Original Article

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Quick Response Code:

Website: www.jorthodsci.org

DOI: 10.4103/jos.jos_5_24

Estimating the validity of Tanaka–Johnston and Moyer's analysis of a Saudi sample

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Abstract

OBJECTIVES: Accurate estimation of unerupted permanent canines and premolars is a crucial step for effective orthodontic treatment planning during mixed dentition. This study aimed to evaluate the validity of Moyers' charts and the Tanaka–Johnston equation in predicting tooth sizes in a sample of the Madina population in Saudi Arabia and propose a new regression equation.

METHODS: Dental casts from 219 subjects (113 males and 106 females) were analyzed. Actual mesiodistal tooth widths were measured using digital calipers with an accuracy of 0.01 mm. Moyers' and Tanaka–Johnston predictions were compared with actual measurements, and a new set of prediction equations was developed.

RESULTS: Tanaka–Johnston predictions consistently overestimated the actual measurements, exhibiting a difference of 1.20 mm for maxillary canines and premolars and a difference of 1.25 mm for mandibular teeth. The Moyers chart showed gender-specific variations with males aligning with the 50th percentile and females aligning with the 65th percentile for upper arches and the 50th percentile for lower arches. Newly derived linear regression equations were established for predicting the sum of upper and lower canines and premolars for the Madina population.

CONCLUSION: The study highlights limitations in the Moyers and Tanaka–Johnston methods used for the current sample as both methods overestimated tooth sizes. New regression equations were developed to offer a more accurate approach for predicting tooth sizes for the study sample.

Keywords:

Mixed dentition analysis, Moyer, Saudi, Tanaka and Johnston

Introduction

Accurate space analysis provides a clinician with valuable diagnostic information for evaluating tooth size and arch length discrepancies in a mixed dentition phase. This estimation is a crucial aspect of planning orthodontic treatment because it enables the planning of interproximal reduction, serial extraction, maintenance of space, regaining of space, guidance of eruption, and monitoring of a patient's condition.[1] Various techniques have been described in the literature for estimating the mesiodistal widths of unerupted permanent canines and premolars. Two primary methods, namely radiographic and statistical, in addition to a combination of both, have been employed to acquire a rough assessment for individual patients.[2-4] Out of these methods, Moyers' probability tables[5] and the Tanaka and Johnston prediction equations[6] have attracted immense interest.

Using the combined sizes of the lower permanent incisors, Moyers created

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Submitted: 12-Jan-2024
Revised: 08-Feb-2024
Accepted: 27-Mar-2024
Published: 17-Sep-2024

How to cite this article: Al-Fraidi AA, Habeeb AT, Alserhani SA, Al-Kaki RT, Alkhathami SS, Bafaqeeh HA. Estimating the validity of Tanaka–Johnston and Moyer's analysis of a Saudi sample. J Orthodont Sci 2024;13:28.

tables based on the probability to estimate the space needed to align the permanent canines and premolars. Later, Tanaka and Johnston also measured the widths of lower permanent incisors and created specific equations to predict the mesiodistal width of unerupted permanent canines and premolars. These methods are widely used in clinical practice due to their simplicity, relative accuracy, and unessential need for radiographic exposure. However, researchers globally evaluated the efficacy of these approaches on different demographic groups, and the findings revealed that their precision is not universally applicable and may overestimate or underestimate the sizes of permanent teeth.[7-11] Hence, although these methods may be effective for a specific population, their accuracy may not persist across other groups.[12-14] Thus, it is crucial to recognize the limitations of these methods and perform additional investigations to identify more precise and comprehensive approaches that can be applied to diverse populations.

Earlier studies that investigated the measurements of Saudis' dentition were limited to small samples.[15,16] However, subsequent research with a larger sample size revealed similar findings, indicating that Saudi individuals tend to have smaller teeth than predicted by the Moyers' 75% confidence level chart and the Tanaka–Johnston equation. Consequently, updated percentiles and formulas were suggested for the Saudi population by Al-Dlaigan *et al*.[17] However, Madina City, which is in the Western Region of Saudi Arabia, is characterized by a more mixed population due to the Haj pilgrimages that have been occurring for more than a thousand years. These characteristics may contribute to results different from other cities in Saudi Arabia.

The aims of this study were to assess the validity of the Moyers charts and the Tanaka–Johnston equation in predicting the sizes of permanent canines and premolars in a sample of the Saudi population in Madina and develop a standard prediction formula for use with this specific population.

Materials and Methods

This retrospective analytical study screened the dental casts of patients who sought treatment at the Department of Orthodontics at The Specialized Dental Center in Madina, Saudi Arabia, between 2015 and 2023.

Inclusion criteria

1) Saudi residents
2) Fully erupted teeth from the first molar on one side to the first molar on the other side
3) Intact dentition with no grossly carious teeth or significant attrition
4) Good-quality impressions (absence of porosity or air bubbles in critical areas).

Exclusion criteria

1) Subjects with any congenital craniofacial and dental anomalies
2) Interproximal caries or restorations
3) History of previous orthodontic or prosthetic treatment.

Out of the 400 screened cases, 219 cases (113 males and 106 females) were included based on the previous criteria. The study was approved by the Institutional Review Board (IRB) in the Ministry of Health, Madina (protocol reference number: IRB log no: 23-086) and conducted accordingly.

Measurement of actual mesiodistal teeth widths

Measurements were calculated using a sliding digital caliper as it is considered accurate and reproducible.[18] Beaks of the digital caliper (VIPQD150; Vito, Santa Maria da Feira, Portugal) were inserted along the long axis of the tooth from the mesial contact point of each tooth and the distal one with an accuracy of 0.01 mm. This procedure was performed for the four mandibular incisors, the maxillary and mandibular canines, and the maxillary and mandibular first and second premolars as described by Jensen *et al*.[18] All measurements were recorded to the nearest 0.01 mm and entered into a Microsoft Excel sheet with relevant data. Consequently, the combined measurements for each subject were compared with the predicted values obtained with the Tanaka–Johnston equation and the Moyers probability charts at different percentile levels. A code was assigned to each sample, and all data were saved on a Microsoft Excel sheet.

Reliability test

The intra-examiner reliability was assessed by repeating the measurements of 10 randomly selected subjects at a 14-day interval. Inter-examiner reliability was assessed by having the two investigators measure 10 subjects and calculating the intraclass correlation coefficient (ICC).

The paired-sample *t*-test indicated no statistically significant difference between the first and the second measurements ($P > 0.6$). Pearson's correlation coefficient exhibited a high correlation between the first and second measurements (0.97).

For the inter-examiner reliability assessment, the ICC was equal to 0.98 with a P value < 0.001, indicating a good correlation between the two examiners.

Statistical analysis

IBM SPSS software package version 20.0 (Armonk, NY: IBM Corp) was used for data analysis. The collected data were assessed and followed a normal distribution. Quantitative data are expressed as the mean and standard deviation. A Student's *t*-test was used to compare males and females and determine any significant difference between the sum of mesiodistal widths of several teeth: 1) lower incisors, 2) upper and lower canines, and 3) premolars in male and female subjects. A paired *t*-test was used to compare Moyers' probability tables and Tanaka–Johnston estimations with the actual tooth measurements. Linear regression analysis was performed between the lower incisors and upper and lower canines and premolars in male and female subjects using the formula: Y = a + b(x) in which (Y) is the sum of mesiodistal widths of the canine and premolars in one quadrant, (x) is the width of the four mandibular incisors, and (a) and (b) are constants. The significance of the results was judged to be at the 5% level.

Results

Table 1 reveals the gender-related variations in tooth width parameters among the 113 male and 106 female participants. Gender-specific differences emerged in dental measurements of participants aged between 13 and 30 years (mean: 17.78 ± 3.69 years). In comparison to females, males exhibited significantly greater mesiodistal widths ($P < 0.001$), specifically in the sum of lower incisors, upper canines, and premolars, and lower canines and premolars. Table 2 outlines the difference between the actual mesiodistal measurement of canines and premolars and the estimated widths obtained from Tanaka–Johnston equations. The Tanaka–Johnston-predicted values consistently overestimated the actual tooth measurement in both the maxilla and mandible ($P < 0.001$).

Tables 3 and 4 show the comparison between the study sample's mesiodistal width and Moyers' charts (5%, 15%, 25%, 35%, 50%, 65%, 75%, 85%, and 95%). Male mesiodistal width matched the 50th percentile of Moyers' analysis (no statistical difference between the two groups; $P > 0.05$), whereas female mesiodistal width matched the 65th percentile of Moyers' analysis for maxillary teeth and 50th percentile for mandibular teeth (no statistical difference between the two groups; $P > 0.05$).

Table 5 presents the new linear regression equations derived from the current sample to predict the width of the unerupted canines and premolars.

Tables 6 and 7 depict predictions of the widths of permanent canines and premolars calculated from the obtained regression equations based on the width of the four permanent mandibular incisors based on the current sample.

Discussion

The aim of this study was to assess the validity of two common mixed dentition analyses, namely, the Moyers analysis and Tanaka–Johnston analysis, on a sample of Saudis living in Madina. Mixed dentition space analysis

Table 1: Comparison between males and females according to different parameters

	Total Mean (mm±SD) (*n*=219)	Males Mean (mm±SD) (*n*=113)	Females Mean (mm±SD) (*n*=106)	*P*
Age	17.78±3.69	17.74±3.77	17.68±3.66	0.918
Sum of				
Lower incisors	22.58±1.43	22.86±1.37	22.28±1.44	<0.001*
Standard error of mean	0.10	0.013	0.14	
Upper canines & premolars	21.09±1.19	21.40±1.08	20.76±1.22	<0.001*
Standard error of mean	0.08	0.10	0.12	
Lower canines & premolars	20.54±1.20	20.89±1.08	20.16±1.21	<0.001*
Standard error of mean	0.08	0.10	0.12	

SD: Standard deviation, *P*: *P* value for comparing between Males and Females. *Statistically significant at $P \leq 0.05$

Table 2: The mean difference between Tanaka and Johnston predicted values and the width obtained from the study sample

Sex	Arch	Mean Difference	SD	95% Confidence Interval	*P*
Combined	Maxillary canine and premolars	1.20*	0.92	1.34–-1.09	<0.001*
	Mandibular canine and premolars	1.25*	0.91	-1.39–-1.15	<0.001*
Males	Maxillary canine and premolars	1.03*	0.91	-1.20–-0.86	<0.001*
	Mandibular canine and premolars	1.04*	0.85	-1.22–-0.9	<0.001*
Females	Maxillary canine and premolars	1.38*	0.90	-1.55–-1.2	<0.001*
	Mandibular canine and premolars	1.48*	0.93	-1.66–-1.3	<0.001*

*$P \leq 0.05$ is significant

Table 3: The mean difference between the widths of maxillary canines and premolars from the study sample compared to values predicted from the Moyers chart at different percentiles (5–95%)

Percentile probability (%)	Females(*n*=135)				Males (*n*=85)			
	Mean difference (mm)	SD	95% CI	*P*	Mean difference (mm)	SD	95% CI	*P*
5	2.07	1.00	1.88-2.26	<0.001	1.39	0.91	1.22–1.56	<0.001*
15	1.42	1.00	1.22-1.61	<0.001	0.88	0.91	0.71–1.05	<0.001*
25	1.04	1.00	0.85-1.24	<0.001	0.58	0.91	0.41– 0.75	<0.001*
35	0.74	1.00	0.55-0.94	<0.001	0.33	0.91	0.16– 0.50	<0.001*
50	0.34	1.00	0.15-0.54	<0.001	-0.003	0.92	-0.17– 0.17	0.97
65	-0.06	1.00	-0.26-0.13	0.53	-0.32	0.91	–0.49–-0.16	<0.001*
75	-0.37	1.00	–0.56- -0.18	<0.001	-0.57	0.91	–0.74–-0.40	<0.001*
85	-0.72	1.00	-0.91- -0.53	<0.001	-0.87	0.91	–1.04–-0.70	<0.001*
95	-1.38	1.00	-1.57- -1.18	<0.001	-1.40	0.91	–1.57–-1.23	<0.001*

CI, Confidence interval; SD, Standard deviation. *Statistically significant at $P \leq 0.05$

Table 4: The mean difference between the widths of mandibular canines and premolars from the current study compared to values predicted from the Moyers chart at different percentiles (5–95%)

Percentile probability (%)	Females (*n*=106)				Males (*n*=113)			
	Mean difference (mm)	SD	95% CI	*P*	Mean difference (mm)	SD	95% CI	*P*
5	1.97	0.94	1.79–2.15	<0.001*	1.80	0.85	1.64–1.96	<0.001*
15	1.23	0.94	1.05–1.41	<0.001*	1.10	0.85	0.94–1.26	<0.001*
25	0.81	0.94	0.63–0.99	<0.001*	0.66	0.85	0.50–0.82	<0.001*
35	0.47	0.93	0.29–0.65	<0.001*	0.30	0.85	0.15–0.46	<0.001*
50	0.004	0.94	-0.18–0.18	0.96	-0.13	0.85	-0.029–0.03	0.1
65	-0.47	0.93	-0.65–-0.29	<0.001*	-0.59	0.84	–0.75–-0.43	<0.001*
75	-0.81	0.93	–0.99–-0.63	<0.001*	-0.92	0.85	–1.08–-0.76	<0.001*
85	-1.23	0.93	-1.40–-1.05	<0.001*	-1.36	0.85	–1.51–-1.20	<0.001*
95	-1.96	0.92	-2.14–-1.78	<0.001*	-2.10	0.85	–2.25–-1.94	<0.001*

CI, Confidence interval; SD, Standard deviation. *Statistically significant at $P \leq 0.05$

Table 5: Regression parameters for the prediction equations of the widths of canines and premolars

		Regression coefficient						
Sex	Teeth Group	*r*	a	*B*	r^2	SEE	*P*	Regression Equation
Combined (*n*=219)	Lower	0.65	8.26	0.54	0.42	0.91	<0.001	Y=0.54*X+8.26
	Upper	0.64	9.11	0.53	0.41	0.92	<0.001	Y=0.53*X+9.11
Males (*n*=113)	Lower	0.62	9.71	0.49	0.39	0.85	<0.001	Y=0.49*X+9.71
	Upper	0.55	11.51	0.43	0.30	0.91	<0.001	Y=0.43*X+11.51
Females (*n*=106)	Lower	0.64	8.22	0.54	0.41	0.94	<0.001	Y=0.54*X+8.22
	Upper	0.68	7.89	0.58	0.46	0.90	<0.001	Y=0.58*X+7.89

SEE, Standard error of estimate; *r*, Coefficient of correlation; r^2, Coefficient of determination; a and b, Linear regression constants

is crucial as it represents an integral part of the diagnosis and treatment planning for young orthodontic patients. The Tanaka and Johnston equations were derived from Northern European subjects, and they have been found to be inaccurate when applied to other populations and ethnic groups. Better accuracy can be obtained by establishing norms that have been derived from the same population.

In this study, the size of teeth varied between the two genders; similar to previously published reports,[6,10,19-27] males were found to have larger teeth, necessitating separate comparisons.

The current study found that males followed the 50th percentile in the upper and lower arches, whereas females followed the 65th percentile in the upper arch and the 50th percentile in the lower arch. Moyers recommended the use of the 75th percentile probability to estimate the width of unerupted premolars and canines; however, this was found to overestimate the width of teeth in the current study. Previously reported studies on different populations have shown a similar pattern.[4,10,12,15,16,22,24,28-37] Moreover, the present study's results contradict the findings of previously published reports concerning the Saudi population [Table 8].

The small sample size may have contributed to different results obtained by Hashim[16] and Al-Khadra.[15] Al-Dlaigan[17] found the 5% percentile chart to fit Saudi males in the upper arch, which

Table 6: A prediction for mesiodistal dimensions of canines and premolars for the Saudi population in Madina based on proposed linear regression equations

Mandibular Incisors	Combined (male and female)	
	Max-CPM	Man-CPM
19.5	19.41	18.80
20	19.68	19.08
20.5	19.95	19.36
21	20.22	19.64
21.5	20.49	19.92
22	20.76	20.20
22.5	21.03	20.47
23	21.30	20.75
23.5	21.57	21.03
24	21.83	21.31
24.5	22.10	21.59
25	22.37	21.87

Man-CPM: Mandibular canines & premolars, Max-CPM: Maxillary canine and premolars. Measurements in millimeter

Table 7: A prediction table for mesiodistal dimensions of canines and premolars for the Saudi population in Madina based on proposed linear regression equations

Mandibular Incisors	Male		Female	
	Max-CPM	Man-CPM	Max-CPM	Man-CPM
19.5	19.94	19.25	19.15	17.76
20	20.16	19.50	19.44	18.00
20.5	20.38	19.74	19.73	18.25
21	20.59	19.99	20.02	18.49
21.5	20.81	20.23	20.31	18.74
22	21.02	20.48	20.60	18.98
22.5	21.24	20.72	20.89	19.23
23	21.46	20.96	21.18	19.47
23.5	21.67	21.21	21.47	19.72
24	21.89	21.45	21.75	19.96
24.5	22.11	21.70	22.04	20.20
25	22.32	21.94	22.33	20.45

Man-CPM: Mandibular canines and premolars, Max-CPM: Maxillary canine and premolars. Measurements in millimeter

had not been reported before. No match was found regarding the suggested percentile for males in the lower arch. This study is the first report concerning validating the mixed dentition analysis in Madina. Notably, the population characteristics may play a role in the identified differences compared to previous Saudi samples.

Tanaka–Johnston Estimation

The Tanaka–Johnston equation overestimated the mesiodistal width of premolars and canines in both arches for males and females ($P < 0.001$, mean: −1.20, SD: 0.92). This finding matches that of black South Africans,[14] Senegalese,[35] North Indians,[23] Hong Kong Chinese,[22] Pakistanis,[38] Australians,[39] Ugandans,[10] and other Arab countries.[15,26,40,41] On the contrary, it was also reported to underestimate the size of the unerupted teeth.[12,42]

The regression analysis in this study indicated that the correlation coefficient in females ranged from 0.68 to 0.64 for upper and lower arches, respectively, whereas it ranged from 0.55 to 0.62 in males for upper and lower arches, respectively, which are considered higher and comparable to values reported in Turkish,[19] Jordanian,[12] Iranian,[9] Australian,[39] and Thai populations,[24] as shown in Table 8.

The coefficient of determination (r^2) is used to indicate the predictivity of the regression equation. In the current study, it ranged from 0.41 to 0.46 in females and 0.30 to 0.39 in males, which were higher or comparable to previous reports[6,24,39,40] and less than the values reported by Arslan *et al*.[19] and Yuen *et al*.,[22] as shown in Table 8.

The standard error of estimate (SEE), which represents the error used in the prediction equation, ranged from 0.90 to 0.91. As shown in Table 8, the SEE value was comparable to most previous studies[6,24,34,39,40] and slightly higher than that reported in others.[19,22]

Nevertheless, the differences were relatively insignificant and unlikely to have any clinical implications. These levels allow the confident use of developed regression equations clinically.

Limitations of this study

The retrospective nature of the sample may have limited our study. A random sample would provide a better representation of the population under study.

Conclusion

The study highlights limitations in the Moyers and Tanaka–Johnston methods that can be generalized to the current sample as both methods overestimated tooth sizes.

The Moyers chart showed gender-specific variations with males aligning with the 50th percentile for both arches and females aligning with the 65th percentile for upper arches and the 50th percentile for lower arches.

New regression equations were developed for predicting unerupted tooth sizes. These equations emphasize the importance of population-specific estimations in mixed dentition analysis.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Table 8: Comparison of regression parameters between the present study and other studies

				Constants				
Author & Year	**Population**	**Gender**	**Arch**	***r***	**α**	***B***	**SEE**	***R*²**
Tanaka and Johnston[6]	White American	M&F	UPPER	0.63	10.41	0.51	0.86	0.40
			LOWER	0.65	9.18	0.54	0.85	0.42
Frankel and Benz[34]	African American	M	UPPER	0.72	9.15	0.58	0.923	–
			LOWER	0.79	5.97	0.72	0.911	–
		F	UPPER	0.61	12.83	0.39	0.672	–
			LOWER	0.66	10.34	0.49	0.709	–
Yuen *et al*.[22]	Hong Kong Chinese	M	UPPER	0.79	7.97	0.66	0.68	0.62
			LOWER	0.77	8.82	0.58	0.61	0.60
		F	UPPER	0.65	8.30	0.61	0.81	0.42
			LOWER	0.69	6.66	0.64	0.82	0.47
Jaroontham and Godfrey[24]	Thai	M	UPPER	0.54	13.36	0.41	0.88	0.29
			LOWER	0.58	11.92	0.43	0.85	0.34
		F	UPPER	0.62	11.16	0.49	0.78	0.39
			LOWER	0.65	9.49	0.53	0.78	0.42
Al-Bitar *et al*.[40]	Jordan	M	UPPER	0.57	11.80	0.43	0.88	0.33
			LOWER	0.65	9.32	0.53	0.87	0.42
		F	UPPER	0.61	11.25	0.44	0.75	0.38
			LOWER	0.68	9.22	0.50	0.72	0.47
Arslan *et al*.[19]	Turkey	M	UPPER	0.79	9.98	0.50	0.72	0.62
			LOWER	0.74	9.54	0.50	0.78	0.54
		F	UPPER	0.83	9.77	0.50	0.72	0.68
			LOWER	0.69	9.14	0.50	0.81	0.47
Abaid *et al*.[39]	Western Australian	M	UPPER	0.74	5.09	0.72	0.88	0.54
			LOWER	0.69	6.34	0.66	0.92	0.47
		F	UPPER	0.58	7.44	0.62	1.04	0.34
			LOWER	0.62	5.59	0.63	0.96	0.39
Present study	Saudi Arabia- Madina	M	UPPER	0.55	11.51	0.43	0.91	0.30
			LOWER	0.62	9.71	0.49	0.85	0.39
		F	UPPER	0.68	7.89	0.58	0.94	0.41
			LOWER	0.64	8.22	0.54	0.94	0.41
		M&F	UPPER	0.64	9.11	0.53	0.92	0.41
			LOWER	0.65	8.26	0.54	0.91	0.42

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