Prediction of canine and premolar size using the widths of various permanent teeth combinations: A cross-sectional study

Kalasandhya Vanjari, Sivakumar Nuvvula, Rekhalakshmi Kamatham

Abstract

Aims: To suggest the best predictor/s for determining the mesio-distal widths (MDWs) of canines (C) and premolars (Ps), and propose regression equation/s for hitherto unreported population. **Methods:** Impressions of maxillary and mandibular arches were made for 201 children (100 boys and 101 girls; age range: 11–15 years) who met the inclusion criteria and poured with dental stone. The maximum MDWs of all the permanent teeth were measured using digital vernier caliper. Thirty-three possible combinations (patterns) of permanent maxillary and mandibular first molars, central and lateral incisors were framed and correlated with MDWs of C and Ps using Pearson correlation test. **Results:** There were significant correlations between the considered patterns and MDWs of C and Ps, with difference noted between girls (range of *r*: 0.34–0.66) and boys (range of *r*: 0.28–0.77). Simple linear and multiple regression equations for boys, girls, and combined sample were determined to predict MDW of C and Ps in both the arches. **Conclusions:** The accuracy of prediction improved considerably with the inclusion of as many teeth as possible in the regression equations. The newly proposed equations based on the erupted teeth may be considered clinically useful for space analysis in the considered population.

Keywords: Analysis, mixed dentition, regression

Introduction

Mixed dentition analysis (MDA) is imperative for diagnosis and timely intervention of arch length discrepancies.[1,2] It calculates the difference between the amount of dental arch space available and that required to accommodate tooth material in perfect alignment.[3,4] The available space in the arch can be equal to, greater or smaller than the un-erupted teeth dimensions, which becomes fundamental in determining the treatment plan, that might involve, serial extractions, tooth eruption guidance, space maintenance, space gain, or simple monitoring of the occlusion.[5] Thus, predicting the size of un-erupted teeth during the mixed dentition period is a critical factor in managing the developing occlusion of a growing child.

Department of Pedodontics and Preventive Dentistry, Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India

Correspondence: Dr. Rekhalakshmi Kamatham,
Department of Pedodontics and Preventive Dentistry, Narayana Dental College and Hospital, Nellore - 524 003,
Andhra Pradesh, India.
E-mail: rekhanagmds@yahoo.co.in

Access this article online	
Quick Response Code:	Website: www.contempclindent.org
	DOI: 10.4103/0976-237X.166829

As an initial attempt to estimate mesio-distal widths (MDWs) of permanent canine (C) and premolars (Ps), tables are suggested based on the average dimensions of teeth.[6] However, these approximations are unreliable clinically due to great variability in tooth sizes among people. Hence, prediction methods based on the measurement of teeth on radiographs,[7] estimation based on the dimensions of primary and erupted permanent teeth using prediction tables[8] (that employ simple or multiple linear regression equations) and a combination of these approaches[9,10] are popular. Among these, radiographic methods are less commonly employed clinically due to the radiation exposures and image distortion problems. Therefore, nonradiographic methods such as Moyers' (based on American white population),[3] Tanaka Johnston's (TJ) analysis[8] (based on Northwest European population), and Melgaco's prediction equations[11] (based on Brazilian population) are frequently practiced. Nevertheless, the major drawback of these methods is the question of reliability when applied to other populations for which they were derived.[5,12] Studies on various other populations proved that these methods either overestimate or underestimate the actual widths of permanent C and Ps.[5,12-19] Another question is the applicability of these

How to cite this article: Vanjari K, Nuvvula S, Kamatham R. Prediction of canine and premolar size using the widths of various permanent teeth combinations: A cross-sectional study. Contemp Clin Dent 2015;6:S210-20.

equations that are based on pooled data (irrespective of gender) to both boys and girls.[5,20] To avoid these inconveniences, many authors proposed prediction tables and regression equations for their populations.[13,19,21] Studies pertaining to this topic on Indian population are also reported in the literature,[12,19,22-26] but, the population in south-east part of India is overlooked.

The existence of a significant linear association between the width of mandibular permanent incisors and un-erupted permanent C and Ps is reported; hence, suggested as the best predictor.[3,8] In the later studies, high values of correlation and determination coefficients are observed on adding the MDWs of the mandibular first permanent molars to the mandibular permanent incisors.[13,19] Also, different combinations of maxillary/mandibular first permanent molars with maxillary/mandibular permanent incisors were suggested for high prediction values to establish multiple regression equations.[11,13,15,19-21,27,28] However, a study, on a single sample population, to compare the capability of tooth/teeth combination to predict the MDWs of C and Ps, is not available in literature.

Evidence of dimensional change of teeth due to secular trends is also reported,[5] which projects the necessity to progressively modify MDA. Hence, the present study is an attempt to suggest the best predictor/s for determining the MDWs of C and Ps and propose new regression equation/s for boys and girls in hitherto unreported population.

Methods

The present study has been carried out in the Department of Pedodontics and Preventive Dentistry for a period of 6 months (from January 2014 to June 2014) after obtaining clearance from the Institutional Ethical Committee.

Sample

The children attending the department and school dental health programs were recruited; those who fulfilled below-mentioned inclusion criteria along with their assent and parental written informed consent to participate were included in the study.

- Age range of 11–15 years (applying gender-stratified random sampling)
- Belonging to the local area (south-east part of India) ancestry, at least from one previous generation
- Presence of fully erupted permanent dentition (except third molars) with intact proximal surfaces, marginal ridges, incisal edges and contact points
- Class I canine and molar relationship
- Minimal wear.

Children with the following factors were excluded from the study:

- Inter-proximal caries or restorations
- Congenitally missing teeth or supernumerary teeth (abnormalities in number)

Table 1: Description of patterns

Pattern	Description
A	MDW of R Max C + R Max Ps
B	MDW of L Max C + L Max Ps
C	MDW L Man C + L Man Ps
D	MDW of R Man C + R Man Ps
E	MDW of R Max C + R Max Ps + L Max C + L Max Ps
F	MDW of R Man C + R Man Ps + L Man C + L Man Ps
1	MDW of R Max M
2	MDW of L Max M
3	MDW of L Man M
4	MDW of R Man M
5	MDW of R Max M + L Max M
6	MDW of R Man M + L Man M
7	MDW of R Max M + R Man M
8	MDW of L Max M + L Man M
9	MDW of R Max M + R Man M + L Max M + L Man M
10	MDW of R Max CI + R Max LI + L Max CI + L Max LI
11	MDW of R Man CI + R Man LI + L Man CI + L Man LI
12	MDW of R Max CI + L Max CI + R Man CI + L Man LI + L Man CI + R Man LI
13	MDW of R Max CI + R Max LI + R Max M
14	MDW of L Max CI + L Max LI + L Max M
15	MDW of R Man CI + R Man LI + R Max M
16	MDW of L Man CI + L Man LI + L Max M
17	MDW of R Max CI + R Max LI + R Man M
18	MDW of L Max CI + L Max LI + L Man M
19	MDW of L Man CI + L Man LI + L Man M
20	MDW of R Man CI + R Man LI + R Man M
21	MDW of R Max CI + L Max CI + R Max M + L Max M
22	MDW of R Max CI + L Max CI + R Man M + L Man M
23	MDW of R Max CI + L Max CI + R Max LI + L Max LI + R Max M + L Max M
24	MDW of R Man CI + L Man CI + R Man LI + L Man LI + R Max M + L Max M
25	MDW of R Max CI + L Max CI + R Max LI + L Max LI + R Man M + L Man M
26	MDW of R Man CI + L Man CI + R Man LI + L Man LI + R Man M + L Man M
27	MDW of L Max CI + L Man CI + L Max LI + L Man LI + L Max M + L Man M
28	MDW of R Max CI + R Man CI + R Max LI + R Man LI + R Max M + R Man M
29	MDW of R Max CI + L Max CI + R Max M + L Max M + R Man M + L Man M
30	MDW of R Man CI + L Man CI + R Man LI + L Man LI + R Max M + L Max M + R Man M + L Man M

Contd...

Table 1: Contd...

Pattern	Description
31	MDW of R Man CI + L Man CI + R Man LI + L Man LI + R Max CI + L Max CI + R Max M + L Max M
32	MDW of R Man CI + L Man CI + R Man LI + L Man LI + R Max CI + L Max CI + R Max M + L Max M + R Man M + L Man M
33	MDW of R Max CI + L Max CI + R Max LI + L Max LI + R Man CI + L Man CI + R Man LI + L Man LI + R Max M + L Max M + R Man M + L Man M

MDW: Mesio-distal widths; Max: Maxillary; Man: Mandibular; R: Right; L: Left; C: Canine; Ps: First and second premolars; CI: Central incisor; LI: Lateral incisor; M: First molar

Table 2: Mesio-distal widths of permanent teeth in boys, girls, and combined sample

	Mesio-distal widths	Mesio-distal widths		
	n=201	Boys (*n*=100)	Girls (*n*=101)	Boys versus girls
	Mean±SD	Mean±SD	Mean±SD	*P*
R Max CI	8.51±0.55	8.69±0.52	8.34±0.53	<0.001***
R Max LI	6.87±0.55	6.97±0.54	6.76±0.54	0.007**
R Max C	7.59±0.48	7.79±0.43	7.39±0.44	<0.001***
R Max P1	6.99±0.42	7.06±0.45	6.91±0.38	0.01**
R Max P2	6.60±0.45	6.71±0.43	6.47±0.43	<0.001***
R Max M	9.94±0.56	10.07±0.58	9.82±0.52	0.002**
L Max CI	8.53±0.54	8.70±0.52	8.35±0.51	<0.001***
L Max LI	6.85±0.54	6.96±0.57	6.73±0.49	0.003**
L Max C	7.55±0.51	7.75±0.43	7.36±0.50	<0.001***
L Max P1	7.01±0.40	7.10±0.41	6.92±0.39	0.001***
L Max P2	6.63±0.44	6.71±0.42	6.55±0.45	0.014*
L Max M	9.96±0.56	10.11±0.58	9.81±0.50	<0.001***
L Man CI	5.47±0.38	5.55±0.34	5.38±0.41	0.001***
L Man LI	5.98±0.42	6.07±0.42	5.90±0.40	0.004**
L Man C	6.63±0.48	6.87±0.45	6.40±0.40	<0.001***
L Man P1	7.00±0.44	7.13±0.40	6.86±0.43	<0.001***
L Man P2	6.97±0.53	7.09±0.53	6.86±0.52	0.002**
L Man M	10.70±0.78	10.91±0.69	10.49±0.80	<0.001***
R Man CI	5.46±0.37	5.54±0.37	5.38±0.36	0.002**
R Man LI	5.94±0.41	6.03±0.41	5.84±0.39	0.002**
R Man C	6.61±0.48	6.85±0.42	6.39±0.42	<0.001***
R Man P1	7.01±0.40	7.13±0.38	6.89±0.40	<0.001***
R Man P2	6.92±0.46	7.03±0.42	6.81±0.47	<0.001***
R Man M	10.74±0.65	10.93±0.64	10.56±0.61	<0.001***

R: Right; L: Left; Max: Maxillary; Man: Mandibular; CI: Central incisor; LI: Lateral incisor; C: Canine; P1: First premolar; P2: Second premolar; M: First molar; SD: Standard deviation. *Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level

- Abnormalities in shape, size, or structure
- History of orthodontic treatment
- Facial disharmony and/or congenital craniofacial anomalies
- Transverse discrepancies such as cross bite
- Apparent loss of tooth substance due to attrition, trauma, massive caries, or artificial crowns on teeth.

Various patterns of tooth/teeth combinations with permanent maxillary and mandibular first molars, central and lateral incisors were framed [Table 1]. Patterns A to F are based on different combinations of permanent C and Ps widths; patterns 1–9 on the maxillary and mandibular first molars, patterns 10–12 on central and lateral incisors, whereas 13–33 are based on the combinations of first molars, central and lateral incisors.

Impressions of maxillary and mandibular arches were made with dentulous, perforated, impression trays (Zhermack® Spa, Italy) using irreversible hydrocolloid, tropicalgin (Chromic Alginate, Zhermack® Spa, Italy), mixed as per manufacturer's recommendations. The impressions were rinsed in running tap water, disinfected with 2% glutaraldehyde, poured with hard dental stone (Goldstone®, Asher Technologies, Kozhikode, Kerala, India) immediately to avoid any dimensional changes, and vibrated manually. The dental casts were neither soaped nor waxed; and each model pair was assigned an identification number to ensure examiner masking for gender.

The maximum MDWs of all the permanent teeth were measured using electronic digital vernier caliper (Aerospace 0–150 mm with a resolution of 0.01 mm, Bearing and Tools Centre, Ahmedabad, Gujarat, India) following the Moorrees and Reed's standard method.[29] This method measures the distance between anatomic contact points (from mesial to distal) at their greatest inter-proximal distance, with the help of sharp end calipers on the buccal or occlusal side. The tooth dimensions were recorded, transferred to the data sheets, tabulated, and analyzed.

The intra-examiner calibration procedure consisted of the primary investigator (KV) measuring 20 randomly selected model pairs twice, separated by 1-week. The inter-examiner calibration was done against a second examiner (RK) who also measured the 20 model pairs twice, separated by 1-week.

Sample size determination

Based on the lowest correlation value in the data obtained from the pilot study (sample of 21 model pairs), taking alpha error as 0.05, power of 95% and considering 10% for errors, a total sample size of 189 was determined.

Statistical analysis

Statistical analysis was carried out using the SPSS statistical package (SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc) with the level of significance set at 0.05. The mean, standard deviation and range of tooth dimensions for boys, girls, and combined sample were tabulated, and

the normality of the data was tested using Shapiro–Wilk test. As the data were found to be normally distributed, the difference between the dimensions of boys and girls was analyzed using unpaired *t*-test. The correlation between the considered patterns and the MDWs of C and Ps was done, using Pearson correlation test. Linear regression was used to derive equations for the prediction of the sum of the widths of C and Ps for both maxilla and mandible. The best combinations of independent variables were determined, and multiple linear regression equations derived. The predicted (both from simple and multiple regression equations) and actual values were analyzed for difference using paired *t*-test.

Table 3a: Correlation of framed patterns in combined sample (boys and girls)

Patterns	1	2	3	4	5	6	7	8	9	10	11
A											
R	0.49	0.51	0.38	0.43	0.53	0.43	0.51	0.49	0.52	0.57	0.63
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.52	0.52	0.4	0.44	0.55	0.44	0.53	0.51	0.54	0.59	0.66
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.52	0.54	0.46	0.57	0.56	0.54	0.61	0.56	0.61	0.60	0.65
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.51	0.51	0.47	0.55	0.54	0.54	0.59	0.56	0.60	0.62	0.67
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.52	0.53	0.40	0.45	0.56	0.45	0.54	0.52	0.55	0.59	0.67
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.53	0.54	0.48	0.57	0.57	0.55	0.62	0.57	0.62	0.62	0.68
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

Table 3b: Correlation of framed patterns in combined sample (boys and girls)

Patterns	12	13	14	15	16	17	18	19	20	21	22
A											
r	0.64	0.63	0.60	0.66	0.65	0.60	0.54	0.58	0.62	0.62	0.56
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.67	0.65	0.63	0.69	0.67	0.61	0.57	0.61	0.64	0.64	0.58
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.66	0.66	0.64	0.68	0.68	0.69	0.60	0.64	0.71	0.65	0.64
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.67	0.66	0.65	0.69	0.68	0.69	0.63	0.66	0.71	0.64	0.64
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.67	0.66	0.64	0.69	0.68	0.62	0.58	0.61	0.65	0.65	0.59
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.68	0.68	0.66	0.70	0.70	0.70	0.63	0.66	0.73	0.66	0.66
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

Results

The intra-examiner and inter-examiner reliability calculated, using Cohen's Kappa, from twenty randomly selected model pairs and were found to be 0.98 and 0.95, respectively, showing consistency of the tooth measurements.

A total of 432 children were screened, of which 201 (100 boys and 101 girls) met the inclusion criteria. The mean and

Table 3c: Correlation of framed patterns in combined sample (boys and girls)

Patterns	23	24	25	26	27	28	29	30	31	32	33
A											
r	0.62	0.67	0.58	0.62	0.63	0.66	0.59	0.64	0.67	0.65	0.65
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.65	0.70	0.61	0.64	0.66	0.68	0.61	0.66	0.70	0.68	0.68
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.66	0.70	0.66	0.70	0.68	0.72	0.66	0.70	0.70	0.71	0.71
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.67	0.70	0.67	0.70	0.69	0.72	0.66	0.70	0.70	0.71	0.72
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.66	0.70	0.61	0.65	0.66	0.69	0.62	0.67	0.70	0.68	0.68
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.68	0.72	0.68	0.71	0.70	0.74	0.68	0.72	0.72	0.73	0.73
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

Table 4a: Correlation of framed patterns in boys

Patterns	1	2	3	4	5	6	7	8	9	10	11
A											
r	0.48	0.45	0.28	0.31	0.51	0.32	0.45	0.42	0.45	0.55	0.57
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.51	0.48	0.32	0.32	0.54	0.34	0.47	0.46	0.48	0.61	0.65
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.56	0.53	0.41	0.51	0.59	0.48	0.60	0.54	0.60	0.61	0.65
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.53	0.49	0.44	0.49	0.55	0.49	0.58	0.53	0.58	0.64	0.65
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.51	0.48	0.31	0.33	0.54	0.34	0.47	0.45	0.48	0.60	0.63
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.57	0.53	0.44	0.52	0.59	0.51	0.61	0.56	0.61	0.65	0.67
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

Table 4b: Correlation of framed patterns in boys

Patterns	12	13	14	15	16	17	18	19	20	21	22
A											
r	0.59	0.63	0.57	0.62	0.59	0.57	0.48	0.49	0.56	0.58	0.47
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.66	0.68	0.63	0.67	0.67	0.61	0.54	0.57	0.60	0.63	0.52
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.66	0.70	0.65	0.70	0.69	0.70	0.59	0.62	0.71	0.66	0.61
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.65	0.70	0.66	0.69	0.66	0.70	0.63	0.63	0.70	0.63	0.61
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.64	0.67	0.61	0.67	0.65	0.61	0.52	0.55	0.60	0.62	0.51
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.68	0.72	0.68	0.72	0.70	0.72	0.63	0.65	0.73	0.67	0.63
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

Table 4c: Correlation of framed patterns in boys

Patterns	23	24	25	26	27	28	29	30	31	32	33
A											
r	0.61	0.63	0.53	0.54	0.57	0.63	0.53	0.58	0.63	0.60	0.61
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.67	0.69	0.59	0.60	0.64	0.68	0.57	0.63	0.69	0.66	0.67
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.69	0.72	0.65	0.68	0.68	0.75	0.66	0.71	0.71	0.72	0.72
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.69	0.70	0.68	0.69	0.69	0.74	0.64	0.70	0.70	0.71	0.73
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.66	0.68	0.58	0.59	0.62	0.68	0.57	0.62	0.68	0.64	0.66
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.71	0.73	0.69	0.71	0.71	0.77	0.68	0.73	0.73	0.74	0.75
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

standard deviation of the MDW of individual teeth in boys, girls and combined sample are represented in Table 2; boys showing significantly larger teeth than girls in both the arches.

Table 3a-c shows the correlation between the considered patterns and MDWs of C and Ps in the combined sample. The lowest correlation coefficients observed were with pattern 3 ($r = 0.38–0.48$) and highest coefficients with the pattern 28 ($r = 0.66–0.74$). However, all the patterns were correlating significantly with MDW of C and Ps. Table 4a-c shows the correlation between the considered patterns and MDWs of C and Ps in boys, whereas Table 5a-c shows for girls. There

Table 5a: Correlation of framed patterns in girls

Patterns	1	2	3	4	5	6	7	8	9	10	11
A											
r	0.42	0.46	0.34	0.42	0.46	0.40	0.47	0.44	0.47	0.47	0.63
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.46	0.47	0.36	0.43	0.48	0.41	0.50	0.46	0.49	0.48	0.62
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.40	0.45	0.39	0.52	0.44	0.47	0.52	0.46	0.51	0.48	0.60
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.41	0.43	0.39	0.50	0.43	0.46	0.51	0.46	0.50	0.51	0.64
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.46	0.48	0.37	0.44	0.49	0.42	0.50	0.47	0.50	0.50	0.65
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.42	0.45	0.40	0.53	0.45	0.48	0.53	0.47	0.52	0.51	0.64
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

Table 5b: Correlation of framed patterns in girls

Patterns	12	13	14	15	16	17	18	19	20	21	22
A											
r	0.62	0.53	0.53	0.63	0.63	0.52	0.48	0.57	0.61	0.56	0.52
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.60	0.54	0.55	0.64	0.62	0.52	0.51	0.56	0.60	0.57	0.53
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.59	0.54	0.52	0.60	0.60	0.58	0.50	0.58	0.64	0.54	0.56
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.61	0.55	0.54	0.62	0.62	0.58	0.53	0.59	0.65	0.54	0.56
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.63	0.55	0.56	0.66	0.65	0.54	0.51	0.59	0.63	0.59	0.55
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.62	0.56	0.54	0.63	0.63	0.60	0.53	0.60	0.66	0.55	0.57
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

are significant correlations in both boys and girls, though the correlation coefficients were less in girls, compared to boys.

Comparison of the tooth dimensions on the right and left sides did not show significant difference between any two contralateral teeth in maxilla, whereas significant differences were observed in the dimensions of right and left lateral incisors and second premolars in mandible. Comparison of the differences in the contralateral teeth between boys and girls did not show significant differences in boys, whereas significant differences in dimensions of right and left mandibular lateral incisors and maxillary second premolars were found in girls.

Table 5c: Correlation of framed patterns in girls

Patterns	23	24	25	26	27	28	29	30	31	32	33
A											
r	0.53	0.64	0.51	0.60	0.58	0.60	0.54	0.61	0.63	0.61	0.60
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
B											
r	0.55	0.64	0.53	0.60	0.60	0.60	0.55	0.61	0.63	0.62	0.61
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
C											
r	0.54	0.61	0.55	0.62	0.59	0.62	0.56	0.62	0.60	0.62	0.61
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
D											
r	0.55	0.63	0.57	0.64	0.61	0.63	0.56	0.62	0.62	0.63	0.63
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
E											
r	0.57	0.67	0.54	0.62	0.61	0.62	0.57	0.63	0.66	0.64	0.63
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
F											
r	0.56	0.64	0.58	0.65	0.61	0.64	0.57	0.64	0.63	0.64	0.63
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

r: Correlation coefficient; *P*: Significance. ***Significant at 0.001 level

For regressions, the average values of right and left contralateral teeth, in both maxilla and mandible were considered. As all the framed patterns were correlating significantly; only simple patterns were considered, following the sequence of eruption. Simple linear regression equations for boys, girls, and combined sample were determined to predict MDW of C and Ps in both the arches, which are represented in Table 6. All the equations were calculated as $y = a + bx$, where y is the dependent variable (sum of the mandibular/maxillary C and Ps); x is the independent variable (the considered pattern). Multiple linear equations were calculated as $y = ax_1 + bx_2 + \ldots$; and the determined equations for boys, girls and combined sample are represented in Table 7.

On comparing the actual values and predicted values from simple and multiple regression equations [Tables 6 and 7], no significant differences were observed.

Discussion

On reviewing the existing literature on MDA, Moyers' and TJ analyses are observed to be popular, widely employed, and proven to be clinically valid.[3,8,17,30] They are based on the predictive capability of permanent mandibular central and lateral incisors; the reported reasons for selecting these teeth being, first in the sequence of eruption, less variability in shape and size, can be easily and accurately measured and high correlation of these teeth with others.[29] Thus, the major proposed advantage of these nonradiographic methods is the ease and speed of use by direct measurement of teeth in the oral cavity with minimum errors.[5,15] In due course, Melgaco analysis, proved to be a good predictor in Brazilian population, came into practice, which employs a combination of mandibular first molar and incisor teeth.[11] However, due to the thrust for a better predictive capability, various studies have projected other teeth like maxillary/mandibular first molars, maxillary central and lateral incisors and different combinations of all the above-mentioned teeth as means to determine the MDW of C and Ps.[11,13,15,19-21,27,28]

Another major drawback of the Moyers' and TJ analyses is the development of these methods based on the data derived from population of North European descent.[1,2,7] Studies comparing these methods with their respective populations have observed either overestimation/underestimation.[3,8,11,16-18,30] Thus, regression equations for their populations were suggested by studies conducted on black Americans,[31] black Africans,[30] Asian-Americans,[32] Egyptians,[33] Mexicans,[33] Americans,[33] Peruvians,[34] Saudi Arabians,[35] Syrians,[15] Hong Kong Chinese,[36] Croatians,[27] Nigerians,[37] Thai,[20] and Senegalese[38] populations. Accordingly, several linear regression equations have been proposed for populations of different ethnic origins, assuming that the most accurate equation for prediction of tooth size should be based on measurements obtained from the population in question. Studies on Indian population are also reported with sample derived from western Uttar Pradesh,[12] Gujarat,[19] Haryana,[22] Central India,[24] Karnataka,[23] West Bengal,[25] and Himachal[26] population. Hence, the present study has been performed with the aim of developing population-specific regression equations that

Table 6: Simple linear regression equations for prediction of widths of canines and premolars

Dependant variable (*y*)	Independent variable (*x*)	Combined				Boys				Girls			
		Correlation		Regression equation	Pre vs Act	Correlation		Regression equation	Pre vs Act	Correlation		Regression equation	Pre vs Act
		r	r^2		*P*	*r*	r^2		*P*	*r*	r^2		*P*
Maxillary Canines and Premolars	Max M	0.56	31.02	*y*=10.014+1.122*x*	0.99^{NS}	0.54	28.84	*y*=11.201+1.027*x*	0.99^{NS}	0.49	23.91	*y*=11.268+0.971*x*	0.98^{NS}
	Man M	0.45	19.9	*y*=13.640+0.703*x*	0.97^{NS}	0.34	11.42	*y*=15.540+0.551*x*	0.96^{NS}	0.42	17.98	*y*=14.308+0.617*x*	1.00^{NS}
	Max M + Man M	0.55	29.92	*y*=10.117+0.535*x*	0.96^{NS}	0.48	23.33	*y*=11.522+0.478*x*	0.98^{NS}	0.5	25	*y*=11.341+0.465*x*	0.98^{NS}
	Max CI	0.59	34.93	*y*=11.260+1.164*x*	0.96^{NS}	0.53	28.3	*y*=12.340+1.061*x*	0.98^{NS}	0.54	29.48	*y*=12.216+1.029*x*	0.97^{NS}
	Man CI	0.6	35.52	*y*=11.615+1.750*x*	0.99^{NS}	0.59	35.28	*y*=11.673+1.782*x*	0.98^{NS}	0.54	29.16	*y*=13.104+1.430*x*	1.00^{NS}
	Man LI	0.64	41.22	*y*=10.926+1.720*x*	1.00^{NS}	0.58	33.64	*y*=12.527+1.494*x*	1.00^{NS}	0.66	43.56	*y*=10.918+1.682*x*	0.99^{NS}
	Man CI + Man M	0.58	33.52	*y*=10.030+0.689*x*	0.96^{NS}	0.52	26.83	*y*=10.653+0.662*x*	0.95^{NS}	0.54	28.62	*y*=11.605+0.578*x*	0.98^{NS}
	Man CI + Max M	0.66	43.56	*y*=7.180+0.908*x*	0.97^{NS}	0.65	42.51	*y*=7.659+0.889*x*	0.98^{NS}	0.59	35.16	*y*=8.845+0.780*x*	0.19^{NS}
	Man CI + Man LI	0.67	44.22	*y*=9.773+0.998*x*	0.96^{NS}	0.63	39.56	*y*=10.730+0.934*x*	0.99^{NS}	0.65	42.12	*y*=10.558+0.910*x*	0.98^{NS}
	Man CI + Man LI + Man M	0.65	41.99	*y*=8.351+0.579*x*	0.93^{NS}	0.59	34.46	*y*=9.253+0.547*x*	0.92^{NS}	0.62	38.94	*y*=9.541+0.517*x*	0.99^{NS}
	Man CI + Man LI + Max M	0.7	49.56	*y*=6.445+0.689*x*	0.91^{NS}	0.68	45.97	*y*=7.406+0.653*x*	0.96^{NS}	0.67	44.62	*y*=7.551+0.629*x*	0.95^{NS}
	Max CI + Man M	0.59	34.34	*y*=9.849+0.589*x*	0.97^{NS}	0.51	25.7	*y*=10.912+0.543*x*	0.99^{NS}	0.55	29.7	*y*=11.110+0.514*x*	0.92^{NS}
	Max CI + Max M	0.65	42.38	*y*=7.597+0.735*x*	0.90^{NS}	0.62	38.44	*y*=8.356+0.703*x*	0.98^{NS}	0.59	34.46	*y*=9.066+0.646*x*	0.97^{NS}
Mandibular Canines and Premolars	Max M	0.57	31.92	*y*=8.438+1.219*x*	0.97^{NS}	0.59	35.05	*y*=9.597+1.135*x*	1.00^{NS}	0.45	20.07	*y*=10.636+0.964*x*	0.99^{NS}
	Man M	0.55	30.36	*y*=10.607+0.929*x*	0.96^{NS}	0.51	25.5	*y*=12.024+0.826*x*	0.98^{NS}	0.48	23.04	*y*=12.123+0.758*x*	1.00^{NS}
	Max M + Man M	0.62	37.95	*y*=7.236+0.645*x*	0.98^{NS}	0.61	37.45	*y*=8.277+0.608*x*	0.96^{NS}	0.52	26.73	*y*=9.501+0.521*x*	0.98^{NS}
	Max CI	0.6	36.12	*y*=9.773+1.267*x*	0.95^{NS}	0.56	31.25	*y*=11.326+1.118*x*	0.99^{NS}	0.53	27.56	*y*=11.117+1.076*x*	0.98^{NS}
	Man CI	0.59	35.16	*y*=10.385+1.864*x*	0.99^{NS}	0.61	37.45	*y*=10.833+1.841*x*	0.99^{NS}	0.52	26.83	*y*=12.100+1.486*x*	0.99^{NS}
	Man LI	0.66	43.96	*y*=9.237+1.901*x*	0.99^{NS}	0.63	40.2	*y*=11.147+1.637*x*	1.00^{NS}	0.66	43.03	*y*=9.455+1.812*x*	0.97^{NS}
	Man CI + Man M	0.66	43.03	*y*=7.032+0.836*x*	0.91^{NS}	0.66	43.03	*y*=7.183+0.842*x*	0.96^{NS}	0.57	32.26	*y*=9.520+0.665*x*	0.98^{NS}
	Man CI + Max M	0.66	44.09	*y*=5.487+0.978*x*	0.90^{NS}	0.7	48.86	*y*=6.098+0.956*x*	1.00^{NS}	0.56	30.8	*y*=8.080+0.791*x*	0.99^{NS}
	Man CI + Man LI	0.68	45.56	*y*=8.174+1.085*x*	0.99^{NS}	0.67	44.62	*y*=9.497+0.996*x*	1.00^{NS}	0.64	40.32	*y*=9.238+0.965*x*	0.98^{NS}
	Man CI + Man LI + Man M	0.71	50.98	*y*=5.454+0.683*x*	0.86^{NS}	0.71	49.98	*y*=6.175+0.660*x*	0.89^{NS}	0.65	41.99	*y*=7.429+0.582*x*	0.94^{NS}
	Man CI + Man LI + Max M	0.72	51.12	*y*=4.558+0.749*x*	0.98^{NS}	0.73	53.44	*y*=5.733+0.706*x*	0.95^{NS}	0.64	40.83	*y*=6.361+0.652*x*	0.99^{NS}
	Max CI + Man M	0.66	43.3	*y*=6.957+0.708*x*	0.89^{NS}	0.63	39.82	*y*=7.754+0.678*x*	0.93^{NS}	0.57	32.72	*y*=9.071+0.584*x*	0.92^{NS}
	Max CI + Max M	0.66	43.82	*y*=5.799+0.800*x*	0.95^{NS}	0.67	44.62	*y*=6.782+0.759*x*	0.91^{NS}	0.55	30.58	*y*=8.111+0.660*x*	0.98^{NS}

Max: Maxillary; Man: Mandibular; CI: Central incisor; LI: Lateral incisor; M: First Molar; *r*: Correlation Coefficient; r^2: Coefficient of determination; Pre: Predicted value; Act: Actual value; *P*: Significance; NS: Not significant

Table 7: Multiple linear regression equations for prediction of widths of canines and premolars

Dependant Variable (y)	Combined		Boys		Girls	
	Regression equation	Pre vs Act (P)	Regression equation	Pre vs Act (P)	Regression equation	Pre vs Act (P)
Maxillary Canines and Premolars	y=9.339+0.922 x_1+0.249 x_2	0.95^{NS}	y=10.940+0.983 x_1+0.064 x_2	0.94^{NS}	y=10.642+0.731 x_1+0.284 x_2	0.96^{NS}
	y=7.131+0.622 x_1+0.114 x_2+1.214 x_3	0.96^{NS}	y=7.560+0.646 x_1+0.010 x_2+1.329 x_3	0.98^{NS}	y=9.101+0.504 x_1+0.131 x_2+1.000 x_3	0.92^{NS}
	y=6.631+0.531 x_1+0.054 x_2+0.572 x_3+0.933 x_4	0.97^{NS}	y=7.579+0.600 x_1-0.044 x_2+0.922 x_3+0.545 x_4	0.99^{NS}	y=7.823+0.376 x_1+0.082 x_2+0.177 x_3+1.272 x_4	0.98^{NS}
	y=6.515+0.499 x_1+0.033 x_2+0.453 x_3+0.844 x_4+0.215 x_5	0.89^{NS}	y=7.188+0.564 x_1-0.064 x_2+0.807 x_3+0.443 x_4+0.256 x_5	0.99^{NS}	y=7.848+0.386 x_1+0.086 x_2+0.216 x_3+1.307 x_4-0.066 x_5	0.65^{NS}
Mandibular Canines and Premolars	y=6.962+0.781 x_1+0.544 x_2	0.94^{NS}	y=7.981+0.864 x_1+0.398 x_2	0.97^{NS}	y=9.491+0.525 x_1+0.519 x_2	0.95^{NS}
	y=4.814+0.490 x_1+0.413 x_2+1.181 x_3	0.99^{NS}	y=4.749+0.541 x_1+0.347 x_2+1.271 x_3	0.98^{NS}	y=7.977+0.301 x_1+0.368 x_2+0.983 x_3	0.95^{NS}
	y=4.241+0.385 x_1+0.344 x_2+0.446 x_3+1.069 x_4	0.99^{NS}	y=4.770+0.490 x_1+0.286 x_2+0.817 x_3+0.608 x_4	1.00^{NS}	y=6.524+0.157 x_1+0.313 x_2+0.048 x_3+1.445 x_4	0.92^{NS}
	y=4.144+0.359 x_1+0.327 x_2+0.346 x_3+0.995 x_4+0.179 x_5	0.98^{NS}	y=4.488+0.464 x_1+0.272 x_2+0.734 x_3+0.535 x_4+0.184 x_5	0.99^{NS}	y=6.570+0.174 x_1+0.321 x_2+0.119 x_3+1.497 x_4-0.118 x_5	0.92^{NS}

x_1: Maxillary first molar, x_2: Mandibular first molar, x_3: Mandibular central incisor, x_4: Mandibular lateral incisor, x_5: Maxillary central incisor, Pre: Predicted value, Act: Actual value, P: Significance, NS: Not significant

can be consistently applied to the population of south coastal Andhra Pradesh (part of southeast India).

Another important aspect that should not be neglected in this field is the consideration of gender differences in the tooth dimensions. Studies conducted to determine the sexual dimorphism in populations of different ethnic origin considered so far, have revealed that the tooth dimensions were significantly high in boys, compared to gi rls,[5,7,8,10,11,16,17,27,28,30,35] which is supported by the findings of the present study. Hence, equations for both the genders separately were formulated in the present study.

Differences between contralateral teeth have been considered in many previous studies, with no significant difference noted.[11,14,16] However, in the present study, significant differences were noticed in mandibular lateral incisors and second premolars; only among the girls, with the left side showing larger dimensions than the right.

All the patterns formulated in the present study, using various tooth/teeth combinations, correlated significantly with the C and Ps MDW in both boys and girls. However, irrespective of the gender, the correlation coefficient values were high, as the number of teeth increased. This entails the significance of including as many teeth as possible for predicting MDW of C and Ps, rather than considering particular tooth/teeth. Thus, we can employ either simple/multiple regression equations depending on the status of dentition, as proposed in the present study. On comparing the actual and predicted values, no significant differences were noted for both simple and multiple linear regression equations, which highlight good applicability of all these equations to this specific population. The findings of the present study can be generalized for south eastern Indian population, derived from the same ethnic background.

Based on the following conclusions, this study thus focuses on the importance of framing particular equations for specific ethnic/racial population groups so that individualized treatment planning can be performed:

- There was a gender discrepancy noticed in the present study, hence, gender separated, population specific new regression equations are proposed as good prediction methods to determine the MDW of C and Ps
- The accuracy of prediction improved considerably by inclusion of as many teeth as possible in the regression equations
- The newly proposed equations may be considered clinically useful for MDA in the contemporary population depending on the erupted teeth
- This paper also demonstrates the necessity of determining distinctive regression equations for various populations.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Bolton WA. Disharmony in tooth size and its relation to the analysis in treatment of malocclusion. Angle Orthod 1958;28:113-30.
2. Bolton WA. The clinical application of a tooth Size analysis. Am J Orthod 1962;48:504-29.
3. Moyers RE. Handbook of Orthodontics for the Student and General Practitioner. 3rd ed. Chicago: Yearbook Medical Publisher Inc.; 1973. p. 369-79.
4. Kirschen RH, O'higgins EA, Lee RT. The Royal London Space Planning: An integration of space analysis and treatment planning: Part I: Assessing the space required to meet treatment objectives. Am J Orthod Dentofacial Orthop 2000;118:448-55.
5. Al-Bitar ZB, Al-Omari IK, Sonbol HN, Al-Ahmad HT, Hamdan AM. Mixed dentition analysis in a Jordanian population. Angle Orthod 2008;78:670-5.
6. Memon S, Fida M. Development of a prediction equation for the estimation of mandibular canine and premolar widths from mandibular first permanent molar and incisor widths. Eur J Orthod 2012;34:340-4.
7. de Paula S, Almeida MA, Lee PC. Prediction of mesiodistal diameter of unerupted lower canines and premolars using 45º cephalometric radiography. Am J Orthod Dentofacial Orthop 1995;107:309-14.
8. Tanaka MM, Johnston LE. The prediction of the size of unerupted canines and premolars in a contemporary orthodontic population. J Am Dent Assoc 1974;88:798-801.
9. Hixon EH, Oldfather RE. Estimation of the sizes of unerupted cuspid and bicuspid teeth. Angle Orthod 1958;28:236-40.
10. Staley RN, Kerber PE. A revision of the hixon and old father mixed-dentition prediction method. Am J Orthod 1980;78:296-302.
11. Melgaço CA, de Sousa Araújo MT, de Oliveira Ruellas AC. Mandibular permanent first molar and incisor width as predictor of mandibular canine and premolar width. Am J Orthod Dentofacial Orthop 2007;132:340-5.
12. Srivastava B, Bhatia HP, Singh R, Singh AK, Aggarwal A, Gupta N. Validation of Tanaka and Johnston's analysis in western UP Indian population. J Indian Soc Pedod Prev Dent 2013;31:36-42.
13. Brito FC, Nacif VC, Melgaço CA. Mandibular permanent first molars and incisors as predictors of mandibular permanent canine and premolar widths: Applicability and consistency of the method. Am J Orthod Dentofacial Orthop 2014;145:393-8.
14. Bherwani AK, Fida M. Development of a prediction equation for the mixed dentition in a Pakistani sample. Am J Orthod Dentofacial Orthop 2011;140:626-32.
15. Nourallah AW, Gesch D, Khordaji MN, Splieth C. New regression equations for predicting the size of unerupted canines and premolars in a contemporary population. Angle Orthod 2002;72:216-21.
16. Arslan SG, Dildes N, Kama JD, Genç C. Mixed-dentition analysis in a Turkish population. World J Orthod 2009;10:135-40.
17. nik Tahere H, Majid S, Fateme M, Kharazi fard, Javad M. Predicting the size of unerupted canines and premolars of the maxillary and mandibular quadrants in an Iranian population. J Clin Pediatr Dent 2007;32:43-7.
18. Altherr ER, Koroluk LD, Phillips C. Influence of sex and ethnic tooth-size differences on mixed-dentition space analysis. Am J Orthod Dentofacial Orthop 2007;132:332-9.
19. Shah S, Bhaskar V, Venkataraghvan K, Choudhary P, Mahadevan G, Trivedi K. Applicability of regression equation using widths of mandibular permanent first molars and incisors as a predictor of widths of mandibular canines and premolars in contemporary Indian population. J Indian Soc Pedod Prev Dent 2013;31:135-40.
20. Jaroontham J, Godfrey K. Mixed dentition space analysis in a Thai population. Eur J Orthod 2000;22:127-34.
21. Boboc A, Dibbets J. Prediction of the mesiodistal width of unerupted permanent canines and premolars: A statistical approach. Am J Orthod Dentofacial Orthop 2010;137:503-7.
22. Mittar M, Dua VS, Wilson S. Reliability of permanent mandibular first molars and incisors widths as predictor for the width of permanent mandibular and maxillary canines and premolars. Contemp Clin Dent 2012;3:S8-12.
23. Sholapurmath SM, Benni DB, Mandroli P. Applicability of two mixed dentition analyses in children of Jangam community of Belgaum city. World J Dent 2012;3:324-9.
24. Nayak A, Hazarey PV. Evaluation of applicability of Moyer's mixed dentition analysis for central India population. J Indian Orthod Soc 2004;37:154-9.
25. Dasgupta B, Zahir S. Comparison of two non-radiographic techniques of mixed dentition space analysis and evaluation of their reliability for Bengali population. Contemp Clin Dent 2012;3:S146-50.
26. Kaur A, Singh R, Mittal S, Sharma S, Bector A, Awasthi S. Evaluation and applicability of Moyers mixed dentition arch analysis in Himachal population. Dent J Adv Stud 2014;2:96-104.
27. Legovic M, Novosel A, Legovic A. Regression equations for determining mesiodistal crown diameters of canines and premolars. Angle Orthod 2003;73:314-8.
28. Bernabé E, Flores-Mir C. Are the lower incisors the best predictors for the unerupted canine and premolars sums? An analysis of a Peruvian sample. Angle Orthod 2005;75:202-7.
29. Moorrees CF, Reed RB. Correlations among crown diameters of human teeth. Arch Oral Biol 1964;9:685-97.
30. Schirmer UR, Wiltshire WA. Orthodontic probability tables for black patients of African descent: Mixed dentition analysis. Am J Orthod Dentofacial Orthop 1997;112:545-51.
31. Ferguson FS, Macko DJ, Sonnenberg EM, Shakun ML. The use of regression constants in estimating tooth size in a Negro population. Am J Orthod 1978;73:68-72.
32. Lee-Chan S, Jacobson BN, Chwa KH, Jacobson RS. Mixed dentition analysis for Asian-Americans. Am J Orthod Dentofacial Orthop 1998;113:293-9.
33. Bishara SE, Jakobsen JR, Abdallah EM, Fernandez Garcia A. Comparisons of mesiodistal and buccolingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico, and the United States. Am J Orthod Dentofacial Orthop 1989;96:416-22.
34. Flores-Mir C, Bernabé E, Camus C, Carhuayo MA, Major PW. Prediction of mesiodistal canine and premolar tooth width in a sample of Peruvian adolescents. Orthod Craniofac Res 2003;6:173-6.
35. al-Khadra BH. Prediction of the size of unerupted canines and premolars in a Saudi Arab population. Am J Orthod Dentofacial Orthop 1993;104:369-72.
36. Yuen KK, Tang EL, So LL. Mixed dentition analysis for Hong Kong Chinese. Angle Orthod 1998;68:21-8.
37. Otuyemi OD, Noar JH. A comparison of crown size dimensions of the permanent teeth in a Nigerian and a British population. Eur J Orthod 1996;18:623-8.
38. Diagne F, Diop-Ba K, Ngom PI, Mbow K. Mixed dentition analysis in a Senegalese population: Elaboration of prediction tables. Am J Orthod Dentofacial Orthop 2003;124:178-83.