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Mixed Dentition Space Analysis in Adolescents of Lahore, Pakistan

Sidra Butt[1*], Mariyah Javed[2], Sarah Ijaz[3], Faiza Awais[4], Arsalan Wahid[5], Salman Aziz[6], Ayyaz Ali Khan[7]
[1,2]Assistant Professor, University Medical & Dental College, Faisalabad, Pakistan
[3,4]Senior Registrar, Shaikh Zayed Medical Complex, Lahore, Pakistan
[5]Assistant Professor, University Medical & Dental College, Faisalabad, Pakistan
[6]Associate Professor, Aljouf University, Aljouf, KSA
[7]Professor, Shaikh Zayed Medical Complex, Lahore, Pakistan

***Corresponding Author:**
Sidra Butt
Email: sid_nmc@hotmail.com

Abstract: Mixed dentition space analysis is very important in orthodontic diagnosis and treatment planning. The present study evaluated prediction methods for the estimation of size of unerupted canine & premolars, and observed any sexual dimorphism in tooth size in a local population. A cross-sectional study was conducted on 192 boys and 192 girls aged 13-15 years who met the inclusion /exclusion criteria from schools of Lahore, Pakistan. Dental impressions of both arches were made and mesiodistal widths of teeth were measured with digital vernier caliper. Students *t*-test, Pearson correlation coefficient analysis and simple linear regression analysis was used to statistically compare tooth size differences in arches, among genders and predict maxillary and mandibular canine and premolars width based on sum of four mandibular incisors; sum of mandibular incisors and first molar; and sum of mandibular incisors and maxillary first molar. New regression equation was formulated for each arch and sex separately based on sum of mandibular incisors and maxillary first molar. Sum of maxillary first molar and mandibular incisors showed high correlation and determination coefficient in prediction of size of unerupted canine and premolars in the study population. Significant gender difference was found in tooth size in this sample. Sum of mandibular incisors and maxillary first molar is the better predictor for estimation of size of unerupted canine and premolars in our study population. Proposed prediction equations showed good accuracy, easy application and can be used in orthodontic treatment planning in local population.
Keywords: Mixed Dentition Analysis, Prediction Equations, Orthodontic Treatment Planning.

INTRODUCTION

Mixed dentition period is very important to establish accurate diagnosis of any developing malocclusion and it also helps to assess future crowding or spacing in the permanent dentition [1]. During this period, large number of dental malocclusion arise due to imbalance between tooth size and arch length discrepancies [2]. Tooth size and arch length relationship can be diagnosed during mixed dentition period and before eruption of permanent canines and premolars early estimation can be made regarding the space available and required in the arch for normal alignment of these teeth [3]. Mixed dentition space analysis (MDSA) is performed for this purpose by which mesiodistal width (MDW) of unerupted permanent canines and premolars and discrepancy in arch space is predicted [4, 9].

Three most common methods have been used to predict MDW of unerupted canines and premolars during mixed dentition: (i) direct measurement of unerupted teeth from dental radiographs [7,10]; (ii) developing prediction equation and table from already erupted primary teeth or permanent teeth (nonradiographic) [4,5,9,11,12]; (iii) combination of both methods [13,14].

Prediction equation and table based on already erupted teeth is the most widely used method; however Moyer Probability table and Tanaka & Johnston equation based on permanent four mandibular incisors in North American children have been most widely used for MDSA [4,5].

Tooth size variations among various racial and ethnic groups, [15-18] among genders with males having larger teeth than females [19-22] have been observed so prediction equations and tables based on four mandibular incisors have been developed separately for each population. Recently many researchers have reported that sum of mandibular incisors is not better predictor for the size estimation of unerupted permanent teeth [9,11,12,20,23,24]. Sum of mandibular incisors and mandibular first molars have been reported to be better predictor in Brazil, India and Pakistani population, [11,23,25] while maxillary first molar and mandibular incisors have also been used by some researchers with better accuracy in Italy, Croatia and Peruvian population [9,20,26]. Inaccurate determination of MDSA may lead to wrong extraction decision that negatively influences patient's facial profile [27]. Since patient's demand for an early orthodontic treatment is rising now a days so it is important for an orthodontist to predict any discrepancy in arch space in advance and commence proper treatment in time [29.

In Pakistani population, four mandibular incisors; combination of mandibular incisors & first molar Has been employed in our population for size estimation but maxillary first & mandibular incisor combination which also has been reported to be better by some researchers has not been employed for our population [23, 28]. The purpose of this study was to evaluate the prediction methods for the estimation of size of unerupted permanent canines and premolars, and observe any sexual dimorphism in study population, suggest prediction equation for estimating total width of unerupted permanent canines and premolars for each arch and gender in local population.

MATERIALS AND METHODS

Study type

Cross sectional analytical

Study setting

Local schools, Department of Oral Health Sciences, Sheikh Zayed Medical Complex, Lahore, Pakistan

Study Sample

384 students (192 boys; 192 girls) aged 13-15 years with all permanent teeth present in the oral cavity and class I occlusion were included. Subjects with decayed, fractured, malformed, restored and crowded and rotated teeth were excluded. Schools were selected randomly from list of schools with minimum enrollment of 500 students. All students of the selected schools were screened as per inclusion/exclusion criteria to recruit the desired study participants.

Ethical approval for the study from institutional review board of Sheikh Zayed Postgraduate Medical Institute and permission from authorities of local schools was obtained. Study purpose was explained and informed consent was taken from students and their parents as well.

Impression, Model & Base Making

Students were examined for dentition status and dental impressions in groups in a specially prepared room in each school were taken by principal investigator (SID). Alginate material (Alginmax®, Italy) was used for making impression in disposable sterilized trays. Impression material was handled by a research assistant for the study who mixed and loaded impression material in sterilized trays. After the impression settled, it was taken out of the mouth and immersed in sodium hypochlorite solution for 1 min to disinfect it. Subjects were also given dental education regarding maintenance of oral hygiene.

The trays were washed under running water to remove any impurities and/or debris. Immediately after disinfection, impression was poured in orthodontic plaster to avoid any dimensional changes by the assistant. After plaster was set, the impression trays were removed and disposed off. Base of each dental cast was made with soft plaster and margin of dental casts were trimmed with lathe machine. A number was assigned to each dental cast. Damaged and distorted casts were discarded.

Teeth Measurements

Teeth were measured from good quality dental cast according to method proposed by Moorrees et al. [29] MDW of teeth were obtained by measuring the greatest distance between contact points on the proximal surfaces of teeth. Digital Vernier caliper with an accuracy of 0.01mm (Mitutoyo®, Japan) was used for the MDW measurement of teeth. All measurements were taken perpendicular to the long axis of the tooth and parallel to occlusal plane with beaks of digital Vernier caliper entering interproximal area from buccal side to make access more accurate. To reduce eye fatigue and error in measurements not more than ten dental casts were measured per day. Teeth were measured from right mandibular first molar to left mandibular first molar in lower arch and then second reading was taken again to reduce prejudice in first measurement. Same was repeated in upper arch. Two readings were taken for each tooth and averaged to improve accuracy. Teeth were measured from each quadrant and values obtained from right and left posterior segment were averaged to have one value for mandibular central and lateral incisors, maxillary and mandibular canine, first and second premolars and first molar. All measurements were recorded on Performa. The measurements were made by the principal investigator.

Data Analysis

Grouping of teeth

Teeth were grouped for MDW measurements into dependent and independent variables; mandibular canines and premolars (first and second); and maxillary canines & premolars (first and second) were summed as dependent variable.

While independent variables were sub grouped into Group I,II III as: sum of four mandibular incisor (MdI) grouped as Group I; sum of mandibular incisors (MdI) and mandibular first molar MdIM1 grouped as Group II; and sum of mandibular incisors and maxillary first molars MdIMxM1 as Group III..

Data was entered and analyzed by using SPSS version 17.0. Normality of data was tested by Kolmogorov-Smirnov test for all variables in both genders separately. Data for MDW for canine and premolars; mandibular incisors; mandibular incisors&

mandibular first molar; and mandibular incisors & maxillary first molar was presented by using mean ± SD. Independent *t*-test was used to observe gender difference in teeth size and paired *t*-test was used to observe difference in tooth size of right and left side of each arch in both genders separately.

Dependent variables were represented as sum of maxillary canine & premolars width (MxCPW) and sum of mandibular canine & premolars width (MdCPW). And independent variables were represented as sum of four mandibular incisors (MdI); sum of mandibular incisors & mandibular first molar (MdIM1); and sum of mandibular incisors & maxillary first molar (MdIMxM1) and were used as predictors.

Pearson correlation coefficient was applied to see association of dependent variables with independent variables in both genders separately and together. Linear regression models were fitted to predict MDW of maxillary canine & premolars (MxCPW) and mandibular canine& premolars (MdCPW) on the basis of above mentioned predictors by using simple linear regression analysis. Comparison of actual and predicted mean width of canine and premolars for all fitted models was compared in term of residuals. Model with least margin of error and highest R-square value among all predictors was considered to be the best predictor. All above mentioned processes were applied for each arch in males and females separately. P value $\leq$ 0.05 was considered to be significant. Regression equations were developed for each arch and gender separately. Simple linear regression equation was defined as

$$Y = a + bX$$

Y = summed width of canine and premolars (MxCPW, MdCPW)
X1= width of four mandibular incisors (MdI)
X2 = width of mandibular incisors and mandibular 1st molar (MdIM1)
X3= width of mandibular incisors and maxillary 1st molar (MdIMxM1)
a = constant, b = regression coefficient

RESULTS

Significant ($p < 0.001$) tooth size difference was observed in present sample showing larger tooth size in boys than girls (Table 1) and also when combined width of teeth were compared in both genders(Table 2). There was no statically significant difference in tooth size between right and left side of each tooth (Table 3); therefore, average value of each tooth was taken in grouping of teeth for data analysis and subsequent simple linear regression analysis.

When Pearson coefficient was applied for association of dependent variable (MdCPW/ MxCPW) with independent variables or predictors (MdI, MdIM1, MdIMxM1), correlation coefficient was found significantly ($p < 0.001$) higher with MdIMxM1 as compared to MdI, MdIM1. Maxillary and mandibular canine and premolars width was regressed on three predictors (Table 4).

Regression models were made and the model with highest R2 and least margin of error and standard error of estimate was found with model 3 in each case which was based on MdIMxM1. Simple regression equation were developed for the estimation of MxCPW and MdCPW for both boys and girls separately pertaining to gender difference in tooth size and observed to be MxCPW = 2.689 + 0.883 MdIMxM1 and and MdCPW = 0.878 + 0.943 MdIMxM1 for boys while MxCPW = 1.159 + 0.947 MdIMxM1and MdCPW = 0.708 + 0.941 MdIMxM1 was established for girls.

Table-1: Comparison of Teeth Sizes between Boys and Girls

Arch	Teeth	Male		Female		*p*-value
		Mean	SD	Mean	SD	
MAXILLA	Canine R	8.36	0.47	7.88	0.44	*
	Canine L	8.36	0.46	7.87	0.44	*
	1st Premolar R	7.43	0.43	7.16	0.40	*
	1st Premolar L	7.45	0.43	7.18	0.41	*
	2nd Premolar R	7.12	0.40	6.87	0.43	*
	2nd Premolar L	7.12	0.42	6.86	0.43	*
	1st Molar R	10.85	0.53	10.43	0.49	*
	1st Molar L	10.82	0.53	10.41	0.49	*
MANDIBE	Central Incisor R	5.66	0.39	5.48	0.34	*
	Central Incisor L	5.64	0.39	5.45	0.33	*
	Lateral Incisor R	6.17	0.39	5.91	0.37	*
	Lateral Incisor L	6.16	0.38	5.91	0.36	*
	Canine R	7.40	0.40	6.87	0.38	*
	Canine L	7.43	0.40	6.88	0.38	*
	1st Premolar R	7.48	0.43	7.19	0.40	*
	1st Premolar L	7.51	0.44	7.22	0.40	*
	2nd Premolar R	7.54	0.46	7.23	0.42	*
	2nd Premolar L	7.59	0.46	7.25	0.42	*
	1st Molar R	11.47	0.55	10.91	0.56	*
	1st Molar L	11.53	0.55	10.95	0.57	*

**p*-value < 0.001, R= Right Quadrant, L= Left Quadrant

Table-2: Comparison in Combination of Teeth between Boys and Girls

Teeth	Boys		Girls		P-value
	Mean	SD	Mean	SD	
MxCPW	22.92	1.07	21.91	1.13	<0.001
MdCPW	22.46	1.09	21.32	1.08	<0.001
Mdl	23.86	1.33	22.75	1.35	<0.001
$MdlM_1$	23.47	1.02	22.34	1.06	<0.001
$MdlMxM_1$	22.90	0.96	21.91	0.96	<0.001

Abbreviations:
Sum of maxillary canine and premolars width= (MxCPW)
Sum of mandibular canine and premolars width =(MdCPW)
Sum of four mandibular incisors= (MdI)
Sum of mandibular incisors and mandibular first molar = ($MdIM_1$)
Sum of mandibular incisors and maxillary first molar = ($MdIMxM_1$)

Table-3: Comparison of Teeth Sizes between Right and Left Side of Each Arch in Boys & Girls

Arch	Teeth	*Boys*			*Girls*		
		Paired Differences		***P*-value**	***Paired Differences***		***P -value***
		Mean	**SD**		**Mean**	**SD**	
Maxillary	Canine Right-Canine Left	0.01	0.14	0.419	0.00	0.10	0.576
	1st Premolar Right-1st Premolar Left	-0.02	0.16	0.130	-0.02	0.11	0.038
	2nd Premolar Right-2nd Premolar Left	0.00	0.20	0.977	0.01	0.12	0.171
	1st Molar Right-1st Molar Left	0.01	0.14	0.419	0.02	0.14	0.015
Mandibular	Central Incisor Right-Central Incisor Left	0.01	0.17	0.356	0.01	0.12	0.516
	Lateral Incisor Right-Lateral Incisor Left	0.01	0.12	0.516	-0.01	0.10	0.422
	Canine Right-Canine Left	-0.02	0.16	0.130	-0.01	0.06	0.042
	1st Premolar Right-1st Premolar Left	-0.03	0.16	0.011	0.01	0.14	0.419
	2nd Premolar Right-2nd Premolar Left	0.00	0.20	0.977	-0.02	0.11	0.038
	1st Molar Right-1st Molar Left	-0.02	0.16	0.130	-0.02	0.16	0.130

Table-4: Association of Dependent Variable with Independent Variable in by Using Pearson Correlation Coefficient

Predictors (independent variable)	Boys n=192		Girls N=192		Both Boys & Girls N= 384		P-value
	MxCPW	MdCPW	MxCPW	MdCPW	MxCPW	MdCPW	
	r	r	r	r	r	r	
MdI	0.611**	0.610**	0.582**	0.605**	0.660**	0.676**	<0.001
MdIM1	0.680**	0.712**	0.649**	0.698**	0.729**	0.770**	<0.001
MdIMxM1	0.787**	0.826**	0.808**	0.835**	0.835**	0.867**	<0.001
** Correlation is significant at the 0.01 level (2-tailed)							

Table-5: Regression Models in Boys

Regression of Maxillary Canine & Premolars (MxCPW) on Independent Variables				
Models	***R^2***	***Least margin of Error***	***SEE***	***Regression Equation***
Model 1	0.371	-2.41915-2.65850	0.853	MxCPW = 11.112 + 0.495 MdI
Model 2	0.46	-2.35633-2.40109	0.789	MxCPW = 6.202 + 0.712MdIM1
Model 3	0.62	-2.39832-1.79903	0.66	MxCPW = 2.689 + 0.883 $MdIMxM_1$
Regression of Mandibular Canine & Premolar (MdCPW) on independent variable				
Models	***R^2***	***Margin of Error***	***SEE***	***Regression Equation***
Model 6	0.369	-2.26120-2.86651	0.87	MdCPW = 10.483 + 0.502MdI
Model 7	0.505	-1.862-2.435	0.77	MdCPW = 4.659 + 0.759 $MdIM_1$
Model 8	0.680	-1.45971-2.03664	0.62	MdCPW = 0.878 + 0.943 $MdIMxM_1$

Table-6: Regression Models in Girls

Maxillary Canine & Premolar Regression on Independent Variables				
Models	***R^2***	***Margin of error***	***SEE***	***Regression Equation***
Model 1 (MdI)	0.335	-2.701-2.3599	0.919	MxCPW = 10.904 + 0.484 MdI
Model 2 (MdIM1)	0.418	-2.3764-2.2844	0.859	MxCPW = 6.444 + 0.692 MdIM1
Model 3 (MdIMxM1)	0.650	-2.2765-1.7761	0.66	MxCPW = 1.159 + 0.947 MdIMxM1
Mandibular Canine & Premolar Width Regressed on Independent Variables				
Models	***R^2***	***Margin of Error***	***SEE***	***Regression Equation***
Model 4	0.363	-1.84578-2.9564	0.863	MdCPW = 10.317 + 0.484MdI
Model 5	0.484	-1.9514-2.2217	0.777	MdCPW = 5.351 + 0.715 $MdIM_1$
Model 6	0.696	-1.6463-1.9812	0.596	MdCPW = 0.708 + 0.941 $MdIMxM_1$

DISCUSSION

The present study completed on 384 subjects with equal number of males and females may be claimed as the largest sample size evaluation of mesio-distal-width (MDW) analysis from Pakistan. Sample size used in this study was large enough to be comparable with studies conducted in Pakistan, India, Italy, Spain, Peru and Croatia; [9, 20, 23-26,28] however it was smaller than studies conducted in Brazil and Syria [11,12].

To improve reliability, electronic digital vernier calipers were used to measure mesiodistal width of teeth on dental casts as recommended by many researchers [7, 30-31]. In the present study, difference between tooth size of right and left side was very small and statically insignificant as observed by other researchers [5,7,20,32] therefore mean value of MDW of these teeth were used for calculation.

Significant tooth size difference was observed in present sample showing larger tooth size in boys than girls and also when combined width of teeth were compared in both genders. There was no statically significant difference in tooth size between right and left side of each tooth; therefore, average value of each tooth was taken in grouping of teeth for data analysis and subsequent simple linear regression analysis. The participants of this study were aged 13-15 years for the good reason that all permanent teeth have erupted in this age and they are less exposed to oral environment and masticatory forces with decreased chances of attrition to reduce bias in study results [11, 23, 28, 33].

Orthodontic literature reveals that tooth size differs among gender with males having larger teeth than females and tooth size difference among males and females in Peruvian, Senegalese, Croatian, Brazilian, Southern Chinese, Turkish, Italian, Ugandan, Indian and Pakistani population have been reported [9,11,20,23,33-36]. Several researchers have not considered sexual dimorphism in their population [2, 10, 12, 13, 28, 37]. In the present study tooth size difference was significant among genders with males having larger teeth than females. This difference was found for each individual tooth and also between sum of widths of MxCPW, MdCPW, MdI, MdIM1, MdIMxM1. Results of present study are in agreement with findings of studies [4, 7, 9, 20, 23, 29, 32, 34, 39] which have reported sexual dimorphism, therefore data was analyzed and regression equations were developed for males and females separately in the present study.

Different combinations of teeth have been used in orthodontic literature. Moyers [4] and Tanaka & Johnston [5] developed regression table and equation based on mesiodistal width of four mandibular Incisors in North American population. Many researchers have doubted the applicability of these prediction equations pertaining to racial and ethnic difference in tooth size and developed regression equation based on four mandibular incisors for their own populations [8, 22, 27, 28, 33-36, 40-46] Recently several researchers have reported that four mandibular incisors are not better predictor for the estimation of MDW of unerupted canine & premolars and introduced additional predictors with better accuracy i.e mandibular and maxillary permanent first molars [9,11,12,20,23,25,26]. Therefore in present study different combinations of teeth were used as predictors to evaluate which combination of teeth gives better prediction in Pakistani population and r and R2 noted in the present study was compared with other studies in which three predictors were used.

Higher Correlation coefficient found in the present study was also compared with radiographic methods and combined method and it was found similar to some of the radiographic methods. Lima *et al.* [2] predicted MDW of canine & premolars by using 45 degree oblique teleradiographs and dental casts of permanent dentition and found very strong correlation coefficient (r = 0.84) which is comparable to findings of present study. Staley & Kerber [13] and Hixon & Oldfather [37], used combination of radiograph and dental casts and they found very high correlation coefficient. However, in the present study high correlation was found with only non-radiographic method for predicting size of unerupted permanent canine and premolars.

Although it has been accepted that combined method are best for predicting MDW of unerupted permanent canine and premolars but disadvantage of radiation exposure are there; this also gives two dimensional measurement of object and require good radiographic technique and equipment therefore non radiographic technique is preferred in mixed dentition period.

Use of the values of MdIMxM1without regression equation to predict sum of maxillary and mandibular canine & premolars appears to be inaccurate. The values obtained from regression equations provide better results, some researchers [11,19,25,26] used simple regression equation as they are easy to memorize but some researchers [9,12,20,39,48] used multiple linear regression equations. Since multiple regression equations provide better accuracy as suggested by many studies but since these equations are complex and difficult to memorize. Using simple linear regression equation is justified by a fact that nonradiographic method must be simple, precise, practical and specific for population from which it has to be developed. In present study simple regressions was applied for estimating MDW of maxillary and mandibular canine & premolars in study sample.

Findings of present study are in agreement with those of other studies which stated that only the mandibular permanent incisors are not better predictors [9, 11, 12, 20]. Difference between actual and predicted value in present study based on mandibular incisors and maxillary first molar as predictor is amongst the smallest that were found in other radiographic and non radiographic methods [2, 9, 14, 20, 34, 37, 39, 49]. Maxillary first molar has advantage over mandibular first molar as it is difficult to measure mandibular first molar as they are covered by distal gingival groove and these are teeth which are more prone to dental caries so maxillary first molar is a better alternative predictor with higher correlation coefficient as compared to mandibular first molar.

An ideal prediction method determines no difference between actual and predicted width of permanent canine and premolars and difference in standard deviation should be as small as possible. Prediction methods are not 100% precise and they can overestimate or underestimate actual width of permanent canine and premolars. In this study difference in predicted and actual values and standard deviations (SD) were small as compared to radiographic and nonradiographic methods [2, 9, 10, 20, 34, 37, 39, 47, 49].

Overestimating size of permanent canine and premolars appears to be better as compared to underestimating as it prevents lack of space but it has disadvantage of wrong extraction decision in some patients [27]. It has been suggested by many researchers [4,6,9,11] that overestimation of only 1mm on each arch side doesn't seriously effect decision of extraction or non-extraction.

CONCLUSION

Prediction equation based on mandibular incisors & maxillary first molar more accurately predict maxillary and mandibular canine & premolar width in study population as compared to sum of four mandibular incisors and sum of mandibular incisors and first molar.

Authors Contributions

SB conceived idea, conducted study and prepared manuscript. MJ, SI, FA contributed in data analysis and manuscript writing. AW, SA, and AAK contributed in manuscript writing. All authors read and approved the final manuscript.

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