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Literature review on the applicability of Tanaka and Johnston's predictive analysis of the mesio-distal size of unerupted permanent canines and premolars in Africa

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ABSTRACT

The Tanaka-Johnston analysis is a widely adopted orthodontic method for predicting the mesio-distal widths of unerupted permanent canines and premolars based on the dimensions of mandibular incisors. Despite its popularity, the method was developed using data from Caucasian populations, raising concerns about its accuracy and relevance for individuals from other ethnic backgrounds, including African populations. This literature review aims to evaluate the validity and applicability of the Tanaka-Johnston analysis for African populations. The goal is to determine whether this method provides reliable estimates for mixed dentition analysis in these populations and to identify any necessary modifications or alternative predictive equations. A systematic literature search was conducted using PubMed, Google Scholar, and Scopus. Keywords used included: *Tanaka-Johnston analysis*, *mixed dentition*, *canine premolar width*, and *Africa*. Inclusion criteria comprised studies that directly assessed the applicability or accuracy of the Tanaka-Johnston method in African populations. Studies focusing on non-African populations or not evaluating the Tanaka-Johnston analysis were excluded. The review included several studies from various African countries. Findings revealed variability in the accuracy of Tanaka-Johnston predictions across different African ethnic groups. Some studies reported overestimation or underestimation of tooth sizes, indicating that the original regression equations may not be universally applicable. Several authors proposed population-specific adjustments or alternative equations to improve predictive accuracy for African children. Although the Tanaka-Johnston analysis remains a valuable tool, its unmodified use in African populations demonstrates limited accuracy. Ethnic variability in tooth size necessitates the development or adaptation of population-specific predictive models to ensure accurate orthodontic assessment and treatment planning. Future research should focus on developing and validating such models tailored to diverse African demographics.

INTRODUCTION

Mixed dentition analysis is a critically important diagnostic step in orthodontics. It enables clinicians to assess the space available for the eruption of permanent teeth and to detect, at an early stage, any disproportion between tooth size and arch length (El-Sayed & El-Housseiny, 2014). Accurate assessment of these parameters is essential to guide the orthodontic treatment plan—whether this involves eruption guidance, serial extractions, space management, or regular monitoring of the patient's dental development (El-Sayed & El-Housseiny, 2014). The early identification and management of space discrepancies can help prevent the development of complex malocclusions that may require more extensive interventions during the permanent dentition phase (Proffit, 2003).

Among the methods of mixed dentition analysis, the Tanaka and Johnston analysis—developed in 1974—is recognised globally for its simplicity and clinical utility (Tanaka & Johnston, 1974). Initially based on data from a Northern European population, this method has gained wide acceptance. It relies on a correlation between the mesio-distal widths of the four permanent mandibular incisors and the combined widths of the unerupted permanent canines and premolars in each quadrant. Its popularity stems largely from its non-invasive nature and ease of application in clinical settings.

However, it is now well established that significant variations in tooth size exist among populations, including racial, ethnic, and sex-based differences (Irish & Kenyhercz, 2018). These inherent differences challenge the universal applicability of prediction methods developed from specific population samples, particularly when those samples are ethnically distinct (Irish & Kenyhercz, 2018). As such, it becomes imperative to conduct population-specific studies to evaluate the validity and accuracy of the Tanaka and Johnston analysis in African populations—populations known for their considerable genetic diversity and unique odontometric characteristics.

This review explores the relevance of the Tanaka and Johnston analysis within African contexts. A literature search will be conducted using the keywords *Tanaka Johnston analysis*, *mixed dentition*, *canine premolar width*, and *Africa* in databases including PubMed, Google Scholar, and Scopus. Studies evaluating the applicability or accuracy of the method in African populations—regardless of publication date—will be included. Studies not involving African populations or not evaluating the Tanaka and Johnston analysis will be excluded. The analysis will synthesise the findings, highlighting ethnic variations and identifying research gaps.

The aim of this literature review is to comprehensively examine studies assessing the application and validity of the Tanaka and Johnston analysis for predicting the mesio-distal widths of unerupted permanent canines and premolars in African populations. It will explore the method's basis, variations in tooth size within these populations, the accuracy of its application in this context, proposed modifications, and its implications for orthodontic treatment planning in African patients.

METHODOLOGY OF THE TANAKA AND JOHNSTON ANALYSIS

The Tanaka and Johnston analysis is a non-radiographic method used to estimate the space required for the eruption of permanent canines and premolars during the mixed dentition phase (Tanaka & Johnston, 1974). It involves the precise measurement of the mesio-distal widths of the four permanent mandibular incisors—that is, the distance between the proximal contact points of each incisor.

Based on these measurements, the combined widths of the canines and premolars in each hemi-arch are predicted using empirical formulas. For the mandibular arch, the formula is: **Estimated canine and premolar width** = *(mesio-distal width of the four mandibular incisors ÷ 2) + 10.5 mm*. For the maxillary arch, the formula is slightly different: **Estimated canine and premolar width** = *(mesio-distal width of the four mandibular incisors ÷ 2) + 11.0 mm*. To obtain the estimated total width for both sides of the arch, this value is simply doubled.

The choice of the mandibular incisors as the basis for prediction is not arbitrary. Tanaka and Johnston postulated a strong correlation between the size of these early-erupting, dimensionally stable teeth and the size of the unerupted permanent canines and premolars that follow. This approach differed from that of Moyer, whose analysis relied on probability tables. Tanaka and Johnston argued that Moyer's confidence intervals had not been sufficiently

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validated by independent studies (Tanaka & Johnston, 1974).

A key advantage of the Tanaka and Johnston analysis is its non-radiographic nature. Unlike other mixed dentition analysis methods that require radiographic imaging to estimate the size of unerupted teeth, this method only requires the use of a caliper to measure the mandibular incisors—either intraorally or on dental models (Tanaka & Johnston, 1974). This simplicity and speed make it a practical tool for initial orthodontic assessment without subjecting patients to unnecessary radiation exposure.

TOOTH SIZE VARIATIONS IN AFRICAN POPULATIONS

It is widely documented in the orthodontic literature that tooth size is not uniform across the human species, and that it shows significant variation based on racial origin, ethnicity, and gender. Sexual dimorphism, characterised by generally larger teeth in males than in females, is a widely observed phenomenon in many populations, including African populations (Abd-elgawad et al., 2023; Abuaffan et al., 2022; Irish & Kenyhercz, 2013; Khan et al., 2007; Laswai et al., 2024; Lindondo et al., 2015).

These intrinsic differences in tooth size underscore the importance of carefully examining the applicability of prediction methods developed for specific populations before applying them to other ethnic groups (Abuaffan et al., 2022; Harris & Rathbun, 1991; Laswai et al., 2024).

Several studies have explored the odontometric characteristics of African populations, revealing specific distinctions compared to other ethnic groups. For instance, individuals of African descent generally exhibit larger mesio-distal tooth dimensions than individuals of European descent (Irish & Kenyhercz, 2018; Khan et al., 2007). Research has also identified differences within African populations, with North Africans tending to have smaller teeth compared to East and Southern African groups (Irish & Kenyhercz, 2018). Within the continent, significant variation has been reported, as seen in the comparison between the Baka Pygmies of Cameroon and their Bantu neighbours (Guéguen et al., 2012; Lindondo et al., 2015).

A study conducted in Senegal reported larger canine and premolar diameters than those recorded in the original studies by Tanaka and Johnston and Moyers, suggesting the influence of racial differences. Conversely, a study on Black South Africans found that the Tanaka and Johnston equations tended to slightly underestimate tooth size in women and slightly overestimate it in men (Khan et al., 2007). Measurements conducted on Tanzanian populations revealed canine and premolar widths smaller than those in Taiwanese populations but larger than those in Northern India, Turkey, Pakistan, Malaysia, and other African countries such as Libya, Egypt, Kenya, Sudan, and Uganda (Harris & Rathbun, 1991). These observations highlight the diversity of tooth sizes within African populations and emphasise the necessity of developing population-specific prediction methods.

Tooth size variation in African populations is influenced by a complex interplay of genetic and environmental factors. Tooth size is strongly associated with ethnicity and gender, with genetic factors playing a predominant role (Harris & Rathbun, 1991). Evolutionary adaptations, including dietary changes throughout human history, have also influenced tooth size and morphology. Understanding these contributing factors is essential to properly interpret the odontometric differences observed across African populations.

EVALUATION OF THE TANAKA AND JOHNSTON ANALYSIS IN DIFFERENT AFRICAN POPULATIONS

Numerous studies have been conducted across Africa to assess the relevance and accuracy of the Tanaka and Johnston analysis in various populations. In Tanzania, one study demonstrated that the method significantly overestimated the combined width of upper canines and premolars in females, while underestimating lower jaw measurements in both sexes (Abuaffan et al., 2022; Khan et al., 2007).

In South Africa, investigations involving Black populations revealed that the methods of Moyers and Tanaka and Johnston were inadequate for predicting tooth size, as they tended to underestimate dental dimensions. One study specifically noted that the Tanaka and Johnston equation slightly underpredicted tooth size in men and slightly overpredicted it in women (Khan et al., 2007).

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In Nigeria, Ajayi (2014) found that the Moyers and Tanaka and Johnston methods had limited applicability to the local population and suggested the development of new probability tables and regression equations tailored to Nigerians. The equations were found to underestimate the mesio-distal widths of permanent canines and premolars in both arches (Ajayi, 2014).

A study conducted in Uganda also reported underestimation of permanent canine and premolar dimensions when applying the Tanaka and Johnston analysis (Buwembo et al., 2012). Similarly, research in Senegal revealed that the method overestimated the combined mesio-distal widths of permanent canines and premolars in the maxillary arch in both sexes (Diop et al., 2023).

Research in Kenya has yielded comparable findings. A 2022 study found statistically significant differences in the Tanaka and Johnston predicted values for canine and premolar widths in both men and women (Kerre et al., 2022). The study also revealed that the Tanaka and Johnston equation significantly underestimated the mesio-distal widths of these teeth (Kerre et al., 2022).

In Sudan, a study on university students reported a high prevalence of impacted canines and found that the Tanaka and Johnston method tended to overestimate mesio-distal widths. An Egyptian study also reported overestimation by the method (El-Sayed & El-Housseiny, 2014).

These results suggest that although the Tanaka and Johnston analysis is widely used, it cannot be universally applied across African populations. The accuracy of the method appears to vary significantly depending on the specific population, with a tendency toward overestimation in some regions and underestimation in others.

Analysis of these studies reveals that the accuracy of the Tanaka and Johnston analysis in African populations is often compromised, with notable discrepancies in the prediction of unerupted permanent canine and premolar sizes (Abd-elgawad et al., 2023; Abuaffan et al., 2022; Ajayi, 2014; Alzubir et al., 2016; Buwembo et al., 2012; Diop et al., 2023; El-Sayed & El-Housseiny, 2014; Guéguen et al., 2012; Kerre et al., 2022). A common finding is the overestimation of tooth size in the maxillary arch, with underestimation sometimes seen in the mandibular arch. These inaccuracies can directly affect orthodontic treatment planning, potentially leading to incorrect space assessments and inappropriate interventions.

Correlation coefficients between mandibular incisor widths and the widths of permanent canines and premolars—the foundation of the Tanaka and Johnston method—have also been studied in African populations. However, these coefficients vary by study. For example, a study in Senegal reported correlation coefficients of 0.53 and 0.70 for the maxillary and mandibular arches, respectively (Diop et al., 2023). A Tanzanian study found values ranging from 0.596 to 0.639 for the maxilla and from 0.623 to 0.65 for the mandible (Laswai et al., 2024). A Yemeni study reported coefficients ranging from 0.51 to 0.61 (Abd-elgawad et al., 2023). While these values suggest positive correlations, they differ from those observed in the original Tanaka and Johnston study, indicating potentially different relationships between incisor and posterior tooth sizes in African populations.

Table 1:
Applicability of Tanaka and Johnston's Analysis in Various African Populations

Authors	Country	Study population	Accuracy of Tanaka and Johnston's analysis	Conclusions
Laswai et al. (2024)	Tanzania	Orthodontic patients	Maxillary overestimation, mandibular underestimation	Imprecise method; new prediction equations generated
Khan et al. (2007)	South Africa	Black South Africans	Underestimation in men; slight overestimation in women	Method not fully applicable; new equations proposed
Ajayi (2014)	Nigeria	Nigerian population	Underestimation in both arches	Limited applicability; new tables and equations recommended
Diop et al. (2023)	Senegal	Senegalese population	Maxillary overestimation	Significant differences from actual values
Kerre et al. (2022)	Kenya	Kenyans of African descent	Significant underestimation	Proposed new equation including mandibular molars
Alzubir et al. (2016)	Sudan	Sudanese students	Overestimation	High prevalence of impacted canines
Abd-elgawad et al. (2023)	Egypt	Egyptian population	Overestimation	Less appropriate method for this population

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This table demonstrates that the Tanaka and Johnston analysis, originally developed for Northern European populations, often results in overestimation and/or underestimation of tooth size in various African populations. These discrepancies are attributable to ethnic variations in tooth size, underlining the need for population-specific predictive formulas. Accordingly, most studies recommend the generation of new regression equations tailored to each population.

MODIFICATIONS AND DEVELOPMENT OF NEW PREDICTION EQUATIONS

In response to the limitations of Tanaka and Johnston's original analysis in African populations, several studies have proposed modifications to the formulas or developed new regression equations specific to local populations. In Tanzania, for instance, researchers generated new sex-specific and arch-specific prediction equations to improve accuracy in estimating the size of unerupted permanent canines and premolars (Kerre et al., 2022). Similar efforts in South Africa led to the creation of new regression equations for Black South African populations, acknowledging that the original method tended to underestimate male and slightly overestimate female tooth sizes (Khan et al., 2007).

In Nigeria, Ajayi (2014) highlighted the limited applicability of existing formulas and proposed new probability tables and regression equations based on the odontometric characteristics of Nigerians. More recently, in Kenya, a study suggested incorporating the widths of both mandibular incisors and permanent first molars into a new predictive equation for improved accuracy (Kerre et al., 2022).

These revised regression equations take into account the specific tooth size characteristics observed in various African populations, thereby reducing prediction errors associated with using Tanaka and Johnston's original formulas. Using such population-specific equations could enable more precise orthodontic treatment planning suited to African patients.

Importantly, the constants and coefficients in these new equations vary across populations, reflecting intrinsic differences in tooth size. This variability suggests that no single predictive equation is universally applicable across the continent, and further research is needed to develop even more targeted tools for homogeneous population subgroups within Africa.

ORTHODONTIC TREATMENT PLANNING IN AFRICA

The direct application of Tanaka and Johnston's original analysis in African clinical contexts is significantly limited (Alzubir et al., 2016). Since the method was based on Northern European populations, using it indiscriminately in Africa can result in inaccurate estimations of unerupted canine and premolar sizes. These errors could lead to incorrect assessments of tooth-arch discrepancies, thereby affecting decisions regarding serial extractions or space management (El-Sayed & El-Housseiny, 2014; Proffit, 2003).

Orthodontists practicing in Africa must be aware of these limitations and cautious when using the Tanaka and Johnston analysis for treatment planning. Employing newly developed regression equations that incorporate population-specific odontometric traits is strongly recommended. These tailored methods enable more accurate diagnosis and predictable outcomes, improving the overall quality of orthodontic care.

The high prevalence of impacted canines and premolars in Africa further underscores the need for precise prediction methods. Estimates of impacted canine prevalence range from 2% to 5.35% (Mustafa & Abuaffan, 2014). Maxillary canines are more frequently affected than mandibular canines (Alhumaid et al., 2020; Diop Ba et al., 2008; Fardi et al., 2011; Mustafa & Abuaffan, 2014; Selmani et al., 2024; Shah et al., 2014; Topkara & Sari, 2012). Although rarer, premolar impactions have also been documented (Alhumaid et al., 2020; Diop Ba et al., 2008; Fardi et al., 2011; Mustafa & Abuaffan, 2014; Selmani et al., 2024; Shah et al., 2014; Topkara & Sari, 2012).

In such cases, accurate prediction of unerupted tooth size is essential to assess whether sufficient space exists for spontaneous eruption or whether orthodontic space-opening procedures are needed. Hence, reliable, population-sensitive prediction models are critical for effective management of tooth impactions, minimising complications such as root resorption or space loss.

Limitations of This Review

As a narrative review, this study may be subject to selection bias. The lack of exhaustive search procedures and the absence of formal quality assessments for the included studies may have influenced the findings. Variability in methodologies among African studies complicates synthesis, and limited region-specific data restrict generalisability. These constraints preclude meta-analysis and robust statistical conclusions.

Suggestions for Future Research

Future research should focus on longitudinal primary studies across diverse African populations to develop highly specific prediction equations. The integration of 3D imaging and artificial intelligence (AI) technologies could enhance accuracy. Additionally, assessing the influence of genetic and environmental factors is crucial. A systematic comparison of Tanaka and Johnston's method with alternative approaches will help identify the most contextually appropriate solutions.

CONCLUSION

In conclusion, although the Tanaka and Johnston analysis is widely used for predicting the size of unerupted permanent canines and premolars, its direct application to African populations is limited due to ethnic variation in tooth size. Studies across the continent consistently demonstrate inaccuracies, with a tendency toward overestimation in some populations and underestimation in others. Therefore, orthodontists in Africa should apply the method cautiously and be aware of its potential inaccuracies.

Improving orthodontic care in Africa requires the development and use of prediction equations specific to each population group, considering their unique odontometric features. Large-scale regional studies, accounting for variables such as age and sex, are essential to enhance the precision and clinical utility of predictive tools.

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