European Journal of Orthodontics 34 (2012) 340–344
doi:10.1093/ejo/cjr015
Advance Access Publication 9 May 2011

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Development of a prediction equation for the estimation of mandibular canine and premolar widths from mandibular first permanent molar and incisor widths

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SUMMARY The aim of this study was to develop a prediction equation for estimating the total widths of the mandibular permanent canines and premolars (TCPW) using the total widths of the mandibular first permanent molars and incisors (TWFMI). The sample comprised 288 mandibular dental casts of orthodontic patients (106 males and 182 females, average age 13.8 and 14.4 years, respectively). A digital vernier calliper was used to measure the mesiodistal tooth widths from the mandibular right to the left first permanent molar. An independent *t*-test was used to determine any gender difference and a multiple linear regression equation to predict TCPW using TWFMI. A paired *t*-test was used to compare the actual and predicted values of the canines and premolars.

The results showed a statistically significant difference ($P < 0.01$) between the mesiodistal tooth widths of males and females. A moderate correlation and determination coefficient between TCPW and TWFMI was found ($r = 0.64$ to $r = 0.67$ and $r^2 = 0.41$ to $r^2 = 0.44$, respectively). There was no significant difference between actual and predicted values for males and females. The regression equations proposed are a good prediction method to determine TCPW.

Introduction

The mixed dentition phase is between 6 and 12 years when simultaneously the primary and permanent teeth are present in the dental arch. Mixed dentition analysis is important in orthodontic diagnosis and treatment planning (Al-Bitar *et al.*, 2008). It is a valuable tool in determining whether the treatment plan will involve serial extractions, guidance of eruption, space maintenance, space regaining, or just periodic observation of the patient (Bishara and Staley, 1984). This analysis helps to predict the widths of unerupted canines and premolars and to determine the difference between the amount of space available in the dental arch and the amount of tooth material that should be accommodated (Moyers, 1958; Tanaka and Johnston, 1974; Bishara *et al.*, 1989; de Paula *et al.*, 1995; Schirmer and Wiltshire, 1997; Bernabé and Flores-Mir, 2005). If the result is significantly negative, future crowding can be predicted. As the number of patients demanding early orthodontic treatment continues to increase, it is important to estimate any deficiency of arch space in advance and initiate appropriate treatment. During the transition from the mixed to the permanent dentition, maxillary arch length is generally diminished and analysis is generally performed in the mandibular arch (de Paula *et al.*, 1995).

Early attempts to estimate the mesiodistal widths of teeth were made by Black (1897) who proposed tables based on average widths. Clinically, these approximations were found unreliable because of the great variability in tooth sizes between subjects. The three most commonly used methods to estimate the mesiodistal widths of unerupted permanent canines and premolars in the mixed dentition are: radiographic based on periapical and cephalometric radiographs (Black, 1897; Moyers, 1958; Tanaka and Johnston, 1974; Bishara *et al.*, 1989; de Paula *et al.*, 1995; Schirmer and Wiltshire, 1997; Bernabé and Flores-Mir, 2005; Lima Martinelli *et al.*, 2005); non-radiographic based on correlation and prediction equations as prediction tables (Moyers, 1958; Tanaka and Johnston, 1974; Bernabé and Flores-Mir, 2005); and a combination of both methods (Staley and Kreber, 1980). Although radiographic and hybrid methods are more precise for mixed dentition analysis, the drawback is that they are more time consuming and require sophisticated equipment. Advances in statistical software have permitted complex calculations of simple and multiple regression models, evaluating simultaneously several explanatory models (Black, 1897; Moyers, 1958; Tanaka and Johnston, 1974; Staley and Kreber, 1980; Bishara *et al.*, 1989; Schirmer and Wiltshire, 1997; Bernabé and Flores-Mir, 2005; Lima Martinelli *et al.*, 2005; Melgaço *et al.*, 2007).

Melgaço *et al.* (2007) reported that the total widths of the mandibular first permanent molars and incisors (TWFMI) had a high prediction correlation (r) and determination (r^2) value from $r = 0.79$ to $r = 0.81$ and $r^2 = 0.59$ to $r^2 = 0.66$, respectively.

A review of the literature revealed tooth size variability in different racial and population groups: Bishara *et al.* (1989) for population samples from Egypt, Mexico, and the USA; Schirmer and Wiltshire (1997) for black Africans; Lee-Chan *et al.* (1998) for Asian-Americans; and Al-Khadra (1993) for Saudi Arabians. Genetic and environmental factors also play a role in determining tooth size. Recent studies reported that the sum of the mesiodistal widths of the lower permanent incisors is not the best predictor for estimating the mesiodistal widths of canine and premolars (Nourallah *et al.*, 2002; Legović *et al.*, 2003; Melgaço *et al.*, 2007). Therefore, the aim of this study was to develop a prediction equation for estimating the total widths of the mandibular permanent canines and premolars (TCPW) using TWFMI. This prediction equation may assist in orthodontic diagnosis and treatment planning in the future.

Materials and methods

A cross-sectional study was conducted using data from the pre-treatment files and mandibular dental casts of orthodontic patients who attended the orthodontic clinic of the Aga Khan University Hospital, Karachi, from June 2002 to June 2009.

National Council for Social Studies, Powerful and Authentic Social Studies (NCSS PASS 2007; www.ncss.com) was used for sample size calculation for the multiple regression equation. A sample size of 288 would achieve an 80 per cent power to detect a change in slope from 0.73 below the null hypothesis to 0.83 under the alternative hypothesis for X (independent variables including the sum of the mesiodistal widths of the mandibular permanent first molars and incisors, age, and gender), when the maximum standard deviation (SD) of X is 2.40, the SD of Y (dependent variable = sum of the mesiodistal width of mandibular canine and premolar) is 2.46 (Melgaço *et al.*, 2007), and the two-sided significance level is 0.05.

The criteria for sample selection were orthodontic patients of Pakistani descent aged between 11 and 20 years, with all permanent teeth erupted from the right first molar to the left first molar, without interproximal caries or restorations and no missing, extracted, or supernumerary teeth. Patients with a previous history of orthodontic treatment and teeth with extra coronal restorations were excluded. A digital calliper (0–150 mm ME00183; Dentaurm, Pforzheim, Germany) with an accuracy of ±0.02 mm and repeatability of ±0.01 mm (manufacturer's specification) was used to measure the mesiodistal widths of the permanent teeth from the mandibular right first permanent molar to the left first permanent molar. All measurements were undertaken by one author (SM) perpendicular to the long axis of the tooth, with the digital calliper entering the interproximal area from either the buccal or occlusal side. The preferred method was from the buccal side unless the tooth was severely rotated. The mesiodistal widths of the mandibular canines and premolars measured on the dental cast were summed. Similarly, the mesiodistal widths of the mandibular permanent first molars and incisors measured on the dental cast were totalled. To assess measurement error, a total of 20 dental casts were randomly selected by the same author and remeasured after a period of 1 month.

Data analysis was carried out using the Statistical Package for Social Science version 16.0 for Windows (SPSS Inc., Chicago, Illinois USA). Firstly, the frequency for gender was generated followed by the mean and SD of age, the widths of the canine and premolars, and the widths of the permanent first molar and incisors. An independent t-test was used to determine gender differences. Pearson's correlation coefficient was used to assess the correlation between the TCPW and the TWFMI. Multiple linear regression equation was used to predict the TCPW using the TWFMI as the main independent variable. Age and gender were used as the other independent variables. Multicollinearity between TWFMI and age was assessed using Pearson's correlation coefficient. Similarly, multicollinearity between gender and the other two independent variables i.e. age and TWFMI was calculated using ETA (a measure of the degree of correlation between an interval level and nominal level variable). A correlation coefficient of 0.6 or greater was considered as multicollinearity and the variable that better explained the model was retained. A value of $P < 0.05$ was considered significant. A paired t-test was used to compare the predicted and actual values of TCPW. Bland–Altman analysis (Bland and Altman, 1986) used to assess intra-examiner reliability for measurements of the mesiodistal widths of the canines and premolars showed good agreement between the two measurements (Figure 1), with a mean difference of 0.0045 (95 per cent confidence interval for the difference −0.002 to 0.011).

Results

A total of 288 plaster study models were obtained of 106 (36.8 per cent) males and 182 (63.2 per cent) females with a mean age of 14.3 (SD = 1.3) and 14.4 (SD = 0.8) years, respectively. The sample showed a greater female composition.

Table 1 shows the means and SDs for TCPW and TWFMI. An independent sample t-test was used to determine gender dimorphism. Gender discrepancy was observed in this study with males showing significantly ($P < 0.01$) greater TCPW and TWFMI. A moderate correlation was found between TCPW and TWFMI for the female (r = 0.56), male (r = 0.67), and total (r = 0.64) sample.

A weak negative correlation was found between TWFMI and age ($r = -0.126$). Similarly, a weak correlation between gender and the other two independent variables i.e. age and TWFMI was found. This can be attributed to constant mesiodistal widths, which do not change with age.

Simple and multiple linear regressions were used to predict the relationship between TCPW (dependent variable) using TWFMI and gender as independent variables. Simple linear regression, predicting TCPW using gender as the independent variable, showed that males had, on average, a 1.48 mm higher TCPW (r^2 = 0.077). Similarly, when predicting TCPW using TWFMI as the independent variable, it was found that every 1 mm increase in TWFMI would result, on average, in a 0.63 mm increase in TCPW (r^2 = 0.409). With multiple linear regressions, when predicting TCPW using TWFMI and gender as independent variables, males had, on average, a 0.27 mm higher TCPW when compared with females, and that every 1 mm increase in TWFMI would result, on average, in a 0.61 mm increase in TCPW. It also showed that 41 per cent of the variation in TCWP can be explained by TWFMI and gender (Table 2).

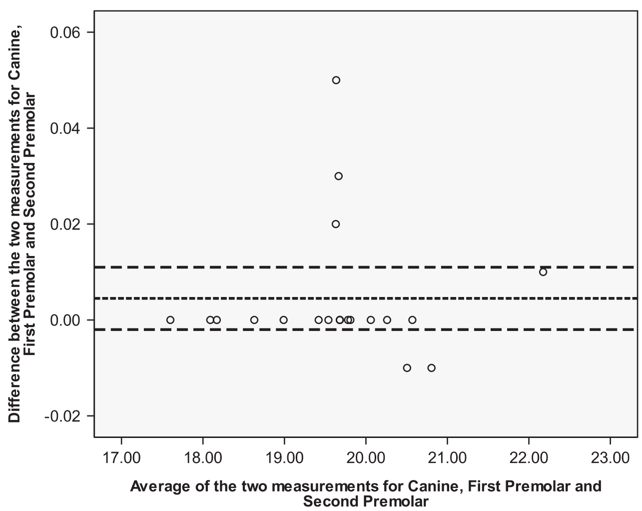

Figure 1 Scatter plot for assessing intra-examiner reliability.

The estimated multiple linear regression model for TCPW is

$$E(\text{TCPW}) = \beta_0 + \beta_1(\text{TWFMI}) + \beta_2(\text{gender}),$$

Where TCPW = total width of canine and premolar (dependent variable); E(TCPW) = predicted value of the total width of canine and premolar; TWFMI = total mesiodistal widths in millimetres of the four mandibular incisors plus the molar on both sides (independent variable); gender = gender of the individual, where 0 = female (reference) and 1 = male (independent variable); b_0 = intercept (average value of the outcome ‘Y’ when the independent variables are equal to baseline or zero); b_1 = regression coefficient for TWFMI; b_2 = regression coefficient for gender.

Both genders:

$$E(\text{TCPW}) = 14.36 + 0.61\ (\text{TWFMI}) + 0.27(\text{gender}).$$

Females:

$$E(\text{TCPW}) = 14.36 + 0.61\ (\text{TWFMI}).$$

Males:

$$E(\text{TCPW}) = 14.63 + 0.61\ (\text{TWFMI}) + 0.27.$$

Table 2 Crude and adjusted regression coefficients for total mesiodistal widths of the mandibular canines and premolars by combined measurement of the total mesiodistal widths of the first molars and incisors (TWFMI) and gender. SE, standard error.

Factor	Crude regression coefficient (SE)	Adjusted regression coefficient (SE)
TWFMI (mm)	0.63 (0.44)	0.61 (0.05)
Gender (female)	1.48 (0.30)	0.27 (0.26)
Constant	—	14.36
R^2	—	0.41

Table 1 Means and standard deviations (SD) of the total mesiodistal widths of the mandibular canines and premolars (TCPW) and total mesiodistal widths of the first molars and incisors (TWFMI) by gender.

Mesiodistal widths	Gender	Mean (mm)	SD	Mean difference (mm)	*P* value
TCPW	Male (n = 106)	42.26	2.45	−1.47	*
	Female (n = 182)	40.79	2.41		
TWFMI	Male (n = 106)	45.35	2.38	−1.98	*
	Female (n = 182)	43.36	2.39		

Independent sample t-test
*$P \leq 0.05$.

Table 3 shows the actual and predicted values of TCPW using the regression equation derived from the present study. A paired *t*-test showed no significant difference between the actual and predicted values for males and females ($P > 0.05$).

Discussion

During the mixed dentition, prediction of the mesiodistal dimensions of unerupted permanent canines and premolars is of importance in diagnosis and treatment planning. Correct assessment of the size of the canines and premolars allows improved treatment to deal with tooth size/arch length discrepancies. Among the different mixed dentition analysis methods reported in the literature, regression equations based on the already erupted permanent teeth in the early mixed dentition are broadly used to predict the widths of unerupted canine and premolars. Therefore, the present research was conducted to corroborate their principles.

The results of the present study were based on the mean widths of the complementary teeth as no difference was found between them. A review of the orthodontic literature revealed that there is a tooth size difference in various populations and between genders (males generally have larger teeth than females). Several investigators (Tanaka and Johnston, 1974; Staley and Kreber, 1980; Al-Khadra, 1993) did not observe a gender difference. However, other investigators found a significant difference between the tooth widths of males and females (Moyers, 1958; Tanaka and Johnston, 1974; de Paula *et al.*, 1995; Schirmer and Wiltshire, 1997; Legović *et al.*, 2003; Bernabé and Flores-Mir, 2005; Melgaço *et al.*, 2007; Al-Bitar *et al.*, 2008) with males having larger teeth. This necessitates distribution of subjects according to gender when performing mixed dentition analysis. As gender dimorphism in tooth widths was found in the present study, these data were analysed separately for males and females.

A moderate correlation was found in the present study between TCPW and TWFMI for the whole sample (r = 0.641), which is comparable with the findings of Bernabé and Flores-Mir (2005) and Melgaço *et al.* (2007). Van der Merwe *et al.* (1991) reported, in their population, that the sum of the four lower incisors was the best predictor for estimating the mesiodistal widths of the canines and premolars. On the other hand, Bernabé and Flores-Mir (2005) and Nourallah *et al.* (2002) concluded that the combined widths of the four mandibular permanent incisors were not a good predictor of the mesiodistal widths of the unerupted mandibular canines and premolars. The results of present study are in reasonable agreement with their findings. However, Melgaço *et al.* (2007), in a similar study in a Brazilian population, found a higher correlation (r = 0.81) when compared with the present findings. This difference may be due to the influence of genetics and the small sample size when compared with the Brazilian study. Legović *et al.* (2003) developed a multiple linear regression equation that also considered buccolingual tooth size. In the present study, buccolingual tooth size was not considered as it often cannot be accurately measured on plaster models, which could bias the results.

Lima Martinelli *et al.* (2005), who used 45 degree oblique teleradiographs of the left side of face in the mixed dentition period and dental casts of the permanent dentition for predicting the mesiodistal widths of the canines and premolars, found a very strong correlation (r = 0.84). The results of the present study are contrary to those findings.

Staley and Kreber (1980) and Hixon and Oldfather (1958), who used a combination of both radiographs and study models for predicting the sizes of unerupted canines and premolars, found a very high correlation. However, the present results are in contrast to their findings as a correlation of r = 0.64 was found only when study casts were used for predicting the mesiodistal widths of the canines and premolars. Although it is clear from the abovementioned studies that hybrid methods are best for predicting the widths of unerupted canine and premolars, a contraindication is the additional radiation exposure. Therefore, in the mixed dentition stage, the non-radiographic method is preferred.

Using only the values of TWFMI to predict TCPW (without a regression equation) is inaccurate. The values obtained from regression equations provide more accurate results. Furthermore, Al-Bitar *et al.* (2008), Melgaço *et al.* (2007), and Lee-Chan *et al.* (1998) used simple rather than multiple linear regression equations as these are easy to memorize. However, in the present study, multiple linear regression equation was used as it provides greater accuracy compared with simple regression equation.

Table 3 Actual and predicted values of total mesiodistal width of the mandibular canines and premolars (TCPW). SD, standard deviation.

Gender	*n*	Actual values of TCPW		Predicted values of TCPW		Difference (predicted−actual values of TCPW)		*P* value
		Mean	SD	Mean	SD	Mean	SD	
Females	100	41.14	2.10	41.12	2.11	0.02	0.30	0.84
Males	100	41.96	2.17	41.98	2.18	−0.01	0.39	0.67

Paired sample *t*-test.

A new multiple regression equation was calculated including gender and TWFMI as the independent variables. Only Hashim and Al-Shalan (2003) have reported the use of gender as an additional predictor, although they did not adequately explain their results.

The influence of each of the two independent variables entered in the multiple linear regression equation could be analysed by checking the regression coefficients (Table 2). TWFMI was the variable with the higher regression coefficient followed by gender. Furthermore, every 1 mm increase of TWFMI will result, on average, in a 0.61 mm increase in TWCP.

When the estimated multilinear regression equation (MLRE) was used to check the validity of the randomly selected study sample, no significant difference was found between actual TCPW and that predicted from estimated MLRE for males and females ($P > 0.05$). The SDs of difference were 0.01 mm for males and 0.00 mm for females (both sides of the mandibular arch). Thus, a linear correlation was found in the present study between the actual TCPW and that predicted from the proposed MLRE.

An ideal mixed dentition prediction method is one that can accurately predict the widths of the canines and premolars without over or underestimation. Therefore, future studies that include more explanatory variables for the prediction of TCPW should be conducted with the aim of explaining the overall variability present in TCPW. Furthermore, the estimated MLRE should be used carefully, even in a Pakistani population, as the present study was clinically based and the sample was predominantly female (63.2 per cent). The accuracy of this equation should be tested in a large sample size from various ethnic groups in Pakistan to further generalize its applicability.

Conclusions

1. There is a linear relationship between TWFMI and TWPW and premolars for both males and females.
2. The regression equations proposed in this study are a good prediction method to determine the widths of the lower permanent canines and premolars.

Funding

University Research Council of the Aga Khan University (#09GS049SUR).

Acknowledgement

Mr Iqbal Azam, University Research Council of the Aga Khan University Hospital.

References

Al-Bitar Z B, Al-Omari I K, Sonbol H N, Al-Ahmed H T, Hamdan A M 2008 Mixed dentition analysis in a Jordanian population. Angle Orthodontist 78: 670–675

Al-Khadra B H 1993 Prediction of the size of unerupted canines and premolars in a Saudi Arab population. American Journal of Orthodontics and Dentofacial Orthopedics 104: 369–372

Bernabé E, Flores-Mir C 2005 Are the lower incisors the best predictors for the unerupted canine and premolars sum? An analysis of a Peruvian sample. Angle Orthodontist 75: 202–207

Bishara S E, Staley R N 1984 Mixed dentition mandibular arch length analysis: a step by step approach using the revised Hixon-Oldfather prediction method. American Journal of Orthodontics 86: 130–135

Bishara S E, Jakobsen J R, Abdullaha E M, Fernanadez Garcia A 1989 Comparisons of mesiodistal and bucccolingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico, and the United States. American Journal of Orthodontics and Dentofacial Orthopedics 96: 416–422

Black G V 1897 Descriptive anatomy of human teeth, 4th edn. S.S. White Dental Manufacturing Company, Philadelphia

Bland J M, Altman D G 1986 Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1: 307–316

de Paula S, Almeida M A, Lee P C 1995 Prediction of mesiodistal diameter of unerupted lower canines and premolars using 45 degrees cephalometric radiography. American Journal of Orthodontics and Dentofacial Orthopedics 107: 309–314

Hashim H A, Al-Shalan T A 2003 Prediction of the sizes of un-erupted permanent cuspids and bicuspids in a Saudi sample: a pilot study. Journal of Contemporary Dental Practice 4: 40–53

Hixon E H, Oldfather R E 1958 Estimation of the sizes of unerupted cuspid and bicuspid teeth. Angle Orthodontist 28: 236–240

Lee-Chan S, Jacobson B N, Chwa K H, Jacobson R S 1998 Mixed dentition analysis for Asian-Americans. American Journal of Orthodontics and Dentofacial Orthopedics 113: 293–299

Legović M, Nonosel A, Legović A 2003 Regression equations for determining mesiodistal crown diameters of canine and premolars. Angle Orthodontist 73: 314–318

Lima Martinelli F, Martinelli de Lima E, Rocha R, Souza Tirre-Araujo M 2005 Prediction of lower permanent canine and premolars width by correlation methods. Angle Orthodontist 75: 805–808

Melgaço C A, de Sousa Araújo M T, de Oliveira Ruellas A C 2007 Mandibular permanent first molar and incisor width as predictor of mandibular canine and premolar width. American Journal of Orthodontics and Dentofacial Orthopedics 132: 369–372

Moyers R E 1958 Handbook of orthodontics, 4th edn. Year Book Medical Publishers, Chicago

Nourallah A W, Gesch D, Khordaji M N, Splieth C 2002 New regression equations for predicting the size of unerupted canines and premolars in a contemporary population. Angle Orthodontist 72: 216–221

Schirmer U R, Wiltshire W A 1997 Orthodontic probability tables for black patients of African descent: mixed dentition analysis. American Journal of Orthodontics and Dentofacial Orthopedics 112: 545–551

Staley R N, Kreber P E 1980 A revision of the Hixon and Oldfather mixed dentition prediction method. American Journal of Orthodontics 78: 296–302

Tanaka M M, Johnston L E 1974 The prediction of the size of unerupted canines and premolars in a contemporary orthodontic population. Journal of the American Dental Association 88: 798–801

Van der Merwe S W, Rossouw P, Van Wyk Kotze T J, Trutero H 1991 An adaptation of the Moyers mixed dentition space analysis for a Western Cape Caucasian population. Journal of the South African Dental Association 46: 475–479