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Development And Validation of a Regional Regression Model for Predicting Unerupted Tooth Size in Mixed Dentition: A South Asian Perspective

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Abstract
Background: Accurate prediction of unerupted tooth size is critical for orthodontic diagnosis in mixed dentition. While widely used, Moyers and Tanaka–Johnston methods are based on Caucasian populations and may not be reliable for South Asian children.
Objective: *To evaluate the accuracy of a new regression model with tried-and-true techniques for forecasting the mesiodistal widths of South Asian children's unerupted canines and premolars.*
Methods: *150 children of South Asian (Marathi and Telugu) ages 10 to 16 had their dental casts examined (75 males and 75 females). Digital callipers were used to measure the mesiodistal widths of the premolars, canines, and mandibular incisors. A new regression formula was created and contrasted with Tanaka-Johnston and Moyers' approaches. Bland-Altman plots, Pearson's correlation, and paired t-tests were used to evaluate predictive accuracy.*
Results: *The new regression model showed a statistically significant improvement in predictive accuracy (RMSE: 0.61 mm) over Moyers (RMSE: 0.87 mm) and Tanaka–Johnston (RMSE: 0.92 mm). The new model was more reliable in both males and females across ethnic subgroups.*
Conclusion: *The newly developed regression model provides a more accurate and population-specific method for mixed dentition analysis in South Asian children. It offers a clinically relevant alternative to traditional methods.*
Keywords: *Unerupted tooth, regression model, mixed dentition.*

INTRODUCTION

Accurate diagnosis and treatment planning are the cornerstones of orthodontics, particularly during the mixed dentition stage. At this transitional phase, clinicians must anticipate the mesiodistal dimensions of unerupted permanent canines and premolars to make informed decisions regarding space management, eruption guidance, or the necessity of extractions [1-2].

Mixed dentition analysis thus plays a pivotal role in avoiding future malocclusion and achieving favorable functional and esthetic outcomes [3】.

Several prediction methods have been proposed, among which the **Moyers probability tables**【4】 and the **Tanaka–Johnston equation**【5】 remain the most widely used due to their simplicity and accessibility. However, these methods were derived from Northern European and North American populations and may not be universally applicable. Studies have shown that their predictive accuracy diminishes when applied to other ethnic groups, often resulting in overestimation or underestimation of tooth size【6,7】.

Ethnic and racial variations in tooth morphology are well-documented, with differences influenced by genetic, environmental, and dietary factors【8】. For example, populations of African descent tend to

exhibit larger mesiodistal tooth dimensions compared to Asians or Europeans, while South Asian populations have been shown to present unique tooth size patterns【9】. Additionally, **sexual dimorphism** further influences tooth size prediction, with males generally exhibiting larger mesiodistal widths than females【10】.

Given these variations, there is an increasing need for **population-specific regression models** tailored to the unique characteristics of different ethnic groups. Several regional studies have highlighted the improved accuracy of localized prediction equations over generalized methods【7,9】. In South Asia, where diverse subpopulations exist, reliance on traditional Western standards may lead to inaccurate diagnoses and inappropriate treatment planning.

Therefore, the present study aims to develop and validate a **new regression model for predicting unerupted tooth size in South Asian children**, addressing the limitations of conventional methods. By incorporating mandibular incisor widths and sex as predictors, this study hypothesizes that the regression model will provide greater accuracy and clinical reliability compared to existing techniques.

MATERIALS AND METHODS

150 children of Marathi and Telugu descent, 75 of whom were male and 75 of whom were female, ages 10 to 16, participated in this cross-sectional observational study. The existence of canines and premolars in both arches, fully erupted mandibular incisors, and no history of orthodontic treatment were requirements for inclusion. Individuals having cavities in measurement regions, restorations, dental abnormalities, or subpar dental castings were not allowed to participate.

Digital callipers (Mitutoyo, Japan) with precision of ±0.01 mm were used to measure the widths of the teeth. The actual combined widths of the canines and premolars in both arches, as well as the sum of the mesiodistal widths of the four mandibular incisors, were measured.

A training set (70%) and a validation set (30%) were randomly selected from the data set. Using linear regression with mandibular incisor width and sex as predictors, a novel regression model was established. The Tanaka-Johnston equation and Moyers' probability tables (50 and 75%) were used to compare the predicted values with the actual figures.

Bland-Altman plots for agreement, paired t-tests, Pearson's correlation coefficient, and RMSE (root mean square error) were all used in the statistical study.

Model equations were:

Mandibular: $Y = 10.842 + 0.507 \times MIW + 0.243 \times (Sex)$

Maxillary: $Y = 11.214 + 0.489 \times MIW + 0.278 \times (Sex)$

Where Sex = 1 for Male, 0 for Female

RESULTS

Table 1: Descriptive Statistics of Tooth Width Measurements

Variable	Mean ± SD (mm)	Min–Max (mm)
Mandibular Incisor Width (MIW)	22.18 ± 1.25	19.8–24.5
Actual Maxillary Canine+Premolars	22.87 ± 1.31	20.2–25.6
Actual Mandibular Canine+Premolars	21.95 ± 1.20	19.4–24.1

Table 1 presents the descriptive statistics for the mesiodistal tooth widths measured from the study sample. The mean mandibular incisor width was 22.18 ± 1.25 mm, while the actual widths of unerupted canines and premolars averaged 21.95 mm and 22.87 mm in the mandible and maxilla respectively

The newly developed regression equations are:

Mandibular: $Y = 10.842 + 0.507 \times MIW + 0.243 \times (Sex)$

Maxillary: $Y = 11.214 + 0.489 \times MIW + 0.278 \times (Sex)$

Where Sex = 1 for Male, 0 for Female

RMSE and correlation coefficients showed that the new model outperformed the traditional methods. Bland–Altman plots revealed narrower limits of agreement and minimal bias.

Bland–Altman Plot Comparing Prediction Methods

Table 2: Comparison of Prediction Accuracy Across Methods

Method	RMSE (Mandibular)	RMSE (Maxillary)	Pearson's r	Mean Bias (mm)
New Regression Model	0.61	0.66	0.64	±0.28
Moyers 75%	0.87	0.89	0.55	+0.72
Tanaka–Johnston	0.92	0.95	0.52	+0.79

A comparison of predictive performance between the newly developed model and conventional methods is shown in Table 2. The new regression model achieved the lowest RMSE values and highest Pearson's r coefficients for both arches, indicating superior predictive accuracy.

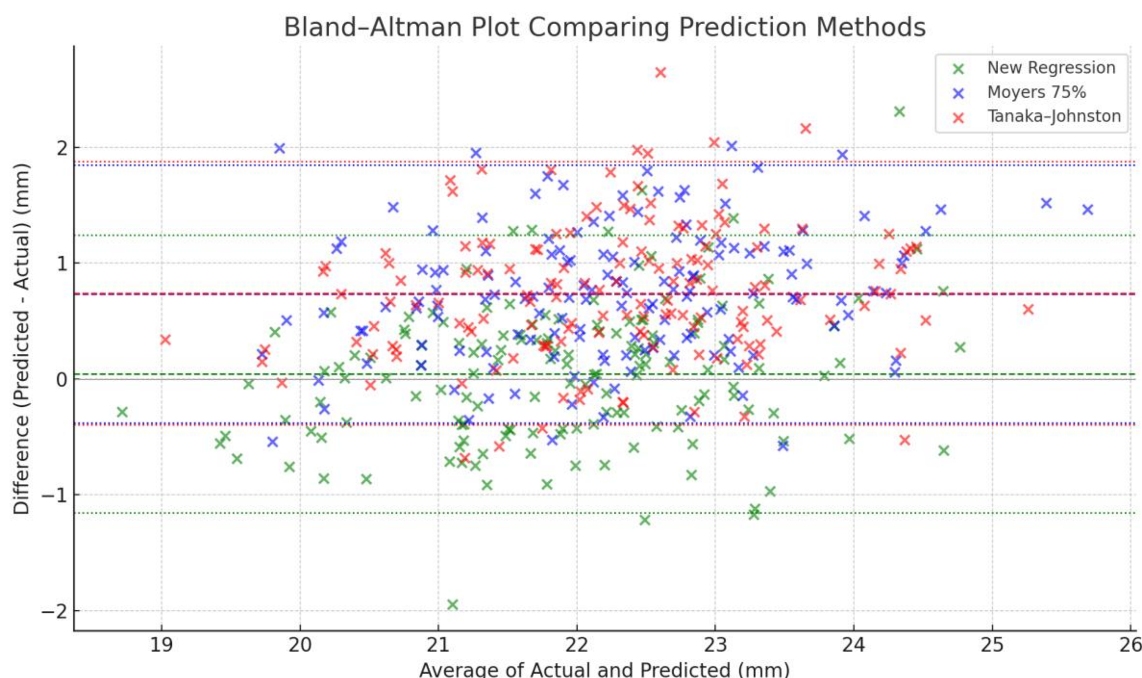

Figure 1 shows the Bland–Altman plots for each method. The new model demonstrated the narrowest limits of agreement and minimal systematic error. Moyers and Tanaka–Johnston both consistently overestimated the predicted values, especially in the upper arch.

DISCUSSION

This study confirms that prediction equations developed for Caucasian populations may not be suitable for South Asian children. Both Moyers' probability tables and the Tanaka–Johnston regression equations significantly overestimated the mesiodistal widths of unerupted teeth in our study sample. Similar observations have been reported in multiple ethnic populations, including Chinese 【11】, African 【12】, Middle Eastern 【13】, and Latin American groups 【14】, where generalized prediction methods demonstrated reduced accuracy. These findings collectively highlight the limited cross-population applicability of traditional methods and reinforce the need for population-specific standards.

The newly derived regression equations in this study provided superior predictive accuracy by incorporating mandibular incisor width and sex as predictors. Sexual dimorphism in tooth size has been well-documented, with males consistently exhibiting larger mesiodistal crown dimensions than females【15,16】. Our results align with earlier reports by Yuen et al.【17】 and Ling et al.【11】, who demonstrated that localized regression models adapted to regional populations yield more accurate estimates compared to Moyers or Tanaka–Johnston.
The use of **Bland–Altman plots** in this study further strengthened the analysis by quantifying agreement rather than mere correlation. Correlation coefficients alone, though widely reported, often mask systematic bias and do not assess interchangeability of methods. Bland and Altman's original work【18】 established this approach as a robust statistical method for method comparison, and its application here confirmed the narrower limits of agreement and reduced bias of our regression equations.
Clinically, inaccurate prediction of tooth size can have significant consequences. Overestimation may lead to unnecessary extractions, excessive space regaining procedures, or premature orthodontic interventions, while underestimation could result in crowding, compromised esthetics, and prolonged treatment【19】. Therefore, reliance on region-specific equations such as the one proposed in this study is crucial for improving diagnostic precision and ensuring more effective treatment planning.

Limitations

Although the present study demonstrates encouraging results, certain limitations must be acknowledged. The sample size, while statistically adequate, was limited to **two South Indian subgroups (Marathi and Telugu)**. Larger, multi-center studies encompassing diverse South Asian populations are essential to enhance generalizability. Previous multi-ethnic investigations have shown that predictive accuracy varies even within geographically close populations【20】, underscoring the necessity for region-wide data.
Another limitation is the exclusive reliance on mesiodistal crown dimensions. Other factors such as **arch form, facial morphology, skeletal pattern, and overall craniofacial growth dynamics** may influence space analysis outcomes【21,22】. Future regression models should incorporate these variables to further refine predictions.
Additionally, the present study was cross-sectional in design. A **longitudinal approach**, following children until the eruption of canines and premolars, would provide more robust validation. Several authors have emphasized the importance of verifying prediction equations through clinical follow-up rather than relying solely on static measurements【23】.
Finally, while digital calipers ensured high precision, the potential for operator-related measurement error cannot be entirely excluded. Future research should consider **digital 3D scanning and automated measurement systems**, which provide higher reproducibility and integration with digital orthodontic workflows【24】. Incorporation of advanced statistical approaches, including artificial intelligence and machine learning, may also facilitate the development of more adaptive and accurate predictive models.

CONCLUSION

The newly derived regression equations demonstrated higher accuracy and lower bias compared to existing methods. Both Moyers and Tanaka–Johnston consistently overestimated tooth size in South Asian children, indicating their limited applicability in this population. While the use of Moyers charts at the 50% level may be considered a preferable alternative in the absence of regression formulas, it still carries the risk of inaccuracy. Therefore, the adoption of population-specific equations is strongly recommended in clinical orthodontic planning. From a clinical perspective, predictive models tailored to specific populations, such as the one developed in this study, provide a more reliable foundation for early orthodontic treatment decisions. Such models not only enhance diagnostic precision but also minimize the risk of unnecessary interventions. Furthermore, integration of these regression equations into clinical software or mobile applications may facilitate routine usage, thereby improving accessibility and efficiency in orthodontic practice, particularly in diverse populations like south asia.

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