TOOTH SIZE PREDICTION IN WHITE BRAZILIAN INDIVIDUALS: applicability of methods

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Recebido em: 13/04/2016 - Aprovado em: 26/05/2017 - Disponibilizado em: 01/07/2017

ABSTRACT

Estimating the mesiodistal widths of unerupted permanent canines and premolars is an essential aspect of mixed dentition analysis that should be considered by dentists treating patients in this stage of developing occlusion. This study aims to evaluate the applicability and accuracy of three non-radiographic prediction methods (Moyers, Tanaka & Johnston and Bernabé & Flores-Mir) and propose new regression equations based on the sum of the widths of the lower four permanent incisors to predict the widths of lower permanent canines and premolars. The sample was consisted of 400 dental casts obtained from white Brazilian patients (200 male and 200 female). The results demonstrated that Moyers' tables at 50^{th} and 75^{th} percentile levels tend to underestimate the actual sum of the widths of lower permanent canine and premolars for male and female samples, with statistical significant differences. Although the same statistical significant differences were found when Tanaka & Johnston's and Bernabé & Flores-Mir's methods were used, these differences were not clinically relevant (less than 1 mm). The regression equations proposed in this study are a good prediction method to determine widths of the lower permanent canine and premolars.
Keywords: Tooth Size. Prediction Method. Orthodontics. Dentistry. Linear Regression.

Introduction

The mixed dentition stage is defined as the period that permanent and deciduous teeth are present in the mouth, simultaneously. The mixed dentition analysis is performed when the four permanent mandibular incisors and the first permanent molars are erupted (BALLARD & WILIE, 1947; BISHARA & JAKOBSEN, 1998; FLORES-MIR et al., 2003) On average, a positive difference can be expected between deciduous teeth (canine, first and second molars) and their successors (permanent canine and premolars). This

difference was described by Nance (1947) and was determined, on average, as 3.4 mm in lower arch and 1.8 mm in upper. It is a well established that arch length decreases during the transition from the mixed to the permanent dentition, particularly in the mandibular arch (NANCE, 1947; GIANELLY, 2002). Thus, mixed dentition analysis is commonly executed in this arch as it is critical in conquering or regaining space (MUCHA & BOLOGNESE, 1985; PAULA & ALMEIDA, 1987).

The prediction of mesiodistal width of unerupted permanent canines and premolars became an important and fundamental procedure to be executed in every patient during mixed dentition stage, in order to determine an accurate diagnosis and treatment plan (TANAKA & JOHNSTON, 1974; SMITH, KING & VALENCIA, 1979; STALEY et al., 1983; VAN DER MERWE et al., 1991; URSUS & WILTSHIRE, 1997; MOK & COOKE, 1998; CECÍLIO & VIGORITO, 2001; GIANELLY, 2002; DIAGNE et al., 2003; LEGOVIC, NOVOSEL & LEGOVIC, 2003; TAUSCHE, LUCK & HARZER, 2004).

The methods commonly used to predict unerupted permanent canine and premolars mesiodistal widths are based on:

1- radiographs – periapical or 45° cephalometric radiographs (LIMA & MONNERAT, 1992; PAULA & ALMEIDA, 1987; MARTINELLI et al., 2005);

2- regression equations (non radiographic methods) – prediction tables or graphics (BALLARD & WILIE, 1947; MOYERS, 1988);

3- regression equations combined with radiographs - combination of both methods above (HIXON & OLDFATHER, 1958; STALEY & HOAG, 1978; STALEY & KERBER, 1980).

All these prediction methods are not totally precise and can overestimate or underestimate the actual size of unerupted teeth (FISK & MARKIN, 1979; MOYERS, 1988). The use of correlation-statistical methods have gained strength due to advances in statistical software and high correlation values obtained with simple and multiple regression models (BALLARD & WILIE, 1947; TANAKA & JOHNSTON, 1974; FERGUSON et al., 1978; MOYERS, 1988; OLIVEIRA, PINZAN & HENRIQUES, 1991; VAN DER MERWE et al., 1991; BISHARA & JAKOBSEN, 1998; YUEN, TANG & SO, 1998; PROFFIT & FIELDS, 2000; NOURALLAH et al., 2002; PAIXÃO, CORDEIRO & JÚNIOR, 2002; FLORES-MIR et al., 2003; LEGOVIC, NOVOSEL & LEGOVIC, 2003). Thus, MOYERS' (1988) tables and TANAKA & JOHNSTON'S (1974) method have achieved widespread clinical use and acceptance (URSUS & WILTSHIRE, 1997; PROFFIT & FIELDS, 2000). Most of Brazilian dentists use Moyers' tables at 75th percentile level (PAIXÃO, CORDEIRO & JÚNIOR, 2002).

Unfortunately Moyers' equations do not mention the sample origin or characteristics (TANAKA & JOHNSTON, 1974; CECÍLIO & VIGORITO, 2001).

The accuracy of methods based in regression equations or prediction tables could be questioned when applied to a different racial group or populations of different ethnic origin (TANAKA & JOHNSTON, 1974; INGERVALL & LENNARTSSON, 1978; VAN DER MERWE et al., 1991; LIMA & MONNERAT, 1992; PAULA & ALMEIDA, 1995; URSUS & WILTSHIRE, 1997; LEE-CHAN et al., 1998; JAROONTHAM & GODFREY, 2000; PAIXÃO, CORDEIRO & JÚNIOR, 2002).

This study aims to evaluate the applicability of three prediction methods (Moyers', Tanaka & Johnston's, Bernabé & Flores-Mir's) to estimate the mesiodistal widths of unerupted lower permanent canines and premolars in white Brazilian individuals from Rio de Janeiro.

Materials and Methods

Initial 400 dental casts (200 from white Brazilian female patients and 200 from white Brazilian male patients – average ages of 13.8 and 14.4 years, respectively) were selected from the archives of private orthodontic clinics in Belo Horizonte. Impressions and study casts were prepared by the use of alginate impression material and high-quality orthodontic model stone (Dental Stone Type III; Vigodent S/A Indústria e Comércio, Rio de Janeiro –RJ – Brasil).

This study was based only in the mandibular arch and all permanent teeth (excluding third molars) should be present and fully erupted. No previous orthodontic treatment, mesiodistal caries, restorations, cavities, fractures, tooth congenital defects or tooth wear should be present. No impression flaws were found. These criteria were in agreement with those proposed by many authors (HUNTER & PRIEST, 1960; STALEY & KERBER, 1980; VAN DER MERWE et al., 1991; LIMA & MONNERAT, 1992; URSUS & WILTSHIRE, 1997; LEE-CHAN et al., 1998; JAROONTHAM & GODFREY, 2000; MARCHIONNI et al., 2001; VERZI, LEONARDI & PALERMO, 2002; LEGOVIC, NOVOSEL & LEGOVIC, 2003; BERNABÉ & FLORES-MIR, 2005; MARINELLI et al., 2005).

The measures were obtained using an electronic digital caliper (0-150 mm ME 00183, LEE TOOLS, Kaje Intermares Comercial Importação & Exportação LTDA, CHINA) with accuracy of ±0,02 mm and repeatability of ±0,01 mm (Manufacturer Specifications). To determine measurement consistencies, one investigator measured 200 tooth mesiodistal widths, three times with intervals of 10 days (total of 600 measures). The sliding caliper was adjusted to tooth

greatest mesiodistal diameter (contact points), parallel to the occlusal surface and perpendicular to tooth long axis, as preconized by other investigators (HIXON & OLDFATHER, 1958; TANAKA & JOHNSTON, 1974; KAPLAN, SMITH & KANAREK, 1977; ZILBERMAN, KAYE & VARDIMON, 1977; BISHARA et al., 1986; BISHARA et al., 1989; URSUS & WILTSHIRE, 1997; LEE-CHAN et al., 1998; YUEN, TANG & SO, 1998; WARREN & BISHARA, 2001; NOURALLAH et al., 2002). **Figure 1.**

Fig 1. Digital caliper used in the present study.

Three prediction methods were used in this study. All three methods results represent the average of right and left sides:

1. Moyers' – probability charts at the 50th and 75th percentile confidence levels were used to indicate the predicted sum of the widths of lower permanent canines and premolars.
2. Tanaka & Johnston's – prediction of the sum of mesiodistal widths of inferior permanent canines and premolars was obtained summing 10.5 mm to the half of the lower four permanent incisors widths.
3. Bernabé & Flores-Mir's – predicted sum of the widths of lower permanent canines and premolars were obtained by regression equation based on the following formula: $Y = 3.763 + 0.37 \times X0 + 1.057 \times X1 + 0.366 \times X2$, 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 zero for the mandible and 1 for the maxilla, and $X2$ is zero for female and 1 for male.

Intraclass Correlation Coefficient (ICC) was used to determine measurement consistencies. To determine right/left sides and gender differences, pared and non-pared Student's t-test was used, respectively. Pared Student's t-test was also used to compare the predicted and actual sums of the inferior permanent canines and premolars (TANAKA & JOHNSTON, 1974; ZILBERMAN, KAYE & VARDIMON, 1977; STALEY et al., 1983; AL-KHADRA, 1993; BISHARA & JAKOBSEN, 1998; MARCHIONNI et al., 2001; MARTINELLI et al., 2001; WARREN & BISHARA, 2001; FLORES-MIR et al., 2003; KESKI-NISULA et al., 2003;

BERNABÉ, MAJOR & FLORES-MIR, 2004; BERNABÉ, VILLANUEVA & FLORES-MIR, 2004; MARINELLI et al., 2005).

Results

High value for ICC was found (ICC=0.995), indicating great precision in measure reproducibility and measure consistency. There was no statistical significant difference between left and right sides of the upper and lower arches in both gender groups. There was a significant statistical difference between male and female widths of permanent teeth in both arches. Male teeth are generally larger than female ones.

The differences and significance (p value) between actual and predicted sum of the widths of lower permanent canines and premolars obtained by Moyers', Tanaka & Johnston's and Bernabé & Flores-Mir's methods are demonstrated in Table I (Male) and Table II (Female).

Table I. Sum of the widths of lower permanent canine and premolars: predicted values, actual values and differences in –[millimeters. Male sample.

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	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*	
Moyers 50% (1988)	20.21	0.41	21.41	1.03	-1.20	0.89	p<0.01
Moyers 75% (1988)	21.78	0.59	22.71	0.99	-0.93	0.89	p<0.01
Tanaka & Johnston (1974)	22.67	0.53	23.41	1.07	-0.74	0.87	p<0.01
Bernabé & Flores-Mir (2005)	22.73	0.94	22.56	1.23	0.17	0.84	p<0.01

Statistical significance p = .01.
S.D. – standard deviation.

Table II. Sum of the widths of lower permanent canine and premolars: predicted values, actual values and differences in millimeters. Female sample.

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	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*	
Moyers 50% (1988)	20.39	0.68	21.68	1.04	-1.29	0.78	p<0.01
Moyers 75% (1988)	21.20	0.67	21.68	1.04	-0.48	0.78	p<0.01
Tanaka & Johnston (1974)	21.88	0.64	21.68	1.04	0.20	0.78	p<0.01
Bernabé & Flores-Mir (2005)	21.78	0.87	21.70	1.07	0.08	0.87	p>0.01

Statistical significance p ≤ .01.
S.D. – standard deviation.

In male sample it was observed that Moyers' charts at 50th and 75th percentile levels tended to underestimate the actual sum of the widths of lower permanent canine and premolars in 1.20 mm and 0.41 mm, respectively. The standard deviation of these

differences was 0.89 mm for both percentile levels. The Tanaka & Johnston's method tended to underestimate the actual sum of the widths of lower permanent canine and premolars in 0.24 mm with standard deviation of 0.87 mm. Bernabé & Flores-Mir's method tended to overestimate the actual values in 0.17 mm with a standard deviation of 0.84 mm.

In female sample it was observed that Moyers' charts at 50^{th} and 75^{th} percentile levels tended to underestimate the actual sum of the widths of lower permanent canine and premolars in 1.29 mm and 0.48 mm, respectively. The standard deviation of these differences was 0.78 mm for both percentile levels. Tanaka & Johnston's and Bernabé & Flores-Mir's methods tend to overestimate the actual sum of the widths in 0.20 mm and 0.08 mm with standard deviations of 0.78 mm and 0.87 mm, respectively.

Based on these results and in order to improve the correlation between predicted and actual values of lower permanent canine and premolars, the following regression equation was proposed: Y= a+bX

"Y" represents the sum of predicted mesiodistal widths (in millimeters) of the lower permanent canine and premolars in one quadrant; "X" represents the mesiodistal widths of the lower four permanent incisors in millimeters. The constant "a+b" represents the constants to be derived, "a" is the y-intercept and "b" is the slope of the regression line. The equations are presented below only for the lower arch:

Male patients : Y= 8.9+0.58X.
Female patients : Y=9.2+0.55X.

The regression equation provided new values for the predicted sum of the mesiodistal widths of the lower permanent canines and premolars. These predicted values are compared to actual ones in Table III.

Table III. Mean values, standard deviation, difference in millimeters and significance between predicted and actual values of the lower permanent canines and premolars (regression equation determined in the present study).

	Predicted values based on regression equation		Actual values of permanent canine and premolars		Difference		Significance (p value)
	Mean	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*	
Female*	21.74	0.75	21.70	1.34	0.04	0.77	p>0.01
Male*	22.59	0.87	22.56	1.23	0.03	0.87	p>0.01

** sample size=200 cases*
S.D. – standard deviation.
Statistical significance p = .01.

The difference between predicted and actual widths was, on average, 0.03 mm for male and 0.04 mm for female patients. The standard deviation of the difference was 0.77 mm for female and 0.87 mm for male patients. There were no statistical significant differences between predicted and actual widths of lower permanent canines and premolars for each male and female sample (p value 0.444 and 0.622, respectively).

The values of constants "a" and "b" found in this study are compared among other studies in Table IV.

Table IV. 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 & Wylie (1947)	*9.41*	*0.52*
Tanaka & Johnston (1974)	*9.18*	*0.54*
Ferguson et al. (1978)	*9.93*	*0.52*
Moyers (1988)*	*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 & Godfrey (2000)	*10.30*	*0.50*
Chan et al. (1998)	*7.46*	*0.62*
Diagne et al. (2003)	*5.67*	*0.70*

** regression equations derived from Moyers' tables (1988) at the 50th percentile.*

Correlation and determination coefficients were also determined. These coefficients were compared to other ones obtained in different studies (Table V).

Table V. Comparison among correlation (r) and determination (r^2) coefficients found in this and other studies.

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

— *coefficient not determined.*

Discussion

Particularities of mixed dentition analysis, as tooth size discrepancies, differ among population. Some of the most used methods to predict widths of unerupted permanent teeth were developed for American children (HIXON & OLDFATHER, 1958; TANAKA & JOHNSTON, 1974; MOYERS, 1988). Studies to confirm the applicability and effectiveness of these methods in different populations are justified.

A digital caliper was used to determine more accurate and precise measures and reduce eye

fatigue. The use of this kind of caliper is recommended by several authors (FERGUSON et al., 1978; BISHARA & JAKOBSEN, 1998; MOK & COOKE, 1998; YUEN, TANG & SO, 1998; WARREN & BISHARA, 2001; KESKI-NISULA et al., 2003). The value of ICC (0.995) found in this study in accordance to the values found by other investigators (HIXON & OLDFATHER, 1958; FERGUSON et al., 1978; STALEY & KERBER, 1980; STALEY et al., 1983; BERNABÉ, MAJOR & FLORES-MIR, 2004; BERNABÉ & FLORES-MIR, 2005). This indicates great measurement precision, repeatability and consistence. Thus, all measures from the 400 dental casts were performed only once.

The results demonstrated no difference between right and left sides of the lower and upper arch. All methods used in this study predict one side of the arch (average of right and left sides). In order to determine the predicted sum of the widths of permanent canines and premolars of both sides, the results must be multiplied by 2 (TANAKA & JOHNSTON, 1974; MOYERS, 1988; BERNABÉ & FLORES-MIR, 2005).

A statistical significant difference was found between male and female tooth mesiodistal widths. Male teeth are generally larger. The literature also describes gender differences in tooth widths (MOYERS, 1988; BISHARA & JAKOBSEN, 1998; VAN DER MERWE et al., 1991; PAULA, ALMEIDA & LEE, 1995; LEGOVIC, NOVOSEL & LEGOVIC, 2003; CABRAL et al., 2004; BERNABÉ & FLORES-MIR, 2005). However, other studies do not consider gender differences (HIXON & OLDFATHER, 1958; TANAKA & JOHNSTON, 1974; VAN DER MERWE et al., 1991; LIMA & MONNERAT, 1992; AL-KHADRA, 1993; MARTINELLI et al., 2005). The data were analyzed separately for each gender. No better correlation or determination coefficient was found when male and female samples were analyzed together.

In both male and female samples, Moyers' tables at 50^{th} and 75^{th} percentile level tended to underestimate the actual sum of the widths of lower permanent canine and premolars. The differences between predicted and actual values were statistically significant (Tables I and II). These results are in accordance to many studies (VAN DER MERWE et al., 1991; URSUS & WILTSHIRE, 1997; PAIXÃO, CORDEIRO & JÚNIOR, 2002; CABRAL ET AL., 2004), but they do not agree with others that found that these percentile levels (specially 75^{th}) tend to overestimate the actual sum of the widths of lower permanent canines and premolars (FISK & MARKIN, 1979; PAULA & ALMEIDA, 1987; AL-KHADRA, 1993; BISHARA & JAKOBSEN, 1998; DIAGNE et al., 2003). However, some authors found no differences when Moyers' method (75^{th}

percentile) was used (LIMA & MONNERAT, 1992; PAULA & ALMEIDA, 1987; MARCHIONNI, SILVA & ARAÚJO, 2001; FLORES-MIR et al., 2003). This variability in results may be explained by the differences in sample sizes and origins.

Although statistically significant ($p<0.01$), no clinical relevant difference was found between the predicted and actual sum of the widths of lower permanent canine and premolars when Tanaka & Johnston's method was applied in male and female samples (Tables I and II). These results are in accordance to some studies (PAULA & ALMEIDA, 1987; MARCHIONNI, SILVA & ARAÚJO, 2001; FLORES-MIR et al., 2003). However, other authors found overestimated results when Tanaka & Johnston's method was used (BISHARA & JAKOBSEN, 1998; LIMA & MONNERAT, 1992; PROFFIT & FIELDS, 2000). The method proposed by Bernabé & Flores-Mir's was tested in the Brazilian sample and no statistical difference was found between predicted and actual sum of the widths of lower permanent canine and premolars in female group. In male group, although the results demonstrated statistical differences, no clinical relevant difference was observed (Tables I and II).

In the present 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 V) are higher than those porposed by Tanaka & Johnston's and are similar to those described by Bernabé & Flores-Mir. The standard deviation of the differences is in accordance to those related in the literature (TANAKA & JOHNSTON, 1974; STALEY et al., 1983; LIMA & MONNERAT, 1992; BISHARA & JAKOBSEN, 1998; NOURALLAH et al., 2002; DIAGNE et al., 2003; BERNABÉ & FLORES-MIR, 2005; MARTINELLI et al., 2005).

High value of ICC (ICC = 0.995) was found, indicating great measurement precision and repeatability. This value of ICC is similar to those described by the literature (HIXON & OLDFATHER, 1958; STALEY & HOAG, 1978; STALEY & KERBER, 1980; MUCHA & BOLOGNESE, 1985; YUEN, TANG & SO, 1998; CABRAL et al., 2004). Thus, tooth mesiodistal widths of all 400 casts were measured only once.

Several authors demonstrated differences between male and female tooth widths (NANCE, 1947; STALEY & HOAG, 1978; SMITH, KING & VALENCIA, 1979; STALEY et al., 1983; MUCHA & BOLOGNESE, 1985; MOYERS, 1988; AL-KHADRA, 1993; PAULA & ALMEIDA, 1987; URSUS & WILTSHIRE, 1997; BISHARA & JAKOBSEN, 1998), although others do not consider gender differences (MOYERS, 1988; VAN DER MERWE et al.,

1991; BERNABÉ & FLORES-MIR, 2005; LIMA & MONNERAT, 1992; HIXON & OLDFATHER, 1958; STALEY & KERBER, 1980). This study also found a statistical difference between male and female tooth widths. Male teeth are generally larger. Data were analyzed separately for male and female samples. In this study, the differences between right and left sides of the lower arch were small and not statistically significant. This symmetry was confirmed by many investigators (STALEY & HOAG, 1978; AL-KHADRA, 1993; PAULA & ALMEIDA, 1987; URSUS & WILTSHIRE, 1997; BISHARA & JAKOBSEN, 1998; MARCHIONNI, SILVA & ARAÚJO, 2001).

Conclusion

Considering the studied sample and the results found in this study, one can conclude:

1. no clinical relevant difference was observed between predicted and actual widths of the lower permanent canine when the methods proposed by Tanaka & Johnston (1974) and Bernabé & Floris-Mir (2005) were applied in the studied sample;
2. the predicted widths determined by Moyers' tables at 50^{th} and 75^{th} percentiles underestimate the actual widths of the lower permanent canine and premolars for male and female patients. These differences were statistically significant;
3. the regression equations proposed in this study are a good prediction method to determine widths of the lower permanent canine and premolars in the studied Brazilian population.

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