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Tanaka-Johnston, Moyers, and Bernabé & Flores-Mir mixed dentition analyses in school going children of Jammu city

Dr. Kumar Nilotpal[1], Dr. Isha Vaid[2], Dr. Akash Tripathi[3], Dr. Pranav Gupta[4]
[1] Department of Pedodontics and Preventive Dentistry, Uttar Pradesh, India
[2] Lecturer, Institute of Dental Sciences, Sehora, Jammu and Kashmiri, India
[3] Senior Lecturer, Department of Periodontology and Implantology, Hazaribagh College of Dental Science and Hospital, Jharkhand, India
[4] Senior Lecturer, Department of Pedodontics and Preventive Dentistry, Kothiwal Dental College and Research Centre, Moradabad, Uttar Pradesh, India
Corresponding author: Dr. Pranav Gupta

Abstract
Introduction: During othodontic treatment planning, accurate space analysis is very important in this period. The present study was planned to determine the mesiodistal widths of lower permanent canines and premolars from Tanaka-Johnston, Moyers 'and Bernabé E & Flores-Mir C mixed dentition analysis; to determine the correlation coefficients and the new prediction equation for Sri Ganganagar population.
Materials and method: 100 children aged 11-16 years of Jammu city were randomly selected. The mesiodistal width of permanent incisors, canines, premolars and molars was measured with the help of digital vernier caliper with an accuracy of ±0.01mm. The measurements of canines and premolars were summed up and compared with those derived from Tanaka and Johnston equations, Moyers probability tables and Bernabé & Flores-Mir equations.
Results: All the three methods overestimated the actual sum of permanent canine and premolars in both the arches in our population.
Conclusion: The predicted values obtained from all the three methods overestimated the actual values. Results derived are more clinically appropriate and reliable for the prediction of tooth size of unrupted permanent canines and premolars, to determine the discrepancy between the available and required space in the dental arch. As this equation is limited only to the city population of school going children, further studies are required incorporating large population size to draw appropriate results.

Keywords: tanaka and johnston, moyers, Bernabé & Flores-Mir

Introduction
The orthodontic diagnosis and treatment planning are the fundamental goals during mixed dentition period to prevent future crowding or spacing in the teeth for the prediction of the space in the dental arch for accommodating unerupted permanent teeth [1]. So, an accurate space analysis is very important in this period for quantifying the degree of crowding and determining whether the treatment plan is going to involve guidance of eruption, serial extractions, space maintenance, space regaining or just periodic observation of the patient [2].
Numerous methods have been proposed till date but the basic approaches for doing this are [1] measurement of the teeth on radiographs such as Nance method [2], estimation from prediction tables such as Moyer's method [3], combination of radiographic and prediction table methods such as Staley-Kerber and Tanaka–Johnston's method and [4] use of multiple regression schemes such as Bernabé & Flores-Mir method [3].
The various researchers have conducted enumerous studies using different methods to derive regression equations but still the population of Sri Ganganagar (Rajasthan) has not been studied yet. As SriGanganagar is a major part of Northern zone of Rajasthan state and is racially and geographically different, the aim of present study was to evaluate the applicability of Moyers', Tanaka-Johnston and Bernabé & Flores-Mir mixed dentition analyses in school going children of age group (11-16) years in Jammu city.

Materials and Method: The present study was done in the Department of Dentistry after obtaining ethical clearance from the college. A total of 100 subjects were randomly selected for the study based on inclusion and exclusion criteria, and were designated as "Study samples".

Inclusion Criteria
- All the subjects aged 11-16 years old, with Angle's Class I molar relation.
- All the permanent teeth to be examined i.e. maxillary and mandibular central incisors, lateral incisors, canines and premolars; and maxillary first molars should be present and fully erupted, with no evidence of proximal dental caries, restorations, fractures, tooth wear and dental anomalies

Exclusion Criteria: The subjects with moderate to severe malocclusion, those undergoing or had undergone an orthodontic treatment, subjects with clinical abnormalities affecting the jaws, congenitally missing or impacted permanent teeth were excluded from the study.
The impressions were taken for all the selected study samples

using muscle moulded rim lock trays no. U3-U5. The trays were selected for each patient by checking the last molar coverage by tray and rims of the trays were 2 mm short of sulcus with the help of alginate impression material. The impressions were washed, disinfected by immersing in 2% gluteraldehyde solution for 10 minutes and then poured immediately with a proper mix of dental stone. The study casts were checked for any distortions, disinfected and trimmed. The standardised bases were made for all the 100 study casts, by keeping teeth in occlusion with the help of base formers.

The measurements of mesiodistal dimensions of the maxillary and mandibular teeth were made using a digital vernier calliper (calibrated to the nearest 0.01mm), with a standard method by Moorees *et al*. [4] To gain easier access to interdental spaces, the measuring tips of digital vernier caliper were narrowed. The eye, instrument and light source lay approximately in a straight line, thus reducing errors of parallax to a minimum. To prevent eye fatigue, not more than 10 casts were measured at a time. The teeth measured were permanent maxillary and mandibular central incisors, lateral incisors, canines, premolars and maxillary first molars. An average value for the canine and premolars was calculated from the values obtained individually for the right and left segments of the arch, for both maxillary and mandibular arch, respectively. This was done to attain one value for maxillary and mandibular canine and premolars, for each value of the mandibular incisors.

Three prediction methods were used in the study to analyze the applicability of mixed dentition analysis:-

1. Tanaka and Johnston Method

The mesiodistal dimensions of maxillary and mandibular canines and premolars were predicted by using the following equation:-

For each of the maxillary left and right permanent canines & premolars dimensions:

$$Y = 11 + 0.5(X)$$

For each of the mandibular left and right permanent canines & premolars dimensions:

$$Y = 10.5 + 0.5(X)$$

Y is the estimate of mesiodistal dimensions of unerupted permanent canine and premolars for each side; X is the sum of mesiodistal dimensions of four permanent mandibular incisors [5].

2. Moyers' Method

The Probability charts at 75th percentile levels were used to estimate the widths of permanent canines and premolars using sum of mandibular permanent incisors [6].

3. Bernabé E and flores-mir C Method

The mesiodistal widths of lower permanent canine and premolars were estimated by the following regression equation. $Y = 3.763 + 0.37 \times X0 + 1.057 \times X1 + 0.366 \times X2$, where X0 is the sum of the of the upper and lower permanent central incisors plus the widths of the upper permanent first molars; X1 is 0 for the mandible and 1 for the maxilla, and X2 is 0 for female and 1 for male [7].

The actual measurements taken from the dental study casts were then compared to those predicted using the Tanaka and Johnston method and discrepancy between the two values was calculated. The new regression equations were determined using the lower four permanent incisors as predictors for the sum of the widths of lower permanent canine and premolars. The correlation and determination coefficients were also obtained.

The data thus obtained was subjected to statistical analysis using IBM SPSS Statistics Windows version '20.0' (Armonk, New York: IBM Corp).

Results

The study sample consisted of 100 pairs of dental casts (both maxillary and mandibular) obtained from 50 males and 50 females with permanent dentition, having fully erupted teeth (maxillary and mandibular permanent teeth except third molars).The subjects included in the study were 11-16 years old with a mean age of 13.77±1.27 years (Table 1).

In male subjects, the mean mesiodistal dimension of maxillary permanent canine was 7.71 ± 0.22, maxillary first premolar was 6.87 ± 0.37 mm and second premolar was 6.30±.43mm. In the mandibular arch, the mean width was 6.49±0.29 for canine, 6.80± 0.47mm for the first premolar and 6.92± 0.38mm for the second premolar. In females, the mean mesio-distal measurement of the maxillary permanent canine was 7.24±0.32mm, maxillary first premolar was 6.13±0.62 and second premolar was 5.74±0.61 mm, whereas the mandibular canine had mean mesio-distal dimension of 5.99±0.47, for the first premolar the values was 6.28±0.41mm and for the second premolar it was 5.91±0.54 mm .

The mesiodistal measurements of canine and premolars between males and females for both maxilla and mandible were statistically analysed by unpaired student's t- test. The dimensions of both maxillary and mandibular canine and premolars were greater in males than in females. The statistical difference was found to be highly significant ($p < 0.01$) for both the genders in maxillary and mandibular arches. The degree of sexual dimorphism was observed to be highest in maxillary canine followed by mandibular canine.

In males, the correlation coefficient between the sum of mandibular incisors and the sum of canine and premolars were 0.42 and 0.53 for maxilla and mandible, respectively. This value in females was 0.51 for maxilla and 0.61 for mandible. The correlation coefficients between the sum of maxillary and mandibular central incisors and maxillary first molars, and the width of canine-premolar segment in male subjects were 0.352 and 0.417 for maxilla and mandible, respectively.

In the female subjects, the correlation coefficient was 0.341 and 0.566 for maxillary and mandibular arch respectively, (Table 2).

The two-tailed t -test was employed to compare the differences between the actual and predicted mesiodistal values of the sum of unerupted permanent canines, first and second premolars. All the three methods, Tanaka and Johnston, Moyers, and Bernabé and Flores-Mir exhibited overestimation when the predicted values were compared with actual sum of permanent canine and premolars in males as well as females. The statistically difference was found to be highly significant ($p < 0.001$).

In males, Kruskal wallis test was applied between the mean difference values of the three different methods, which showed Tanaka Johnston and Moyers' methods were

insignificant with each other (p>0.01), while both the methods showed highly significant difference with Bernabé E & Flores-Mir C method for maxillary and mandibular permanent canines and premolars in both males (Table 3) and females (Table 4).

Discussion

The most important factors in the reliability of a study based on odontometric data are the characteristics of the sample chosen. The age range between 11- 16 years was chosen, as these children have minimal dental attrition and the teeth to be measured would have been erupted into the oral cavity in both the dental arches. The study was cross sectional study with random sampling, having 73 males and 77 females study subjects. Random but almost equal distribution of males and females has been taken as there is strong evidence that tooth sizes are expressed through X-linked inheritance. Garn SM *et al*. [8] hypothesized that possession of two X-chromosomes in females provided a higher measure of control which is lacked in males with only one X-chromosome.

In the present study, Angle's Class I molar relation was used because this relation is a stable relation for all the teeth. The teeth that were to be measured should be fully erupted to measure any discrepancy between the predicted and actual value. So for the finer measurements and results, fully erupted teeth were required. The teeth to be measured were selected on the basis of exclusion and inclusion criteria, so that there was no alteration in mesiodistal dimensions of the tooth.

The alginate material was chosen for taking impressions as it makes an accurate impression, allows for undercuts recording and less time consuming process. The impressions were washed and immersed in 2% gluteraldehyde solution for 10 minutes to maintain aseptic conditions. The standardised bases were prepared for all the 100 study casts that provided occlusal representation to identify Angle's classification of malocclusion, defining the relationship of the maxillary and mandibular teeth in the sagittal plane.

The measurement reliability is one of the most important aspects of odontometric studies; thus the measurements were made from the dental casts rather than taking measurements intraorally, as they are more consistent and accurate than intraoral measurements, particularly in the posterior segments where measuring becomes unwieldy. The measurements were made using a digital sliding vernier caliper as suggested by Hunter WS and Priest WR [9], who found the sliding calipers to be accurate and precise. The greatest mesiodistal diameter was measured at the contact points parallel to the occlusal surface of the teeth and also parallel to the vestibular surface of the model, as suggested by Moorrees CFA [4]. When a tooth was rotated or malposed in relation to the dental arch, the measurement was taken between the points on the approximate surface of the crown.

To diminish ocular fatigue, not more than 10 sets of casts were measured per day. To test the intraexaminer variability, 20 study models were randomly selected and were measured three times at an interval of 1 week, so that the first measurement did not prejudice the previous. Moyers' method has minimal systematic error and does not require sophisticated clinical judgement and saves time. Bernabé E & Flores-Mir C (2005) developed regression equations for Peruvian adolescents to forecast the size of unerupted teeth. There have been several studies of mixed dentition space analysis in various population groups, disagreed with use of Moyers and Tanaka and Johnston methods. In addition, there is some evidence of secular trends of changing dimensions of the teeth, which may require progressive modifications of mixed dentition space analysis for different populations.

The present study showed consistently higher values of measurements of incisors, canines and premolars in males than in females; although the correlation observed was statistically insignificant. Studies conducted by Al-Khadra BH [10] and Lee-Chan S *et al*. [11] have found similar results between males and females while Moyers RE [6], Priya S and Munshi AK [12] and Jaroontham J and Godfrey [13] found statistically significant differences between the two measurements. In the present study, the t-tests were done to compare the mean values of tooth widths of males and females, revealed highly significant differences ($p < 0.01$), with males having the larger values for both maxilla and mandible arches. This is in accordance to the studies conducted by Yuen KKW *et al*. [14] Singh SP and Goyal A [15], Arslan SG *et al*. [16], Durgekar SG and Naik V 17 [17].

The correlation coefficients between the mesiodistal widths of canine and premolars and combination of maxillary and mandibular central incisors and maxillary first molars in male subjects and female subjects originally described by Bernabe and Flores-Mir. The difference can be attributed to racial and ethnic variations. This indicates that overall, the sum of lower incisors is a better predictor of size of permanent canine and premolars in North western zone of Indian population.

In the present study, Tanaka and Johnston method overstimated the sum of mesiodistal widths of canine and premolars in both the sexes for both the arches. The results obtained were in accordance with the studies conducted by Diagne F *et al*. [18] Arslan *et al*. [16] whereas underprediction has also been found with some studies Lee-Chan S *et al*. [11], Yuen KKW *et al*. [14] and Alhaija ESJ and Qudeimat MA [19].

The result of our study indicated that the frequently used Moyers analysis was not sufficiently accurate to predict the canine – premolar segment in North western zone of India. Moyers' prediction tables tended to overestimate the mesiodistal dimensions of canine-premolar segments at 75th percentile value. Studies in accordance to these results were Kaplan RG *et al*. [20] Al Khadra BH [10] Durgekar SG and Naik V [17].

In the present study, Bernabé E & Flores-Mir C regression equations were found to overestimate the size of canine and premolars in maxilla as well as mandible for both males and females. The mean difference between the actual values of canine and premolars in males and females was statistically significant and greatest among the three methods compared. Since the degree of associations between the sum of maxillary and mandibular central incisors and maxillary first molars and the actual size of permanent canine and premolars was low as compared to that observed for sum of lower incisors, this method of prediction was least accurate in use when applied to north western zone population of India. The results of present study were in accordance with the study conducted by Juneja S *et al*. [21] also showed the same results.

Table 1: Socio-demographic characteristics of the study sample.

Gender	N	Age (Mean ± S.D)
Male	50	13.85±1.24
Female	50	13.69±1.33
Total	100	13.77±1.28

SD=Standard Deviation

Table 2: Determination of correlation coefficients for maxilla and mandible in both males and females.

Statistical analysis	Maxilla		Mandible	
	Males	Females	Males	Females
Correlation coefficient (r) between sum of mandibular incisors with actual value of sum of canine and premolars	0.42	0.51	0.53	0.61
p- value	0.002*	0.003*	0.0002*	<0.0001*
Correlation coefficient (r) sum of maxillary and mandibular central incisors and sum of maxillary permanent first molars with width of canine – premolars segment	0.319	0.463	0.431	0.481
p- value	0.006*	<0.001*	0.0001*	<0.001*

*p-value < 0.01 is highly significant

Table 3: The comparison of predicted values based on methods of Tanaka and Johnston, Moyers', and Bernabé E & Flores-Mir C in male subjects.

Prediction Method	Tanaka and Johnston		Moyers'		Bernabé E & Flores-Mir C		p- value[$$]
	Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible	
Predicted values (in mm)	21.94±0.58[a]	21.44±0.53[a]	21.65±0.78[a]	21.40±0.48[a]	29.91±1.06[b]	28.85±1.01[b]	<0.01*
Actual values (in mm)	20.12±1.23	19.29±1.24	20.12±1.23	19.29±1.24	20.12±1.23	19.29±1.24	
Difference (Predicted – Actual values)	1.82±0.92	2.15±0.81	1.53±0.97	2.11±0.79	9.79±1.13	9.56±1.09	
p-value	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	

[$$]Kruskal-Wallis test; values in the column with different letters indicate significant differences at p- value< 0.01, whereas same letters denotes insignificant difference.

Table 4: The comparison of predicted values based on methods of Tanaka and Johnston, Moyers', and Bernabé E & Flores-Mir C in female subjects.

Prediction Method	Tanaka and Johnston		Moyers'		BernabéE & Flores-Mir C		p- value[$$]
	Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible	
Predicted values (in mm)	21.69±0.64	21.19±0.63	20.88±0.50	20.51±0.55	29.46±1.51	28.41±1.48	<0.01*
Actual values (in mm)	20.04±1.09[a]	19.40±1.01[a]	20.04±1.09[b]	19.40±1.01[b]	20.04±1.09[c]	19.40±1.01[c]	
Difference (Predicted – Actual values)	1.65±0.77	1.79±0.78	0.84±0.72	1.11±0.69	9.42±1.14	9.01±1.17	
p-value	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	

[$$]Kruskal-Wallis test; values in the column with different letters indicate high significant differences at p- value< 0.01

Conclusion

All the three methods overestimated the actual sum of permanent canine and premolars in both the arches and genders. Moyers prediction method showed the least mean overprediction followed by Tanaka and Johnston and Bernabé E & Flores-Mir C which exhibited the maximum overestimation. Moyers probability tables at 75th percentile also overpredicted, however, the predicted values were closest to the actual widths of canine and premolars among the three methods. Tanaka and Johnston method of mixed dentition space analysis overpredicted the width of canine and premolars. Because of the discrepancy observed, new regression analyses were formulated similar to those proposed by Tanaka and Johnson originally but separately for males and females in an attempt to improve prediction accuracy.

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