Original Article

Applicability of Three Tooth Size Prediction Methods for White Brazilians

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ABSTRACT
The objectives of this study were to evaluate the applicability of the methods of Moyers; Tanaka and Johnston; and Bernabé and Flores-Mir to Brazilian individuals and to propose new regression equations using the lower four permanent incisors as predictors for the sum of the widths of the lower permanent canine and premolars. Five hundred dental study casts (250 male and 250 female white patients) were used. The methods of Moyers and Tanaka and Johnston were tested on a sample consisting of 240 female and 223 male patients. The method of Bernabé and Flores-Mir and the new regression equations were based on the complete sample. At the 50th and 75th percentile levels, Moyers' tables tended to underestimate the actual sum of the lower permanent canine and premolars for male and female samples, with statistically significant differences. Although the same statistical significant differences were found when Tanaka and Johnston's and Bernabé and Flores-Mir's methods were used, these differences were not clinically relevant. The new regression equations proposed demonstrate similar correlation and determination coefficients to those found in other studies based on the lower four permanent incisors as predictors. Validating studies (based on similar samples) must be conducted to confirm the applicability and precision of the proposed new regression equations.

KEY WORDS: Tooth width prediction; Mixed dentition analysis; Regression equations

INTRODUCTION

Nance[1] described the mean Leeway Space as 3.4 mm in the mandible and 1.8 mm in the maxilla. Thus, arch length discrepancy can be defined as the difference between the amount of dental arch space that is available and the amount of tooth size that needs to be accommodated.[2–7] Arch length is generally diminished during the transition from mixed to permanent dentition, particularly in the mandibular arch.[1,8] Because conserving or regaining space is critical in the mandible, arch length discrepancy analysis is commonly performed in this arch.[9,10]

Methods to estimate the mesiodistal width of unerupted permanent canines and premolars are an important and fundamental procedure for every patient in the mixed dentition stage.[3,8,10–23] Three methods are commonly used.

- Radiographic methods: based on periapical and 45° cephalometric radiographs.[5,24,25]
- Nonradiographic methods: based on correlation and regression equations, as prediction tables;[2,7,11]
- Combinations of both methods.[26–35]

Methods based on 45° cephalometric radiographs are considered the most precise.[3,5,24,26,29,30] However, they require time, specific equipment, and are less practical.[11,16,17] Because of the advances in statistical software, simple and multiple regression equation models have been adopted in many studies,[2,3,7,11,18,23,30,31] but the accuracy of regression equations or prediction tables could be questioned when applied to a different racial group or populations of different ethnic origin.[1,3–5,14,24,31–39]

This study aims to evaluate the applicability of the methods of Moyers; Tanaka and Johnston; and Bernabé and Flores-Mir to estimate the mesiodistal widths of lower permanent canines and premolars in white Brazilian individuals from Rio de Janeiro and to propose new regression equations using the widths of the lower four permanent incisors as predictors.

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MATERIALS AND METHODS

Five hundred dental study casts (250 from white Brazilian female patients and 250 from white Brazilian male patients: average ages of 13.8 and 14.4 years, respectively) were selected from the orthodontic archives of the Faculdade de Odontologia da Universidade Federal do Rio de Janeiro, Brazil. Impressions and study casts were obtained from alginate impression material using high-quality orthodontic model stone (Dental Stone Type III; Vigodent S/A Indústria e Comércio, Rio de Janeiro, RJ, Brazil). The sample size was determined by statistic calculation, on the basis of a previous pilot study of 100 cases.

All permanent teeth (excluding third molars) should be present and fully erupted. No previous orthodontic treatment, mesiodistal cavities, fractures, tooth congenital defects, tooth wear, or restorations should be present. These criteria were adopted by many authors.[3,7,14,18,23,28,37–41]

An electronic digital caliper (0–150 mm ME 00183, Lee Tools, Rio de Janeiro, Brazil, Kaje Intermares Comercial Importação & Exportação LTDA, China) with an accuracy of $\pm$0.02 mm and repeatability of $\pm$0.01 mm (manufacturer specifications) was used to measure the teeth. To better adjust for interdental spaces, the measuring tips were narrowed.[14,18] The caliper was held at the tooth's greatest mesiodistal diameter (contact points), parallel to the occlusal surface and perpendicular to the tooth's long axis.[15,18,23,26,32,37,40] Only 15 casts were measured per day. To determine measurement reliability, one investigator measured 10 plaster casts randomly selected (first to first permanent molars, 240 tooth measures) three times, with intervals of 10 days.

Three prediction methods used in this study

- Moyers[2] method: probability charts at 50th and 75th percentile levels were used to estimate the widths of lower permanent canines and premolars. The sum of the lower four permanent incisors was smaller than 19.5 mm or larger than 25.5 mm (limits of Moyers'[5] tables) in 10 female patients and 27 male patients. Thus, the sample consisted of 240 female and 223 male patients.
- Tanaka and Johnston[11] method: mesiodistal widths of inferior permanent canine and premolars were estimated by summing 10.5 mm to the half of the sum of the lower four permanent incisor. This sample also consisted of 240 female and 223 male patients.
- Bernabé and Flores-Mir[7] method: mesiodistal widths of lower permanent canine and premolars were estimated by the following regression equation. $Y = 3.763 + 0.37 \times X0 + 1.057 \times X1 + 0.366 \times X2$, where X0 is the sum of the of the upper and lower permanent central incisors plus the widths of the upper permanent first molars, X1 is 0 for the mandible and 1 for the maxilla, and X2 is 0 for female and 1 for male. The sample consisted of 250 male and 250 female patients.

New regression equations were determined using the lower four permanent incisors as predictors for the sum of the widths of lower permanent canine and premolars. Correlation and the determination coefficients were also obtained. The sample consisted of 250 male patients and 250 female patients. The results of this study are based only on the mandibular arch and represent the average of the right and left sides.

Intraclass correlation coefficient (ICC) was used to determine measurement consistency. To compare male and female results, nonpaired Student's *t*-test was used. To compare the results of different methods in the same sample, paired Student's *t*-test was used ($P = .05$).[5,15,17,24,34,38,40,42–44]

RESULTS

A high value of ICC $= 0.995$ was found, indicating great measurement reliability. There was no statistical significant difference between the left and right sides of the upper and lower arches in both sex groups. There was a significant statistical difference between the widths of male and female teeth. Male teeth generally were larger.

In the male sample, Moyers'[2] charts at the 50th and 75th percentile levels tended to underestimate the actual sum of the lower permanent canine and premolars by 1.20 and 0.41 mm, respectively. The standard deviation of these differences was 0.89 mm for both percentile levels. Tanaka and Johnston's[11] method tended to underestimate the actual sum of the lower permanent canine and premolars by 0.24 mm with a standard deviation of 0.87 mm. Bernabé and Flores-Mir's[7] method tended to overestimate the actual values by 0.17 mm with a standard deviation of 0.84 mm (Table 1).

In the female sample, Moyers'[2] charts at the 50th and 75th percentile levels tended to underestimate the actual sum of lower permanent canine and premolars by 1.29 and 0.48 mm, respectively. The standard deviation of these differences was 0.78 mm for both percentile levels. Tanaka and Johnston's[11] and Bernabé and Flores-Mir's[7] methods tend to overestimate the actual sum by 0.20 and 0.08 mm with a standard deviation of 0.78 and 0.87 mm, respectively (Table 2).

New regression equations were proposed for male and female patients to estimate the sum of mesiodistal widths of permanent canine and premolars based on the sum of the lower four permanent incisors.

Male patients: $Y = 8.9 + 0.58X$.

TABLE 1. Predicted Values Based on the Methods of Moyers; Tanaka and Johnston; and Bernabé and Flores-Mir. Male Sample[a]

Male Patients	Predicted Values of Permanent Canine and Premolars		Actual Values of Permanent Canine and Premolars		Difference Predicted Minus Actual Values		Significance (P Value)*
	Mean	SD	Mean	SD	Mean	SD	
Moyers 50% (1988)[b]	21.21	0.52	22.41	1.07	−1.20	0.89	$P < .01$
Moyers 75% (1988)[b]	22.00	0.52	22.41	1.07	−0.41	0.89	$P < .01$
Tanaka and Johnston (1974)[b]	22.17	0.58	22.41	1.07	−0.24	0.87	$P < .01$
Bernabé and Flores-Mir (2005)[c]	22.73	0.94	22.56	1.23	0.17	0.84	$P < .01$

[a] SD indicates standard deviation.
[b] Sample size = 223 cases.
[c] Sample size = 250 cases.
* Statistical significance $P = .01$.

TABLE 2. Predicted Values Based on the Methods of Moyers; Tanaka and Johnston; and Bernabé and Flores-Mir. Female Sample[a]

Female Patients	Predicted Values of Permanent Canine and Premolars		Actual Values of Permanent Canine and Premolars		Difference Predicted Minus Actual Values		Significance (P Value)*
	Mean	SD	Mean	SD	Mean	SD	
Moyers 50% (1988)[b]	20.39	0.68	21.68	1.04	−1.29	0.78	$P < .01$
Moyers 75% (1988)[b]	21.20	0.67	21.68	1.04	−0.48	0.78	$P < .01$
Tanaka and Johnston (1974)[b]	21.88	0.64	21.68	1.04	0.20	0.78	$P < .01$
Bernabé and Flores-Mir (2005)[c]	21.78	0.87	21.70	1.07	0.08	0.87	$P > .01$

[a] SD indicates standard deviation.
[b] Sample size = 240 cases.
[c] Sample size = 250 cases.
* Statistical significance $P = .01$.

TABLE 3. Predicted and Actual Values of the Sum of Lower Permanent Canine and Premolars[a]

	Predicted Values Based on Regression Equation		Actual Values of Permanent Canine and Premolars		Difference		Significance (P Value)*
	Mean	SD	Mean	SD	Mean	SD	
Female[b]	21.74	0.75	21.70	1.34	0.04	0.77	$P = .622$
Male[b]	22.59	0.87	22.56	1.23	0.03	0.87	$P = .444$

[a] SD indicates standard deviation.
[b] Sample size = 250 cases.
* Statistical significance $P = .01$.

Female patients: $Y = 9.2 + 0.55X$.

The difference between predicted and actual widths of permanent canine and premolars was, on average, 0.03 mm for the male and 0.04 mm for the female patients. This difference was not statistically significant. The standard deviation of the difference was 0.87 and 0.77 mm, respectively (Table 3).

The values of constants "a" and "b" found in this study are compared with other studies in Table 4. Correlation and determination coefficients were determined and compared with others obtained in different studies (Table 5).

DISCUSSION

Tooth and facial characteristics differ among populations of different racial or ethnic origin.[3,5–7,10,14,23,24,30,32–41,45] Some of the most used methods to predict widths of unerupted permanent teeth were developed for United States children.[2,11,26] Studies to confirm the applicability and effectiveness of these methods in different populations are appropriate.

A digital caliper was used to determine more accurate and precise measures, as stated by many au-

TABLE 4. Comparison Among Various Values of "a" and "b" Constants

	Regression Coefficients	
	a	b
Present study	9.20 (female)/8.90 (male)	0.55 (female)/0.58 (male)
Ballard and Wylie (1947)	9.41	0.52
Tanaka and Johnston (1947)	9.18	0.54
Moyers (1988)[a]	8.25 (female)/10.79 (male)	0.52 (female)/0.45 (male)
Van Der Merwe et al. (1991)	7.46	0.60
Al-Khadra (1993)	8.60	0.55
Jaroontham and Godfrey (2000)	10.30	0.50
Lee-Chan et al. (1998)	7.46	0.62
Diagne et al. (2003)	5.67	0.70

[a] Regression equations derived from Moyers' tables (1988) at the 50th percentile.

TABLE 5. Comparison Among Correlation (r) and Determination (r^2) Coefficients Found in This and Other Studies[a]

	Male		Female		Male + Female	
	r	r^2	r	r^2	r	r^2
Present study	0.704	0.496	0.694	0.482	—	—
Tanaka and Johnston (1974)	—	—	—	—	0.648	0.419
Bernabé and Floris-Mir (2005)	0.710	0.504	0.720	0.518	0.777	0.604

[a] —Indicates coefficient not determined.

thors.[15,42,43] The value of ICC (0.995) found in this study is in accordance with the values found by other investigators.[7,13,22,26–28,35,44,46] This indicates great measurement reliability. Thus, all tooth measures of the 500 dental casts were performed only once.

No differences between the right and left sides of the lower arch were found. All prediction methods used in this study were based on the average of both sides. Statistical significant differences were found between male and female tooth widths. Thus, data analysis was performed separately for each sex. This is in accordance with studies of many authors.[2,3,5–7,13,16–18,27,32,34,39,40] However, others do not consider sex differences.[3,4,11,24–26,28,31]

In both the male and female samples, Moyers'[2] tables at the 50th and 75th percentile levels tended to underestimate the actual sum of lower permanent canine and premolars. The differences were statistically significant (Tables 1 and 2). These results have been confirmed before[3,6,14,16,23,24,39] but do not agree with other studies, which found that these percentile levels (especially the 75th) tended to overestimate.[4,10,17,29,30,37,40,45,47] However, some authors found no differences when Moyers'[5] method (75th percentile) was used.[5,24,39]

When Tanaka and Johnston's[11] method was applied in the male and female samples, there was a statistically significant difference ($P < .01$), but no clinical relevant difference (less than 1 mm) was found between the predicted and actual sum of lower permanent canine and premolars (Tables 1 and 2). These results are in accordance with some studies.[5,39] However, other authors found an overestimation when this method was used.[24,37]

The variability in results found when the methods of Moyers and Tanaka and Johnston were applied in Brazilian individuals may be explained by the differences in sample sizes and origins. These two methods were developed for North American individuals and were tested in many others of different origins. There are differences in colonization and ethnic characteristics of the population when individuals of United States and Brazil are compared. In Brazil, there are several different characteristics within the population of the same ethnic origin. Most of the studies conducted in Brazil were based on small or middle size samples (this study has the largest sample).

Bernabé and Flores-Mir's[7] method had not been tested in different populations besides the original one. In the female sample, no statistical difference was found between the predicted and actual sum of the lower permanent canine and premolars. In the male group, although a statistically significant difference was present, it was not clinical relevant (less than one mm) (Tables 1 and 2). Similar population origins and colonization (Latin America) are observed in this study and in the studies of Bernabé and Flores-Mir.

In this study, new regression equations were developed using the widths of the lower four permanent incisors as predictors for the sum of the widths of lower permanent canine and premolars. The correlation coefficients found (Table 5) were higher than those found in Tanaka and Johnston[11] and are similar to those proposed by Bernabé and Flores-Mir.[7] On an average, no statistical significant difference was found between the predicted and actual values. The standard deviation of the differences is in accordance with those in the literature.[7,11,13,17,24,25,31,37,38]

The simple linear regression is defined by the formula: $Y = a + bX$. The parameter of interest is the slope in the linear regression (b constant). This study found b coefficients of 0.55 for female and 0.58 for male patients (Table 4). These values are similar to those found in many studies,[2–4,11,17,37,38] indicating that a reasonable correlation exists between the lower four permanent incisors and the actual widths of lower permanent canine and premolars in white Brazilian individuals.

CONCLUSIONS

- No clinical relevant difference was observed between predicted and actual widths of the lower permanent canine when the methods proposed by Tanaka and Johnston (1974) and Bernabé and Floris-Mir (2005) were applied.
- The predicted widths determined by Moyers' tables at 50th and 75th percentiles underestimate the actual widths of the lower permanent canine and premolars for male and female patients.
- The regression equations proposed in this study are a good prediction method to determine widths of the lower permanent canine and premolars.
- Validating studies (based on similar samples) must be conducted to confirm the applicability and precision of the new regression equations proposed.

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