

# New prediction equations for the estimation of maxillary mandibular canine and premolar widths from mandibular incisors and mandibular first permanent molar widths: A digital model study

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**Objective:** The primary aim of the study was to generate new prediction equations for the estimation of maxillary and mandibular canine and premolar widths based on mandibular incisors and first permanent molar widths.

**Methods:** A total of 2,340 calculations (768 based on the sum of mandibular incisor and first permanent molar widths, and 1,572 based on the maxillary and mandibular canine and premolar widths) were performed, and a digital stereomicroscope was used to derive the the digital models and measurements. Mesiodistal widths of maxillary and mandibular teeth were measured via scanned digital models. **Results:** There was a strong positive correlation between the estimation of maxillary ( $r = 0.85994$ ,  $r^2 = 0.7395$ ) and mandibular ( $r = 0.8708$ ,  $r^2 = 0.7582$ ) canine and premolar widths. The intraclass correlation coefficients were statistically significant, and the coefficients were in the strong correlation range, with an average of 0.9. Linear regression analysis was used to establish prediction equations. Prediction equations were developed to estimate maxillary arches based on  $Y = 15.746 + 0.602 \times \text{sum of mandibular incisors and mandibular first permanent molar widths (sum of mandibular incisors [SMI] + molars)}$ ,  $Y = 18.224 + 0.540 \times (\text{SMI} + \text{molars})$ , and  $Y = 16.186 + 0.586 \times (\text{SMI} + \text{molars})$  for both genders, and to estimate mandibular arches the parameters used were  $Y = 16.391 + 0.564 \times (\text{SMI} + \text{molars})$ ,  $Y = 14.444 + 0.609 \times (\text{SMI} + \text{molars})$ , and  $Y = 19.915 + 0.481 \times (\text{SMI} + \text{molars})$ . **Conclusions:** These formulas will be helpful for orthodontic diagnosis and clinical treatment planning during the mixed dentition stage.

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**Key words:** Mixed dentition analysis, Mesiodistal tooth size, Digital dental model, Prediction equation

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## INTRODUCTION

To accomplish good occlusion with proper inter-digitation and a good vertical and horizontal relationship, there must be optimal mesiodistal (MD) dimensions with regard to the teeth and good seating of the occlusion.<sup>1</sup> Dental malocclusion is a very common condition in populations worldwide. Despite the fact that the specific characteristics of malocclusion vary in specific populations, tooth size arch length discrepancy is considered to be a universally important etiological factor. If the tooth size and arch dimension is accurately estimated before the onset of malocclusion, then such estimations can be utilized to eliminate or reduce the seriousness of malocclusion; either by serial extraction, guidance of eruption, space maintenance, space gaining, or periodic observation of the patient prior to orthodontic treatment.<sup>2</sup>

Various methods have been used to predict the MD widths of unerupted teeth in the planning of orthodontic treatment, including radiographic methods,<sup>3,4</sup> dental models,<sup>5-8</sup> and combinations of both radiographic methods and dental models.<sup>9,10</sup> The current study is important because it utilized digital dental models, and the study population was regionally specific; in order to control for global variations in tooth size<sup>1</sup> and mixed dentition investigations in orthodontics.<sup>2,7,8</sup> Population specific prediction models are required in this context. The aim of the current study was to generate new prediction equations for the estimation of maxillary and mandibular canine and premolar widths based on mandibular incisors and mandibular first permanent molar widths, via digital dental models, for the first time. To eliminate the potentially confounding effects of racial differences in the relevant parameters, this was undertaken in a Pakistani population. As well as the primary aim of generating new prediction equations for the estimation of maxillary and mandibular canine and premolar widths based on mandibular incisors and first permanent molar widths, the secondary aims of the study were:

1. To evaluate the amount of sexual dimorphism for the sum of MD crown width of maxillary canines and premolars (SMaxCPM)
2. To evaluate the amount of sexual dimorphism for the sum of MD crown width of mandibular canines and premolars (SMandCPM)
3. To evaluate the side disparities for the sum of MD crown width of maxillary and mandibular canines and premolars
4. To determine new prediction equations to estimate the MD crown width of maxillary canines and premolars in males, females, and males and females combined

5. To determine new prediction equations to estimate the MD crown width of mandibular canines and premolars in males, females, and males and females combined

## MATERIALS AND METHODS

Ethical approval was granted by the Ethics Committee of the University of Science, Malaysia (USM/JEPeM/140376), and informed consent was obtained from all subjects. This investigation was in accordance with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines, and we applied the STROBE specifications in this study.<sup>11</sup> The following inclusion and exclusion criteria were used:

### Inclusion criteria

- Pakistani origin as determined via interviews, with mutual paternities and ancestors without any multi-ethnic nuptials
- Age 18 to 24 years
- Well-aligned maxillary and mandibular arches, with normal patterns of growth and development
- Had not undergone orthodontic treatment, and had sound erupted permanent teeth (except third molars)
- Ideal occlusion with Class I molar and canine relationships with the incisors according to the British Standards Institute<sup>12</sup>
- No crowding, cross bite, or abnormal spacing
- A straight profile (as determined by examining their profile view)
- No craniofacial anomalies

### Exclusion criteria

- Interproximal caries or restorations
- Missing or supernumerary teeth
- Abnormal size or morphology of teeth
- Tooth wear that affected the tooth size measurements
- Damage to casts

### Sample size calculation

In this retrospective study, a total of 200 models from 370 archived models satisfied the inclusion and exclusion criteria. Stratified random sampling was conducted to select 128 models from these 200 models. As sampling was conducted after the application of inclusion and exclusion criteria, drop-outs were not considered when determining sample size.

The sample size for objectives 1–3 was calculated (PS software version 3.0; <http://biostat.mc.vanderbilt.edu/wiki/Main/PowerSampleSize>) at a power of 80%, utilizing estimated standard deviations of 0.60 mm,<sup>13</sup> a biologically meaningful mean difference of 0.3 mm, and equal sample sizes.<sup>14</sup> The calculated sample size was 128

subjects (64 males and 64 females). The sample size for objectives 4 and 5 was calculated based on simple linear regression, incorporating regression of subjects' yvar (dependent variable) values against xvar (independent variable) values. A preliminary study yielded a standard deviation of xvar of 1.12, and a standard deviation of regression errors of 2.77. Assuming a true slope of the line obtained by regressing yvar against xvar of 0.9 yielded a required sample size of 61 to be able to reject the null hypothesis that this slope equals zero with a probability (power) of 0.8. The type I error probability associated with testing this null hypothesis is 0.05.<sup>14</sup> For this study we selected a higher sample size based on the sexual dimorphism objectives. As the sample size was calculated after the inclusion and exclusion criteria were applied, drop-outs were not considered when determining sample size.

Oral and dental investigations were carried out with careful selection of subjects. Cross-examination of subjects was undertaken to diminish sample bias and error; with an experienced orthodontist and dentists contributing throughout the screening sittings. Dental impressions of the upper and lower arches of each subject were obtained with alginate impression material

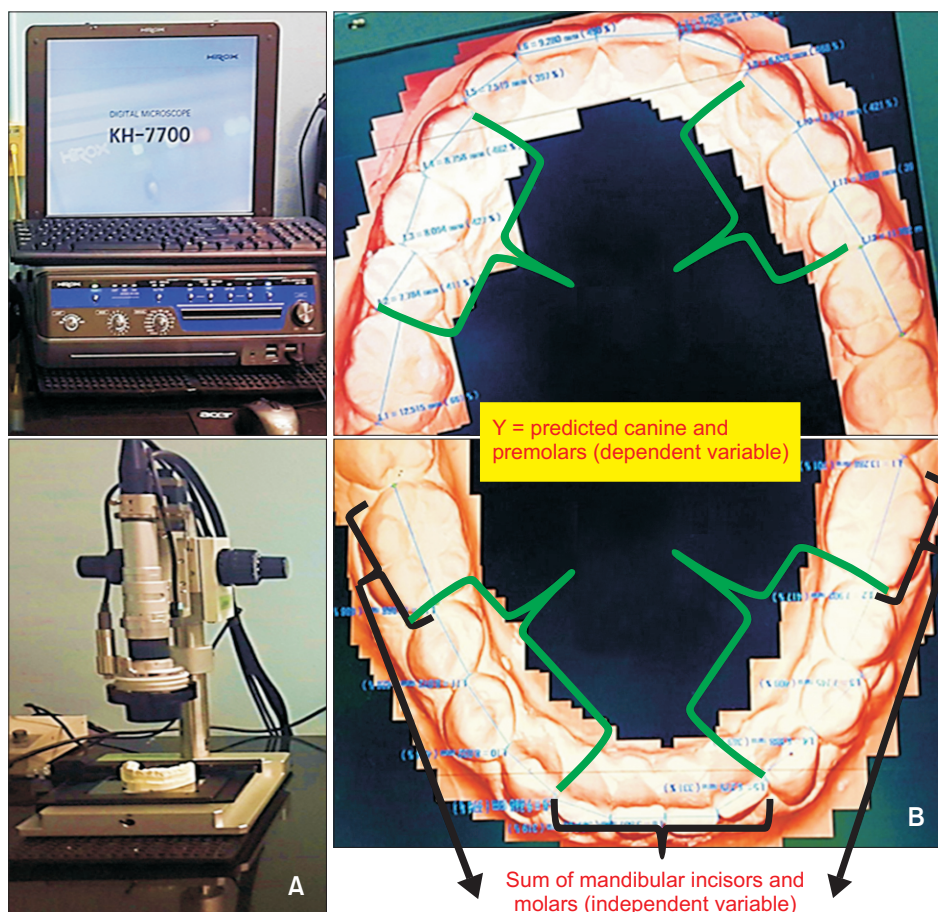
and poured with dental stone (Type III hard plaster quick stone) in accordance with to the manufacturer's instructions. A total of 2,340 variables, 768 for the sum of mandibular incisors and first permanent molar widths (SMI + molars) and 1,572 for the maxillary and mandibular canine and premolar widths were measured.

**Measurement of tooth size**

Dental models of each subject's maxillary and mandibular arches were scanned using a Hirox digital stereomicroscope (SM) (Hirox KH7700; Hirox, Tokyo, Japan), for the generation of the digital models (Figure 1A). Maxillary and mandibular tooth sizes were determined via SM scanned digital models. Stereomicroscopy is a reputable, valid,<sup>15</sup> and reliable tool for such measurements, with an accuracy of  $0.1 \times 10^{-6}$  mm. The acquisition of measurements for tooth sizes were conducted as follows:

*MD crown diameters*

The MD crown diameter of the tooth was measured from the point of anatomical contact of it with another tooth on the occlusal side perpendicular to the long axis of the teeth (Figure 1B).<sup>16,17</sup> The dependent variables



**Figure 1.** Generation of the digital models. **A,** The stereomicroscope. **B,** The sum of mesiodistal crown diameters for dependent and independent variables.

of the study were the SMaxCPM and SMandCPM. The independent variable was the SMI + molars (Figure 1B).

**Error assessment**

About 20% of the digital dental casts were selected to assess intra-observer error. The time interval between the first and second readings was approximately 2 weeks. Method error (ME) was analyzed via Dahlberg’s formula:  $ME = [\sum (x_1-x_2)^2 / 2(128)]^{1/2}$ , where  $x_1$  is the first measurement and  $x_2$  is the second measurement.<sup>18</sup>

**Statistical analyses**

The data were verified and analyzed statistically using IBM SPSS version 22.0 (IBM Co., Armonk, NY, USA) with the confidence level set at 5% ( $p < 0.05$ ) to test for statistical significance. The independent *t*-test was used to investigate gender differences in SMaxCPM and SMandCPM. The paired *t*-test was used to compare side disparities. Linear regression equations were used for the generation of prediction equations.

**Table 1.** Sexual disparities in sum of maxillary and mandibular canines and premolars

Variable	Sex	Mean±SD	95% CI	p-value
SMaxCPM	Male	43.616 ± 2.202	0.46–1.99	0.002**
	Female	42.389 ± 2.162		
SMandCPM	Male	42.369 ± 2.140	0.20–1.67	0.014*
	Female	41.436 ± 2.071		

SMaxCPM, Sum mesiodistal crown diameters of maxillary canines and premolars; SMandCPM, sum mesiodistal crown diameters of mandibular canines and premolars; SD, standard deviation; CI, confidence interval.

\*\* $p < 0.01$  and \* $p < 0.05$ .

**Table 2.** Male side disparities

Variable	Sample (n)	Mean ± SD	95% CI	p-value
SMaxCPMR	64	21.80 ± 1.13	-0.13–0.09	0.738
SMaxCPML	64	21.82 ± 1.11		
SMandCPMR	64	21.13 ± 1.11	-0.22–0.02	0.088
SMandCPML	64	21.24 ± 1.08		

SMaxCPMR, Sum of maxillary canine and premolars for the right side; SMaxCPML, sum of maxillary canine and premolars for the left side; SMandCPMR, sum of mandibular canine and premolars for the right side; SMandCPML, sum of mandibular canine and premolars for the left side; SD, standard deviation; CI, confidence interval.

**RESULTS**

**Error of the method for measurements**

Dahlberg’s formula yielded a method error value of 0.006 mm for the MD crown diameter measurements. Thus, the method error was within an acceptable range.<sup>18</sup>

**Intraclass correlation coefficient for intra-observer reliability**

The intraclass correlation coefficients were statistically significant ( $p < 0.001$ ), and the coefficient values indicated a strong correlation, with an average range of 0.009.<sup>19</sup>

**Sexual disparities for SMaxCPM and SMandCPM**

There were significant sexual disparities detected for SMaxCPM and SMandCPM (Table 1), and the mean for males was significantly greater than that for females ( $p < 0.05$  to  $p < 0.001$ ).

**Canine and premolar side disparities**

There were no side disparities for the sum of maxillary or mandibular canines and premolars in males or females (Tables 2 and 3 respectively).

**Prediction equation for maxillary and mandibular arches**

Tables 4 and 5 respectively show new prediction equations for the estimation of maxillary and mandibular canine and premolar widths from SMI + molars for males, females, and males and females combined.

**Accuracy of prediction equations and correlations for measured and predicted values**

Figures 2 and 3 respectively show the accuracy of the proposed formulas for the estimation of maxillary and mandibular canine and premolar widths from mandibular incisors and mandibular first permanent molar widths for males, females, and males and females combined. The average errors of prediction were -0.708,

**Table 3.** Female side disparities

Variable	Sample (n)	Mean ± SD	95% CI	p-value
SMaxCPMR	64	21.22 ± 1.08	-0.15–0.17	0.311
SMaxCPML	64	21.17 ± 1.12		
SMandCPMR	64	20.67 ± 1.01	-0.24–0.03	0.121
SMandCPML	64	20.77 ± 1.12		

SMaxCPMR, Sum of maxillary canine and premolars for the right side; SMaxCPML, sum of maxillary canine and premolars for the left side; SMandCPMR, sum of mandibular canine and premolars for the right side; SMandCPML, sum of mandibular canine and premolars for the left side; SD, standard deviation; CI, confidence interval.



**Table 4.** Prediction equations for the maxillary arch with correlational *r* and *r*<sup>2</sup> coefficients

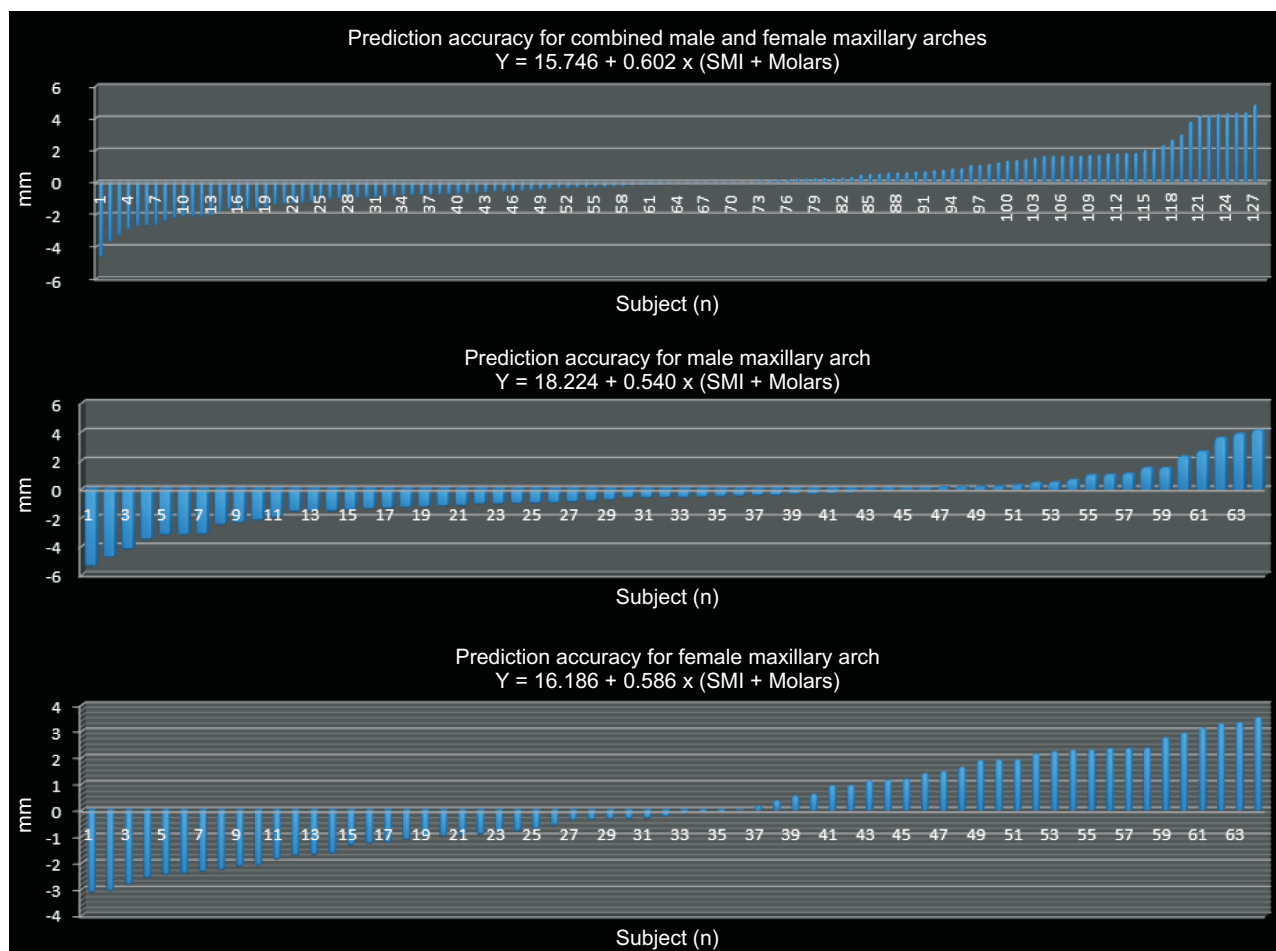
Sex	Prediction equations	<i>r</i>	<i>r</i> <sup>2</sup>
Male (M)	$Y = 18.224 + 0.540 \times (\text{SMI} + \text{Molars})$	0.896	0.722
Female (F)	$Y = 16.186 + 0.586 \times (\text{SMI} + \text{Molars})$	0.833	0.732
Combined M and F	$Y = 15.746 + 0.602 \times (\text{SMI} + \text{Molars})$	0.856	0.739

Y, Dependent variable for canines and premolars; SMI + Molars, sum of mandibular incisors and molars (independent variable).

**Table 5.** Prediction equations for the mandibular arch with correlational *r* and *r*<sup>2</sup> coefficients

Gender	Prediction equations	<i>r</i>	<i>r</i> <sup>2</sup>
Male (M)	$Y = 14.444 + 0.609 \times (\text{SMI} + \text{Molars})$	0.866	0.716
Female (F)	$Y = 19.915 + 0.481 \times (\text{SMI} + \text{Molars})$	0.863	0.723
Combined M and F	$Y = 16.391 + 0.564 \times (\text{SMI} + \text{Molars})$	0.870	0.758

Y, Dependent variable for canines and premolars; SMI + Molars, sum of mandibular incisors and molars (independent variable).



**Figure 2.** Accuracy of proposed prediction equation for maxillary arch.

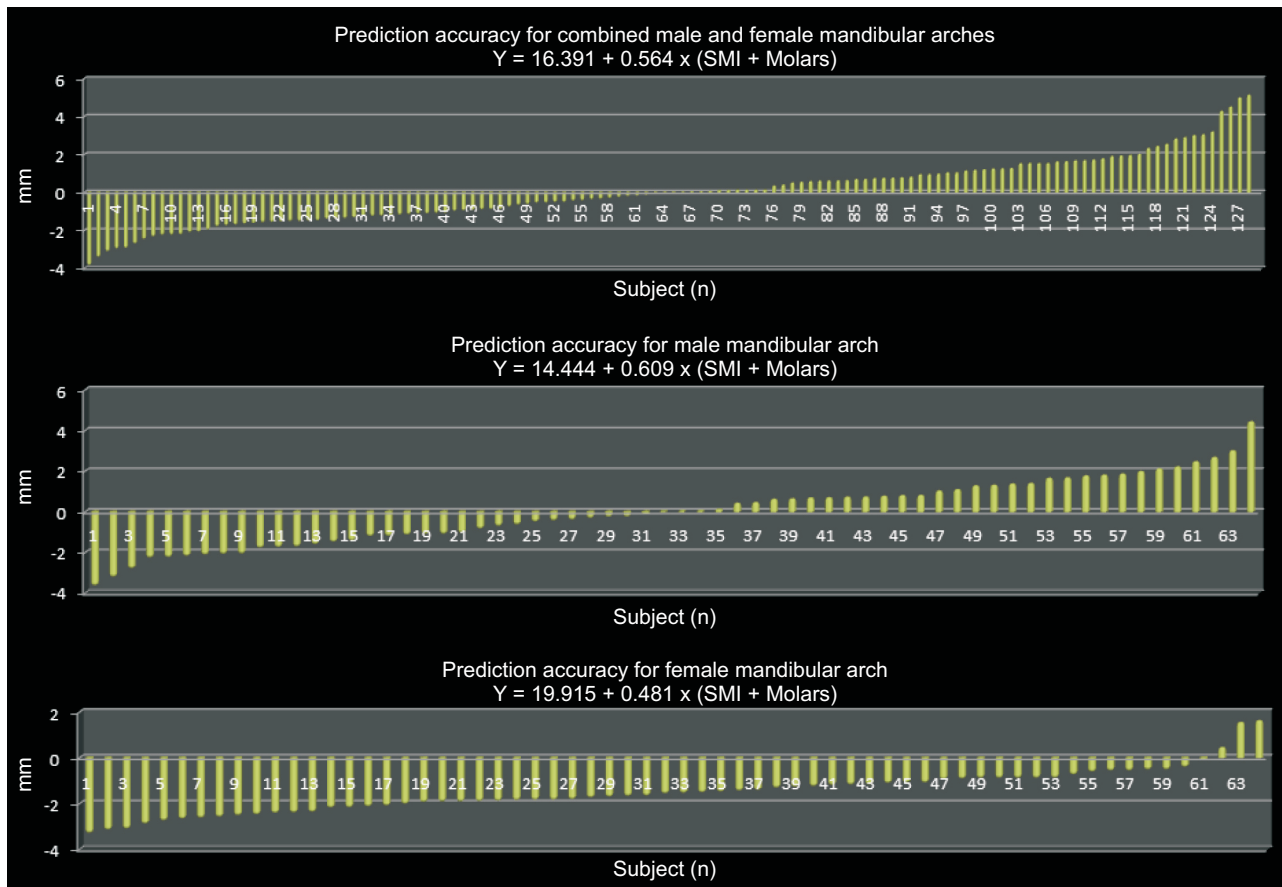


Figure 3. Accuracy of proposed prediction equation for mandibular arch.

-1.744, and -1.290 mm in the maxillary arch for males and females combined, males, and females respectively, and they were -0.260, -2.650, and -2.136 mm in the mandibular arch. Figure 4 shows the positive correlation for the estimation of maxillary ( $r = 0.85994$  and  $r^2 = 0.7395$ ) and mandibular ( $r = 0.8708$  and  $r^2 = 0.7582$ ) canine and premolar widths. The  $r$  and  $r^2$  coefficients determined in this study are compared with those previously reported by others in Table 6.

### DISCUSSION

During the mixed dentition stage, the prediction of the MD dimensions of unerupted permanent teeth is of great importance for diagnosis and treatment planning. Correct assessment of the size of an unerupted tooth facilitates an improved treatment plan for dealing with tooth size/arch length discrepancies.<sup>20</sup> For mixed dentition, direct measurement methods for tooth size and arch dimensions including hand-held calipers, graphs, and scales to record dimensions and tooth sizes on dental casts have been used.<sup>21</sup> Recent developments in technology have made it possible for dental casts to

be reproduced in the form of digital dental models.<sup>21,22</sup> These digital models are accurate and reliable tools for obtaining measurements and carrying out dental analysis.<sup>15,23</sup> Moreover, they have additional benefits such as accessibility of the images produced, reduction in storage costs, and the ability to analyze images with sophisticated software.<sup>23,24</sup>

For the prediction of the MD widths of unerupted canines and premolars many methods have been reported in the literature, and regression equations based on the already erupted permanent teeth in the early mixed dentition have been widely used to predict the widths of unerupted canines and premolars.<sup>7,20,25</sup> Therefore, the current study investigated new prediction equations for the estimation of maxillary and mandibular canine and premolar widths from SMI + molars via digital dental models, for the first time (Tables 4 and 5). The current investigation was conducted using SM digital dental model acquisition, which is a valid and reliable tool for such measurements.<sup>15</sup>

In the present study, there were sexual differences in the sum of canines and premolars for both arches. However, no significant side disparities were detected

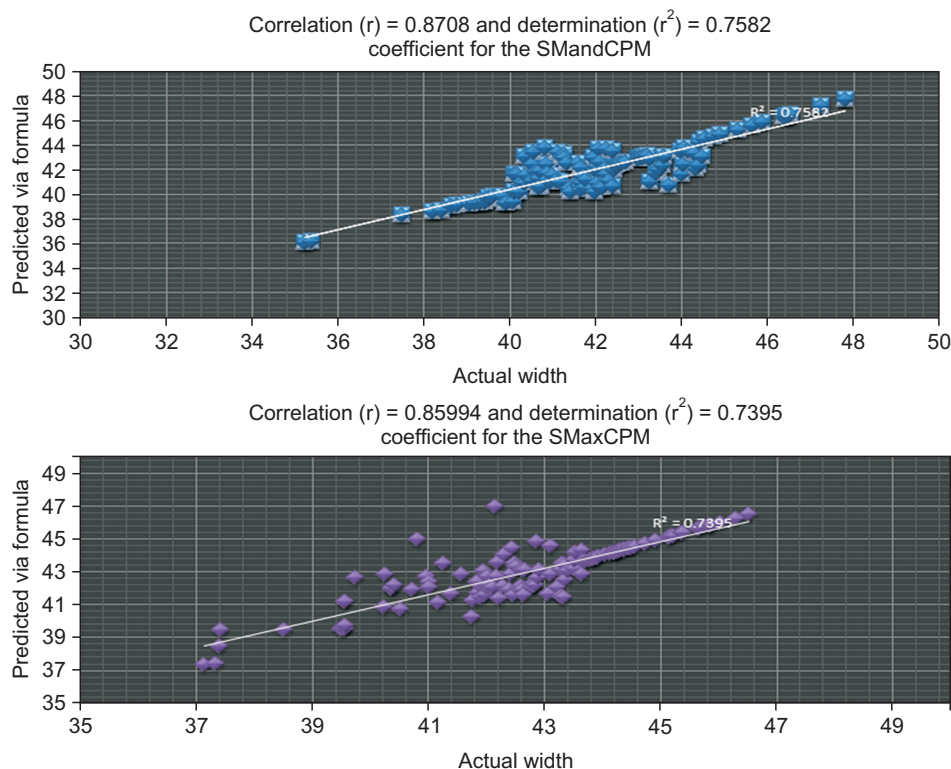


Figure 4. Correlational r and r<sup>2</sup> coefficients.

Table 6. Comparisons between the correlational r and r<sup>2</sup> coefficients determined in the present study and those reported in previous studies for males, females, and both genders combined

Studies	Male		Female		Both	
	r	r <sup>2</sup>	r	r <sup>2</sup>	r	r <sup>2</sup>
Present study	0.866	0.716	0.863	0.723	0.870	0.758
Melgaço et al. <sup>25</sup>	0.795	0.632	0.774	0.599	0.810	0.656
Bernabé et al. <sup>37</sup>	0.710	ND	0.720	ND	0.720	0.604
Tanaka and Johnston <sup>6</sup>	ND	ND	ND	ND	0.648	ND
Ballard and Wylie <sup>5</sup>	ND	ND	ND	ND	0.640	ND

ND, Coefficient not determined.

between them. A review of the orthodontic literature revealed that there were sexual disparities in the tooth sizes of various populations, as well as genders. Male teeth were reportedly bigger overall than those of females in one study,<sup>17</sup> while other researchers<sup>9,26</sup> did not observe any sexual disparities. However, numerous investigators have reported significant sexual disparities for the MD<sup>6,8,25,27</sup> tooth dimensions, with males having larger teeth in this respect. This necessitates the analysis of subjects according to gender when performing such predictions in mixed dentition orthodontic analysis. As gender dimorphism in tooth widths was found in the present study, these data were analyzed separately for

males and females.

Side differences have been reported by various researchers with regard to tooth sizes in the maxillary and mandibular arches.<sup>28-30</sup> However, others have reported no significant side differences in tooth size comparisons.<sup>19,31</sup> In the comparisons of right and left side maxillary and mandibular tooth sizes, we observed no asymmetries. However, the current study used a digital model methodology to predict the combined widths of canines and premolars in the upper and lower arches. Consequently, all the prediction equations were investigated for the prediction of canines and premolars on both sides.

The current study investigated new formulas derived via digital dental models. The accuracy of the linear regression formula, and estimation of maxillary and mandibular canine and premolar widths from SMI + molars were within a highly acceptable range (Figures 2 and 3). The new prediction equations developed for estimation in the maxillary arch were  $Y = 15.746 + 0.602 \times (\text{SMI} + \text{molars})$ ,  $Y = 18.224 + 0.540 \times (\text{SMI} + \text{molars})$ , and  $Y = 16.186 + 0.586 \times (\text{SMI} + \text{molars})$ , and the average errors of prediction were  $-0.708$ ,  $-1.744$ , and  $-1.290$  mm respectively. The new prediction equations developed for estimation in the mandibular arch were  $Y = 16.391 + 0.564 \times (\text{SMI} + \text{molars})$ ,  $Y = 14.444 + 0.609 \times (\text{SMI} + \text{molars})$ , and  $Y = 19.915 + 0.481 \times (\text{SMI} + \text{molars})$ , and the average errors of prediction were  $-0.260$ ,  $-2.650$ , and  $-2.136$  mm respectively. The investigation may be of high value as an adjunct for diagnosis and treatment planning for orthodontists treating patients in the mixed dentition stage.

Given the limitations of the current study, the prediction formulas generated need to be checked for clinical applicability in orthodontics. The reported norms and available databases need to be investigated in other populations, to determine possible ethnic and racial differences. Due to advances in technology in this digital era, the investigated norms and formulas need to be scrutinized via three-dimensional digital dental models. The prediction equations provided will be helpful for clinical treatment planning and analysis in the mixed dentition stage. The accuracy of these equations determined via digital dental models needs to be tested in a large sample including various ethnic groups, to assess their wider applicability. MD crown diameters exhibited sexual disparities, which is consistent with previous published studies utilizing various ethnic groups.<sup>17,32-37</sup> Due to variations in tooth sizes and advances in digital dental model technology, such research needs to be done in other populations to assess its wider applicability as an adjunct for treatment planning and diagnosis in orthodontics during the mixed dentition stage.

## CONCLUSION

- Sexual disparities were detected for the SMaxCPM.
- Sexual disparities were detected for the SMandCPM.
- No side differences were detected for the sum of MD crown width of maxillary and mandibular canines and premolars.
- The new prediction equations developed for the prediction of SMaxCPM from SMI + molars were  $Y = 15.746 + 0.602 \times (\text{SMI} + \text{molars})$ ,  $Y = 18.224 + 0.540 \times (\text{SMI} + \text{molars})$ , and  $Y = 16.186 + 0.586 \times (\text{SMI} + \text{molars})$  for males and females combined, males, and

females respectively.

- The new prediction equations developed for the prediction of SMandCPM from SMI + molars were  $Y = 16.391 + 0.564 \times (\text{SMI} + \text{molars})$ ,  $Y = 14.444 + 0.609 \times (\text{SMI} + \text{molars})$ , and  $Y = 19.915 + 0.481 \times (\text{SMI} + \text{molars})$  for males and females combined, males, and females respectively.

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