Original article

A study to establish a formula for predicting the mesiodistal size of permanent canines and premolars for use in space analysis

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Abstract

Background: This study was conducted to determine the correlation between the mesiodistal width of the mandibular incisor group and that of the permanent canines and premolars, thereby establishing a predictive formula for permanent tooth eruption space, applicable in space analysis. **Materials and methods:** A cross-sectional descriptive study was carried out on 200 students of Hue University of Medicine and Pharmacy. Measurements were taken directly on dental casts. The correlation between the mesiodistal widths of the mandibular incisors and the permanent canines and premolars was assessed using Pearson's correlation coefficient. Based on this, a linear regression model was developed to estimate the measurements. **Results:** The predictive formulas for the maxillary and mandibular arches are: Maxillary: Y = 0.51X + 10.25; Mandibular: Y = 0.54X + 8.74; Where: X = Mesiodistal width of the mandibular incisor group; Y = Mesiodistal width of the canine and premolar group in both arches. **Conclusion:** In clinical practice, the established regression equations can be used to estimate the eruption space of permanent teeth (canines and premolars) based on the existing mesiodistal width of the mandibular incisors.

Keywords: *Mesiodistal width of canines and premolars; space analysis.*

1. INTRODUCTION

Diagnosis and treatment planning in interceptive orthodontics during the mixed dentition stage require accurate estimation of the available space for the eruption of permanent teeth [1]. Therefore, mixed dentition space analysis methods have been established and are considered among the most effective approaches. By comparing the required space with the currently available space, space analysis allows orthodontists to estimate the alignment of teeth in the dental arch and the degree of future discrepancy. This aids in making appropriate treatment decisions for each patient, such as serial extraction, eruption guidance, space maintenance, space gaining, or periodic check-ups [2].

Several studies have shown that the total mesiodistal width of the mandibular permanent incisors is the best predictor of the combined width of the unerupted permanent canines and premolars [3], [4]. As a result, many researchers have estimated the size of unerupted permanent teeth based on the mesiodistal widths of the four mandibular incisors, such as Moyers' probability tables (1973) and the Tanaka-Johnston prediction equations (1974). Some authors have established formulas to estimate the size of unerupted permanent teeth (canines and premolars) specifically for Northern European and Caucasian populations [5, 6].

In Vietnam, researchers including Duong Tu Hanh, Van Thi Thuy Trang, Huynh Kim Khang (2016), and Cao Thuy Nhat Khanh (2020) have studied and established formulas to estimate the mesiodistal dimensions of canines and premolars in Vietnamese children. Their results demonstrated that these regression equations could provide more accurate predictions of the sizes of unerupted permanent teeth in Vietnamese children [7, 8, 9].

However, the size of each tooth varies across different ethnic groups, regions, and genders [10], leading to discrepancies among the estimation formulas from various studies. Furthermore, to enable orthodontists to predict space and plan early treatment for better outcomes accurately, it is necessary to establish region- and population-specific prediction equations or tables.

Thus, we propose the research titled: **"A study to establish a formula for predicting the mesiodistal size of permanent canines and premolars for use in space analysis"** with the following objectives:

1. To determine the average mesiodistal width of the mandibular incisors and the permanent canines and premolars in a study sample from Hue University

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of Medicine and Pharmacy.

2. To develop a formula for predicting the mesiodistal size of permanent canines and premolars for use in space analysis.

2. SUBJECTS AND METHODS

2.1. Study subjects: 200 students from Hue University of Medicine and Pharmacy.

Inclusion criteria:

- Vietnamese students of Kinh ethnicity who consent to participate in the study.
- Presence of all four permanent mandibular incisors (MI) and the permanent canines and premolars (CP) in both arches.
- Teeth are arranged relatively evenly in the dental arches.
- Permanent mandibular incisors, canines and premolars are still intact.

Exclusion criteria:

- Permanent MI and CP with restorations, proximal fillings, anomalies, or discontinuous proximal surfaces.
- Malpositioned, rotated, or supernumerary permanent MI and CP.

Study location and duration: The study was conducted at Hue University of Medicine and Pharmacy from June 2024 to August 2025.

2.2. Methods

2.2.1. Study design: Cross-sectional descriptive study.

2.2.2. Sampling method

- Sample size: The sample size was calculated using the formula n = , with : represents the standard deviation based on the study by Duong Tu Hanh et al. (2016) [7], and is the desired margin of error. The resulting sample size was n = 182. To account for potential sample loss, the sample was increased by 10%, resulting in a final sample of 200 participants.
- Sampling technique: A convenience sampling method was applied, with a male-to-female ratio of 1:1.

2.2.3. Research Instruments

- Impression materials and model-making tools (tray, bowl, alginate, dental stone).
- Mitutoyo digital caliper.

2.2.4. Data Collection

Participants underwent dental impressions and measurements of the mesiodistal width of the teeth at the Department of Odonto-Stomatology, Hue University of Medicine and Pharmacy.

Method for measuring the mesiodistal width of the tooth crown:

- The mesiodistal width of the anatomical crown is defined as the greatest distance between the contact points on the mesial and distal surfaces of the tooth crown [11].

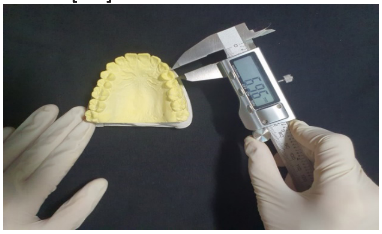

Figure 1. Measuring the mesiodistal width of the teeth under study

+ Step 1: Place the dental model on a flat surface. Identify the greatest distance between the mesial and distal surfaces of each tooth (the widest point) on a line perpendicular to the long axis or on a plane parallel to the occlusal surface using a parallelometer, and mark it with a pencil.

+ Step 2: Use a Mitutoyo digital caliper (calibrated with a precision of 0.01 mm), following the standard method of Moorrees and Reed [11]. To improve access to the interproximal space between teeth, the measuring tips of the caliper were narrowed.

+ Step 3: Align the eyes, measuring device, and light source as closely as possible to a straight line to minimize parallax error. To avoid eye strain, no more than 10 teeth were measured at one time. The teeth measured included the MI and CP.

+ Each model was measured twice, and the final result was recorded as the average of the two measurements.

- Reliability assessment of the measurements: After completing the first round of measurements for all dental casts, 20 models were randomly selected for a second round of measurements. The same steps were followed as in the first measurement, and results were recorded for comparison.

2.2.5. Research variables and evaluation methods

Table 1. Independent variables in the study

No.	Variable name	Variable type	Unit
1	Mesiodistal width of permanent mandibular central incisors: R31, R41	Quantitative, continuous	mm

2	Mesiodistal width of permanent mandibular lateral incisors: R32, R42	Quantitative, continuous	mm
3	Mesiodistal width of permanent maxillary canines: R13, R23	Quantitative, continuous	mm
4	Mesiodistal width of permanent mandibular canines: R33, R43	Quantitative, continuous	mm
5	Mesiodistal width of permanent maxillary first premolars: R14, R24	Quantitative, continuous	mm
6	Mesiodistal width of permanent maxillary second premolars: R15, R25	Quantitative, continuous	mm
7	Mesiodistal width of permanent mandibular first premolars: R34, R44	Quantitative, continuous	mm

Correlation analysis and regression modeling

- The relationship between each variable and the total mesiodistal width (MDW) of the permanent canines and premolars (CP) was analyzed using Pearson's correlation coefficient. The variables included the total MDW of the mandibular incisors (MI) and the total MDW of the canines and premolars in the maxillary and mandibular arches.

- Variables that demonstrated a strong correlation ($|r| > 0.5$) and statistical significance ($p < 0.05$) with the total MDW of the CP group were selected for inclusion in simple linear regression models. These models were developed separately for males, females, and the combined sample.

- The regression equations were formulated in the standard form: **Y = aX + b**, where:

+ **X** is the total mesiodistal width of the mandibular incisors (mm).

+ **Y** is one-half of the total mesiodistal width of the permanent canines and premolars in each dental arch (mm).

+ **a** and **b** are the regression coefficients.

2.2.6. Measures to minimize measurement error

- A sufficiently large sample size was selected to ensure statistical validity.

- Measurement procedures were standardized across all samples, standardized and calibrated measuring instruments were employed, all measurements were performed by a single examiner to reduce inter-examiner variability.

- The examiner's consistency was monitored throughout the measurement process.

- Each measurement was conducted twice, and the mean of the two measurements was recorded as the final value.

- Reliability Assessment: twenty dental models were randomly selected for a second measurement under identical conditions. The second measurement was performed after completing all first measurements to prevent bias. Paired t-tests were used to evaluate differences between the two sets of measurements.

3. RESULTS

3.1. Mean mesiodistal widths of mandibular incisors and permanent canines and premolars in the study sample from Hue University of Medicine and Pharmacy

Table 2. Mean mesiodistal widths of the mandibular incisors and the permanent canines and premolars in both arches

Mean mesiodistal widths (mm)	Male (n = 100) $\bar{X} \pm SD$	Female (n = 100) $\bar{X} \pm SD$	Total sample (n = 200) $\bar{X} \pm SD$	p-value
R31	5.51 ± 0.36	5.37 ± 0.34	5.44 ± 0.36	0.008
R32	6.12 ± 0.36	5.98 ± 0.40	6.05 ± 0.39	0.015
R41	5.50 ± 0.34	5.40 ± 0.33	5.42 ± 0.34	0.002
R42	6.12 ± 0.36	5.94 ± 0.36	6.03 ± 0.37	0.000
R13	7.97 ± 0.46	7.65 ± 0.51	7.81 ± 0.51	0.000
R14	7.46 ± 0.39	7.20 ± 0.49	7.33 ± 0.46	0.000

R15	7.04 ± 0.40	6.80 ± 0.41	6.92 ± 0.42	0.000
R23	7.92 ± 0.46	7.62 ± 0.51	7.77 ± 0.51	0.000
R24	7.47 ± 0.42	7.24 ± 0.43	7.36 ± 0.44	0.000
R25	7.05 ± 0.42	6.77 ± 0.39	6.91 ± 0.43	0.000
R33	7.06 ± 0.42	6.70 ± 0.44	6.88 ± 0.47	0.000
R34	7.33 ± 0.38	7.06 ± 0.44	7.20 ± 0.43	0.000
R35	7.38 ± 0.04	7.00 ± 0.45	7.19 ± 0.47	0.000
R43	7.03 ± 0.35	6.72 ± 0.43	6.88 ± 0.42	0.000
R44	7.28 ± 0.41	7.06 ± 0.40	7.17 ± 0.42	0.000
R45	7.30 ± 0.41	6.97 ± 0.44	7.14 ± 0.45	0.000

When analyzed by sex, the mesiodistal widths of the mandibular incisors and the mean widths of the permanent canines and premolars in both arches were consistently greater in males than in females across all measured parameters. These differences were statistically significant ($p < 0.05$).

Table 3. Measurement error between two repeated measurements

		First measurement ± SD (mm)	**Second measurement ± SD (mm)**	**p-value**
Maxilla	**Male (n = 10)**	7.440.41	7.530.57	0.211
	Female (n = 10)	7.380.43	7.310.57	0.343
	Total (n = 20)	7.410.41	7.420.55	0.698
Mandible	**Male (n = 10)**	6.730.41	6.76 0.46	0.316
	Female (n = 10)	6.64 0.52	6.660.51	0.148
	Total (n = 20)	6.680.46	6.710.47	0.135

Across both sexes and the total sample in both jaws, the results indicate that there were no statistically significant differences between the two measurement sessions (p > 0.05).

3.2. Establishing predictive equations for the mesiodistal width of permanent canines and premolars for space analysis

Table 4. Regression equations and correlation coefficients between mandibular incisors and the canines and premolars in both arches

Groups		**Regression Coefficient**		**Regression Equation**	**r**
		a	**b**		
Maxilla	**Male (n = 100)**	0.45	12.10	Y = 0.45X + 12.10	0.578
	Female (n = 100)	0.50	10.60	Y = 0.50X + 10.60	0.561
	Total (n = 200)	0.51	10.25	Y = 0.51X + 10.25	0.599
Mandible	**Male (n = 100)**	0.45	11.33	Y = 0.45X + 11.33	0.626
	Female (n = 100)	0.53	8.73	Y = 0.53X + 8.73	0.614
	Total (n = 200)	0.54	8.74	Y = 0.54X + 8.74	0.641

X: Sum of mesiodistal widths of the four permanent mandibular incisors (mm)

Y: Sum of mesiodistal widths of permanent canines and premolars in each dental arch segment (mm).

In both sexes and the total sample of the maxillary arch, the sum of mesiodistal widths of the mandibular incisors showed a positive and strong correlation with the sum of mesiodistal widths of the permanent canines and premolars, with correlation coefficients of 0.578, 0.561, and 0.599, respectively.

In both sexes and the total sample of the mandibular arch, the sum of mesiodistal widths of the mandibular incisors also showed a positive and strong correlation with the sum of mesiodistal widths of the permanent canines and premolars, with correlation coefficients of 0.626, 0.614, and 0.641, respectively

Table 5. Mean mesiodistal widths of permanent canines and premolars estimated using the established regression equations

Groups		Mean mesiodistal widths of permanent canines and premolars (mm)		p-value	Mean difference ± SD (mm)	Max difference (mm)	Min difference (mm)
		Regression equation ± SD	Direct measurement ± SD				
Maxilla	Male (n = 100)	22.11 ± 0.66	22.45 ±1.00	0.196	-0.35 ± 0.82	1.66	-3.24
	Female (n = 100)	21.80 ± 0.63	21.64 ± 1.08	0.202	0.15 ± 0.89	2.08	-3.03
	Total (n = 200)	21.95 ± 0.66	22.05 ±1.11	0.124	-0.97 ± 0.89	2.08	-3.24
Mandible	Male (n = 100)	21.79 ± 0.60	21.69 ±0.92	0.170	-0.40 ± 0.73	1.92	-2.49
	Female (n = 100)	20.73 ± 0.65	20.76 ± 1.07	0.768	0.21 ± 0.84	2.21	-3.84
	Total (n = 200)	21.13 ± 0.70	21.22 ± 1.10	0.118	-0.09 ± 0.84	2.21	-3.48

- When comparing by sex and across the total sample in both arches, the difference between the estimated mean mesiodistal width of the canine-premolar segment obtained using the newly established regression equations and the direct measurement results was not statistically significant ($p > 0.05$).

- By sex, the greatest mean discrepancy between the regression-based estimation and the direct measurement was observed in the mandibular arch of males (−0.40 ± 0.73 mm), while the smallest discrepancy was found in the maxillary arch of females (0.15 ± 0.89 mm).

- In terms of the total sample, the mean discrepancy between the regression-based estimation and the direct measurement was:

+ Maxillary arch: −0.09 ± 0.89 mm.

+ Mandibular arch: −0.09 ± 0.84 mm.

4. DISCUSSION

4.1. Determining the mesiodistal dimensions of the permanent mandibular incisors and the canine-premolar groups in the study sample at Hue University of Medicine and Pharmacy

The results in table 2 show that the mesiodistal (MD) widths of the mandibular incisors and the canine-premolar groups in males are consistently larger than those in females, with statistically significant differences ($p < 0.05$). These findings align with previous studies, both domestic (Duong Tu Hanh et al., 2016 [7]) and international (Edward R. Altherr et al., 2007 [12]; Doda Aashima et al., 2021 [13]). This consistency is reasonable, as male teeth and facial structures are generally coarser and larger than those of females [14].

Thus, tooth size is closely associated with gender. Additionally, genetic and environmental factors play a role in this size variation [10]. Therefore, when establishing regression equations to estimate the space needed for the eruption of permanent teeth, our study considers not only the overall sample but also gender-specific results to provide more accurate estimations for each group.

Regarding measurement reliability, table 3 indicates that the differences between the first and second measurements were not statistically significant ($p > 0.05$), suggesting consistency and reliability in our measurements.

4.2. Establishing regression equations to predict the mesiodistal dimensions of the permanent canine and premolar group for space analysis applications

Space analysis in the mixed dentition stage involves estimating the MD widths of unerupted permanent teeth (canines and premolars) to compare the space needed with the available arch space. According to Sivakumar Nuvvula et al. (2016), the Boston method can estimate the widths of permanent canines and premolars in the primary dentition [15]. However, this method has limited clinical value due to changes in arch size, tooth position, and angulation [16].

Several studies have demonstrated that the total MD width of the permanent mandibular incisors is a strong predictor of the total width of unerupted canines and premolars [3, 4], due to clinical advantages such as early eruption, ease of accurate measurement, and low incidence of anomalies. Therefore, we selected the mandibular incisor group for estimating the space required for permanent tooth eruption.

According to our results in tables 4 and 5:

- In both males, females, and the overall sample for the maxillary arch, the total MD width of the mandibular incisors positively and strongly correlates with the total MD width of the maxillary canine-premolar group (correlation coefficients: 0.578, 0.562, 0.599, respectively). These values are consistent with findings from Van Thi Thuy Trang et al. (2016) (r = 0.68; 0.74; 0.68) [9], Duong Tu Hanh et al. (2016) (r = 0.8; 0.7; 0.77) [7], Jamal Giri et al. (2018) (r = 0.73; 0.64) [16], See Yen Chong et al. (2021) (r = 0.45; 0.71) [17], and Sidra Abaid et al. (2022) (r = 0.739; 0.582) [18].

- For the mandibular arch in males, females, and the overall sample, the correlation coefficients are 0.626, 0.614, and 0.641, respectively. These findings align with domestic studies (Van Thi Thuy Trang et al., 2016; Duong Tu Hanh et al., 2016 [7], [9]) and international studies (Jamal Giri, 2018; See Yen Chong et al., 2021; Sidra Abaid et al., 2022 [16, 17, 18]).

The differences between our regression equations and those from other studies may stem from regional and racial variations. Since tooth size is influenced by genetic and environmental factors [10], these differences in measurement results are expected. Other contributing factors may include sample size and potential errors during impression-taking and model pouring, as well as inaccuracies in identifying the mesial and distal contact points, which can lead to MD measurement discrepancies.

Table 5 shows no statistically significant difference between the estimated and directly measured total MD widths of the canine-premolar group for both genders and the total sample in both arches. This is consistent with findings from Duong Tu Hanh et al. (2016), Van Thi Thuy Trang et al. (2016), and See Yen Chong et al. (2021) for Vietnamese and Taiwanese populations [7, 9, 17].

Therefore, we conclude that the regression equations established in this study can be used to estimate the MD widths of unerupted permanent canines and premolars in both arches. These estimates can assist orthodontists in predicting future alignment and crowding, supporting clinical decisions such as sequential tooth extraction, eruption guidance, space maintenance or expansion, and periodic monitoring.

5. Conclusion and Recommendations

In clinical practice, the regression equations developed in this study can be applied to estimate the space required for the eruption of permanent canines and premolars in children from Hue City and Central Vietnam. Further research should investigate the relationship between mandibular incisor width and the canine-premolar group in other regions or patients with various types of malocclusion in order to evaluate the applicability of these equations across a broader range of clinical scenarios.

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