Original Article

The Applicability of the Moyers, Tanaka–Johnston, and Gross–Hasund Analysis and a New Formula for the Vietnamese Population

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ABSTRACT

Aim: Our aim is to determine the applicability of other analyses and develop a new formula appropriate for the Vietnamese population. **Materials and Methods:** A cross-sectional descriptive analysis was conducted on a total of 120 dental arch samples (18–25 years old, 60 males, and 60 females) with <5 mm of tooth crowding, complete teeth on the dental arch, no missing teeth, and no fillings on the mesial or distal sides. Each study sample will be imprinted and measured using conventional as well as digital methods. **Result:** There was a significant discrepancy between the overall mesiodistal width from canine to second premolar in the maxilla and mandibular measured with electronic calipers on the cast model and the values calculated by the Moyer, Tanaka - Johnston, Gross - Hasund formulae in the mandibular, and measured by digital scanning and results calculated by the Gross-Hasund formula for maxilla and mandibular and the Moyers, Tanaka-Johnston formula for mandibular. The values obtained were compared with those calculated using the Moyers, Tanaka–Johnston, and Gross–Hasund formulae for the mandibular. Additionally, measurements were taken by digital scanning, and the results were calculated using the Gross–Hasund formula for both the maxilla and mandibular, and the Moyers and Tanaka–Johnston formulae for the mandibular. When used to estimate space analysis in the Vietnamese population, the estimation formula for each gender had greater accuracy and reliability than other widely used methods. **Conclusions:** As the central incisor and first molar are the first permanent teeth to erupt, the mesiodistal width may be readily measured. This new formula may be used to predict the width in the early stages of the mixed dentition.

Keywords: *Digital scanner, electronic caliper, mesiodistal width, the Vietnamese population*

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Introduction

As dental aesthetics become increasingly essential, the demand for orthodontics has grown in recent years, and there is a trend toward a decreasing age at which orthodontic intervention is required.[1,2] One of the most common reasons for orthodontic intervention is the misalignment of tooth and jaw sizes. Therefore, orthodontists quickly recognized the need to properly forecast tooth size and anticipate abnormal deviations.[1,3] This is the most important aspect in managing occlusion development during

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the construction of the permanent dentition. It helps address the question of whether there is enough space for replacement permanent teeth. As a result, it allows orthodontists to identify potential indications for early treatment and develop appropriate treatment plans for serial extraction, tooth eruption guidance, space maintenance, interproximal reduction, widening the space, extracting permanent teeth, or simply performing regular follow-up examinations to monitor development.[1] Simplicity, precision, and safety are critical criteria for space analysis to become a useful tool for orthodontists. As a result, various research has been conducted throughout the world to identify simple interval analysis formulae, such as the Moyers formula (1973), Tanaka–Johnston (1974), Tränkmann (1990), Backmann (1986), and Gross–Hasund (1989).[1,4] Moyers' estimation table and the Tanaka–Johnston formula are the two most widely utilized approaches.[1] Accurate prediction of the mesiodistal width of an unerupted permanent tooth plays a very important role in making a diagnosis and deciding on the start time of an orthodontic treatment plan for each case suitable.[1,5] When measuring the overall mesiodistal width from canine to second premolar, the reliability of each approach is based on two crucial indicators: the correlation coefficient and the median dimension of canine to second premolar. The higher the correlation coefficient, the more trustworthy the results. The approximated formulae' average overall dimension from canine to second premolar. If the values of digital measurements do not differ, then that formula may be used for estimating. The fast advancement of scientific and technological accomplishments, especially 4.0 technology, has infiltrated and been used in every aspect of medicine.[6,7] Few research initiatives are studying the applicability of space analysis methods for the Vietnamese population resulting from actual studies.

Materials and Methods

Study participants

Inclusion criteria include being between the ages of 18 and 25, agreeing to engage in the study, having dental arches arranged normally with tooth crowding <5 mm, having complete teeth on the dental arch, no missing teeth, and no mesial or distal fillings. Exclusion criteria for the dental arch include abnormal tooth numbers and shapes, a history of orthodontic surgery, the presence of cavities or restorations, and sensitivity to impression materials.

Study methods

A cross-sectional descriptive study was conducted on a total of 120 dental arches, using convenient sampling. Individuals participating in the research subjects underwent a general examination, took analytical impressions, and were then selected based on meeting the established standards for sampling at Can Tho University of Medicine and Pharmacy. The Can Tho University of Medicine and Pharmacy Ethics Council in Biomedical Research, under the research no. 22.332. HV/PCT-H, approved the study on August 11, 2022.

Study procedure

To begin, gather general information through intraoral and extraoral examinations, record the number of teeth in the dental arch, and complete the data collecting forms. The following steps involved taking impressions and creating a research model cast for individuals who met the sampling standards and agreed to participate in the study. Then, using a digital scanner, intraoral imprints were taken by scanning images with the Sirona Primescan-Dentsply. The patient's maxilla, mandibular, and occlusion were scanned in turns, creating virtual three-dimensional models. Then, two techniques are used for calculating tooth width. First, measurements are taken with an electronic caliper on the model cast, specifically using a Mitutoyo 500-151-30 with parameters 0–150 mm/0.01 mm (measuring range: 0–150 mm, resolution: 0.01 mm, and accuracy: ±0.02 mm). Second, a digital scanner is used. In this method, a computer with Primescan scanning software is employed to estimate the mesiodistal width of each tooth. Measurements were taken directly on the software program. Finally, data were entered into the data collecting table and analyzed using SPSS 20.0 statistical software.

Statistical analysis

The statistical analysis was performed using SPSS (version 18.0; IBM Corp., Armonk, New York). The findings of descriptive statistical analysis include mean and standard deviation of mesiodistal width measured on the model cast with an electronic caliper and measured with a digital scanner. Paired t test and Wilcoxon test were employed to evaluate the overall width from canine to the second premolar in the upper and lower, right and left segments. The t test for two independent groups (normally distributed variables) or the Mann–Whitney U test (non-normally distributed variables) was used when describing the average result. The total mesiodistal width from canine to second premolar was measured with electronic calipers on model cast, measured with a digital scanner, and calculated from different formulas using Pearson correlation (variable with normal distribution) and Spearman correlation coefficient (variable with non-normal distribution). Pearson correlation was used for variables with normal distribution, while Spearman correlation coefficient used for variables with non-normal distribution.

Results

In both males and females, the overall mesiodistal width from canine to second premolar calculated using the Moyers method exhibited a greater value in most quadrants compared to the average measurement with electronic calipers, and this difference was statistically significant ($P < 0.05$) [Table 1]. The overall mesiodistal width from canine to second premolar determined by the Moyers method displayed larger values in most quadrants in both genders than measured by digital scanner, which was statistically significant ($P < 0.05$) [Table 2]. In comparison to electronic calipers, the average total mesiodistal width from canine to second premolar calculated using the Tanaka–Johnston formula was lower in males and mean values in all quadrants and greater in females in all quadrants. This difference was statistically significant in males for the maxilla and in females for the mandibular mean value ($P < 0.05$) [Table 3]. In comparison to those measured by digital scanner, the average total mesiodistal width from canine to second premolar calculated via the Tanaka–Johnston formula was lower in males and a mean value in all quadrants and higher in females in all quadrants ($P < 0.05$) [Table 4].

The Gross–Hasund formula indicated a smaller mean total mesiodistal width from canine to second premolar in all quadrants in both genders than electronic calipers. Table 5 shows that this difference was statistically significant ($P < 0.001$). The average

Table 1: Comparison of mean overall mesiodistal width from canine to second premolar measured by an electronic caliper (group 1) and Moyers (paired *t* test)

		Group 1 (mm)	Moyers (mm)	*P*
Maxilla				
Quadrant 1	Males	23.36 ± 1.2	23 ± 0.82	0.004
	Females	22.59 ± 1.14	22.62 ± 0.73	0.764
	Mean ± SD	22.98 ± 1.23	22.81 ± 0.79	0.049
Quadrant 2	Males	23.31 ± 1.22	23 ± 0.82	0.014
	Females	22.49 ± 1.11	22.62 ± 0.73	0.24
	Mean ± SD	22.9 ± 1.23	22.81 ± 0.79	0.284
Mandibular				
Quadrant 3	Males	22.54 ± 1.13	22.66 ± 0.87	0.265
	Females	21.77 ± 1.06	22.24 ± 0.78	<0.001
	Mean ± SD	22.15 ± 1.16	22.45 ± 0.85	0.001
Quadrant 4	Males	22.5 ± 1.26	22.66 ± 0.87	0.211
	Females	21.69 ± 1.09	22.24 ± 0.78	<0.001
	Mean ± SD	22.09 ± 1.24	22.45 ± 0.85	0.001

SD, standard deviation

Table 2: Comparison of mean overall mesiodistal width from canine to second premolar measured by digital scanner (group 2) and Moyers (paired *t* test)

		Group 2 (mm)	Moyers (mm)	*P*
Maxilla				
Quadrant 1	Males	23.02 ± 1.08	22.76 ± 0.77	0.032
	Females	22.22 ± 1.16	22.35 ± 0.69	0.344
	Mean ± SD	22.62 ± 1.19	22.55 ± 0.76	0.43
Quadrant 2	Males	22.95 ± 1.14	22.76 ± 0.77	0.139
	Females	22.16 ± 1.16	22.35 ± 0.69	0.136
	Mean ± SD	22.55 ± 1.21	22.55 ± 0.76	0.998
Mandibular				
Quadrant 3	Males	22.33 ± 1.09	22.41 ± 0.81	0.507
	Females	21.61 ± 1.15	21.96 ± 0.73	0.007
	Mean ± SD	21.97 ± 1.17	22.18 ± 0.8	0.013
Quadrant 4	Males	22.38 ± 1.2	22.41 ± 0.81	0.84
	Females	21.49 ± 1.09	21.96 ± 0.73	0.001
	Mean ± SD	21.93 ± 1.23	22.18 ± 0.8	0.006

SD, standard deviation

Table 3: Comparison of mean overall mesiodistal width from canine to second premolar measured by an electronic caliper (group 1) and Tanaka–Johnston formula (paired *t* test)

		Group 1 (mm)	Tanaka–Johnston (mm)	*P*
Maxilla				
Quadrant 1	Males	23.36 ± 1.2	23 ± 0.82	0.004
	Females	22.59 ± 1.14	22.62 ± 0.73	0.764
	Mean ± SD	22.98 ± 1.23	22.81 ± 0.79	0.049
Quadrant 2	Males	23.31 ± 1.22	23 ± 0.82	0.014
	Females	22.49 ± 1.11	22.62 ± 0.73	0.24
	Mean ± SD	22.9 ± 1.23	22.81 ± 0.79	0.284
Mandibular				
Quadrant 3	Males	22.54 ± 1.13	22.66 ± 0.87	0.265
	Females	21.77 ± 1.06	22.24 ± 0.78	<0.001
	Mean ± SD	22.15 ± 1.16	22.45 ± 0.85	0.001
Quadrant 4	Males	22.5 ± 1.26	22.66 ± 0.87	0.211
	Females	21.69 ± 1.09	22.24 ± 0.78	<0.001
	Mean ± SD	22.09 ± 1.24	22.45 ± 0.85	0.001

SD, standard deviation

Table 4: Comparison of mean overall mesiodistal width from canine to second premolar measured by digital scanner (group 2) and Tanaka–Johnston formula (paired *t* test)

		Group 2 (mm)	Tanaka–Johnston (mm)	*P*
Maxilla				
Quadrant 1	Males	23.02 ± 1.08	22.76 ± 0.77	0.032
	Females	22.22 ± 1.16	22.35 ± 0.69	0.344
	Mean ± SD	22.62 ± 1.19	22.55 ± 0.76	0.43
Quadrant 2	Males	22.95 ± 1.14	22.76 ± 0.77	0.139
	Females	22.16 ± 1.16	22.35 ± 0.69	0.136
	Mean ± SD	22.55 ± 1.21	22.55 ± 0.76	0.998
Mandibular				
Quadrant 3	Males	22.33 ± 1.09	22.41 ± 0.81	0.507
	Females	21.61 ± 1.15	21.96 ± 0.73	0.007
	Mean ± SD	21.97 ± 1.17	22.18 ± 0.8	0.013
Quadrant 4	Males	22.38 ± 1.2	22.41 ± 0.81	0.84
	Females	21.49 ± 1.09	21.96 ± 0.73	0.001
	Mean ± SD	21.93 ± 1.23	22.18 ± 0.8	0.006

SD, standard deviation

total mesiodistal width from canine to second premolar calculated using the Gross–Hasund method was similarly smaller in most quadrants in both genders than measured using a digital scanner. Table 6 shows that this difference was statistically significant ($P < 0.05$).

According to the results, there was a significant discrepancy between the overall mesiodistal width from canine to second premolar measured with electronic calipers on the cast model and the values calculated by the Moyers, Tanaka–Johnston, Gross–Hasund formulae in the mandibular. Similar to the mean value, there was a strong correlation between the total mesiodistal width from canine to second premolar measured with electronic calipers on the cast model and the results estimated by the Moyers, Tanaka–Johnston, Gross–Hasund formulas in both genders [Table 7]. There was a significant correlation between mesiodistal width from canine to second premolar, measured by digital scanning, and results calculated by the Gross–Hasund formula for maxilla and mandibular, as well as the Moyers and Tanaka–Johnston formula for mandibular. Similar to the mean value, there was a strong correlation between the total mesiodistal width measured by the digital scanner and the results estimated by the Gross–Hasund formulas for maxilla and mandibular, as well as the Moyers formula and Tanaka–Johnston in the mandibular [Table 8].

The formula involves calculating X (sum of mesiodistal width from canine to second premolar of quadrants 1 and 2 in the maxilla) and Y (sum of mesiodistal width from canine to second premolar of quadrants 3 and 4 in mandibular) using both electronic calipers and a digital scanner. These recently created methods resulted in

Table 5: Comparison of mean overall mesiodistal width from canine to second premolar measured by an electronic caliper (group 1) and Gross–Hasund formula (paired *t* test)

		Group 1 (mm)	Gross–Hasund (mm)	*P*
Maxilla				
Quadrant 1	Males	23.36 ± 1.2	23 ± 0.82	0.004
	Females	22.59 ± 1.14	22.62 ± 0.73	0.764
	Mean ± SD	22.98 ± 1.23	22.81 ± 0.79	0.049
Quadrant 2	Males	23.31 ± 1.22	23 ± 0.82	0.014
	Females	22.49 ± 1.11	22.62 ± 0.73	0.24
	Mean ± SD	22.9 ± 1.23	22.81 ± 0.79	0.284
Mandibular				
Quadrant 3	Males	22.54 ± 1.13	22.66 ± 0.87	0.265
	Females	21.77 ± 1.06	22.24 ± 0.78	<0.001
	Mean ± SD	22.15 ± 1.16	22.45 ± 0.85	0.001
Quadrant 4	Males	22.5 ± 1.26	22.66 ± 0.87	0.211
	Females	21.69 ± 1.09	22.24 ± 0.78	<0.001
	Mean ± SD	22.09 ± 1.24	22.45 ± 0.85	0.001

SD, standard deviation

Table 6: Comparison of mean overall mesiodistal width from canine to second premolar measured by digital scanner (group 2) and Gross–Hasund formula (paired *t* test)

		Group 2 (mm)	Gross–Hasund (mm)	*P*
Maxilla				
Quadrant 1	Males	23.02 ± 1.08	22.76 ± 0.77	0.032
	Females	22.22 ± 1.16	22.35 ± 0.69	0.344
	Mean ± SD	22.62 ± 1.19	22.55 ± 0.76	0.43
Quadrant 2	Males	22.95 ± 1.14	22.76 ± 0.77	0.139
	Females	22.16 ± 1.16	22.35 ± 0.69	0.136
	Mean ± SD	22.55 ± 1.21	22.55 ± 0.76	0.998
Mandibular				
Quadrant 3	Males	22.33 ± 1.09	22.41 ± 0.81	0.507
	Females	21.61 ± 1.15	21.96 ± 0.73	0.007
	Mean ± SD	21.97 ± 1.17	22.18 ± 0.8	0.013
Quadrant 4	Males	22.38 ± 1.2	22.41 ± 0.81	0.84
	Females	21.49 ± 1.09	21.96 ± 0.73	0.001
	Mean ± SD	21.93 ± 1.23	22.18 ± 0.8	0.006

SD, standard deviation

Table 7: The correlation coefficient between total mesiodistal width measured by electronic caliper from canine to second premolar (group 1) and the Moyers, Tanaka–Johnston, and Gross–Hasund formula (one sample *t* test)

Group 1			Moyers	Tanaka–Johnston	Gross-Hasund
Maxilla	Quadrant 1	Males	0.648	0.673	0.798
		Females	0.67	0.676	0.728
		Mean ± SD	0.682	0.697	0.781
	Quadrant 2	Males	0.635	0.663	0.79
		Females	0.653	0.662	0.724
		Mean ± SD	0.669	0.687	0.776
Mandibular	Quadrant 3	Males	0.652	0.673	0.812
		Females	0.675	0.694	0.725
		Mean ± SD	0.688	0.704	0.786
	Quadrant 4	Males	0.611	0.628	0.772
		Females	0.632	0.647	0.726
		Mean ± SD	0.649	0.662	0.768

SD, standard deviation

Table 8: The correlation coefficient between total mesiodistal width measured by the digital scanner from canine to second premolar (group 2) and the Moyers, Tanaka–Johnston, and Gross–Hasund formula (one sample *t* test)

Group 2			Moyers	Tanaka–Johnston	Gross–Hasund
Maxilla	Quadrant 1	Males	0.519	0.548	0.709
		Females	0.524	0.535	0.627
		Mean ± SD	0.556	0.574	0.688
	Quadrant 2	Males	0.522	0.562	0.695
		Females	0.555	0.572	0.633
		Mean ± SD	0.571	0.597	0.686
Mandibular	Quadrant 3	Males	0.64	0.669	0.773
		Females	0.6	0.614	0.636
		Mean ± SD	0.647	0.665	0.724
	Quadrant 4	Males	0.57	0.594	0.736
		Females	0.6	0.617	0.681
		Mean ± SD	0.617	0.634	0.731

SD, standard deviation

Table 9: Total width from canine to second premolar on maxilla (*X*), and mandibular (*Y*) measured by electronic caliper (group 1)

Group 1		Formula	*r*
Maxilla	Males	$X = 1.3*LL6 + 8.24$	0.69
	Females	$X = 2*LR2 + 9.95$	0.687
Mandibular	Males	$Y = 1.175*LL6 + 8.9$	0.63
	Females	$Y = 2*LR2 + 9.5$	0.703

UR = upper right, UL = upper left, LL = lower left, LR = lower right; $X = ½ * (UR3 + UR4 + UR5 + UL3 + UL24 + UL5)$; $Y = ½ * (LL3 + LL4 + LL5 + LR3 + LR4 + LR5)$

Table 10: Total width from canine to second premolar on maxilla (*X*), and mandibular (*Y*) measured by digital scanner (group 2)

Group 2		Formula	*r*
Maxilla	Males	$X = 1.35*LR1 + 7.35$	0.77
	Females	$X = 2.16*LR1 + 10.5$	0.65
Mandibular	Males	$Y = 1.173*LL6 + 8.78$	0.67
	Females	$Y = 1.9*LR1 + 11.23$	0.616

UR = upper right, UL = upper left, LL = lower left, LR = lower right; $X = ½ * (UR3 + UR4 + UR5 + UL3 + UL24 + UL5)$; $Y = ½ * (LL3 + LL4 + LL5 + LR3 + LR4 + LR5)$

estimated results that were extremely similar to findings with a correlation coefficient $r > 0.6$ [Tables 9 and 10].

Discussion

The Moyers probability tables

Using both the electronic caliper and the digital scanner, the male total mesiodistal width was greater than the female total mesiodistal width in all four quadrants, with a statistically significant difference in the maxilla (from canine to second premolar in quadrants 1 and 2) between male and female ($P < 0.05$). This result matched the findings of DeVaughan.[8] In this study, the total mesiodistal width from canine to second premolar calculated by the Moyers formula was smaller than the actual measurement with electronic calipers on the male maxilla and the overall study sample, and the difference was statistically significant with $P < 0.05$. When Moyers' estimating approach was compared to real measurements using electronic calipers on model castings, this finding was identical to the results of several investigations in other races. Ravinthar and Gurunathan[9] studied 1000 children in the Indian city of Chennai, including 500 girls and 500 boys aged 11–15. They found that the Moyers method yielded lower measurements in female patients in both the maxilla and mandibular, and this difference was statistically significant with $P < 0.001$.[9] However, while measuring the maxilla in women and the mandibular in both sexes, the total mesiodistal width from canine to second premolar predicted using the Moyers method in this study produced a greater estimate than the measurement obtained with an electronic caliper on the model cast. This conclusion was also related to a study by Bhatnagar *et al.*,[10] which was done on 120 children in India, comprising 60 males and 60 girls aged 11–14 years old. In comparison to electronic caliper results, the Moyers approach tends to overstate results.[10] According to Ravinthar and Gurunathan's study[9] on 1000 children in Chennai, India, including 500 girls and 500 boys between the ages of 11 and 15 years old, the Moyers estimated method resulted in a lower amount than the actual measurement in female patients in both the maxilla and mandibular, and this difference was statistically significant with $P < 0.001$. Similar to the previously mentioned findings, when comparing the total mesiodistal width of the canine and second premolars measured by the digital scanner technique with Moyers' method, it was found that the Moyers method resulted in a lower estimate than the digital scanner method maxilla in male. In the study, the total mesiodistal width from canine to second premolar, calculated using the Moyers formula, was greater than the actual measurement using electronic calipers on a model cast when evaluating maxilla in women and measuring mandibular in both genders. This conclusion was also consistent with the findings of Bhatnagar *et al*.,[10] who performed research on 120 youngsters aged 11–14 in India, comprising 60 males and 60 girls. The Moyers approach overestimates results when compared to authentic measurement results in Ref. [9]. The difference between the value measured by the digital scanner and estimated by Moyers formula is statistically significant with $P < 0.05$ in quadrant 1 for men, quadrant 3 and quadrant 4 for women, and the total study sample. The difference in other quadrants was not statistically significant ($P > 0.05$). When the correlation coefficient of size estimated by Moyers' formula was compared to other methods, such as Tanaka–Johnston and Gross–Hasund, in this study (r ranges from 0.556 to 0.688), the research results show that Moyers' r coefficient was the lowest compared to other methods. This was similar to the results of Durgekak and Naik,[11] Wang *et al*.,[12] or Schirmer and Wiltshire.,[13] who tested the precision and dependability of the Moyers method on different populations and identified weak correlation coefficients. There were discrepancies in the conclusions regarding whether the Moyers approach overestimates or underestimates reality in this research. However, all agree that the Moyers estimating method yielded data with a low correlation with the population under study. As a result, using Moyers' approach to identify the range for comparable investigations was challenging. In our study, however, the Moyers formula, while showing a lower correlation coefficient than other methods, was still within the average limit when compared to the digital scanner measurement method, and had a strong correlation coefficient in using electronic calipers. This suggests that the Moyers formula may be applied to studies with population characteristics, individuals, and the number of samples similar to ours.

The Tanaka–Johnston analysis

The Tanaka–Johnston method was commonly used in children during the time of mixed dentition. This method has been studied by many authors and is considered by clinical practitioners to be the most useful in estimating orthodontic spaces in mixed dentition. It consists of two simple formulas and only requires minimal measurements on the model cast, unlike Moyers' method, which requires the use of the patient's radiographs or tables for predictions.[1,9,10] When the Tanaka–Johnston formula was used in the research sample, it was projected that the total mesiodistal width from canine to second premolar was smaller in males. The mean value was then compared to the value calculated using electronic calipers and a digital scanner in both the maxilla and the mandible. This was consistent with previous studies in other races, indicating that the Tanaka–Johnston method produced smaller estimations than actual measured dimensions.[14] The Tanaka–Johnson formula produced greater values than electronic calipers and digital scanners when measuring both maxilla and mandibular in females. This might be attributed to the Tanaka–Johnson formula being a common formula applicable to both sexes regardless of gender. However, as previous portions of the study have shown, there was a statistically significant difference in the mesiodistal width in both genders. When applied to a group of people in Europe, the Tanaka–Johnson approach was thought to be the most accurate, but it showed bias when applied to different races.[15,16] The Tanaka–Johnston method, in particular, tended to overestimate when used on Caucasian female patients in both mandibles and underestimate when applied to African American male patients' mandibulars.[14,17] Tanaka and Johnston[18] explained this by conducting a study on 506 patients in Cleveland. As a consequence, there was a statistically significant difference in the measurement results on the total study sample, including maxilla and mandibular, when compared to the Tanaka–Johnson estimating technique. However, when comparing the results that were obtained, the predicted value using the Tanaka–Johnston formula with conventional and digital measuring methods in our study achieved similarities. When measured using the conventional method, the difference in dimension calculated from estimations using the Tanaka–Johnston formula was statistically significant for the maxilla in males, the mandibular in females, and the mean value; for females in quadrants 2, 3, and 4. When the Tanaka–Johnson method was compared to the electronic caliper method, the correlation coefficient r was in the range of 0.687–0.697 in the maxilla and 0.662–0.704 in the mandibular. In comparison to the digital measuring method, r in the maxilla different from 0.574 to 0.597 and in the mandible from 0.634 to 0.665 in the whole study sample. The Tanaka–Johnson method's coefficient r was only slightly higher than Moyers' and significantly lower than the other methods. The fact that the Tanaka–Johnston method's correlation coefficient was lower than that of the Gross–Hasund method was consistent with the results of Liu *et al*.'s[19] systematic review study. According to Liu *et al*.'s[19] research and comparison, studies that used univariate regression formulas, such as Tanaka–Johnson's method, had a lower correlation coefficient r than methods that used multivariate regression formulas, such as Gross–Hasund's method. This could be explained by the outcome variable, which was that the total size of the unerupted canines and premolars was frequently impacted by factors other than the overall size of the four mandibular incisors. As a result, when using a multivariate regression formula with more variables, the anticipated results would be closer to the real results and had less variability.

The Gross–Hasund analysis

The Gross–Hasund method was a multivariate regression method that used the total mesiodistal width index of the lateral incisors to predict the entire size of the canine and two unerupted premolars (from canine to second premolar).[14] The study's findings demonstrated that the Gross–Hasund approach may be used to measure the maxilla in both genders. Furthermore, when the correlation coefficient of the Gross–Hasund method was compared to actual measurements with the two methods, we discovered that the correlation coefficient r of the Gross–Hasund method was highest in the mandibular ($r = 0.786$) when compared to the value measured by traditional methods. Gross–Hasund r correlation values varied from 0.686 to 0.688 in the maxilla and 0.724 to 0.831 in the mandible when evaluated digitally. Gross–Hasund *et al*. found an association between the total size of unerupted permanent canines and premolars and the buccolingual size of the lower left first molar in 1989. The significance of this connection has been demonstrated to be greater than the relationship with the lower left first molar's mesiodistal width.[4,20] As a result, in this investigation, overthinking the exterior and internal dimensions of the lower left first molar influenced the estimated results. As a result, in the formula for determining the overall size of unerupted canines and premolars used by Vietnamese people, the outside and internal dimensions of the lower left first molar teeth played an essential role and had a tight association. Gross–Hasund's formula, on the other hand, was a multivariate regression model. When there are numerous factors, the estimated results will be more accurate and less unpredictable. However, the formula's disadvantages were that it was difficult to remember, had too many odd coefficients, and used too many variables, including the mesial-distal and buccal-lingual dimensions of many teeth; thus, the formula's application in interval estimation still faces many difficulties and limits its use by clinicians.[12,21]

A new formula for the Vietnamese population

Tanaka–Johnson and Moyers were considered to be the least dependable for performing correlation coefficient analysis and evaluating the difference between estimated and actual total canine and premolar size since the correlation coefficients were equal. The lowest or next lowest level was recorded. In quadrants with no discrepancy between estimations and actual measurements, the Gross–Hasund technique had the greatest observed correlation coefficient r. The gap between the projected and real findings was not too substantial, with the average difference between the actual and estimated size being less than 1.5 mm across all methods. However, no method had formulas that could be used for both maxilla and mandibular in both genders when considering the two elementary variables, which were the average mesiodistal width from canine to second premolar and the correlation coefficient. As a result, the study developed a new estimating formula based on the univariate regression model to apply to both genders in the maxilla and mandibular, while also establishing a simple, easy-to-remember, and readily used formula. Furthermore, the newly developed formula showed a strong correlation coefficient r, with r ranging from 0.69 to 0.77 in the maxilla and 0.63 to 0.67 in the male mandibular; from 0.65 to 0.687 in the maxilla and 0.616 to 0.703 in the female mandibular. At the same time, the new formula's coefficient was greater than the table of correlation coefficients of the Moyers, Tanaka–Johnston methods in both genders. Although the new formula was not as convenient, simple, and easy-to-remember when compared to Gross–Hasund's formula when recorded in both sexes, it still had the advantage of being easier to use, straightforward, and easy-to-remember with fewer variables.

As a result of comparing the average total mesiodistal from canine to second premolar and the correlation coefficient with two conventional measurement methods and a digital scanner, the newly established formula used to estimate intervals for each gender, male, and female, applied to interval analysis had higher accuracy and reliability than other commonly used methods when used to estimate intervals in the Vietnamese population.

Conclusions

Compared to the digital measuring method, the Moyers method's correlation coefficient was strong compared to the electronic caliper and not as high as other methods of measurement, but it was still within the average limit. This renders it useful for predicting dimensions. When the observed findings were compared to the estimated values using the Tanaka–Johnson estimation method, there was a statistically significant difference. In comparing the value obtained using the conventional approach with the correlation coefficient (r) of the Gross–Hasund method, the mandibula had the greatest value ($r = 0.786$).

LR1, LR2, and LL6 are the first permanent teeth to develop; hence, their mesiodistal width can be easily assessed. As a result, the above method may be used to predict the range in the early phases when children's teeth have just been replaced.

The electronic caliper measuring approach developed a new formula

- Maxilla
  - Male: $X = 1.3*LL6 + 8.24$
  - Female: $X = 2*LR2 + 9.95$
- Mandibular
  - Male: $Y = 1.175*LL6 + 8.9$
  - Female: $Y = 2*LR2 + 9.5$

The digital scanner measuring approach developed a new formula

- Maxilla
  - Male: $X = 1.35*LR1 + 7.35$
  - Female: $X = 2.16*LR1 + 10.5$
- Mandibular
  - Male: $Y = 1.173*LL6 + 8.78$
  - Female: $Y = 1.9*LR1 + 11.23$

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Conflicts of interests

The authors have no conflicts of interest to declare.

Author contributions

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