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THREE-DIMENSIONAL ANALYSIS OF DENTAL ARCH FORM IN RELATION TO THE VERTICAL FACIAL PATTERN IN CLASS I PATIENTS: A CROSS-SECTIONAL STUDY

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Introduction: Understanding the relationship between dental arch form and vertical facial pattern is crucial in orthodontic diagnosis and treatment planning. Variations in vertical facial morphology can influence dental arch form, which in turn impacts the effectiveness and stability of orthodontic interventions.

Objectives: The study explores the associations between dental arch form with the different vertical facial patterns, including hyperdivergent, normodivergent, and hypodivergent patterns in skeletal Class I patients.

Methods: A cross-sectional observational design was employed to examine a sample of 48 patients with skeletal Class I seeking orthodontic treatment; of which 24 males and 24 females. Each patient was categorized into one of three groups: hyperdivergent, normodivergent, or hypodivergent. Digital intraoral scans were used to analyze the dental arch form, including arch width, depth, length, and shape. Cephalometric radiographs were utilized to classify the vertical facial pattern. Statistical analyses, including ANOVA and post hoc Tukey's tests, were performed to investigate the relationships between dental arch form and vertical facial pattern variables.

Results: The analysis revealed a significant association between dental arch width (specifically intercanine and interpremolar widths) and vertical facial patterns. Patients with hyperdivergent facial patterns had significantly narrower dental arches compared to those with normodivergent or hypodivergent patterns. No significant associations were found between intermolar width or arch length and vertical facial patterns. In females, a significant correlation was observed between palatal height and vertical facial patterns, with higher palatal height linked to increased vertical facial dimensions. High-angle facial patterns were associated with a 'V'-shaped arch form, while low-angle patterns typically displayed an ovoid arch form. Additionally, males exhibited significantly larger dental arch widths compared to females.

Conclusions: Significant associations were identified between dental arch widths (especially intercanine and interpremolar widths) and vertical facial patterns, with hyperdivergent facial patterns linked to narrower dental arches. In females, a significant correlation was observed between palatal height and vertical facial patterns, with higher palatal height associated with increased vertical facial dimensions. Furthermore, males had significantly larger dental arch widths compared to females.

Keywords: Three-dimensional analysis, Dental arch form, Vertical facial pattern, Class I malocclusion, Dental arch width, Dental arch depth, Dental arch length, Dental arch shape, Intraoral scans

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The authors declare no conflicts of interest.

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ORIGINAL ARTICLE / ARTICLE ORIGINAL

***Orthodontics** / Orthodontie*

ANALYSE TRIDIMENSIONNELLE DE LA FORME DE L'ARCADE DENTAIRE EN RELATION AVEC LE SCHÉMA FACIAL VERTICAL CHEZ LES PATIENTS DE CLASSE I: UNE ÉTUDE TRANSVERSALE

Introduction: Comprendre la relation entre la forme de l'arcade dentaire et le schéma facial vertical est essentiel pour le diagnostic orthodontique et la planification du traitement. Les variations de la morphologie faciale verticale peuvent influencer la forme de l'arcade dentaire, ce qui impacte l'efficacité et la stabilité des interventions orthodontiques.

Objectifs: Cette étude explore les associations entre la forme de l'arcade dentaire et les différents schémas faciaux verticaux, y compris les schémas hyperdivergents, normodivergents et hypodivergents chez les patients de classe squelettique I.

Méthodes: Une étude observationnelle transversale a été menée sur un échantillon de 48 patients de classe squelettique I en quête de traitement orthodontique, comprenant 24 hommes et 24 femmes. Chaque patient a été classé dans l'un des trois groupes : hyperdivergent, normodivergent ou hypodivergent. Des scans intraoraux numériques ont été utilisés pour analyser la forme de l'arcade dentaire, y compris la largeur, la profondeur, la longueur et la forme de l'arcade. Des radiographies céphalométriques ont permis de classifier le schéma facial vertical. Des analyses statistiques, incluant l'ANOVA et les tests post hoc de Tukey, ont été réalisées pour examiner les relations entre la forme de l'arcade dentaire et les variables du schéma facial vertical.

Résultats: L'analyse a révélé une association significative entre la largeur de l'arcade dentaire (notamment la largeur intercanine et interprémolaire) et les schémas faciaux verticaux. Les patients présentant un schéma facial hyperdivergent avaient des arcades dentaires significativement plus étroites que ceux avec des schémas normodivergents ou hypodivergents. Aucune association significative n'a été trouvée entre la largeur intermolaire ou la longueur de l'arcade et les schémas faciaux verticaux. Chez les femmes, une corrélation significative a été observée entre la hauteur palatine et les schémas faciaux verticaux, une hauteur palatine plus élevée étant associée à des dimensions faciales verticales accrues. Les schémas faciaux à angle élevé étaient associés à une forme d'arcade en «V», tandis que les schémas à angle faible présentaient généralement une arcade de forme ovale. De plus, les hommes présentaient des largeurs d'arcade dentaire significativement plus grandes que les femmes.

Conclusions: Des associations significatives ont été identifiées entre les largeurs de l'arcade dentaire (notamment les largeurs intercanine et interprémolaire) et les schémas faciaux verticaux, les schémas hyperdivergents étant liés à des arcades dentaires plus étroites. Chez les femmes, une corrélation significative a été observée entre la hauteur palatine et les schémas faciaux verticaux, une hauteur palatine plus élevée étant associée à des dimensions faciales verticales accrues. Par ailleurs, les hommes présentaient des largeurs d'arcade dentaire significativement plus grandes que les femmes.

Mots clés: Analyse tridimensionnelle, Forme de l'arcade dentaire, Schéma facial vertical, Malocclusion de classe I, Largeur de l'arcade dentaire, Profondeur de l'arcade dentaire, Longueur de l'arcade dentaire, Forme de l'arcade dentaire, Scans intraoraux

Introduction

Orthodontics is a specialized field of dentistry that focuses on the diagnosis, prevention, and treatment of malocclusions, aiming to achieve optimal dental and facial harmony. In orthodontic treatment planning, the establishment of an ideal dental arch form is of paramount importance for ensuring stable occlusion, proper function, and esthetic balance. The dental arch form is a three-dimensional representation of the arrangement of teeth within the alveolar bone, and it plays a crucial role in defining the spatial relationships of individual teeth and dental arches [1].

Each person has unique facial features and proportions, as well as dental arches. Arch forms can be classified as narrow, normal, and wide. The patient's pretreatment arch form should be determined to achieve an esthetic, functional and stable arch after treatment [2].

The dental arch form is determined by the configuration of the bony ridge, which is estimated by linear (arch length and width) and angular measurements. Arch width is measured as intercanine, interpremolar, and intermolar width. The angular measurements (Ang. 1, Ang. 2R, Ang. 2L) represent the anterior arch form, while the angular measurements (Ang. 3R, Ang. 3L) correspond to the posterior arch form [3, 4]. Arch form measurements can be affected by several factors which range from genetics, gender, bone growth and development to environmental factors such as muscle pressure and stomatognathic system [5].

Opdebeeck & Bell [6] described the two extremes of vertical facial dysplasia as the short face syndrome (SFS) and the long face syndrome (LFS). Patients with short faces are characterized by forward rotating mandible due to relatively large vertical condylar growth and small amount of vertical growth of process and/or anterior facial sutures. While patients with long faces are characterized by backward rotating mandible due to the opposite differential growth pattern [7].

An individual's facial pattern may be considered as one of the key determinants of treatment selection because identification of the facial type influences the anchorage requirement, growth prediction of maxillofacial structures and goal of orthodontic treatment [8].

Several studies linked long-faced individuals with narrower transverse arch dimensions, while linking short face individuals with wider transverse dimensions [3, 9, 10].

Regarding the difference in arch form measurements between genders, several studies were performed. Shubha et al. [11] found that males have significantly wider arch length and arch width compared to females and found that male subjects have a significantly larger palatal height compared to female subjects. Forster et al. [12] showed that the transverse dimension was reduced in both males and females with high vertical pattern.

The arch wire is a vital component in fixed orthodontic treatment; however, many orthodontists routinely use preformed arch wires regardless the facial type and gender. Orthodontic arch wires are commercially available in different arch forms to enable orthodontists to choose what best suits each patient. Proper determination of arch shape and width is mandatory to avoid relapse following orthodontic treatment [13, 14].

The present study was conducted to evaluate the relationship between dental arch form measurements and vertical facial patterns in skeletal Class I patients. The null hypothesis is that there is no significant relationship between dental arch form and vertical facial pattern. This research uniquely examines the relationship between dental arch form and vertical facial pattern specifically in Class I patients with no prior orthodontic treatment. Additionally, it utilizes digital intraoral scans for dental arch form measurements.

Materials and Methods

Before conducting the study, the study was approved by the institutional review board at Beirut Arab University, Beirut, Lebanon (BAU IRB code: 2023-H-0125-D-M-0544). The study utilized a cross-sectional observational design to examine a sample of 48 skeletal Class I patients (24 males and 24 females) seeking orthodontic treatment. The subjects were selected from a total of 65 patients based on specific selection criteria. Sample size estimation was performed using 80% power of the study and sample size using https://epitools.ausvet.com.au. The estimated sample size was calculated, assuming a confidence level of 95% and a study power of 80%.

Inclusion criteria

- Patients with skeletal Class I pattern and Angle's Class I molar relation having minimum/no crowding, spacing, rotation were selected.
- Full dentition except third molars.
- The age is between 18 and 35 years.

Exclusion criteria

- Previous orthodontic treatment.
- History of trauma.
- Anterior and posterior cross bites.
- Extensive restorations or prosthetics.
- Craniofacial anomalies like cleft lip and palate.

Measurements

Cephalometric Measurements

The radiographs were first divided into two groups according to the gender, then each group was subdivided according to the vertical skeletal pattern into 3 groups based on the measurement of mandibular plane angle. All lateral cephalometric x-rays were taken by the same operator using the same device (Kodak 3D, Carestream Health, Inc., Rochester, NY, USA), with the patient standing. The head was oriented in a way that the Frankfort Horizontal Plane (FHP) was parallel to the horizontal plane. Teeth were occluding in centric occlusion and lips were maintained at rest with no lip strain. All digital files of radiographs were traced and exported to be analyzed by the candidate via an online Software (WebCeph, South Korea).

Key cephalometric measurements included the mandibular plane angle (SN/Go-Me) representing the vertical growth pattern, and the angle ANB to confirm the Class I skeletal relationship. Hyperdivergent patients exhibited a high mandibular plane angle, normodivergent patients had an average mandibular plane angle, and hypodivergent patients had a low mandibular plane angle. Specifically, patients with mandibular plane angles >36° were classified as hyperdivergent, 27°-36° as normodivergent, and <27° as hypodivergent.

Dental Arch Measurements

Digital intraoral scans of the upper dental arch were obtained using an intraoral scanner. (Aoralscan 3, Shining3D). The scans were analyzed to measure various dental arch dimensions using a three-dimensional (3D) software (Maestro 3D ortho studio® software, AGE Solutions®, Pontedera, Italy), including intercanine width, interpremolar width, intermolar width, arch length, palatal height and five internal angles (Ang. 1, Ang. 2R, Ang. 2L, Ang. 3R, Ang. 3L). Only the upper dental arch width was utilized for analysis to facilitate easier measurements and statistical evaluation. This selection aligns with the counterpart principle proposed by Enlow and Hans [15], which posits that the upper and lower dental arches are interdependent.

- **Intercanine width:** The distance between the cusp tips of the maxillary canines (Figure 1).
- **Interpremolar width:** The distance between the buccal cusp tips of the maxillary first premolars (Figure 1).
- **Intermolar width:** The distance between the mesiobuccal cusp tips of the maxillary first molars (Figure 1).
- **Arch length:** Measured from the contact point between the permanent central incisors perpendicular to the line of intermolar width (Figure 2).
- **Palatal height:** Measured as the perpendicular distance from the deepest point of the palatal vault to the palatal width (central fossa of the first permanent molar) (Figure 3).

Five internal angles of the pentagon: A vertex of the pentagon was placed between the two central incisors; two other vertices lie on the cusp of the canines, and the other two were placed at the center of first molars. Internal angles of the pentagon were measured. The angular measurements (Ang. 1, Ang. 2R, Ang. 2L) represent the anterior arch form and angular measurements (Ang. 3R, Ang. 3L), represent the posterior arch form (Figure 4).

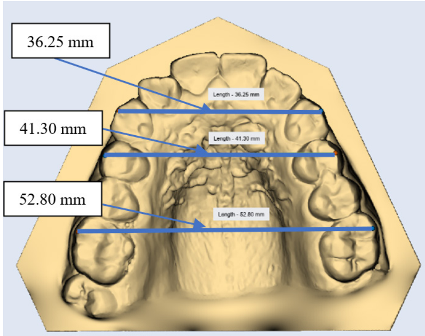

Figure 1. Intercanine, interpremolar, and intermolar width measurement

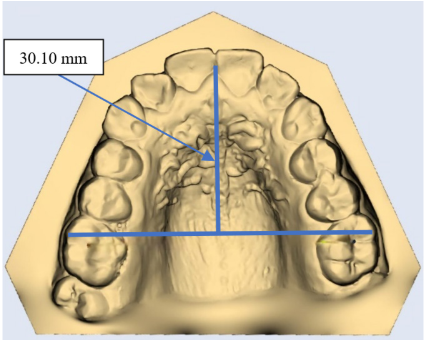

Figure 2. Arch length measurement

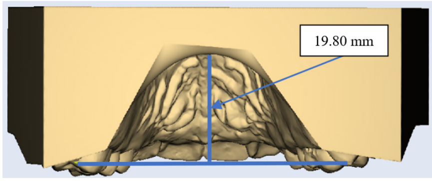

Figure 3. Palatal height measurement

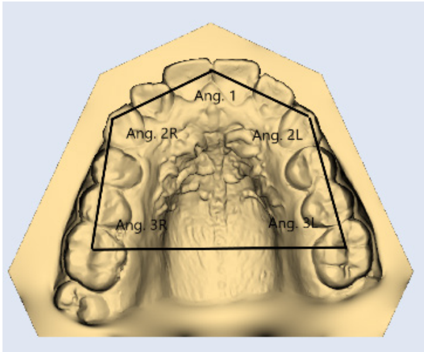

Figure 4. Five internal angles of a pentagon

Statistical Analysis

The collected data were analyzed to explore the relationship between dental arch form and vertical facial patterns. Descriptive statistics, including means and standard deviations, were calculated for all measured variables. An analysis of variance (ANOVA) was conducted to determine whether there were statistically significant differences in dental arch dimensions among the different vertical facial pattern groups (hyperdivergent, normodivergent, hypodivergent). Post hoc Tukey's tests were performed to identify specific group differences when ANOVA results were significant.

Additionally, independent t-tests were used to compare dental arch dimensions between male and female participants. A significance level of $p < 0.05$ was used for all statistical tests. Statistical analyses were performed using SPSS software (version 25.0).

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Reliability

Intra-examiner reliability was assessed by retracing and remeasuring all cephalometric X-rays after 3 days under the same conditions by the same operator. The intra-class correlation coefficient (ICC) was calculated for each measurement, with ICC values for cephalometric measurements ranging from 0.91 to 0.96, accompanied by a 95% confidence interval, indicating excellent reliability. Similarly, digital scans were remeasured under identical conditions after 3 days, with ICC values for these measurements also demonstrating excellent reliability, ranging from 0.92 to 0.95.

Results

This descriptive cross-sectional study included 48 orthodontic patients (aged 18 to 35 years) from Beirut Arab University's clinics. Patients were categorized by gender and further classified into vertical skeletal patterns (hyperdivergent, normodivergent, and hypodivergent) based on mandibular plane angle measurements. The low-angle group had 8 males and 8 females, the average-angle group included 8 males and 8 females, and the high-angle group also had 8 males and 8 females.

Comparison of Dental Arch Dimensions in Different Vertical Facial Patterns (Total Population): (Figure 5)

Across the total population (Table 1), significant differences were observed in intercanine width (p=0.020*) and interpremolar width (p=0.007*) among vertical facial patterns. Specifically, intercanine widths were higher in the low (36.04 mm ± 1.68) compared to average (34.53 mm ± 1.38) and high (34.45 mm ± 1.36) patterns. Interpremolar widths followed a similar trend, with higher values in the low (43.92 mm ± 2.31) compared to average (41.92 mm ± 1.79) and high (41.41 mm ± 1.39) patterns. Intermolar width differ-

Table 1. Comparison of dental arch dimensions in different vertical facial patterns (Total Population)

	Low Angle (N=16)		Average Angle (N=16)		High Angle (N=16)		one-way ANOVA P-value
	Mean	SD	Mean	SD	Mean	SD	
Intercanine width[a]	36.04	1.68	34.53	1.38	34.45	1.36	**.020***
Interpremolar width[a]	43.92	2.31	41.92	1.79	41.41	1.39	**.007***
Intermolar width[a]	54.59	2.76	52.26	2.89	52.26	2.11	.057
Arch length[a]	30.82	2.10	29.59	2.48	31.18	2.34	.206
Palatal height[a]	17.09	3.26	16.63	2.51	18.13	2.12	.444
Ang. 1[b]	126.33	8.24	129.47	9.51	123.90	9.04	.316
Ang. 2R[b]	128.75	4.45	127.47	3.20	129.40	6.74	.587
Ang. 2L[b]	128.17	5.72	127.27	4.91	129.20	3.05	.616
Ang. 3R[b]	75.50	4.17	74.93	2.40	76.60	3.20	.466
Ang. 3L[b]	74.33	3.92	75.13	3.38	75.90	2.88	.572

*Statistically significant at $p<0.05$ / [a] = Millimeters (mm); [b] = Degrees (°)

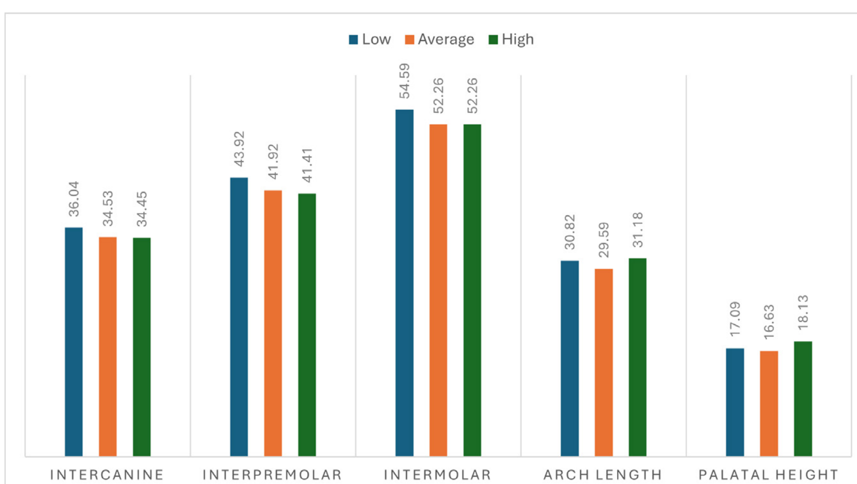

Figure 5. Comparison of dental arch dimensions in different vertical facial patterns (Total Population)

ences were not statistically significant (p=0.057). No significance was found in the remaining measurements.

Comparison of dental arch dimensions in different vertical facial patterns (Males): (Figure 6)

In male patients (Table 2), significant differences were found in intercanine width (p=0.006*) and interpremolar width (p=0.025*) across vertical patterns. Specifically, intercanine widths were higher in the low (36.93 mm ± 0.65) compared to average (34.55 mm ± 1.54) and high (34.78 mm ± 1.24) patterns. Interpremolar widths showed a similar pattern, with higher values in the low (45.30 mm ± 1.49) compared to average (42.35 mm ± 2.80) and high (42.30 mm ± 0.86) patterns. Other measures did not show any significant differences.

Comparison of Dental Arch Dimensions in Different Vertical Facial Patterns (Females): (Figure 7)

For female patients (Table 3), significant differences were observed only in palatal height (p=0.034*), with higher values in the high (18.58 mm ± 2.34) compared to average (15.71 mm ± 2.30) and low (14.40 mm ± 1.82) patterns. Other measures did not show any statistically significant differences.

Table 2. Comparison of dental arch dimensions in different vertical facial patterns (Males)

	Low Angle (N=8)		Average Angle (N=8)		High Angle (N=8)		one-way ANOVA P-value
	Mean	SD	Mean	SD	Mean	SD	
Intercanine width[a]	36.93	.65	34.55	1.54	34.78	1.24	.006*
Interpremolar width[a]	45.30	1.49	42.35	2.80	42.30	.86	.025*
Intermolar width[a]	55.91	1.72	52.75	3.18	53.78	2.31	.111
Arch length[a]	31.04	2.40	29.80	2.11	31.42	2.67	.608
Palatal height[a]	18.43	3.03	18.48	1.99	17.23	1.57	.767
Ang. 1[b]	126.43	10.15	128.75	6.99	124.75	6.99	.811
Ang. 2R[b]	129.29	3.35	128.25	2.50	127.75	7.93	.866
Ang. 2L[b]	127.43	4.76	126.50	1.73	129.00	2.71	.640
Ang. 3R[b]	75.43	2.70	74.75	1.26	75.00	4.24	.929
Ang. 3L[b]	73.86	2.27	75.75	1.89	75.50	2.52	.344

*Statistically significant at p<0.05 / [a] = Millimeters (mm); [b] = Degrees (°)

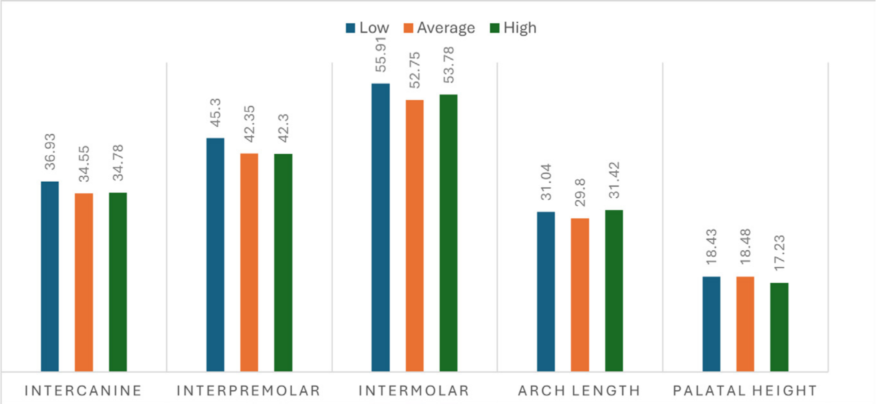

Figure 6. Comparison of dental arch dimensions in different vertical facial patterns (Males)

Table 3. Comparison of dental arch dimensions in different vertical facial patterns (Females)

	Low Angle (N=8)		Average Angle (N=8)		High Angle (N=8)		one-way ANOVA P-value
	Mean	SD	Mean	SD	Mean	SD	
Intercanine width[a]	34.80	1.97	34.53	1.39	34.23	1.51	.835
Interpremolar width[a]	41.98	1.82	41.76	1.42	40.82	1.41	.380
Intermolar width[a]	52.74	3.03	52.08	2.92	51.25	1.32	.644
Arch length[a]	30.50	1.82	29.52	2.69	31.02	2.35	.465
Palatal height[a]	14.40	1.82	15.71	2.30	18.58	2.34	.034*
Ang. 1[b]	126.20	5.67	129.73	10.56	123.33	10.80	.440
Ang. 2R[b]	128.00	6.04	127.18	3.49	130.50	6.35	.433
Ang. 2L[b]	129.20	7.33	127.55	5.70	129.33	3.50	.774
Ang. 3R[b]	75.60	6.07	75.00	2.76	77.67	2.07	.356
Ang. 3L[b]	75.00	5.79	74.91	3.83	76.17	3.31	.831

*Statistically significant at p<0.05 / [a] = Millimeters (mm); [b] = Degrees (°)

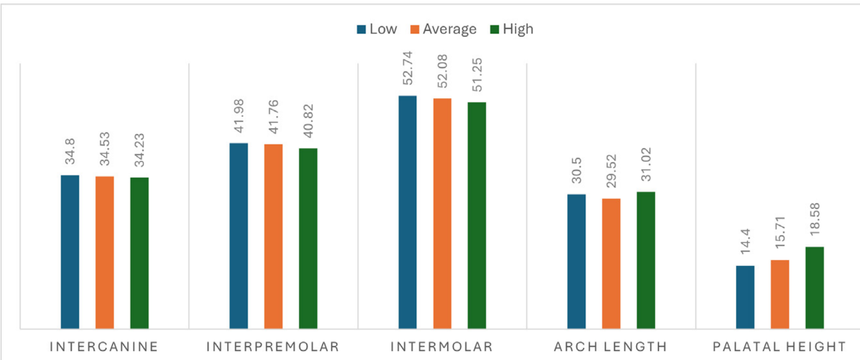

Figure 7. Comparison of dental arch dimensions in different vertical facial patterns (Females)

Table 4. Comparison of dental arch dimensions between genders

	Gender	N	Mean	Std. Deviation	Independent Samples t-test P-value
Intercanine width[a]	Male	24	35.720	1.549	.023*
	Female	24	34.509	1.497	
Interpremolar width[a]	Male	24	43.713	2.269	.001*
	Female	24	41.555	1.512	
Intermolar width[a]	Male	24	54.500	2.568	.006*
	Female	24	52.005	2.550	
Arch length[a]	Male	24	30.813	2.315	.410
	Female	24	30.150	2.419	
Palatal height[a]	Male	24	18.169	2.348	.085
	Female	24	16.494	2.684	
Ang. 1[b]	Male	24	126.600	8.210	.851
	Female	24	127.182	9.743	
Ang. 2R[b]	Male	24	128.600	4.485	.839
	Female	24	128.273	4.939	
Ang. 2L[b]	Male	24	127.600	3.582	.616
	Female	24	128.409	5.422	
Ang. 3R[b]	Male	24	75.133	2.722	.510
	Female	24	75.864	3.603	
Ang. 3L[b]	Male	24	74.800	2.274	.684
	Female	24	75.273	4.038	
	Female	24	0.667	0.039	

*Statistically significant at $p<0.05$ / a = Millimeters (mm); b = Degrees (°)

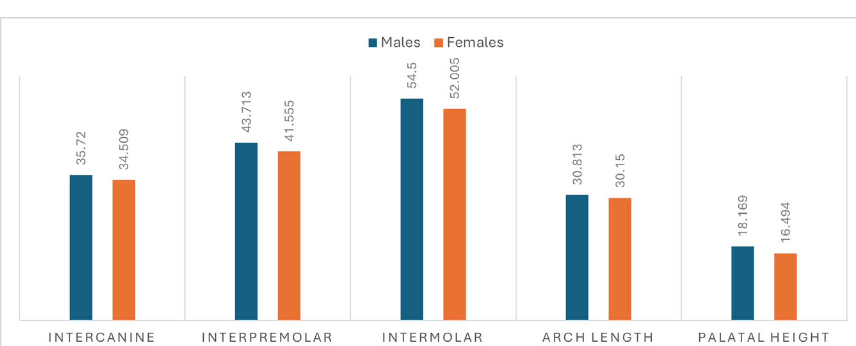

Figure 8. Comparison of dental arch dimensions between genders

Comparison of Dental Arch Dimensions Between Genders: (Figure 8)

Table 4 revealed significant gender differences in dental arch dimensions. Specifically, males showed higher measurements in intercanine width (35.720 mm ± 1.549 vs. 34.509 mm ± 1.497, p=0.023*), interpremolar width (43.713 mm ± 2.269 vs. 41.555 mm ± 1.512, p=0.001*), and intermolar width (54.500 mm ± 2.568 vs. 52.005 mm ± 2.550, p=0.006*). However, there were no significant gender disparities observed in other measured dimensions.

Discussion

The null hypothesis of the present study, which states that there is no significant relationship between the dental arch form and the vertical facial pattern, was rejected based on the results. The analysis demonstrated a statistically significant relationship between the two variables.

Understanding vertical facial form is crucial in orthodontics, as it relates vertical facial height to dental arch form, essential for accurate diagnosis and treatment planning. Variations in vertical dimension require tailored orthodontic approaches, as misjudging facial type can lead to poor outcomes [16]. Each patient's dentofacial form is unique, making it vital to assess dental arch form in relation to the three facial types: short, average, and long, where long faces exhibit excessive vertical growth, and short faces show reduced growth [17].

This study focused solely on skeletal Class I patients, determined by the ANB angle, to minimize the impact of dental compensation, which could obscure the relationship between vertical facial morphology and transverse dental arch widths, particularly in skeletal Class II or III patients. Only patients with no history of prior orthodontic treatment were included to eliminate any potential influence on the vertical development of the dentoalveolar process or mid-face structures [12]. We analyzed untreated adult males and females separately, acknowledging established gender differences in skeletal facial dimensions and arch widths reported in prior studies [18, 19].

Our research concentrated on adult individuals, unlike previous studies that included growing children [20]. We selected patients with permanent dentition, as significant changes occur during the transitional dentition phase, and only minor changes continue after a functional permanent dentition is established [21].

In the current study, each patient underwent standardized lateral cephalogram and digital model assessments to confirm the absence of any exclusion criteria. Vertical facial height was derived from lateral cephalograms, while digital intraoral scans were employed to assess the dental arch form in the upper arch. The SN-MP angle was utilized as a metric for vertical facial morphology, while dental arch measurements (intercanine width, interpremolar width, intermolar width), arch length, palatal height, and angular measurements (Ang. 1, Ang. 2R, Ang. 2L, Ang. 3R, Ang. 3L) were recorded. These measurements have been widely adopted as standard parameters for dental arch forms by numerous researchers [3, 12].

Recent advances in digital technology have greatly improved the diagnostic phase of orthodontic treatment, with analog records being replaced by digital formats [22]. Numerous studies have validated the accuracy of angular and linear measurements on the three-dimensional digital models using various software [23]. Three-dimensional images enable the evaluation of linear and angular measurements that describe the arch form [24].

This study identified a statistically significant difference between vertical facial patterns and dental arch width, particularly in the intercanine and interpremolar dimensions. This finding was consistent with the observations of Jumani et al. [25], Kumari et al. [26], and Dasgupta et al. [27], who noted a general decrease in arch width with increasing MP-SN angle, showing significant reductions in maxillary intercanine and interpremolar widths.

Forster et al. [12] investigated the relationship between dental arch width and vertical facial morphology, finding significant differences in intercanine, interpremolar, and intermolar widths in males, and interpremolar width in females. These results align with our findings for intercanine and interpremolar widths in males. This difference can be attributed to their inclusion of a broader range of facial patterns and possibly different age groups.

Khera et al. [19] found that in males, hypodivergent patients had larger maxillary intercanine, interpremolar, and intermolar widths compared to hyperdivergent patients. Similarly, in females, hypodivergent individuals exhibited greater maxillary interpremolar and intermolar widths compared to their hyperdivergent counterparts. This study partially aligned with Khera et al.'s findings, specifically in the relationship between intercanine and interpremolar widths with vertical facial patterns in males. The discrepancies between our findings and Khera et al.'s may be attributed to differences in the sample population, including demographic variations.

Grippaudo et al. [10] found that individuals with an increased vertical dimension had proportionally smaller intercanine diameters, whereas those with a decreased vertical dimension had larger intercanine diameters. This aligns with Amber et al. [28], who reported significant differences in intercanine widths among low, normal, and high angle classes, both of which are consistent with this study's results. Similarly, Sharma et al. [3] found that the upper arch shape changed with smaller intercanine diameters in high-angle cases and larger intercanine diameters in low-angle cases, which also mirrors our findings.

Prasad et al. [29] and Narkhede et al. [30] reported a significant decrease in maxillary inter-arch width (intercanine, interpremolar, and intermolar) with an increase in the MP-SN angle in an untreated adult South Indian population in both males and females. These findings were consistent with this study regarding intercanine and interpremolar width.

The present study suggests that the maxillary arch lengths are similar across different vertical facial patterns in both males and females, with no significant differences. However, palatal height in females showed significant results, with higher palatal height observed in individuals with high vertical facial patterns and shallower palatal height in those with low vertical facial patterns. These findings partially align with Khera et al. [19], who found that both males and females with hyperdivergent patterns had greater palatal heights, while hypodivergent individuals had shallower palates. This study did not observe these relationships in males.

Concerning the angular measurements, angles (Ang. 1, Ang. 2R, Ang. 2L, Ang. 3R, and Ang. 3L) did not show any significant relationship with vertical facial patterns nor with gender in this study. These angles have been used by several authors, including Oliva et al. [4] and Sharma et al. [3], to assess the dental arch form. However, other researchers, such as Sharma et al. [3], have noted that arch forms are influenced by arch dimensions.

Therefore, the inverse relationship found in this study between intercanine and interpremolar width and vertical facial patterns can be interpreted as the prevalence of 'V' shaped arch forms in subjects with high angles and ovoid arch forms in low-angle patients.

The significant relationship between the dental arch dimensions and vertical facial patterns found in this study can be best attributed to the influence of masticatory muscles and tongue base position. The strong masticatory muscles associated with a brachyfacial pattern could explain the wider dental arches observed in individuals with low-angle growth patterns. This has been shown in studies by Tircoveluri et al. [31] and Satiroğlu et al [32]. Conversely, the position of the tongue base and its influence on mandibular rotation and arch constriction could account for the narrower dental arches seen in high-angle individuals [33].

The results of this study showed a statistically significant gender difference in arch variables with linear measurements (intercanine, interpremolar, and intermolar); however, this was not the case for variables with angular measurements. Other researchers agree with the observed disparity in dental arch size between genders, including Eröz et al. [20] and Forster et al. [12]. Unlike this study, Eröz et al. [20] analyzed patients during their growth phase and found that intermolar distance values were gender-specific, with males exhibiting greater values on average. The results of the present study corroborate the finding that female arches were smaller than male arches [34].

In terms of arch form, our results align with those of Ferrario et al. [35] and Camporesi et al. [36], who reported that in Caucasians, the shape of dental arches does not differ significantly between genders, irrespective of size. This suggests that while males and females differ in arch size, the arch shape remains consistent across genders. The lack of significant differences in angular measurements between genders in this study further supports this conclusion, confirming a strong similarity in arch shape between males and females.

It was suggested that the observed differences in arch dimensions between males and females may be attributed to various factors, including genetic predisposition, hormonal influences, and environmental factors such as nutrition and masticatory muscle strength [25, 37, 38).

Conclusion

- Significant associations were found between dental arch width (specifically intercanine and interpremolar widths) and vertical facial patterns.
- Patients with hyperdivergent facial patterns exhibited significantly narrower dental arches compared to those with normodivergent or hypodivergent patterns.
- Significant correlation was observed in females between palatal height and vertical facial patterns, with higher palatal height associated with increased vertical facial dimensions.
- Dental arch widths were found to be significantly larger in males compared to females.

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