 1·69** | 1·32 | 1·46–1·92 | 2·22** | 1·64 | 1·89–2·55 |
| 25 | 1·52** | 0·99 | 1·39–1·65 | 1·26** | 0·92 | 1·10–1·42 | 1·87** | 0·99 | 1·66–2·07 |
| 35 | 1·22** | 1·48 | 1·03–1·41 | 1·00** | 1·32 | 0·77–1·23 | 1·52** | 1·63 | 1·19–1·85 |
| 50 | 0·82** | 0·99 | 0·69–0·95 | 0·56** | 0·92 | 0·40–0·72 | 1·17** | 0·99 | 0·96–1·37 |
| 65 | 0·42** | 1·48 | 0·23–0·61 | 0·15 | 1·48 | −0·16–0·45 | 0·77** | 1·54 | 0·45–1·08 |
| 75 | 0·12 | 1·0 | −0·01–0·25 | −0·13 | 0·93 | −0·29–0·03 | 0·47** | 0·99 | 0·26–0·67 |
| 85 | −0·27** | 1·48 | −0·46–−0·07 | −0·50** | 1·32 | −0·73–−0·27 | 0·06 | 1·62 | −0·27–0·39 |
| 95 | −0·88** | 1·0 | −1·01–−0·75 | −1·14** | 0·92 | −1·30–−0·98 | −0·54** | 0·99 | −0·74–−0·33 |

CI, confidence interval.
SD, standard deviation.
*$P < 0·05$.
**$P < 0·001$.

canines and premolars of Jordanian adolescents and those derived from Tanaka and Johnston equations for subjects from northwestern European ancestry [3]. Sexual dimorphism has also been reported in previous studies [6,19–21]. In a former study, it was found that, with the exception of lower central incisors, Jordanian men had greater mesiodistal widths of all permanent teeth than Jordanian women

[13]. This is supported by this study where Jordanian males presented with statistically significant larger widths of canines and premolars than females; however, no such differences were observed in the sum of the lower incisors.

The determination of mesiodistal widths of unerupted permanent teeth is considered an important aspect of orthodontic diagnosis and treatment planning in the mixed dentition stage. It helps in the assessment of the degree of crowding or spacing of the teeth in order to predict whether there is sufficient space in the dental arch to accommodate the unerupted teeth at a certain stage of dentition development. Various techniques of mixed dentition space analysis are available for use in children. The two most commonly used are the Tanaka and Johnston [3] and the Moyers [2] techniques.

The Tanaka and Johnston technique of space analysis is considered by many authors as the most clinically useful of all other analysis techniques because it requires no radiographs or tables to predict the size of unerupted teeth [22]. It was noted, however, that two factors must be considered when using the Tanaka and Johnston space analysis technique. First, it tends to over-predict the widths of unerupted permanent teeth for children of northwestern European origins [22,23]. Second, for children who are not of northwestern European background, it is difficult to know whether the techniques over- or underestimate the actual widths of unerupted teeth [22]. Where some researchers reported an overestimation of the size of unerupted canines and premolars when using the Tanaka and Johnston prediction equations [12,20,23–25], others reported an underestimation of the technique for the actual mesiodistal widths of unerupted permanent teeth [25,26]. It was, therefore, concluded that because of the differences in mesiodistal widths of mandibular permanent incisors, canines and premolars among different ethnic groups, data collected from one ethnic group for the purpose of predicting the size of unerupted permanent teeth might not be applicable to another [10,12,20,23–28]. In this study, except for the maxillary unerupted canines and premolars in male subjects, the Tanaka and Johnston technique underestimated the actual size for Jordanian teeth widths (difference between regressions values ranged between 0·16 and 0·78 mm). This difference can be explained by the difference in the racial origins of the sample between this study and the sample of Tanaka and Johnston. It was therefore inevitable to derive regression equations and coefficients of correlation between the combined mesiodistal widths of the four permanent mandibular incisors and the combined widths of canines and premolars for Jordanians.

Data from this study were used to generate statistically significant regression equations that can be used in prediction of unerupted canines and premolar widths for Jordanian children. For both sexes, the prediction of mandibular unerupted canines and premolars can be made from the following equation: $Y = 9{\cdot}41 + 0{\cdot}56\ (X)$ and for the prediction of maxillary unerupted canines and premolars $Y = 10{\cdot}55 + 0{\cdot}53\ (X)$, where $(X)$ is the summed mesiodistal widths of the four permanent mandibular incisors. The correlation coefficients between the sum of mesiodistal widths of the four permanent mandibular incisors and permanent canine and premolars of each arch for Jordanians in this study ranged from 0·51 to 0·64 (standard error 0·92–1·0). This range of correlation coefficients is comparable to previously published data [12,15,19–21,24,29] and is considered as a moderate correlation that could be attributed to individual variation within the population of this study. The slope of the simple linear regression, which indicates the strength of the relationship between the predicted and actual canines and premolars widths, ranged from 0·43 for the maxillary teeth in male subjects to 0·64 for the maxillary teeth in female subjects. These were comparable to those reported for the black American [7,19], Thai [21], Hong Kong Chinese [20], Senegalese [24], and Saudi [27].

Moyers mixed dentition analysis is based on the correlation of tooth size between the sum of lower permanent incisors and unerupted canines and premolars. Moyers recommended using the 75th percentile level of probability in his tables to protect on the crowded side [2]. In disagreement with former studies, where authors concluded that Moyers's regression equations are not an accurate method for the prediction of size of unerupted permanent teeth in different populations [12,15,21,30], it was shown in this study that Moyers's tables can be used at the 65% and 75% probability levels for male subjects' upper and lower arches, respectively, and at the 85% probability level for the upper and lower arches in female subjects. The 95% confidence interval ranged from 0·00 to 0·61 mm for male subjects and −0·73 to −0·18 mm for female subjects.

Although many studies [10,12,15,20,21,24–28,30] have reported the need for specific prediction regressions for different racial and ethnic groups, based

on differences from Tanaka and Johnson and Moyers techniques, very few have addressed the clinical significance of these differences. Authors anecdotally claimed that with a combined mesiodistal width of canines and premolars within 1 mm of the predicted value derived from Tanaka and Johnson and Moyers techniques should be considered clinically acceptable as it is not possible to compensate for the biological and growth variations in children during the transition from primary to permanent dentition [2,8,30,31]. The clinical significance of the difference between predicted and actual teeth width in the growing child, however, remains unsubstantiated by any scientific evidence. Therefore, the results of Tanaka and Johnson and Moyers space analysis techniques when applied for growing children of non-northwestern European origins should be interpreted with caution.

**What this paper adds**

- This paper investigated the reliability of Moyer's charts and the Tanaka and Johnston equations for mixed dentition space analysis in Jordanians.
- While Tanaka and Johnston prediction method was not accurate, Moyer's space analysis technique can be used at different probability levels for Jordanian children than the proposed 75% level.

**Why this paper is important for paediatric dentists**

- The outcomes of the different mixed dentition space analysis techniques when applied for growing children of non northwestern European origins should be interpreted with caution.

## Conclusions

**1** The sum of mesiodistal widths of canine and premolars differed between sexes.

**2** The use of the Tanaka and Johnston prediction method is not accurate when applied to a Jordanian population.

**3** For both sexes, the following regression equations were developed for prediction of widths of unerupted canines and premolars in Jordanian children:

a. In the mandible: $Y = 9{\cdot}41 + 0{\cdot}56\ (X)$.

b. In the maxilla: $Y = 10{\cdot}55 + 0{\cdot}53\ (X)$.

(Where $Y$ = the sum of the mesiodistal widths of the unerupted canine and premolars for each quadrant and $X$ = the sum of the mesiodistal widths of the four permanent mandibular incisors).

**4** Moyers method for prediction of size of unerupted permanent teeth can be used for Jordanian children at the 65% and 75% probability levels for male subjects and at the 85% level for female subjects for both upper and lower arches.

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