APPLICABILITY OF TANAKA AND JOHNSON'S EQUATIONS IN A SAMPLE OF NIGERIAN POPULATION

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ABSTRACT

BACKGROUND: Tanaka and Johnson's probability equations are used to predict the future sizes of the permanent canines and premolars based on the measurements of the mandibular four incisors. This tool has been applied in numerous settings, including Nigeria, and has been found by many researchers to exhibit ethnic and gender variations.

AIM: Applicability of Tanaka and Johnson's probability equation among mixed dentition patients of the Yoruba ethnic group in southwest Nigeria.

METHOD: A total of 504 casts from patients aged 12 to 20 years were analyzed. The mesio-distal tooth measurements of the four mandibular incisors and the canines and premolars of both the maxilla and the mandible from one contact point to the other were done using a digital caliper.

RESULTS: A total of 504 pairs of upper and lower cast models were obtained from 252 males and 252 females, each with a mean age of 15.68±1.50 and 16.38±1.72 years, respectively. In the maxilla and mandible, highly significant differences (p-value: 0.000–0.001) were observed between the actual measurements of the cuspid and bicuspids in the study group and those predicted by Tanaka and Johnson.

CONCLUSION:
A statistically significant difference was observed between the mean mesio-distal value of the actual and predicted measures. Hence, Tanaka and Johnson's equation was found to overestimate the predictive mesio-distal width of the canines and premolars in the current study sample.

KEYWORDS: Tanaka and Johnson's equations, Mixed dentition analysis, Yoruba ethnic group

INTRODUCTION

The mixed dentition stage of the development of occlusion is the stage where both the primary dentition and permanent dentition co-exist in the oral cavity. The mixed dentition stage, which occurs between the ages of 6 and 12 years, is significant for dental assessment and interventions in orthodontics. In the early mixed dentition stage, accurately predicting the sizes and number of permanent teeth is crucial for effective orthodontic treatment planning, space analysis of the maxillary and mandibular arches, and assessing treatment needs and interventions to prevent future malalignment of the teeth and occlusion. A study[1] reported a significant reduction in the need for extensive and comprehensive orthodontic management in the future following early and accurate assessment of the occlusion. Hence, there is a need for a reliable predictive model for the un-erupted permanent teeth in this context.

The widely used methods for predicting the sum of the unerupted permanent canines and premolars are seen to depend on the statistical correlation of the sum of the four permanent mandibular incisors. The Tanaka and Johnson[4] probability equation is a predictive tool that can be used to predict the sizes of the un-erupted permanent canines and premolars in the dentition based on the measurement of the mandibular four incisors teeth. This tool has been applied globally in different settings, including Nigeria. The application of Tanaka and Johnson's[4] probability equations in mixed dentition clinical cases in Nigeria could provide a valuable tool for predicting the sizes of permanent canines and premolar teeth, as well as planning orthodontic interventions. Tanaka and Johnson[4] used a sample of 506 children of North Western European descent to create equations and formulas for each arch based on simple regression. Using correlation and regression statistics, they arrived at the following formulas;

- mesio-distal width of the maxillary canine and premolars (in one quadrant) =
½ × Sum of mesio-distal widths of the mandibular incisors + 11.0 millimeter (mm)
- mesio-distal width of the mandibular canine and premolars (in one quadrant) =
½ × Sum of mesio-distal widths of the mandibular incisors + 10.5 millimeter (mm)

Although the reliability of this equation could be questionable in some populations, Tanaka and Johnson's equation [4] is still widely accepted because it does not require radiographs and is quick and straightforward to perform. Additionally, it can be tailored to fit local populations, thereby enabling practitioners to make regionally specific predictions. They are arguably more readily applied today by a range of clinicians [6-11]. However, the standard errors of the estimates for the correlations were observed to be relatively high (0.86 mm for the maxillary teeth and 0.85 mm for the mandibular teeth). A Middle Eastern study[10] reported an overestimation of mesiodistal widths of canines and premolars in a Syrian population when subjected to Tanaka & Johnson's[4] equation. Furthermore, several separate studies[11,13] reported that this tool is not applicable in their respective populations, and as a result, they proposed a new linear regression equation.

In predicting permanent mesiodistal tooth width sizes in Nigeria, Ajayi[14] evaluated the Tanaka & Johnson's[4] equation among fifty-four (54) south-south and south-eastern Nigerians and reported that its applicability was limited among the studied population. Apart from this study, several other studies in Nigeria have also utilized this tool to determine the mesio-distal width of the canines and premolars in children during the mixed dentition stage. Okafor and Ogunlewe[15] demonstrated that the applicability of this equation yielded reliable predictions that helped in the development of preventive orthodontic strategies. Hence, they reported a good correlation between measurements of the mesio-distal width of the permanent mandibular incisors and the predicted value obtained from Tanaka and Johnson's equation calculation[4], thereby reinforcing the usefulness of the equation. However, with an understanding of how ethnic and gender dimorphism affects odontometric measurements, care should be taken in applying Tanaka and Johnson's equation. In a study[16] that helped to explore these variabilities, it was reported that while this tool is broadly applicable, adjustments might be necessary for specific Nigerian ethnic groups. Therefore, the author of the study[16] proposed modified coefficients developed from a researcher's study on the local population, which improved the prediction accuracy in both genders. The Tanaka and Johnson's4 equation has also been proposed by an author study[17] to be integrated into clinical dental assessment rather than used in isolation. In a calibration study[17] that employed Tanaka and Johnson's method alongside standard orthodontic assessments, it was observed that integrating probabilistic equations with comprehensive clinical assessments provides a more holistic approach, thereby enhancing the predictive capacity for future orthodontic needs in mixed dentition.

The accuracy and applicability of these equations strictly hinge on the quality of the data collected, which can vary significantly from one region to another. While dental models have been generally adopted in Nigeria for carrying out assessment measurements of the mandibular incisors, there remains a need for comprehensive studies to validate these modification coefficients universally across different ethnic groups. Therefore, the aim of this study is to investigate the applicability of Tanaka and Johnson's equation[4] in a sample of the Yoruba population in south-western Nigeria.

MATERIALS AND METHOD

A cross-sectional descriptive study was conducted among selected secondary school students aged 12 to 20 years who fulfilled the selection criteria. The study models were created for 504 subjects (252 male and 252 female) from the Yoruba ethnic group in south-western Nigeria. All selected eligible subjects had their maxillary and mandibular arch impressions made with alginate impression material (Elastic Cromo, Spofa Dental) and disinfected with Cidex (2% glutaraldehyde) for five minutes. The impressions were poured immediately at the field locations using dental stone (Kerr Orthodontic Model Mix, a stone type). The set cast models were then carefully retrieved from the impression to avoid breakage or crack of any of its parts, especially the dental structures (teeth). Each subject model was then carefully articulated manually and secured with paper tape to prevent frictional wear of occlusal landmarks during storage. They were then serialized and stored in a secure location for future reference.

The Institutional Scientific Review Board approved the study design and methodology, and the study was conducted in conformity with the Helsinki Declaration for the conduct of human studies.

The inclusion criteria for sample selection were the following:

- All subjects were of the Yoruba ethnic group of South Western origin of Nigeria.
- The permanent mandibular incisors, maxillary and mandibular canines, and premolars were all fully erupted.
- The study casts made were free of distortion.
- The subjects had no previous history of orthodontic treatment.
- Subjects without any clinically obvious tooth material loss due to interproximal caries, interproximal attrition, congenital defects, and fractures.

Mesio-distal tooth measurements of the mandibular central and lateral permanent incisors, the maxillary and mandibular permanent canines, and the maxillary and mandibular first and second premolars were measured. Measurements were made using a digital Vernier caliper (CB Mitutoyo Corp., Tokyo, Japan, accuracy of 0.01 mm). The caliper was calibrated before each measurement session by following the accompanying instruction manual. The measurements were determined by measuring the greatest distance between two contact points at the most bulbous level of the tooth, holding the calipers parallel to the occlusal surface18. To predict the mesio-distal widths of the canines and the premolars, the measurements obtained from the mesio-distal incisal sum evaluation are subjected to the Tanaka and Johnson's4 equations.

All measurements were entered in a spreadsheet, and statistical analyses were performed using the Statistical Package for Social Sciences software (Windows version 19; SPSS Inc., Chicago, IL, USA). The level of significance was set at 5%. The means, ranges, standard deviations in millimeters (mm), and coefficient of variation of the mesio-distal tooth widths were calculated for each arch. A paired t-test was used to test for significance between the predicted and the measured (actual) values. An Independent t-test was used to assess the difference between the predicted and the actual measured mesio-distal width of the canines and premolars in males and females. The results were presented in tables and charts.

RESULTS

Five hundred and four participants, comprising 252 males and 152 females, had a mean age of 15.68 ± 1.50 years and 16.38 ± 1.72 years for males and females, respectively. The mean mesio-distal mandibular teeth width was found to be larger all through in males than in females. In males, it was observed to range between 5.28 and 7.36 mm, while in females, it was observed to range between 5.23 and 7.20 mm. The mean gender difference was found to be statistically significant except for the central incisors and second premolar on the right quadrant (Tables 1 and 2).

However, the mean difference in tooth width is statistically significant between genders in the maxillary and mandibular teeth except for the left and right mandibular central incisors and the right mandibular second premolar (Tables 1, 2, 3, 4). Among the male subjects, there was a high dispersion in the mesio-distal tooth widths of the second premolars on both the left and right quadrants (standard deviation (SD); 0.54mm on the right and 0.55mm on the left). The least dispersion was observed with the central incisors (SD: 0.41 mm on the right and 0.42 mm on the left side). The left central incisors showed the greatest variability with a coefficient of variation (CV) of 7.94%, and the left first premolar had the least variability with CV of 6.66%. Regarding the female subjects, the greatest dispersion in mesio-distal width was observed with the second premolars on both sides (SD; 0.56mm), while the least dispersion was observed in the right central incisor (SD; 0.38mm). The left second premolar showed the greatest variability with CV 7.91%, and the left canine had the least variability of CV 6.44%. (Tables 1, 2, 3, and 4)

The descriptive statistics for measurements of the right and left maxillary canines and premolars are shown in Tables 3 and Table 4. The mean maxillary mesio-distal tooth widths were generally found to be larger in males than in females. The observed gender difference was found to be statistically significant (p = 0.000).

In the male gender, the greatest dispersion and variability were observed with the left second premolar (SD; 0.58mm) and (CV; 8.75%), respectively, while the least dispersion was seen with the left canine and right first premolar (SD; 0.48mm). However, the least variability was observed with the left canine (coefficient of variation, CV; 6.06%). Regarding the female gender, the greatest dispersion and variability were observed with the right second premolar (SD, 0.51 mm) and 7.89%, respectively, while the least dispersion and variability were seen with the left canine (SD, 0.43 mm) and CV, 5.69%, respectively.

Due to the normality of the mandible and maxilla data assumed following its subjection to Kolmogorov Smirnov test, paired t-test was used to assess significant differences between the measured actual value of mesio-distal width and the predicted mesio-distal tooth size by Tanaka and Johnson's equations. The results are presented in Table 5. In the maxilla and mandible, highly significant differences (p-value: 0.000–0.001) were observed between the actual measurements of the cuspid and bicuspids in the study group and those predicted by Tanaka and Johnson. Hence, the predicted values were overestimated when compared with the actual measured values.

Table 1: Right mandibular mesio-distal tooth widths of males, females and total population

Tooth (Male and female)	Male				Female				Comparison of Male and Female Mean tooth widths			Total sample			
	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Mean diff. (mm)	P-value	t value	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)
Central Incisor	3.33-6.34	5.28	0.41	7.77	4.30-6.56	5.23	0.38	7.27	0.05	0.219	1.23	4.30-6.56	5.25	0.41	7.62
Lateral Incisor	4.99-7.39	6.06	0.43	7.10	4.93-7.24	5.93	0.46	7.76	0.13	0.001*	3.21	4.93-7.39	5.99	0.45	7.51
Canine	5.59-8.62	7.20	0.51	7.08	5.14-8.41	6.83	0.48	7.03	0.37	0.000*	8.45	5.14-8.62	7.01	0.53	7.56
First Premolar	6.20-8.93	7.35	0.49	6.67	5.95-9.09	7.19	0.54	7.51	0.16	0.000*	3.51	5.95-9.09	7.27	0.52	7.15
Second Premolar	5.94-8.59	7.15	0.54	7.55	5.81 8.81	7.06	0.56	7.93	0.09	0.078	1.77	5.81-8.81	7.11	0.55	7.73

SD* Standard deviation, CV* Coefficient of variation, Mean diff – Mean difference. *Statistically significant

Table 2: Left mandibular mesio-distal tooth widths of males, females, and total population

Tooth (Male and Female)	Male				Female				Comparison of Male and Female Mean tooth widths			Total Sample			
	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Mean diff. (mm)	P-value	t value	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)
Central Incisor	4.25-6.37	5.29	0.42	7.94	4.11-6.57	5.24	0.41	7.62	0.05	0.166	1.39	4.11-6.57	5.26	0.42	7.98
Lateral Incisor	4.34-7.40	6.03	0.45	7.46	5.01-7.06	5.95	0.42	7.06	0.08	0.031*	2.16	4.34-7.40	5.99	0.44	7.35
Canine	5.66-8.42	7.16	0.51	7.12	5.71-8.20	6.83	0.44	6.44	0.33	0.000*	7.84	5.66-8.42	7.00	0.50	7.14
First Premolar	6.01-8.80	7.36	0.49	6.66	5.74-8.85	7.20	0.54	7.50	0.16	0.001*	3.42	5.74-8.85	7.28	0.52	7.14
Second Premolar	5.89-8.85	7.27	0.55	7.57	5.55 9.03	7.08	0.56	7.91	0.19	0.000*	3.81	5.55-9.03	7.17	0.55	7.67

SD* Standard deviation, CV* Coefficient of variation, Mean diff – Mean difference. *Statistically significant

Table 3: Right maxillary mesio-distal tooth widths of males, females, and total population

Tooth (Male and Female)	Male				Female				Comparison of Male and Female Mean tooth widths			Total Sample			
	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Mean diff. (mm)	P-value	t value	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)
Canine	6.58-9.26	7.91	0.52	6.57	5.93-9.06	7.53	0.47	6.24	0.38	0.000*	8.40	5.93-9.26	7.72	0.53	6.87
First Premolar	6.20-8.75	7.27	0.48	6.60	6.16-8.50	7.15	0.48	6.71	0.12	0.009*	2.63	6.16-8.75	7.21	0.48	6.66
Second Premolar	5.12-8.08	6.62	0.55	8.31	4.68 7.75	6.46	0.51	7.89	0.16	0.001*	3.26	4.68-8.08	6.54	0.53	8.10

SD* Standard deviation, CV* Coefficient of variation, Mean diff – Mean difference. *Statistically significant

Table 4: Left maxillary mesio-distal tooth widths of males, females, and total population

Tooth (Male and Female)	Male				Female				Comparison of Male and Female Mean tooth widths			Total Sample			
	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)	Mean diff. (mm)	P-value	t value	Range (mm)	Mean (mm)	*SD (mm)	*CV (%)
Canine	6.67-9.59	7.92	0.48	6.06	6.58-8.91	7.55	0.43	5.69	0.37	0.000*	9.15	6.58-9.59	7.73	0.49	6.34
First Premolar	5.95-8.57	7.27	0.51	7.02	6.08-8.76	7.18	0.47	6.55	0.09	0.040*	2.06	5.95-8.76	7.22	0.49	6.79
Second Premolar	4.89-6.06	6.63	0.58	8.75	5.05 7.53	6.47	0.48	7.42	0.16	0.001*	3.35	4.89-8.06	6.55	0.54	8.24

SD* Standard deviation, CV* Coefficient of variation, Mean diff – Mean difference. *Statistically significant

Table 5: Comparison of the Tanaka and Johnsons predicted values and actual measurements of mesio-distal widths of maxillary and mandibular permanent canine, first and second premolars for the total sample

Prediction Method	Mean actual width ±SD* (mm)	Mean predicted width ±SD* (mm)	Absolute mean difference ±SD* (mm)	t – value	p – value.
Maxillary	21.49±1.23	22.25±1.46	-0.76±0.98	-10.01	0.000*
Mandibular	21.42±1.31	21.75±1.46	-0.33±1.00	-7.35	0.000*

DISCUSSION

Tanaka and Johnson's[4] probability equation has emerged as a pivotal tool in predicting the size of permanent canines and premolar teeth based on the measurements of the mandibular four incisors. It is one of the space analysis methods used to predict the mesio-distal width of these teeth. Tanaka and Johnson developed a formula for each arch from a sample of 506 children of northwestern European descent[4]. A simple linear regression equation was derived from the relationship between the sum of the mandibular four incisors and the un-erupted canine and premolars to establish a prediction. Tanaka and Johnson[4] stated that the probability table they generated was quite similar to those of Moyers at all the percentile confidence levels. This is so because of the similarities in the studied population by both researchers. This probability equation has also been observed to be the quickest and easiest method of space analysis employed today[6]. However, the standard errors of estimate for the correlation were rather high (0.86 mm for the maxillary teeth and 0.85 mm for the mandibular teeth)[8]. Understanding their application within the Nigerian population is essential, given the unique demographic, ethnic, and morphologic variability that characterizes the Nigerian nation.

In the current study, Tanaka and Johnson's probability method overestimated the mesio-distal width of the canine and premolars. This observation was also found in a similar study[10] in a Syrian population but at variance with what was reported by Ajayi[14] in a similar study among samples obtained from the south-south and south-eastern part of Nigeria, where he observed that Tanaka and Johnson's probability equation table underestimated the mesio-distal width of the un-erupted canine and premolars for both the mandible and maxillary teeth especially when the sum of the mesio-distal width of the mandibular incisors are less than 23mm. However, other global studies[11,12,13] all reported that the equation was not applicable in their respective populations and thus had to develop new simple linear regression equations for each of these populations.

The importance of a fairly accurate prediction of the un-erupted permanent teeth in a mixed dentition individual is centered on making an appropriate treatment plan, and this could be whether to treat, not to treat, or the type of treatment that will be most appropriate for the case at hand which will be based on the outcome of the space analysis. The space management protocol will likely be significantly affected if it is based on an incorrect estimation of the unerupted tooth sizes, ultimately resulting in poor treatment outcomes.

Other studies [2,4,5] on prediction methods based on the measurements of the mesio-distal width of permanent mandibular incisors have reported moderate correlations. However, the correlation from Tanaka and Johnson was r = 0.648 for the mandibular teeth and r = 0.625 for the maxillary teeth. There have been variations of these correlation coefficients in the findings of different studies[7,14,19,20,21,22,] especially when these methods were applied to non–Caucasian groups.

As a result of the statistically significant overestimation of the un-erupted mesio distal width of the canine and premolars by Tanaka and Johnson's[4] equations for this current study, the development of a new probability equations specifically for the Yoruba ethnic group is advocated and this can aid achieving a better prediction of the un-erupted canine and premolars thereby improving treating choice and by extension treatment outcome for patients of mixed dentition of the Yoruba ethnic group of Nigeria.

CONCLUSION

Tanaka and Johnson's equation was found to overestimate the predictive mesio-distal width of the canines and premolars in the current study sample. The application of this equation in mixed dentition cases in Nigeria could prove valuable in orthodontic treatment planning. While this tool has proven effective in some studies, challenges remain in data quality and ethnic variation in dental morphology, underscoring the need for localized research. A longitudinal study that enhances understanding of mixed dentition in a diverse Nigerian population is advised.

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