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New Equations for Egyptian Children Based on Tanaka and Johnston Mixed Dentition Analysis

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ABSTRACT
Background: The role of different ethnic backgrounds in mixed dentition analyses cannot be overlooked and a customized means of diagnosis should be the goal of every population.

Objective: This study aimed at investigating the applicability of the Tanaka and Johnston mixed dentition analysis as a diagnostic aid in Egyptian children and deriving new equations, if relevant.

Materials and methods: 180 pairs of stone casts of 13–16-year-old children were traced using TracerNet software. The predicted sum of sizes of 345 from Tanaka and Johnston equations was compared to the actual sum and two regression equations were derived and compared.

Results: There was a significant difference between the actual and predicted sizes of teeth; $p<0.05$. The derived equations for the upper and lower arches were significant; $p=0.008$ and $p<0.001$; respectively. They were also significantly different from the tested equation and had a lower mean square error. The mean square error of the derived equations was 4.10 and 6 for the upper and lower arches; respectively, while the Tanaka and Johnston lower arch equation had a mean square error of 9.93 and 12.86 for the upper arch.

Conclusions : Tanaka and Johnston analysis could not be an accurate diagnostic aid for Egyptian children and new more accurate and specially tailored equations were derived.

Keywords: Malocclusion, Space analysis, Tanaka and Johnston analysis, Mixed dentition analysis, Egyptian population.

INTRODUCTION
Predicting the size of canines and premolars that have not yet erupted is essential for accurate diagnosis and planning of the optimal course of action throughout the mixed dentition. The exact forecast reveals the difference between the amount of space needed and that which is now available, providing the first component of a successful therapy [(1,2)].

There are several ways to gauge the size of the unerupted canines and premolars; some of which depended on the use of either periapical or 45^0 cephalometric radiographs, as suggested by **de Paula *et al.***[(3)].

However, this method was not considered practical as it demanded extra time and cost[(4)].

Moreover; in some cases the radiographic picture might be distorted or the teeth rotated in their crypts, which could affect the efficiency of the measurements[(5)].

Therefore, **Moyers**[(6)] recommended the use of prediction tables instead, while others used a combination of both the radiographic and the prediction table techniques as was recommended by **Hixon and Oldfather**[(7)] **and Bishara *et al.*** [(8)].

Some others devised specific formulae based on linear regression equations like Tanaka and Johnston equations, and the Sitepu method[(9,10)].

Tanaka and Johnston analysis has become an admired mixed dentition analysis ever since it was presented[(11)].

Its premise is based on the application of linear regression equations to predict the size of unerupted canines and premolars based on the size of erupted mandibular incisors. The equations were calculated based on the arches of Northern American children, but due to its simplicity and ease of application, it has become a universal mixed dentition analysis. However, the role of the different ethnic backgrounds cannot be overlooked; setting a possibility that it might not fit all types of populations[(12,13)].

Based on these observations, this study aimed at investigating the applicability of the Tanaka and Johnston mixed dentition analysis as a diagnostic aid in Egyptian children and deriving new equations, if relevant.

MATERIALS AND METHODS
Upper and lower pairs of stone casts were used in this cross-sectional study. They were selected from those of school children from Alfayoum Governorate taken as a part of a project by the National Research Centre. The cast of 300 children was selected (180 males and 120 females) with an age range of 13-16 years. They all met the selection criteria, which were: good quality dental casts with full permanent dentition except for the second and third molars and no or minor crowding or spacing in the arch (2-3 mm).

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No apparent skeletal malocclusion and no previous orthodontic treatment. The exclusion criteria were the presence of any hypoplasia or hypocalcification defect, impacted or carious teeth, restorations, significant attrition or fracture.

After taking pictures of the casts and loading them into the programme, TracerNet (Nile Delta Co., version II) was used to trace the castings [14].

Using a millimetre ruler, the castings were calibrated in both the horizontal and vertical directions. The ruler's magnification in the two axes was then measured, and the casts' magnification was determined. The two scales' maximum precision was attained when they were perpendicular. Two skilled operators noted the spots required for each measurement, and the programme automatically calculated the readings in millimetres.

The sum of the mesiodistal widths of the four mandibular incisors, as well as the sum of the widths of the canine and two premolars (345) per quadrant in each arch, were measured in order to apply the Tanaka and Johnston analysis (tested equations) to the upper and lower arches. Using a line parallel to the occlusal surface and perpendicular to the long axis of the teeth, the maximum mesiodistal distance between the anatomical contact points of one tooth and another was measured to determine the sizes of the teeth (Figure 1). The sum of widths of the lower incisors was used in the following equation to predict the combined size of 345 in one quadrant in each arch:

$Y=11+0.5X$ for the maxillary arch and $Y=10.5+0.5X$ for the mandibular arch, where X is the sum of the incisors and Y is the sum of 345.

After predicting the sizes of the 345 in each quadrant in the upper and lower arches using the equations, the previously measured actual sum of 345 was compared to the predicted sum.

On the other hand, two regression equations (derived equations) for the upper and lower arches were computed for the given sample of the population; however, each equation predicted the sizes of 345 in both quadrants of each arch.

A separate sample consisting of 50 casts with the same selection criteria and age range was used to test the derived upper and lower equations. The castings were traced, and the bilateral 345 measurements in the upper and lower arches were taken; the actual and projected values were compared. The projected values of Tanaka and Johnston equations were then multiplied by two and compared to the newly developed equations.

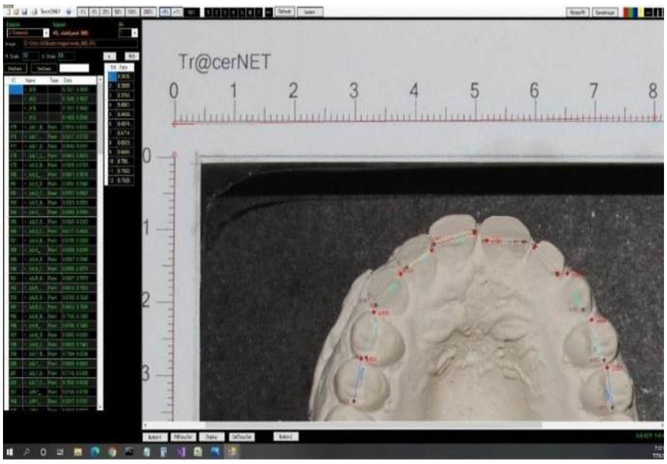

Figure (1): The measurements taken on the TracerNet

Ethical approval:

The study was approved by the Medical Research Ethical Committee of the National Research Centre, reference number: (16-343). All the caregivers of the participants signed an informing consent after a thorough explanation of the goals of the study. The Helsinki Declaration was followed throughout the study's conduct.

Statistical method

Each tooth's mean and standard deviation, as well as the groupings of teeth in both genders, were computed. All measures were compared between males and females using an unpaired t-test. The actual and expected values of the Tanaka and Johnston equations and the derived equations, as well as the comparison of the tested equations to the derived equations, were compared using a paired t-test. The cutoff for significance was <p0.05. Coefficient of determination (r^2) was used to indicate the predictive accuracy of the derived equations. The mean square error for the derived equations as well as for the Tanaka and Johnston equations was calculated.

Measurement repeatability was assessed by randomly picking 20 castings from the sample and repeating the measurements with the same operator (Intra-examiner error) and two different operators (Inter-examiner error). The variance of measurements in either case came within the recognised range of accuracy (3%-5%), as demonstrated statistically by calculating the mean and standard deviation of the measurements obtained. IBM® SPSS® Statistics Version 20 for Windows was used for statistical analysis.

RESULTS

Descriptive data for all study variables, including means and standard deviations are shown in t**ables 1, 2, and 3**. There was an insignificant difference between the sizes of 345 on one side and the contralateral side; p>0.05.

Table (1): Descriptive data of the widths of the lower incisors

Gender		LL1	LL2	LR1	LR2	LL12	LR12	L12
Males	Mean	4.81	5.51	4.93	5.19	10.32	10.12	20.43
	SD	0.68	0.63	0.52	0.42	1.11	0.82	1.77
Females	Mean	4.92	5.41	4.73	5.07	10.33	9.80	20.13
	SD	0.55	0.39	0.32	0.58	0.86	0.71	1.54
Total	Mean	4.85	5.47	4.85	5.14	10.32	9.98	20.31
	SD	0.61	0.53	0.45	0.48	0.99	0.77	1.64

LL=lower left, LR=lower right, L=lower

Table (2): Descriptive data of the widths of the lower premolars

Gender		LL3	LL4	LL5	LR3	LR4	LR5	LL345	LR345	L345
Males	Mean	6.44	6.75	6.89	6.50	6.46	6.80	20.09	19.76	39.84
	SD	1.03	0.67	0.49	0.68	0.52	0.57	1.95	1.44	3.20
Females	Mean	6.15	6.63	6.88	5.74	6.54	6.70	19.66	18.98	38.64
	SD	0.68	0.61	0.63	0.75	0.80	0.61	1.71	1.71	3.28
Total	Mean	6.32	6.70	6.89	6.19	6.49	6.76	19.91	19.44	39.35
	SD	0.89	0.63	0.53	0.79	0.63	0.57	1.81	1.56	3.18

LL=lower left, LR=lower right, L=lower

Table (3): Descriptive data of the widths of the upper premolars

Gender		UL3	UL4	UL5	UR3	UR4	UR5	UL345	UR345	U345
Males	Mean	7.10	6.52	6.31	7.07	6.65	6.31	19.93	20.03	39.95
	SD	0.80	0.43	0.62	0.78	0.64	0.63	1.19	1.65	2.76
Females	Mean	6.51	6.33	6.27	6.60	6.47	6.30	19.11	19.37	38.48
	SD	0.80	0.55	0.69	0.61	0.55	0.35	1.47	1.15	2.45
Total	Mean	6.86	6.44	6.30	6.88	6.58	6.30	19.59	19.76	39.35
	SD	0.83	0.48	0.63	0.73	0.59	0.52	1.33	1.46	2.66

UL=Upper left, UR=Upper right, U=upper

The paired t-test revealed a significant difference between the anticipated and actual sizes of 345 when the Tanaka and Johnston equations were used (**Table 4**). There was no discernible difference in tooth size between genders, according to the unpaired t-test.

Table (4): Paired t-test comparing the predicted size of teeth (345) using Tanaka and Johnston equations to the actual size of teeth

	Mean	SD	t	df	p-value
Actual L345/Predicted L345	-1.96	2.54	-3.18	16.00	0.006*
Actual U345/Predicted U345	-2.96	2.09	-5.84	16.00	0.000*

*=Significant; t=t-value; df=degree of freedom

Accordingly, two regression equations were derived from the studied sample for the upper and lower arches. The lower arch regression model was significant ($p<0.001$, $r^2=0.372$) and the equation was: Y = 15.258+1.186X. The upper arch regression model was significant ($p=0.008$, $r^2=0.385$) and the equation was: Y=18.841+1.01X; where "Y" denoted the size of 345 and "X" denoted the size of the four lower incisors. The actual and expected sizes of 345 were not significantly different ($p>0.05$).

There was a significant difference between the Tanaka and Johnston equations and the derived equations; $p<0.01$ and the mean square error of the derived equations was lower than that of the tested equations. The mean square error of the derived equation for the upper arch was 4.10 and for the lower arch was 6, while the Tanaka and Johnston lower arch equation had a mean square error of 9.93 and 12.86 for the upper arch.

DISCUSSION

The proper planning of preventive or interceptive treatment relies mainly on the accurate use of a suitable mixed dentition analysis for diagnosis. Regression equations are one of the most commonly used mixed dentition analyses to predict the sizes of unerupted canines and premolars. They are usually affected by genetic inheritance that varies with the ethnic group, which is also affected by sexual dimorphism[12,15].

Due to the importance of the Tanaka and Johnston analysis, which was initially developed on North American children, in diagnosis and the ease of its application; assessing it on Egyptian children and deriving new equations was of great interest. The chosen age group ranged from 13 to 16 years which was considered ideal for the study because all the required permanent teeth have already erupted. It was also reported previously that this age group had the advantage of having a minimal caries incidence, restorations and attrition; which are more common in older ages[15].

On applying the equations, a significant difference between the predicted and the actual size of teeth was found ($p<0.05$), with a high mean square error of 9.93 in the lower arch and 12.86 in the upper arch. The equations over-evaluated the actual size of 345 similar to other studies on different races[15-17]. This denoted that the applicability of the analysis on an ethnic group other than that it was derived from was not utterly correct. Several previous investigations reported similar results on other ethnic groups [8,18-24]**;** which entailed deriving new equations that could more properly fit the Egyptian children from Alfayoum Governorate.

Additionally, there was no significant difference in the sizes of teeth between males and females, which was in contrast to other studies and could be resorted to ethnic differences[12,19-20]. However, it complied with the idea suggested by **Suma *et al.***[16] and **Jaroontham and Godfrey**[24] that it was possible to unspecify the sex without impairing the results.

Since there was no significant difference between the sizes of teeth on both sides of the arch, and in the interest of further simplification of the analysis, the derived equations were formulated to predict the size of 345 bilaterally in each arch, unlike the tested equations. This was meant to decrease the diagnostic steps involved and make them less complicated compared to the tested equations and the derived ones reported by other studies[17, 25-26]. Furthermore, it also rendered the equations more comparable, which was in contrast to **Refai and Khattab**[27] who derived equations based on the size of the first permanent molars.

The derived equation for the maxilla was Y=15.258 +1.186X, while that for the mandible was Y=18.841+1.01X. When the predicted bilateral size of 345, using the derived equations, was compared to the actual size; there was no significant difference between them. This finding along with the r^2 value that was higher than other studies[9,22] indicated the validity and reliability of the derived equations for use on Egyptian children.

For the sake of obtaining comparable and valid results, the Tanaka and Johnston equations were multiplied by two to be able to equate them to the derived equations. A significant difference was observed between the derived and tested equations ($p<0.05$) and the mean square error of the derived equations was lower. This showed that the newly derived equations were valid for predicting the combined width of canines and premolars in Egyptian Children from Alfayoum Governorate.

Within the limitations of this study, it could be concluded that the ethnic variations can greatly affect the applicability of the Tanaka and Johnston equations. Tailored equations must be obtained for different populations to facilitate proper diagnosis in the mixed dentition. It is also recommended to conduct similar studies on the Egyptian population using a larger sample size and in different governorates as the Egyptian population is a mixed population.

CONCLUSION

Tanaka and Johnston analysis could not be an accurate diagnostic aid for Egyptian children and new more accurate and specially tailored equations were derived.

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- **Competing interests:** Nil.

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