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Regression Equations for Prediction of Permanent Canine and Premolar Mesiodistal Width in Thai Population: A Cross-sectional Study

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Abstract

Objectives: This study aimed to formulate regression equation(s) for predicting human permanent canine and premolar mesiodistal (MD) widths of Thai population.

Methods: 176 Mae Fah Luang University students with Thai nationality were selected for this study. Based on their domicile, participants were grouped by four different regions of Thailand, including central, northern, southern, and northeastern. An intraoral scanner was used to record digital dental models, and the tooth MD widths were measured using SolidWorks 2020 EP1 software. Significant differences were tested by two-sample *t*-test or one-way ANOVA. By Pearson's correlation coefficient, the relationships between the maxillary and/or mandibular incisor MD width and the upper and/or lower canine and premolar MD widths were determined for prediction equations.

Results: There were statistically significant differences in a sum of the maxillary and mandibular incisor and in that of the upper and lower canine and premolar MD widths between males and females ($p<0.001$). Statistically significant differences in the sum of the mandibular incisor MD width and in that of the maxillary and mandibular central incisor MD width were found among four different regions ($p<0.05$). By linear regression analysis, correlation coefficients of eight prediction equations were between 0.62 and 0.75 with the percentages of prediction accuracy from 47.16 to 53.41. These percentages were significantly greater than those predicted by previous models for the upper canine and premolar MD widths ($p<0.01$).

Conclusions: Our novel regression equations may predict the MD width of unerupted canine and premolars of Thai population precisely enough to be applicable for mixed dentition space analysis.

Keywords: canine, intraoral scanner, mixed dentition, premolar, regression equation, tooth size prediction

Introduction

Analysis of a mixed dentition space is a crucial step in orthodontic treatment planning. Thus, determination of mesiodistal (MD) width of unerupted canine and premolars from that of fully erupted maxillary and/or mandibular incisors is beneficial for treatment planning of orthodontists in order to select a proper treatment of choice.(1) Prediction of the MD width of the unerupted canine and premolars can be carried out by three ways: 1) a direct measurement of the unerupted teeth from dental radiographs(2), 2) an estimation from proportionality tables or prediction equations(3,4), and 3) a combination of the two methods, as aforementioned.(5) The Moyers' probability tables(3) and the Tanaka and Johnston prediction equations(4) gain popularity due to no need for dental radiography. However, both tables and equations are derived from data of Northern European populations, limiting their use in other countries. Thus, their orthodontic applications in other ethnic groups should be proceeded with caution because tooth sizes vary owing to differences from several intrinsic and extrinsic factors, such as, ethnicity, genetic, sex, and nutrition.(6) The distinction in tooth sizes among different ethnic groups of Asian populations was demonstrated in five previous studies, including 1) a study in Hong Kong Chinese;(7) 2) that in northeastern Thai population;(8) 3) that in northeastern Han Chinese;(9) 4) that in Nepalese mongoloids;(10) and 5) that in Pakistani population.(11) However, the equations obtained from these studies do not precisely predict the real MD width of canine and premolars; therefore, their clinical implications in orthodontic treatment planning are questionable.

Among the five studies, a plaster model was used to measure the tooth size. Nowadays, use of an intraoral scanner (IOS) has, however, increasingly gained popularity because it offers greater reliability and accuracy than the traditional impression.(12) Consequently, tooth size measurement from a digital dental model can yield an accuracy sufficiently to determine the MD width of permanent canine and premolars.(13) This study aimed to formulate new prediction equations for the MD width of permanent canine and premolars in a Thai population, based on the MD widths of their maxillary and/or mandibular incisors, measured from the digital dental models. Furthermore, this study was conducted in four different regions of Thailand to represent data of general Thais.

Material and Methods

Eligible participants were 14,432 university students of Mae Fah Luang University (MFU) in 2023 with Thai nationality. Of these students, a total of 238, whose domicile was from each of the four regions of Thailand, including central (n=62), northern (n=64), northeastern (n=48), or southern (n=64), were interested to enroll into this study (Figure 1). According to the sample size calculation, determined by the finite population mean formula with standard deviation at 1.36, standard error at 0.20,(8) and an alpha value at 0.05, a cohort of 176 students was required to have enough power of test. The mean age of 176 participants was 20.93 years. There were an equal number of 44 selected participants (male=22, female=22) within each region (Figure 1). The selection of 22 male and 22 female participants within each region was based on their first arrival for oral examination after enrollment with the selection criteria as follows: i) participants with all fully erupted permanent teeth, except their third molars, ii) those without tooth malformations, missing, or severe tooth crowding, iii) those without proximal caries or restorations, and iv) those without previous orthodontic treatment. An ethical approval was granted by the Human Ethics Committee of MFU, Thailand (EC 23186-22), and written informed consent was obtained. The IOS (Primscan, Dentsply Sirona, Bensheim, Germany) was used to create digital dental models.

Before actual measurements, five examiners were standardized to yield intra- and inter-examiner reliabilities, as assessed by Cohen's Kappa and Dahlberg's error, respectively. The inter-examiner standardization of MD width measurement was performed by comparisons with an experienced examiner. To test the intra-examiner reliability, the same digital dental model was randomly selected and measured twice within one week by the same examiner. The inter and intraclass correlation coefficients were 0.95 and 0.92-0.98, respectively.

Measurement of MD width

The Standard Tessellation Language files derived from the IOS were measured using SolidWorks 2020 EP1 software (Dassault Systèmes SolidWorks Corp., Bensheim, Germany). The MD width of each tooth was first determined from the mesial to the distal point of anatomical contact with the adjacent tooth, viewed at the labial or the buccal surface (Figure 2A or B). Then, the first MD width was confirmed by the greatest proximal contour of

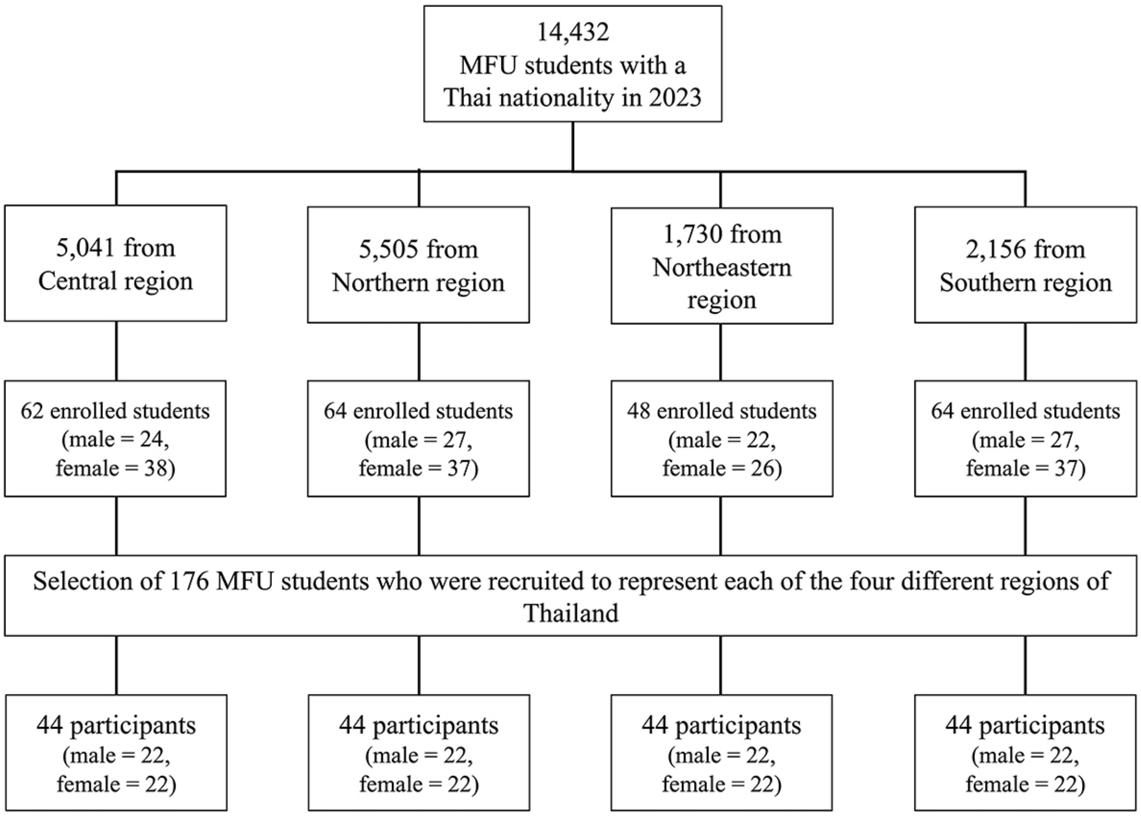

Figure 1: A flow chart of selected 176 university students of Mae Fah Luang University (MFU), recruited to represent each of the four regions of Thailand.

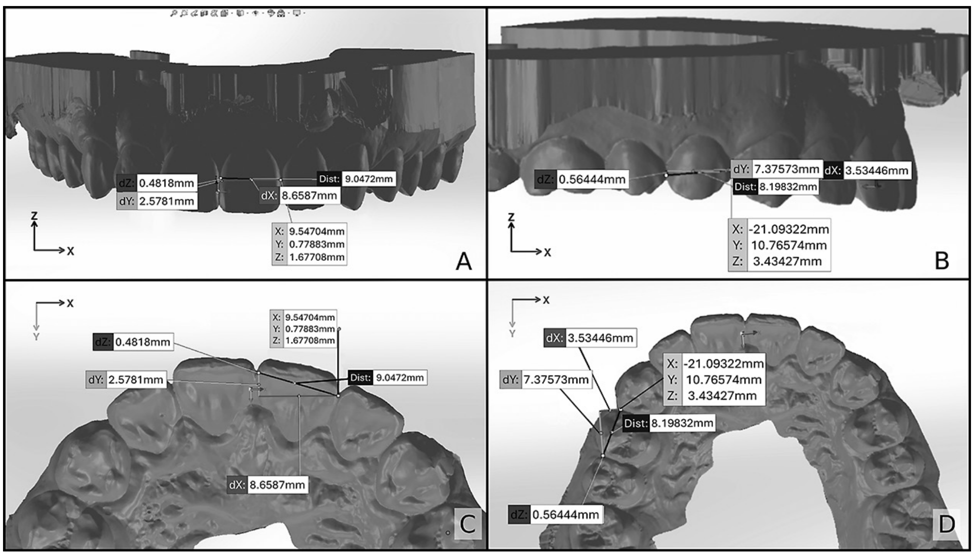

Figure 2: Representative images of a digital dental model, used in the measurement of mesiodistal width of permanent left central incisor, viewed at the labial surface (A) and the incisal edge (C). Those used in the measurement of mesiodistal width of permanent right first premolar, viewed at the buccal surface (B) and the occlusal plane (D). Numbers in the boxes indicate values on x, y, and z axes, the distance of mesiodistal width (Dist=distance), dX, dY, and dZ (Δ distance of x, y, z axes).

that tooth, viewed at the incisal edge or the occlusal plane (Figure 2C or D).

Statistical analysis

The datasets were analyzed using STATA software version 16.1 (StataCorp, TX, USA) with the confidence level at 5%. Categorical variables were described by frequencies and percentages. Based on normal distribution, continuous variables were presented with mean and standard deviation. Comparisons of MD width between sexes and among regions were analyzed by Student's *t*-test and one-way ANOVA, respectively.

Two pre-reducing models were created by generalized linear regression for sums of upper/lower canine and premolars using four predictors, including a sum of mandibular incisors, that of maxillary central incisors, that of mandibular central incisors, and that of maxillary and mandibular central incisors. The post-reducing models were created by a stepwise backward elimination method upon removal of variables (sexes, regions, or four predictors) if $p>0.05$.

The acceptable prediction accuracy of two outcomes was within ±0.5 mm. The relationships between prediction accuracy of our equations, the Moyers' probability tables, or the Tanaka and Johnston prediction equations, and an exact width of the sum of upper/lower canine and premolars, measured form digital models, were analyzed by Pearson's correlation.

Results

Comparisons of MD widths between males and females or among four regions

Male participants had significantly greater mean MD widths than females in all four predictors and two outcomes ($p<0.001$; Table 1). Of the four predictors, significant differences were found in the three predictors ($p<0.05$; Table 2). Note that the greatest mean MD widths of three predictors were found in participants from the southern region (Table 2). However, no significant differences in the mean MD width of the two outcomes were found among four different regions (Table 2).

Correlations between predictors and outcomes used to generate regression equations

Since different sexes had a significant impact on prediction of the MD widths of upper/lower canine and premolars ($p<0.001$; Tables 3 and 4, respectively), whereas distinct regions had no significant effect ($p>0.05$), the constants and coefficients of eight formulated equations were adjusted in the post-reducing model, based on the sex parameter.

The first four (Table 3) and the second four equations (Table 4) were used to predict a sum of the MD width of canine (3), first premolar (4), and second premolar (5). U=upper; L=lower; XX=female; XY=male.

1. U345=13.41-0.48(XX=1 or XY=0) + 0.44(sum of 42, 41, 31, 32)
2. U345=14.40-0.52(XX=1 or XY=0) + 0.54(sum of 11, 21)
3. U345=14.58-0.49(XX=1 or XY=0) + 0.81(sum of 41, 31)
4. U345=12.30-0.44(XX=1 or XY=0) + 0.40(sum of 41, 31, 11, 21)
5. L345=10.76-0.47(XX=1 or XY=0) + 0.51(sum of 42, 41, 31, 32)
6. L345=11.81-0.52(XX=1 or XY=0) + 0.63(sum of 11, 21)
7. L345=12.12-0.49(XX=1 or XY=0) + 0.94(sum of 41, 31)
8. L345=9.40-0.43(XX=1 or XY=0) + 0.47(sum of 41, 31, 11, 21)

Comparisons of the eight prediction equations with Moyers' probability tables and Tanaka and Johnston prediction equations

The correlation coefficients for eight prediction equations were found to be moderate to strong, or from 0.62 to 0.75 (Table 5). The percentages of prediction accuracy of the eight prediction equations, ranging from 47.16 to 53.41 (Table 5), were compared with those using the Moyers' tables and the Tanaka and Johnston equations. For the first four equations, the percentages of prediction accuracy were significantly greater than that using the Moyers' tables ($p<0.001$) and that using the Tanaka and Johnston equations ($p<0.01$; Table 5). For the second four equations, the percentages of prediction accuracy were significantly greater than that using the Moyers' tables ($p<0.05$; Table 5).

Discussion

To predict the MD widths of upper/lower canine and premolars from various combinations of the sum of the

Table 1: Comparisons of the mean mesiodistal (MD) widths of four predictors and two outcomes between Thai male and female participants. U= upper, L= lower.

	MD width	Male Mean±SD (mm)	Female Mean±SD (mm)	*p*-value
Predictors	sum of 42, 41, 31, 32	23.83±1.46	23.08±1.21	<0.001
	sum of 11, 21	17.54±1.14	17.01±0.83	<0.001
	sum of 31, 41	11.39±0.74	11.01±0.63	<0.001
	sum of 11, 21, 31, 41	28.94±1.70	28.02±1.32	<0.001
Outcomes	U345	23.82±1.08	23.02±0.91	<0.001
	L345	22.86±1.09	22.01±0.93	<0.001

Table 2: Comparisons of the mean mesiodistal (MD) widths of four predictors and two outcomes among four different regions of Thailand. U= upper, L= lower.

	MD width	Northern Mean±SD (mm)	Central Mean±SD (mm)	Northeastern Mean±SD (mm)	Southern Mean±SD (mm)	*p*-value
Predictors	sum of 42, 41, 31, 32	23.29±1.51	23.19±1.34	23.29±1.19	24.00±1.36	0.020*
	sum of 11, 21	17.05±1.17	17.24±1.02	17.24±0.95	17.52±0.93	0.185
	sum of 31, 41	11.06±0.72	11.02±0.71	11.18±0.59	11.52±0.71	0.004**
	sum of 11, 21, 31, 41	28.12±1.74	28.26±1.55	28.43±1.38	29.04±1.57	0.029*
Outcomes	U345	23.23±1.07	23.36±0.94	23.42±0.91	23.59±1.31	0.441
	L345	22.28±1.27	22.36±0.98	22.41±1.05	22.62±1.07	0.513

*$p<0.05$; **$p<0.01$

Table 3: Regression parameters for the correlation of predictor and outcome variables of upper canine and premolars (upper 3 4 5) upon pre- and post-reducing models.

	Upper 3 4 5				
	Pre-reducing model		Post-reducing model		
	Coefficient	*p*-value	Coefficient	*p*-value	Power
Sex	-0.490	<0.001	-0.480	<0.001	1
Region	0.030	0.570	-	-	-
sum of 42, 41, 31, 32	0.430	<0.001	0.440	<0.001	1
Constant	13.490	<0.001	13.410	<0.001	-
Sex	-0.530	<0.001	-0.520	<0.001	1
Region	-0.050	0.355	-	-	-
sum of 11, 21	0.530	<0.001	0.540	<0.001	1
Constant	14.510	<0.001	14.400	<0.001	-
Sex	-0.500	<0.001	-0.490	<0.001	1
Region	0.005	0.935	-	-	-
sum of 31, 41	0.810	<0.001	0.810	<0.001	1
Constant	14.600	<0.001	14.580	<0.001	-
Sex	-0.440	0.001	-0.440	0.001	1
Region	0.010	0.863	-	-	-
sum of 11, 21, 31, 41	0.400	<0.001	0.400	<0.001	1
Constant	12.330	<0.001	12.300	<0.001	-

Table 4: Regression parameters (sex and region) for the correlation of predictor and outcome variables of lower canine and premolars (lower 3 4 5) upon pre- and post-reducing models.

	Lower 3 4 5				
	Pre-reducing model		Post-reducing model		
	Coefficient	*p*-value	Coefficient	*p*-value	Power
Sex	-0.470	<0.001	-0.470	<0.001	1
Region	0.005	0.924	-	-	-
sum of 42, 41, 31, 32	0.510	<0.001	0.510	<0.001	1
Constant	10.770	<0.001	10.760	<0.001	-
Sex	-0.530	<0.001	-0.520	<0.001	1
Region	0.030	0.588	-	-	-
sum of 11, 21	0.620	<0.001	0.630	<0.001	1
Constant	11.880	<0.001	11.810	<0.001	-
Sex	-0.490	<0.001	-0.490	<0.001	1
Region	0.030	0.619	-	-	-
sum of 31, 41	0.950	<0.001	0.940	<0.001	1
Constant	12.030	<0.001	12.120	<0.001	-
Sex	-0.420	<0.001	-0.430	<0.001	1
Region	0.020	0.665	-	-	-
sum of 11, 21, 31, 41	0.470	<0.001	0.470	<0.001	1
Constant	9.320	<0.001	9.400	<0.001	-

Table 5: Comparisons of eight prediction equations with Moyer's proportionality tables and Tanaka and Johnston prediction equations. U= upper, L= lower.

		% accuracy in this study	Correlation coefficient (r)	% accuracy using Moyers	Correlation coefficient (r)	Chi-Square *p*-value (1)	% accuracy using Tanaka and Johnston	Correlation coefficient (r)	Chi-Square *p*-value (2)
U345	sum of 42, 41, 31, 32	48.30	0.66	10.91	0.55	<0.001	31.25	0.63	0.001
	sum of 11, 21	48.30	0.62			<0.001			0.001
	sum of 31, 41	47.73	0.64			<0.001			0.002
	sum of 11, 21, 31, 41	47.16	0.68			<0.001			0.002
L345	sum of 42, 41, 31, 32	53.41	0.73	38.79	0.69	0.007	51.14	0.70	0.670
	sum of 11, 21	48.30	0.69			0.017			0.920
	sum of 31, 41	51.14	0.70			0.022			1.000
	sum of 11, 21, 31, 41	51.14	0.75			0.022			1.000

p-values (1) or (2), comparisons between % accuracy in this study and that by Moyers' tables or that by Tanaka and Johnston equations, respectively.

MD widths of incisors, this study has proposed eight novel prediction equations, whose percentages were found to be significantly greater than those using Moyers' tables. The correlation coefficients for the upper canine and premolars from 0.62 to 0.68 were greater than that at 0.55 using the Moyers' tables, while those for the lower canine and premolars from 0.69 to 0.75 were comparable to that using the Moyers' tables or the Tanaka and Johnston equations. Collectively, these percentages and coefficients suggest the accuracy and reliability of our eight prediction equations be acceptable for prediction of the upper/lower permanent canine and premolar MD width of Thai population.

The Moyers' tables were developed from Northern European populations that are neither accurate nor applicable for other populations of distinct ethnic origins. The ideal correlation coefficient at 0.75, as recommended by the author,[3] is not observed in seven of the eight equations in this study (Table 5), nor is it found in another study.[14] When the Moyers' tables were applied for the Thai population in this study and in the Chinese population[7,9,15], it was found to underestimate the real MD width of upper canine and premolars that would affect orthodontic treatment planning, because more space than the predicted MD width is required for a good alignment of the erupting canine and premolars. In comparison with the Tanaka and Johnston equations, our equations were found to significantly better predict a sum of the MD width of upper canine and premolars. Note that the Tanaka and Johnston equations overestimate the mixed dentition space analysis of female Caucasians, while they underestimate the same analysis of male and female Negroids.[16] In this study, the Tanaka and Johnston equations also underestimate the mixed dentition space analysis of upper canine and premolars of Thai males and females (data not shown).

Of the eight equations, only six that did not include maxillary and mandibular lateral incisors are clinically applied in patients, whose lateral incisors are frequently afflicted by congenital missing and/or abnormal tooth size. A recent article[17] has reviewed using different predictors other than the incisors, particularly the MD width of permanent first molar. These predictors include a sum of the MD width of mandibular central incisor, lateral incisor, and first molar, and that of two mandibular central incisors and first molar. Hence, various combinations of predictors, considered to be advantageous in terms of a more diverse manner, are created. Note that the correlation coefficients of our eight prediction equations are found to be comparable to those using the combinations of the MD width of incisors and molars.[17] Nonetheless, tooth defects from dental caries or restoration involving the MD surface of permanent first molar often take place, affecting its real MD width, necessitating use of anterior teeth instead to predict the MD width of unerupted canine and premolars. In this study, sex evidently affects tooth size, by which the average size of each tooth type of males was found to be significantly larger than that of females. This finding is consistent with the previous findings in the Thai population.[8] Correspondingly, a study in the Taiwanese population[15] has shown a similar result that indicates a significantly larger tooth size in men than in women. The sex effect on tooth size could be attributed to genetic factors and sex hormones that influence tooth development.[6,18,19] Each of the four regions in Thailand differs in terms of geography, ethnicity, cultural heritage, and cuisine. Our findings indicated that regional differences had a significant effect on three of the four predictors with the greatest mean MD widths found in participants from the southern region of Thailand. These results agree with the findings from a previous study,[8] which suggest that regional differences influence tooth size. Nevertheless, regional variables, which were not found to have any significant impact in a pre-reducing model (Tables 3 and 4), were not included in the formulation of our equations in a post-reducing model, thus, making these equations simpler and more generalizable for use in the Thai population. Because of its convenience, intraoral scanning has increasingly gained popularity in orthodontic treatment nowadays.[11-13] The digitized dental images can be indirectly obtained from scanning the plaster models[11], whereas our digital dental models were derived directly from intraoral scanning. A previous study[20] has shown no significant difference between these two approaches, since an excellent agreement in the measurement of MD width obtained from either direct or indirect way was demonstrated. Thus, due to its ease, convenience, time saving, cost effective, reliability, and accuracy, intraoral scanning is recommended to directly create digital dental models. However, it is noteworthy that the measurement of MD width in this study was performed by only a specific brand of intraoral scanner; therefore, differences in the scanner accuracy, resolution, and software algorithms between the different scanners may have influenced the validity and generalizability of our findings.

Conclusions

In the Thai population, significantly larger tooth sizes in males than in females affect the prediction of upper and lower canine and premolar MD widths.

The eight MFU regression equations are precise to predict the sum of the MD width of upper/lower canine and premolars, proposing a possibility to use these equations to predict the MD width of unerupted permanent canine and premolars for orthodontic treatment planning during the mixed dentition.

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