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Analyzing Tonn's formula for predicting permanent maxillary incisor widths in a South Tamil Nadu population

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Abstract:

Given that tooth-size relationships are population-specific, the accuracy of Tonn's formula in predicting permanent maxillary incisor widths remains unverified for the South Tamil Nadu population. Therefore, it is of interest to evaluate the applicability of Tonn's formula for predicting the combined mesiodistal widths of permanent maxillary incisors in a South Tamil Nadu population. The mesiodistal tooth widths were measured by a digital Vernier calliper and the predicted maxillary incisor widths were calculated using Tonn's formula. A total of 147 pairs of maxillary and mandibular dental casts were studied of children aged 9–18 years. The measured and predicted values showed no statistical difference ($p = 0.842$), indicating total agreement between the two methods and a very strong positive correlation ($r = 0.923$, $p < 0.001$) was found between the total mesio-distal widths of mandibular and maxillary incisors, which supports the predictive validity of the formula.

Keywords: Mixed dentition analysis, Tonn's formula, incisor liability, tooth size prediction, South Indian population

Background:

Malocclusion developing during the mixed dentition period is most commonly attributed to discrepancies between the total tooth size and available arch circumference [1]. Early identification of such discrepancies is fundamental to preventive and interceptive orthodontics, as timely intervention can significantly reduce the severity and complexity of malocclusion in the permanent dentition [2]. One of the major challenges during the mixed dentition phase is the Incisor liability, wherein the erupting permanent maxillary incisors are considerably wider than their deciduous predecessors, but the space available for the permanent incisors to erupt in the dental arch does not show much change [3]. Failure to accommodate the large-sized permanent incisors in the upper anterior dental arch often results in crowding, increased overjet, or crossbite, adversely affecting aesthetics and function [4]. Mixed dentition analysis is an essential diagnostic tool that evaluates whether sufficient dental arch space exists for the eruption of permanent teeth. Based on the space discrepancy identified, treatment modalities such as serial extraction, proximal stripping, guidance of eruption, space maintenance, space regaining, arch expansion or observation may be planned [5]. Most of the mixed dentition analyses employ regression equations to predict the widths of unerupted canines and premolars so that a total space analysis becomes possible long before the eruption of permanent canines and premolars [6]. Mixed dentition analyses are done to assess if there is sufficient space for premolars and permanent canines to erupt into the dental arches during the mixed dentition phase. Once the lower permanent incisors erupt at around 6 years of age, at the beginning of the transitional period, mixed dentition analysis is used to predict the total widths of premolars and permanent canines in both arches [7]. The widths of the permanent upper incisors are usually measured once they erupt, but eruption of upper permanent lateral incisors can be delayed till about 9.5–10.5 years of age. If it is possible to predict the total

widths of upper permanent incisors using lower permanent incisor width measurements at 6 years of age, very early assessment of total space requirement for permanent upper teeth is possible [8]. Total space requirements for all the upper premolars, permanent canines and incisors can be calculated in advance. Bolton established proportional relationships between maxillary and mandibular anterior teeth, emphasizing inter-arch tooth size harmony. Paul Tonn further proposed a formula to predict maxillary incisor widths from mandibular incisor measurements [9]. However, several studies have showed that tooth-size relationships are population-specific and influenced by ethnic and racial variations [10–12]. Certain studies reported limited applicability of Tonn's formula, while other authors stressed the need for regional validation [9, 13]. Therefore, it is of interest to evaluate the accuracy of Tonn's formula in predicting total permanent maxillary incisor widths in a South Tamil Nadu population.

Materials and Methods:

This cross-sectional study included 147 pairs of maxillary and mandibular diagnostic dental casts obtained from the archives of the Departments of Orthodontics and Pedodontics, Sree Mookambika Institute of Dental Sciences, Kulasekharam, Tamil Nadu. All the casts belonged to patients of pure Tamil ethnicity and had familial roots in Kanniyakumari, South Tamil Nadu. Ethical approval was obtained from the Institutional Human Ethical Committee (SMIDS/IHEC No: 5/Protocol No: 41/2024). The inclusion criteria were fully erupted permanent maxillary and mandibular incisors, no proximal restorations, caries, or fractures and high-quality unpolished study casts without distortion. The exclusion criteria were a history of orthodontic treatment, congenital anomalies affecting tooth size, shape, number or structure, severe attrition or developmental defects. The age group of 9–18 years was selected to ensure complete incisor eruption while minimizing attrition effects.

The sample size for the present study was estimated using the formula.

$$n = [2 \times (Z_{1-\alpha/2} + Z_{1-\beta})^2 \times \sigma^2] / \delta^2$$

Where:

$$\sigma = \sqrt{(S_1^2 + S_2^2) / 2}$$

Where σ : Pooled standard deviation; S_1 : Standard deviation in the first group; S_2 : Standard deviation in the second group, based on a prior study [14]; δ : Mean difference between the groups; α : Significance level; $1-\beta$: Power; sample size=147 sets of casts (maxillary & mandibular). Henceforth, the total sample size of the study= 147.

Measurement of tooth widths:

Mesiodistal widths of permanent mandibular and maxillary central and lateral incisors were measured using a digital Vernier calliper with 0.01 mm accuracy, following the method described by Hunter and Priest. Measurements were taken at the greatest mesiodistal dimension, perpendicular to the occlusal plane. Each measurement was repeated twice by a single examiner; discrepancies ≤ 0.2 mm was averaged. Larger discrepancies were re-measured and the average of the closest two values was recorded. Intra-examiner reliability was assessed by re-measuring 10 randomly selected casts after one week. Predicted maxillary incisor widths were calculated using Tonn's formula. Direct measurements from the dental stone casts served as the gold standard for comparison.

Statistical analysis:

Statistical analysis was performed using SPSS software. Mean and standard deviation were calculated. Paired t-test compared the measured and predicted mean total widths of upper permanent incisors. Pearson's correlation co-efficient (r) assessed the interrelationship between the total mesiodistal width of lower permanent incisors and total mesiodistal widths of upper permanent incisors. $P < 0.05$ was considered statistically significant. Sum total mesiodistal widths of lower permanent incisors (Sum A) and sum total mesiodistal widths of upper permanent incisors (Sum B) were directly measured from casts using a digital Vernier calliper. Sum A was used to calculate/Predict the total mesiodistal widths of upper permanent incisors (Sum P) assuming that they haven't still erupted, using Tonn's Formula. Total mesiodistal widths of upper permanent incisors= (total mesiodistal widths of lower permanent incisors $\times 4/3$) + 0.5 mm.

Results:

Comparison of mean width of sum (B) with sum (P) showed no statistically significant difference, with a p-value of 0.842. **Table 1** illustrates the comparison between measured and predicted total widths of upper permanent incisors, which showed no statistically significant difference ($p = 0.842$; $p > 0.05$). A very strong positive correlation was observed between the total

mesiodistal widths of mandibular permanent incisors (sum A) and total mesiodistal widths of maxillary permanent incisors [sum B] ($r=0.923$). Measured maxillary incisors (Sum B): 29.97 ± 0.14 ; Predicted maxillary incisors (Sum P): 29.93 ± 0.13 ; No statistically significant difference was observed between measured and predicted maxillary incisor widths (p -value=0.842). Comparison of mean width of sum (A) with Sum (B) showed a statistically significant difference with a p-value of 0.001. **Table 2** shows comparison of Mandibular and Maxillary Incisor Widths. Mandibular incisors (Sum A): 22.08 ± 1.23 ; Maxillary incisors (Sum B): 29.97 ± 0.14 ; A statistically significant difference was noted, reflecting normal incisor size relationships ($p<0.001$). A very strong positive correlation was observed ($r = 0.923$).

Table 1: Comparison of mean sum (B) with Sum (P)

Groups	MEAN $\pm$ SD	p value
Sum (B)	29.97 $\pm$ 0.14	0.842
Sum (P)	29.93 $\pm$ 0.13	

$p>0.05$ shows no significant difference between B and P

Table 2: Comparison of sum (A) with sum (B)

Groups	MEAN $\pm$ SD	p value
Sum (A)	22.08 $\pm$ 1.23	0.001**
Sum (B)	29.97 $\pm$ 0.14*	

$P<0.05$ significant difference between A and B

Discussion:

The present study showed that Tonn's formula can be used to predict the combined mesiodistal widths of permanent maxillary incisors in the South Tamil Nadu population under study with a fairly good amount of accuracy. This finding contrasts with studies conducted in Middle Eastern populations that reported poor applicability [14]. Ethnic variation in odontometric characteristics has been well documented [15]. Indian and Asian population studies have shown greater reliability of traditional mixed dentition analyses when region-specific validation is performed [16, 17]. The strong correlation observed between mandibular and maxillary incisor widths in this study supports Bolton's concept of inter-arch proportionality [9, 12]. The ratio between the sum of maxillary permanent incisor widths and the sum of mandibular permanent incisor widths is similar across populations. It demonstrates relative stability because of shared developmental and functional constraints; however, small yet statistically and clinically relevant variations exist among races/ethnic groups and between sexes [1]. The proportional relationship between the sums of mandibular permanent incisors and maxillary permanent incisors is governed by several biologically conserved mechanisms. Maxillary and mandibular incisors develop under common genetic and epigenetic control, resulting in proportional tooth-size relationships rather than random dimensional variation [18]. Also, functional occlusal requirements such as efficient incisal coupling, overjet, overbite, mastication and speech require a predictable proportional relationship between maxillary and mandibular incisors [19]. According to morphogenetic field theory of Butler-Dahlberg, teeth within the same developmental field, like incisors, tend to maintain proportionality even when absolute tooth size varies

among individuals or populations [20]. These biological principles explain why proportional analyses such as Tonn's formula and Bolton's ratios function reasonably well across different populations. Despite these biological constraints, race/ethnicity, sex and population-specific growth patterns introduce measurable differences [12, 21]. Most classical proportional formulas, including Tonn's and Pont's analyses, were derived from Caucasian samples, limiting their universal applicability. Sexual dimorphism in tooth size is also well documented. Males generally present with larger teeth than females, particularly mandibular incisors, which can subtly but significantly influence the ratio even within the same ethnic group [22]. Application of Tonn's original constant without local validation may result in systematic over- or under-prediction of maxillary incisor widths. Across studies, correlation coefficients between the total widths of upper permanent incisors and total widths of lower permanent incisors are consistently high ($r \approx 0.85-0.95$). The correlation coefficient in the current study among children aged 9-18 years in South Tamil Nadu was 0.923, showing a strong positive correlation between the sums of lower permanent incisors and upper permanent incisors. However, regression slopes and constants vary among populations and small mean differences of approximately 0.3–0.8 mm may be clinically significant. Actual Mean sum of upper incisors as measured by a single examiner from 147 pairs of casts using a digital vernier calliper (B) was 29.97 mm with a standard deviation of 0.14 and the Mean predicted sum of upper permanent incisors (P) using Tonn's Formula was 29.93mm with a standard deviation of 0.13, difference being only 0.04 mm. p-value was 0.842 which was clinically insignificant showing that Tonn's formula can be used effectively to predict the total widths of upper permanent incisors in this south Tamil Nadu population.

Conclusion:

Tonn's formula is a reliable and clinically useful method for predicting permanent maxillary incisor widths in the South Tamil Nadu population under study. Its application can aid early diagnosis and interceptive orthodontic planning. Early prediction of incisor widths enables clinicians to plan preventive orthodontic interventions during the mixed dentition phase.

Advancement to knowledge:

Tonn's formula is a reliable and clinically useful method for predicting permanent maxillary incisor widths in the South Tamil Nadu population, supporting early diagnosis and

interceptive orthodontic planning. Early prediction of incisor widths can help clinicians plan preventive orthodontic interventions during the mixed dentition phase.

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