Original Article

Digital Assessment of Transverse Maxillary Arch Measurements for Predicting Arch Length: Implications for Early Orthodontic Diagnosis and Preventive Dentistry

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Abstract

Objective: The aim of this study was to investigate the possible correlation between the maxillary dental arch length and three other transverse linear measurements on three-dimensional digital models for developing a predictive model to be applied in early orthodontic diagnosis and prevention of the possible future malocclusion.

Methods: A sample of 108 digital models of maxillary dental arches was derived from the scanned images belonging to orthodontic patients aged 18 to 25 years in Sulaimani City. Transverse dimensions and arch length were digitally measured, and the data were analyzed with the Statistical Package for the Social Sciences (SPSS, V. 25).

Results: A pilot study was conducted to assess the reliability of measurements between conventional and digital methods for evaluating dental arch dimensions. The results showed no statistically significant differences between the two approaches. No significant gender differences were found in regard to the measurements. Correlation analysis demonstrated no significant relationship between dental arch length and inter-molar width (rho = 0.028, p = 0.776), inter-premolar width (rho = 0.004, p = 0.965), or inter-canine width (rho = 0.046, p = 0.638). However, significant positive correlations were observed among the three transverse arch dimensions: inter-molar and inter-premolar widths (rho = 0.687), inter-molar and inter-canine widths (rho = 0.682), and inter-premolar and inter-canine widths (rho = 0.926).

Conclusions: Within the study's limitations, no significant correlations were found between arch length and transverse linear measurements; therefore, a predictive model could not be established. Although inter-premolar and inter-molar widths showed statistically significant correlations, they did not contribute meaningfully to predicting arch length. Personalized evaluation using digital tools remains essential for accurate orthodontic planning and prevention of future malocclusion.

Keywords: *Digital dental model, Maxillary arch, Transverse dimensions, 3D analysis, Arch length prediction.*

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Introduction

Analysis of dental arch dimensions is essential in orthodontic practice to support accurate diagnosis, treatment planning, and the long-term stability of therapeutic outcomes, thereby preventing any possible malocclusion. Dental arch length is a critical parameter that influences the prevalence of malocclusion, particularly dental crowding and spacing anomalies. Accurate prediction of arch length remains complex due to the interplay of multiple factors, including individual variations in tooth size, arch width, arch form, palatal morphology, and craniofacial skeletal relationships. These variables are influenced by genetic, racial, cultural, and environmental elements, emphasizing the need for population-specific data[1-6].

A comprehensive understanding of arch dimensions provides clinicians with the ability to assess space availability, predict orthodontic treatment needs, and make informed decisions regarding extractions, expansions, or interproximal reductions. Conventionally, these assessments relied on physical impressions and plaster models. However, the evolution of dental technology has led to the widespread adoption of digital tools that offer higher accuracy, reproducibility, and convenience. The shift towards digitalization in dental practice has significantly improved diagnostic precision and workflow efficiency. Digital impressions and three-dimensional (3D) models have become increasingly preferred due to their enhanced patient comfort, reduced chairside time, cost-effectiveness, and ease of data storage and transfer[7-10].

For such systems to be effective, diverse and representative datasets are necessary. Currently, most orthodontic prediction models are derived from Western or East Asian populations, with limited data available from Middle Eastern or Kurdish populations, which may exhibit distinct craniofacial morphologies[3, 11-13].

Several studies have attempted to correlate dental arch length with transverse measurements such as inter-canine, inter-premolar, and inter-molar. While some have reported moderate to strong correlations, others found little to no association, highlighting the variability among populations and methodologies. The inconsistency in findings underscores the need for region-specific research using standardized digital protocols[14-19].

The use of intraoral scanners and advanced image analysis software enables accurate and reproducible measurements, eliminating the limitations of material distortions and manual handling errors. These digital technologies also facilitate arch symmetry evaluation, simulation of treatment outcomes, and communication among interdisciplinary teams. In addition to the integration of artificial intelligence into dental diagnostics that is revolutionizing the field[20, 21].

Despite the advancements in digital analysis and a growing body of literature on arch dimensions, no study has investigated the association between maxillary arch length and other linear dental measurements, specifically in a Kurdish population. This knowledge gap is particularly significant given the growing use of digital models.

An investigation of the utility of intercanine and intermolar widths of the maxilla in gender determination concluded that these measurements exhibit dimorphic patterns and may serve as supportive tools in forensic identification across different populations and contexts[22]. Lavelle (1972) examined variations in tooth size across different racial groups and occlusal categories, highlighting significant disparities that underscore the need for population-specific dental standards in both clinical and anthropological applications[23]. Hassanali and Odhiambo (2000) analyzed dental arch widths in a Kenyan population, reporting distinct dimensional characteristics that are essential for effective orthodontic diagnosis and culturally tailored treatment planning[24]. In parallel, Mangano et al. (2022) conducted a narrative review on the role of intraoral scanners in modern dentistry, emphasizing their accuracy, reproducibility, and patient-centered advantages over traditional impression techniques[25]. These findings collectively demonstrate the importance of considering anatomical, demographic, and technological factors when assessing dental arch dimensions.

This study aimed to evaluate the correlation between maxillary arch length and transverse linear measurements. Establishing such correlations can provide a foundation for developing population-specific predictive models.

Materials and methods

Sample Selection

This cross-sectional study analyzed 3D digital images acquired through intraoral scanning using a Medit i700 Wireless scanner. The images were collected from patients aged 18 to 25 years (considering the skeletal maturity) attending orthodontic clinics in Sulaimani City. Sample size calculation, conducted using G*Power software (version 3.1), indicated a minimum of 108 images based on a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, power = 0.80, and three predictors. Out of 112 scans, 108 were included in the analysis.

Scanning procedure

Intraoral scanning was performed using the Medit i700 scanner according to a standardized protocol to ensure methodological rigor and reproducibility. Patients were positioned in an upright seated posture with the occlusal plane aligned parallel to the floor, and instructed to remain motionless throughout the procedure. The scanning sequence commenced with the maxillary arch, followed by the mandibular arch, and concluded with the buccal scan to record the occlusal relationship.[26-28]

To minimize operator-dependent variability, all scans were conducted by calibrated personnel. Scan quality was evaluated based on predefined criteria, including complete surface coverage, absence of stitching artifacts or voids, and clear visualization of key anatomical structures. Any scans failing to meet these quality control standards were repeated to ensure the accuracy and reliability of the digital data. Medit Design software was used which allows precise measurement of distance, area, and angles on 3D models.

Inclusion Criteria

The 3D models of the scanned images were selected for the investigation according to the following criteria:

-Complete permanent dentition (excluding third molars) without extensive dental caries that may affect the readings

- Class I dental and skeletal relationships from the clinical records

- No more than mild dental crowding indicated by the clinical records

- Absence of systemic or congenital diseases affecting craniofacial development

- No previous orthodontic treatment or trauma

- A self-reported Kurdish ancestry for at least three generations

Exclusion criteria

Patients who declined to provide informed consent, those with distorted or low-quality digital scans, and patients with esthetic or restorative dental treatments that significantly modified the natural morphology, size, were excluded from the study

Measurements: Each maxillary 3D model of dental arch was prepared for measurement by first trimming any excess borders, followed by proper alignment along the X, Y, and Z axes. The occlusal plane and midline were then adjusted, and specific anatomical landmarks were identified on each tooth. The model bases were constructed in accordance with the standards of the American Board of Orthodontics (ABO). Subsequently, the necessary data were generated using the designated software. The selected parameters were chosen based on their potential impact on the overall arch length and alignment. The following measurements were obtained from the 3D digital models:

- Inter-molar width (IMW): Distance between the central fossae of the first permanent molars

- Inter-premolar width (IPMW): Distance between the distal pits of the first premolars

- Inter-canine width (ICW): Distance between the cusp tips of the canines

- Upper dental arch length (UDAL): Sum of the mesiodistal widths of all teeth (linear tooth widths) from the first molar on one side to the first molar on the opposite side.

Posterior teeth were assessed occlusally, and anterior teeth were measured facially (The Mesio-distal width of the teeth was measured by tracing distances from point-to-point on the digital models). Magnification tools were used to enhance accuracy.

To ensure reliability, 10% of the cases were randomly selected and remeasured by a second examiner. Inter-examiner consistency was evaluated using Cohen's kappa (Kappa value = 1).

Ethical Considerations

Ethical approval was granted by the Ethics Committee of the College of Dentistry, University of Sulaimani (Reg. No. 750 on February, 5th 2025). Additionally, verbal informed consent was obtained from all participants prior to their voluntary involvement in the study. All data were anonymized, and the study adhered to the principles of the Declaration of Helsinki.

Pilot Study

A pilot study involving 15 randomly selected cases (not included in the main analysis) was conducted to assess the applicability of the methods and reliability of the readings. Each subject had both plaster and digital models. Blind measurements were taken conventionally using a digital Vernier caliper (Mitutoyo, Japan with accuracy: 0.01 mm) and digitally using 3D software. The two sets of readings were compared using Cohen's kappa to assess method reliability.

Statistical Analysis

Data analysis was performed using SPSS version 25. Normality was assessed with the Shapiro-Wilk test. Mann-Whitney tests compared mean ranks by gender. Correlations were analyzed using Spearman's rho. Significance was set at $p \leq 0.05$.

Results

A reliability test was done on the data from the pilot study. The results showed no significant differences between the conventional and digital methods for linear measurements of the dental arches (Table 1). No statistically significant difference was observed between the 2 readings.

The normality of data was tested by the Shapiro-Wilk test. Accordingly, the inter-molar width was the only variable with normally distributed data, while the rest were abnormally distributed (Table 2).

No statistically significant differences were detected between males and females regarding the mean ranks of the following variables: Inter-molar width ($p = 0.728$), inter-premolar width ($p = 0.332$), inter-canine width ($p = 0.397$), and dental arch length ($p = 0.936$). Accordingly, correlations were made for the whole sample (Table 3).

No statistically significant correlation was found between dental arch length and inter-molar width (rho = 0.028, $p = 0.776$) (Figure 1).

It is evident in Figure 2 that there was no statistically significant correlation between dental arch length and inter-premolar width (rho = 0.004, $p = 0.965$) (Table 3).

No statistically significant correlation was found between dental arch length and inter-canine width (rho = 0.046, $p = 0.638$) (Figure 3).

Positive statistically significant correlation was found between the following sets of variables: Inter-molar width and inter-premolar width (rho = 0.687, $p < 0.001$); inter-molar width and inter-canine width (rho = 0.682, $p < 0.001$); inter-premolar width and inter-canine width (rho = 0.926, $p < 0.001$), as presented in Table 4.

Discussion

The development and growth of the dental arches undergo a dynamic process characterized by continuous changes that influence the linear dimensions of both arches.

Advancements in digital technology now allow for accurate, safe, and relatively rapid measurements using three-dimensional (3D) models[13].

Table 1: Reliability of the data, comparing the conventional versus digital method of measurement.

Measuring method	Mean	N	Std. Deviation	p value
Conventional_IMW	43.66	15	2.82	0.104
Digital_IMW	43.80	15	2.91	
Conventional_IPMW	34.68	15	3.74	0.073
Digital_IPMW	34.93	15	3.76	
Conventional_ICW	31.46	15	2.59	0.995
Digital_ICW	31.26	15	2.67	
Conventional_UDAL	87.88	15	2.55	0.670
Digital_UDAL	87.05	15	2.47	

Table 2: Testing the normality of data.

	Shapiro-Wilk test		
Variables	**Statistic**	**df**	**p-value**
Inter-molar width	0.984	108	0.240
Inter-premolar width	0.969	108	0.013
Inter-canine width	0.959	108	0.002
Dental arch length	0.934	108	< 0.001

Table 3: The study variables by gender.

	Gender	N	Mean	SD	Mean rank	P*
Inter-molar width	Male	51	44.84	2.33	55.61	0.728
	Female	57	44.65	2.33	53.51	
Inter-premolar width	Male	51	34.30	2.83	57.59	0.332
	Female	57	33.76	2.71	51.74	
Inter-canine width	Male	51	31.90	2.75	57.20	0.397
	Female	57	31.40	2.32	52.09	
Dental arch length	Male	51	89.71	2.29	54.25	0.936
	Female	57	89.72	2.75	54.73	

Table 4: Correlations between the three independent variables of the study.

Variable Y	Variable X	rho	p-value
Inter-molar width	Inter-premolar width	0.687	< 0.001
Inter-molar width	Inter-canine width	0.682	< 0.001
Inter-premolar width	Inter-canine width	0.926	< 0.001

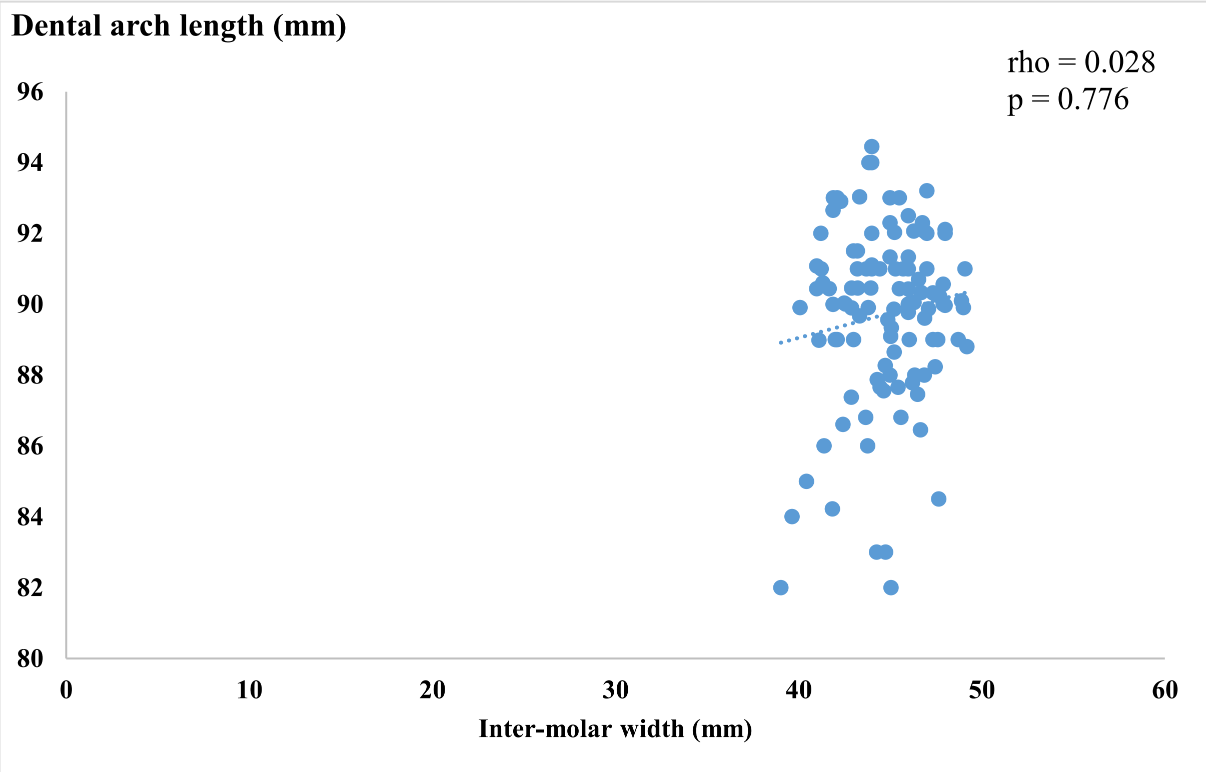

Figure 1: Correlation between dental arch length and inter-molar width.

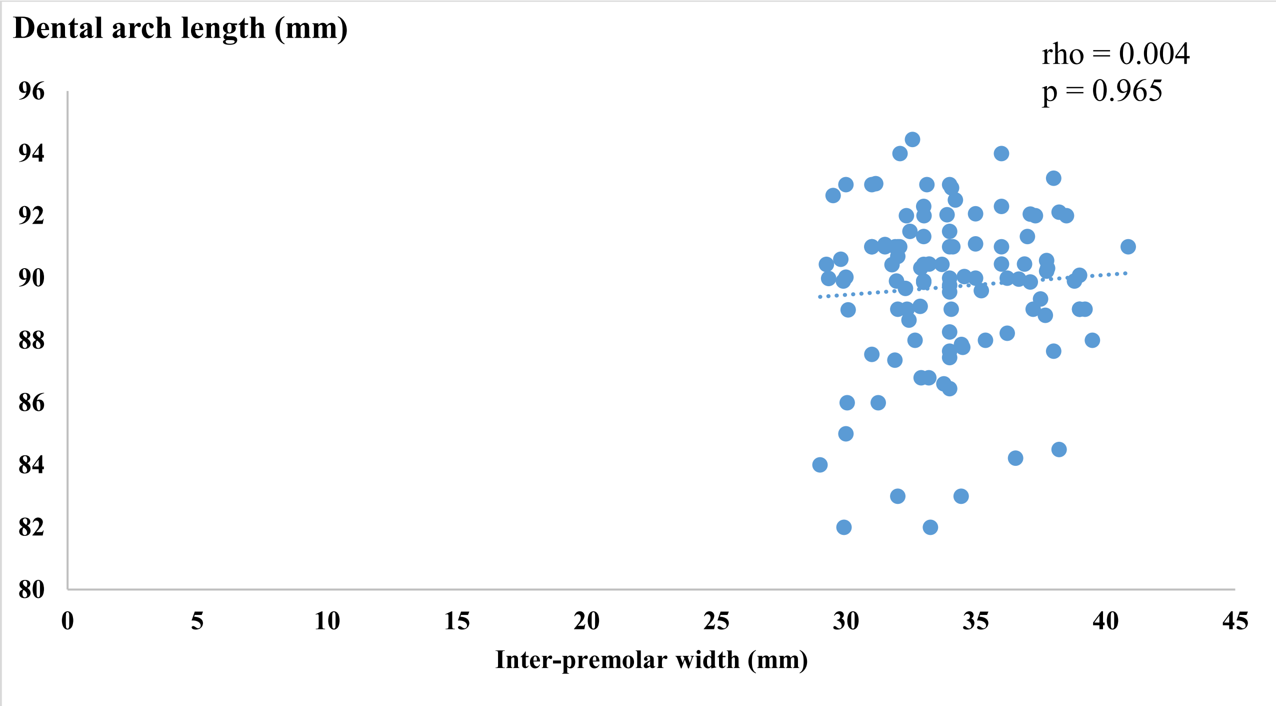

Figure 2: Correlation between dental arch length and inter-premolar width.

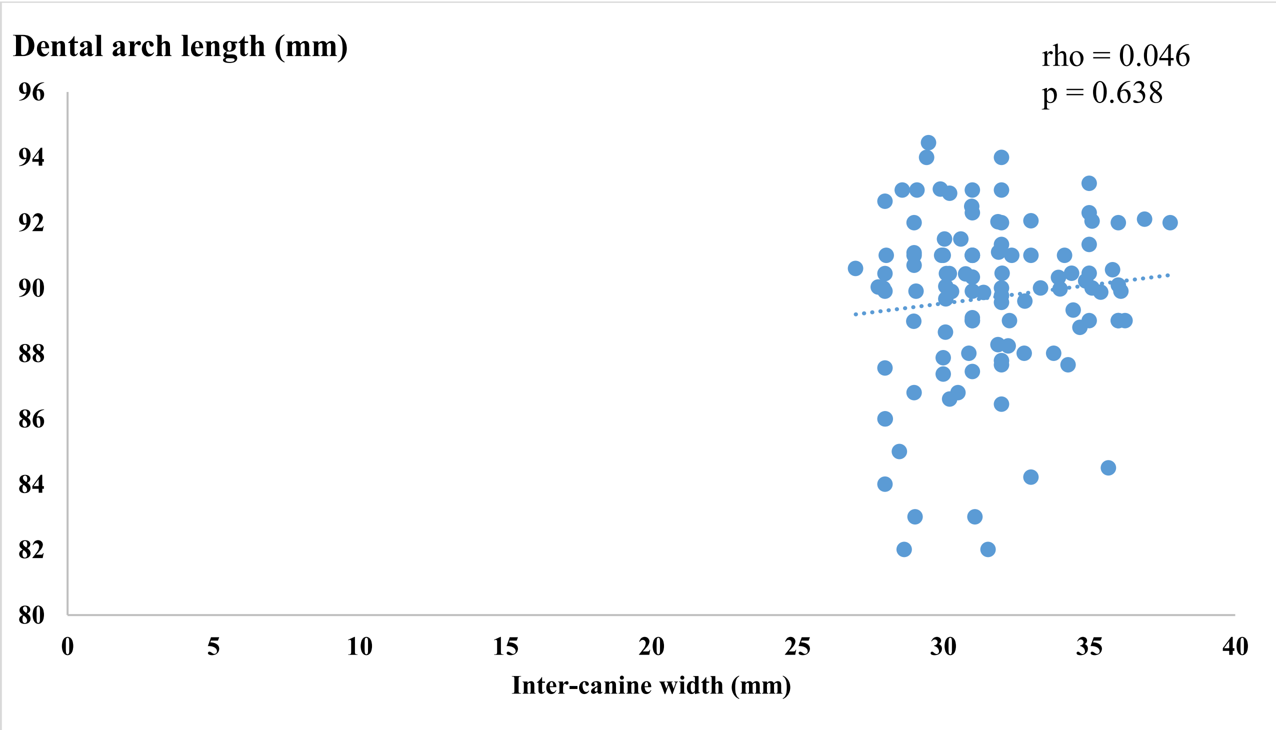

Figure 3: Correlation between dental arch length and inter-canine width.

Several authors have reported varying degrees of correlation among different dental arch measurements[4,15-17], while others have found weak or no correlations at all[14, 18]. The current findings revealed no significant correlations between dental arch length and transverse arch dimensions, particularly in terms of width measurements. This absence of correlation may be attributed to variations in growth patterns, diverse alveolar and palatal morphologies, and racial or ethnic differences.

This study explored the gender differences and inter-variable correlations. No statistically significant differences were found between males and females across the measured variables: intermolar width, interpremolar width, intercanine width, and dental arch length. These findings are consistent with previous studies that reported minimal or non-significant sexual dimorphism in transverse dental arch dimensions among late adolescents and young adults, especially when sample sizes are relatively balanced and age ranges are controlled[29,30].

The use of the Mann–Whitney U test for non-parametric comparisons further supports the validity of these findings, as it does not require standard distribution assumptions. Although some earlier studies have reported slightly larger arch dimensions in males,[28] our results suggest that gender may not play a substantial role in influencing transverse arch dimensions or dental arch length in this population.

Crucially, these results indicate that dental arch length functions independently of transverse arch parameters, challenging the previous assumption that arch width can serve as a reliable predictor of arch length[32,33]. A possible explanation for this lack of correlation lies in the complex three-dimensional curvature and geometry of the dental arch, which may not be adequately represented by linear transverse measurements alone.

Conversely, highly significant and strong positive correlations were observed among the three transverse variables themselves. Inter-premolar and inter-canine widths suggest a strong structural interdependence within the anterior-posterior segments of the arch. These findings align with previous studies that report coordinated growth and proportional relationships among the transverse dimensions of the dental arch[34,35]. This internal coherence likely reflects genetic and developmental constraints in craniofacial morphology, resulting in harmonious dimensional scaling across the transverse plane.

From a clinical standpoint, the study's findings underscore the importance of evaluating each dimension of the dental arch independently during orthodontic diagnosis and treatment planning. Comprehensive digital assessments or direct measurements are essential for accurate arch evaluation[33].

This study emphasizes three key points: (1) transverse dental measurements are strongly interrelated but do not predict arch length; (2) gender does not significantly influence these variables in the sample studied; and (3) anterior dental arch alterations have a more pronounced effect on arch length than posterior changes. Sample size, measurement artifacts, or population-specific racial characteristics may influence these outcomes.

Finally, incorporating transverse arch width measurements into routine orthodontic evaluations provides valuable clinical insight. For example, greater inter-molar width may indicate increased space availability, which can influence the decision between arch expansion and tooth extraction during treatment planning[37]. It is also noteworthy that conventional plaster models and digital models yielded comparable results[38]. Due to the absence of significant correlations in this study, regression analysis was not conducted, and consequently, no predictive equation was developed.

Study limitations

Future research using 3D digital models and larger, more diverse populations may further elucidate the spatial dynamics of dental arch morphology and refine predictive modeling for clinical applications in the field of preventive dentistry and early orthodontic practice.

Conclusion

The study concludes that maxillary arch length cannot be reliably predicted based on inter-molar, inter-premolar, or inter-canine widths alone. In the examined Kurdish population, these linear width measurements did not exhibit a significant correlation with arch length, therefore, a predictive model could not be established. Although inter-premolar and inter-molar widths showed statistically significant correlations, they did not contribute meaningfully to predicting arch length. Hence, personalized evaluation using digital tools remains essential for accurate orthodontic planning and prevention of malocclusion.

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