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Original Article

Tanaka and Johnston Space Analysis: Does It Apply to All Populations?

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Abstract

Objectives An accurate analysis is considered a crucial factor that enables the clinician to select the appropriate treatment plan which may include serial extractions, guiding of eruption, maintenance of space or regaining it, or just intervallic patient observation during this period. This study aims to test the applicability of the Tanaka and Johnston prediction equations on Iraqi population.

Materials and Methods One hundred pairs of stone models belonged to 100 Iraqi adult individuals with normal occlusal relationship were utilized in this study. The greatest crown diameters of all teeth except the maxillary incisors and molars in both jaws were measured using digital calipers. The Tanaka and Johnston prediction equations were applied and modification for these equations was developed for Iraqis.

Results The original Tanaka and Johnston method of prediction tends to overestimate the mesiodistal widths of the canine and premolars among Iraqis. Novel regression equations (modified Tanaka and Johnston method) were formulated for Iraqi population and seem to be more accurate than the original one.

Conclusions The original Tanaka and Johnston method cannot be applied for Iraqi population; hence, new equations were developed for both genders and in both dental arches to accurately predict the mesiodistal widths of the unerupted canine and premolars.

Keywords
- orthodontic
- Tanaka and Johnston space analysis
- study models

Introduction

At the age of 6 to 7 years, when the first molars and central incisors erupt, the mixed dentition phase begins. Around this time, future spacing or crowding events are evaluated to forecast the child's dental development. This is critical to the orthodontic process.[1–3] The space needed for the canines and premolars before they erupt must, therefore, be calculated using a technique called mixed dentition analysis,[4] which is the estimation of the mesiodistal diameters of unerupted cuspids and bicuspids in order to compare the sum of space

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needed in each dental arch with the sum of space that is already available.[5]

An accurate analysis is considered a crucial factor that enables the clinician to select the appropriate treatment plan which may include serial extractions, guiding of eruption, maintenance of space or regaining it, or just intervallic patient observation during this period.[6]

Three basic methods were available for the mixed dentition analysis: measuring the unerupted teeth on radiographs,[7–9] using regression equations to correlate the crown diameters of unerupted teeth to that of erupted teeth,[10,11] and combining measurements from erupted teeth and radiographs of unerupted teeth.[12–14] Usually, measurements of the erupted permanent mandibular incisors have been used to extrapolate the mesiodistal dimensions of unerupted canines and premolars using the Tanaka and Johnston prediction equations[10] or Moyers probability tables.[11] However, both methods were created by using a population of North European descent. In their approach, Tanaka and Johnston[10] utilized the mesiodistal dimensions of lower incisors in predicting the mesiodistal widths of unerupted canines and premolars in the mixed dentition stage as they erupted early.

Different racial groups' permanent tooth sizes were discussed by Bailit[15] in 1975. Due to the racial variation in tooth size, prediction methods based on a particular racial group might not be considered worldwide.[16] In addition, several kinds of research examined the applicability of the Tanaka and Johnston prediction approach to various population groups. The findings of these studies showed that the Tanaka and Johnston prediction approach is unreliable when used on such groups.[4,16–23] Furthermore, other research has documented differences between gender regarding the sum of the mesiodistal width of canines and premolars.[24–26]

As a result, this study aims to determine whether the Tanaka and Johnston prediction approach works in a population of Iraqis and, if not, to endeavor to create a novel prediction formula specifically for Iraqis.

Materials and Methods

Sample

The sample in this retrospective study comprised 100 pairs of stone models, for 50 males and 50 females, retrieved from the archives of the Department of Orthodontics at the University of Baghdad/ College of Dentistry.

Inclusion Criteria

1. All models belong to Iraqi Arabs aged 15 to 20 years old to ensure full eruption of maxillary canines.
2. All permanent teeth should be present regardless of the wisdom teeth.
3. Minimal crowding of less than 3mm.
4. Normal shape, size, number, and position of teeth, with a normal occlusal relationship.

Exclusion Criteria

The exclusion criteria included the presence of:

1. Craniofacial anomaly or facial asymmetry.
2. A history of orthodontic treatment.
3. Visually apparent interproximal caries, restorations or fractures.
4. Defective or fractured models.

Methods

The largest mesiodistal dimensions of all maxillary and mandibular canines, premolars, and mandibular incisors were measured at the level of the anatomical contact areas of each tooth utilizing electronic digital calipers (Mitutoyo, Japan) with 0.01 mm sensitivity held perpendicular to the long axis of the tooth.[27] Before measuring procedure, the caliper jaws responsible for measurements were cleaned, then gear was moved back and forth to make sure that it is moving without any hindrance. The next step was zeroing and rezeroing the caliper to set zero reading, then a gauge block of predetermined dimensions was inserted between the caliper jaws and held with light pressure to record the measurements at three time intervals. These measurements were checked with the original dimension of the block.

The following methods were used to predict the mesiodistal crown dimensions of the maxillary and mandibular permanent canines and premolars:

Method of Tanaka and Johnston

By using the following equations[10]:

- ➢ Mesiodistal widths of maxillary permanent canines and premolars $= 11 + 0.5$ (sum mesiodistal widths of permanent mandibular incisors)
- ➢ Mesiodistal widths of mandibular permanent canines and premolars $= 10.5 + 0.5$ (sum mesiodistal widths of permanent mandibular incisors).

Modified Tanaka and Johnston's Method

Using regression equations derived from correlating the crown widths of mandibular anterior teeth with those of maxillary and mandibular canines and premolars in the Iraqi sample, measurements were made.

Statistical Analyses

The data were analyzed statistically using the SPSS program (IBM, Chicago, Illinois, United States, version 26). The statistical analyses consisted of the following:

1. Descriptive statistics, including means, standard deviations, and the standard error of estimate (SEE).
2. Inferential statistics, which included:
   a) Intraclass correlation coefficient (ICC) to assess inter- and intra-examiner reliability.
   b) Unpaired *t*-test to verify the gender differences in the measurements.
   c) Paired sample *t*-test to determine if there is a statistically significant difference between the right and left sides and to examine methodological differences.
   d) Pearson's correlation coefficient (r) to determine the relationship between the crown widths of the

mandibular anterior teeth and the canines and premolars of the maxillary and mandibular arches.

e) Simple regression analysis to formulate regression equations that can be used to predict the combined mesiodistal widths of maxillary and mandibular cuspids and bicuspids in one quadrant based on the crown widths of mandibular anterior teeth.

The level of significant was set at 0.05, so probability value of more than 0.05 was considered nonsignificant.

Results

To ensure the accuracy of the measurements, randomly selected 10 pairs of study models were remeasured by the same examiner 2 weeks after the initial measurements and compared to the original measurements. To ensure interexaminer consistency, a second examiner measured the same models. The results of the ICC test revealed high inter- and intraexaminer reliability (0.93 and 0.96, respectively).

The descriptive statistics and gender differences for the mesiodistal widths of the measured teeth are presented in ►**Table 1**. Most measured teeth exhibited significant gender differences ($p \leq 0.05$).

The descriptive statistics and side differences of the mesiodistal widths of the measured teeth are presented in ►**Table 2**. According to the results, both genders exhibited insignificant side differences ($p > 0.05$).

After applying the regressions equations of Tanaka and Johnston, the predicted widths of the maxillary and mandibular canines and premolars were compared to the actual widths and the results indicated the presence of highly significant differences ($p \leq 0.001$) with overestimating widths (►**Table 3** and ►**Fig. 1**); consequently, new regression equations were developed from the Iraqi data by correlating the widths of mandibular anterior teeth with the widths of maxillary and mandibular canines and premolars.

Gender	Males			Females		
Arch	Modified T&J equations	*r*	SEE	Modified T&J equations	*r*	SEE
Maxillary arch	10.360 + 0.510X	0.728	0.646	8.579 + 0.577X	0.562	0.923
Mandibular arch	9.649 + 0.508X	0.696	0.704	8.992 + 0.528X	0.573	0.820

Table 1 Descriptive statistics and gender difference for the mesiodistal widths of all teeth

Arch	Side	Teeth	Descriptive statistics				Gender difference		
			Males		Females				
			Mean	SD	Mean	SD	Mean difference	*t*-test	*p*-Value
Maxillary	Right	Canine	8.054	0.402	7.599	0.406	0.455	5.639	≤0.001
		First premolar	7.107	0.358	6.906	0.397	0.201	2.661	0.009
		Second premolar	6.766	0.408	6.619	0.496	0.147	1.617	0.109
	Left	Canine	8.066	0.492	7.572	0.423	0.494	5.387	≤0.001
		First premolar	7.044	0.363	6.951	0.398	0.092	1.209	0.229
		Second premolar	6.712	0.359	6.588	0.491	0.124	1.442	0.152
Mandibular	Right	Central incisor	5.369	0.329	5.167	0.304	0.203	3.196	0.002
		Lateral incisor	6.014	0.448	5.678	0.319	0.336	4.318	≤0.001
		Canine	6.984	0.429	6.660	0.377	0.325	4.017	≤0.001
		First premolar	7.041	0.406	6.904	0.437	0.137	1.621	0.108
		Second premolar	7.146	0.403	6.916	0.463	0.231	2.657	0.009
	Left	Central incisor	5.332	0.373	5.197	0.319	0.136	1.956	0.053
		Lateral incisor	5.987	0.360	5.714	0.317	0.274	4.037	≤0.001
		Canine	7.025	0.497	6.603	0.322	0.422	5.037	≤0.001
		First premolar	7.088	0.412	6.880	0.419	0.209	2.511	0.014
		Second premolar	7.207	0.443	6.986	0.446	0.221	2.482	0.015

Abbreviation: SD, standard deviation.

Table 2 Descriptive statistics and side difference for the mesiodistal widths in both genders

Genders	Arch	Teeth	Descriptive statistics				Side difference		
			Right		Left				
			Mean	SD	Mean	SD	Mean difference	*t*-test	*p*-Value
Males	Maxillary	Canine	8.054	0.402	8.066	0.492	−0.011	−0.287	0.776
		First premolar	7.107	0.358	7.044	0.363	0.064	2.011	0.051
		Second premolar	6.766	0.408	6.712	0.359	0.054	1.635	0.109
	Mandibular	Canine	5.369	0.329	5.332	0.373	0.037	1.298	0.200
		First premolar	6.014	0.448	5.987	0.360	0.027	0.597	0.553
		Second premolar	6.984	0.429	7.025	0.497	−0.041	−1.030	0.308
		Central incisor	7.041	0.406	7.088	0.412	−0.047	−1.143	0.259
		Lateral incisor	7.146	0.403	7.207	0.443	−0.061	−1.386	0.172
Females	Maxillary	Canine	7.599	0.406	7.572	0.423	0.027	0.962	0.341
		First premolar	6.906	0.397	6.951	0.398	−0.045	−1.136	0.261
		Second premolar	6.619	0.496	6.588	0.491	0.031	1.886	0.065
	Mandibular	Central incisor	5.167	0.304	5.197	0.319	−0.030	−0.848	0.400
		Lateral incisor	5.678	0.319	5.714	0.317	−0.036	−1.331	0.189
		Canine	6.660	0.377	6.603	0.322	0.056	1.202	0.235
		First premolar	6.904	0.437	6.880	0.419	0.024	0.687	0.495
		Second premolar	6.916	0.463	6.986	0.446	−0.071	−1.510	0.138

Abbreviation: SD, standard deviation.

Table 3 Descriptive statistics and method differences in both genders and arches

Genders	Arch	Methods	Descriptive statistics		Method difference		
			Mean	SD	Mean difference	*t*-test	*p*-Value
Males	Maxillary	Actual	21.928	0.932	−0.424	−4.684	≤0.001
		T&J	22.352	0.666			
		Actual	21.928	0.932	−0.011	−0.119	0.906
		Iraqi	21.939	0.679			
	Mandibular	Actual	21.171	0.971	−0.680	−6.899	≤0.001
		T&J	21.852	0.666			
		Actual	21.171	0.971	−0.011	−0.109	0.914
		Iraqi	21.182	0.677			
Females	Maxillary	Actual	21.124	1.104	−0.753	−5.805	≤0.001
		T&J	21.877	0.538			
		Actual	21.124	1.104	−0.007	−0.055	0.956
		Iraqi	21.132	0.621			
	Mandibular	Actual	20.479	0.991	−0.898	−7.814	≤0.001
		T&J	21.377	0.538			
		Actual	20.479	0.991	0.001	0.008	0.994
		Iraqi	20.478	0.568			

Abbreviations: SD, standard deviation; T&J, Tanaka and Johnston.

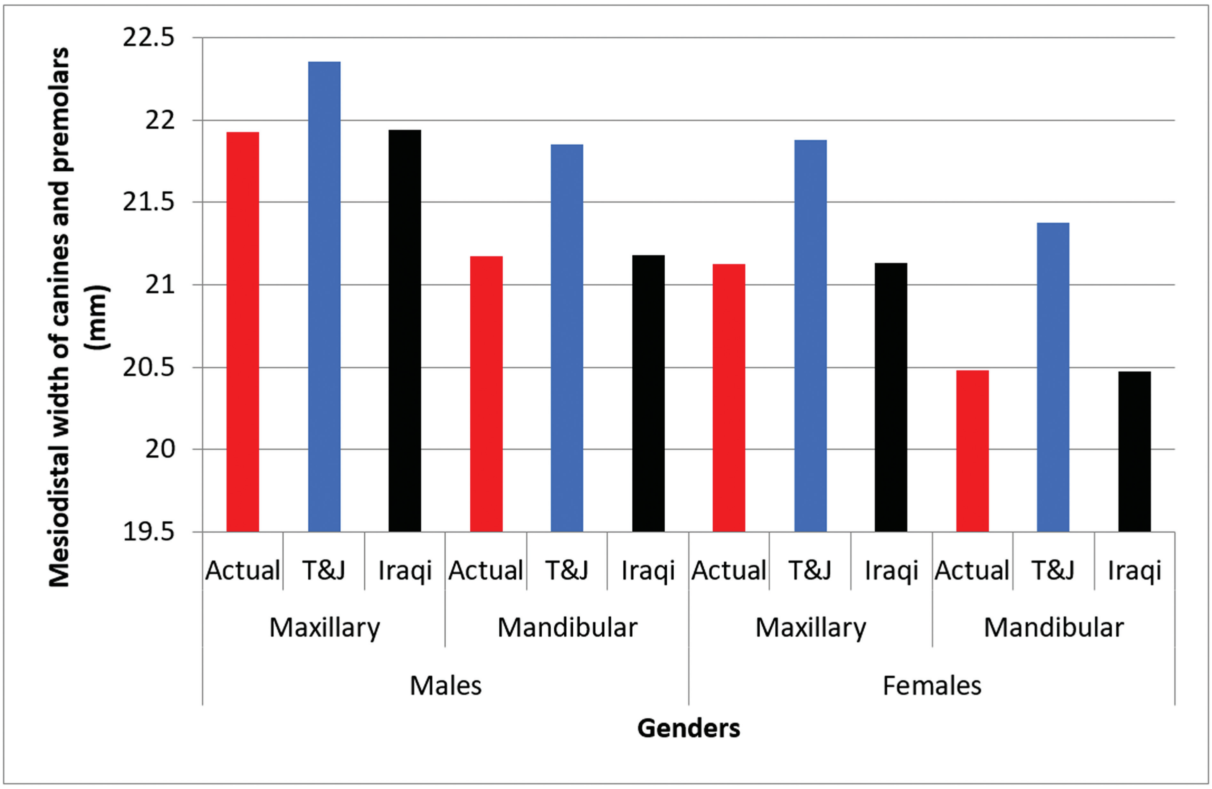

Fig. 1 The mean values of the mesiodistal widths of canines and premolars in both genders and arches using three methods. T&J, Tanaka and Johnston.

Pearson's correlation coefficient values indicated a moderate-to-strong correlation between the variables. After applying these equations, the predicted and actual widths were compared, and the results revealed no statistically significant method differences in both gender and arches (►**Table 3**), with standard errors of estimate ranging from 0.646 to 0.906.

Discussion

In order to better serve their growing patients, clinicians are interested in forecasting the likelihood of tooth size-arch length disparity. Clinicians may attempt to stop developing malocclusions if precise predictions can be made while patients are in deciduous or mixed dentition.[27] On the other hand, one will have to anticipate the necessity for such operations if such inconsistencies cannot be correctly forecast. The regression equations based on already erupted permanent teeth are the most often utilized mixed-dentition analysis techniques; this is particularly true for the Tanaka–Johnston equations[10] and Moyers' probability charts.[11]Both were created for American children; therefore, it is appropriate to do studies to determine the applicability and efficacy of these two approaches in various populations, as there are teeth size differences between racial groups, and the cause is not fully understood. Genetic factors undoubtedly play a substantial part, and nutrition and environmental exposure during tooth development may also play supporting roles.[28]

In an early investigation about the effect of genetic and environmental factors on the human teeth diameters, Townsend[29] in his study on full-sibling, half-sibling, and parent-offspring found that approximately 50 to 60% of the total variability of permanent tooth size might be accredited to additive genetic effects, while 14% was attributed to common environment. This is supported by another studies that found a strong genetic component responsible for the variation in tooth size in addition to the epigenetic and environmental aspects could contribute to phenotypic disparity, so an interaction among these factors will affect the size of the teeth.[30,31] On the other hand, Zameer et al[32] suggested that the nutritional status did not significantly affect the determination of human tooth size.

Many studies have been conducted in Iraq to predict the mesiodistal width of the unerupted canine and premolars depending on the crown diameter of the permanent incisors and first molars.[33–41] This study aims to test the applicability of the original Tanaka–Johnston equations on the Iraqi population and to develop a new one if not applicable.

The sample size chosen for this study comprised 100 pairs of stone models obtained from 100 Iraqi Arabs (50 males and 50 females) was sufficient to guarantee the reliability and clinical importance of the prediction equation. To minimize the effect of attrition, caries, or tooth loss on the mesiodistal width of teeth, the age range of the sample in this study was between 15 and 20 years old.[42,43]

As many other authors recommended, an electronic digital caliper was utilized for the measurements.[22,44,45] The value of ICC revealed high inter- and intraexaminer reliability (0.93 and 0.96, respectively), indicating a high measurement reliability. Thus, the tooth was measured once for each of the 100 dental casts.

In this study, the measurement of the mesiodistal width of the teeth revealed that the widths of males' permanent teeth were larger than that of females (►**Table 1**), as the majority of the measured teeth exhibited significant gender differences ($p \leq 0.05$). This result is in accordance with the results of other studies.[16,22,38–41,46] This indicates that we need separate linear regression equations for males and females. In addition, the results of the current analysis, which agreed with other studies,[22,38–41,47,48] revealed minimal differences (statistically insignificant) in the mesiodistal crown diameters between the right and the left side in both dentitions of the same sample (►**Table 2**).

This study demonstrated that the prediction method of Tanaka and Johnston overestimated the width of the unerupted canines and premolars for both sexes' in both mandibular and maxillary arches. This result agrees with many other population studies.[4,16,22,23,48–52] While few studies found the opposite, as they concluded that Tanaka–Johnston prediction equations underestimate the width of the unerupted canines and premolars,[6,17] this could be attributed to the racial variations in the mesiodistal dimensions of the teeth; therefore, new linear regression equations have been developed to predict the crown sizes of unerupted maxillary and mandibular canines and premolars for the Iraqi females and males separately.

To check the accuracy of these equations, Pearson's correlation was applied, and the coefficient values indicated moderate-to-strong direct significant correlations between the variables. On applying the new equations, the predicted and actual widths were compared, and the results revealed statistically nonsignificant differences for both genders and in both arches (►**Table 3**) with low standard errors of estimate that were lower than those reported by Asiry et al.[43]

According to these findings, the new regression equations formulated for Iraqis fulfill the criteria for creating an accurate prediction method with statistically nonsignificant difference between the anticipated canines and premolars' widths and their actual widths.

The major limitation in this study was taking a sample with normal occlusion. Further studies are needed to address the reliability of this type of space analysis in twins and children with different nutritional status to verify these effect of crown size in those samples. Additional measurements using intelligent software may be utilized too for analysis.

Conclusion

When applied to the Iraqi sample, the universally used Tanaka and Johnston prediction equations were less reliable because they overestimated the actual measures; hence, novel regression equations for the Iraqis were formulated for males and females separately. These linear regression equations created for the mixed dentition analysis for the Iraqi population are simple to utilize with no need for special software or equipment and this study confirms that Tanaka and Johnston prediction equations may not apply to all populations, and a new regression equation is necessary for various populations.

Conflicts of Interest
None declared.

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