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Cephalometric Evaluation of Facial Height Ratios and Growth Patterns: A Retrospective Cohort Study

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Abstract: (1) Background: This retrospective cohort study aimed to investigate the cephalometric evaluation of facial height ratio (FHR) and growth patterns. (2) Methods: We assessed facial height ratios, the *y*-axis to SN angle, and growth patterns in 94 participants from Timis County using digital cephalograms. Angle's classification guided the categorization of participants. We digitally traced and analyzed cephalograms using the WebCeph imaging software. We conducted the statistical analysis using Python version 3.11.9. We performed the following statistical tests: Welch's *t*-test or ANOVA (analysis of variance), Mann–Whitney U test or the Kruskal–Wallis test, χ^2 test or Fisher's, and logistic regression. (3) Results: Significant correlations were observed between FHR and craniofacial development, especially in hypodivergent growth patterns. Among the molar classes, the most predominant growth pattern in Class I was normodivergent (61.5%), followed by hypodivergent (33.3%). In Class II, hypodivergent growth was the most common (52%), with a smaller proportion of normodivergent cases (30.8%). Class III was characterized by a mix of growth patterns, with hypodivergent being predominant (14.7%). Across all groups, the *y*-axis to SN angle remained within normal limits, and a strong negative correlation with Jarabak's ratio was found ($r = -0.72$, $p < 0.001$). This shows the importance of using holistic assessment methods in orthodontic practice. (4) Patients from Timis County mostly have a hypodivergent growth pattern across all types of malocclusions. Understanding these patterns is essential for comprehensive orthodontic treatment planning. We need to conduct further research to investigate the implications of these findings on treatment outcomes and patient care.

Keywords: artificial intelligence; dentistry; digital analysis; normodivergent; hyperdivergent; hypodivergent; orthodontics; sagittal relationship; WebCeph

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1. Introduction

Cephalometry, an essential diagnostic tool in orthodontics, allows for the evaluation of the relationship between skeletal, dental, and soft tissue components of the face. It is important to look at both the anteroposterior (AP) and vertical dimensions when determining the severity of a malocclusion, especially in the AP direction, which can affect changes in the vertical direction [1].

Facial growth, relative to the cranial base line, comprises horizontal forward development and vertical downward growth. Mandibular growth significantly influences facial development, with hypodivergent patterns observed in short faces and hyperdivergent patterns in long faces [2,3]. Various factors influence cranial development, leading to diverse facial morphologies. This variability in growth patterns underscores the multifactorial nature of cranial development, giving rise to diverse facial morphologies [4].

Orthodontic diagnosis emphasizes the anteroposterior connection between maxillary and mandibular apical bases. Vertical disharmonies are often accompanied by sagittal discrepancies in the jaw relationship. These can be found by carefully analyzing the linear and angular measurements of the skull [5]. Achieving appropriate vertical proportions during orthodontic treatment involves categorizing vertical facial forms into distinct categories, such as long, average, and short faces. Yadav observed clear associations between facial patterns and anterior vertical facial proportions, measured by parameters like anterior facial height (AFH) and posterior face height (PFH) [6].

The accurate diagnosis and evaluation of developing patients are imperative in orthodontics for effective therapy planning and prognostic assessments [7]. However, predicting individual facial growth remains a formidable challenge due to the inherent variability in growth direction and magnitude [8,9]. Genetic and environmental influences on the craniofacial system further compound this challenge, necessitating the development of predictive models to infer dentoalveolar imbalance progression in line with growth principles [10,11].

Genetic and environmental influences on the craniofacial system determine the complexity of growth pattern prediction [11]. Predictive models use relevant parameters to predict how the dentoalveolar imbalance will worsen over time based on growth principles [12]. Facial structure development involves variable growth vectors along the horizontal and vertical axes. Balanced growth along these axes is essential to prevent facial imbalances. Extreme facial forms result from disproportionate vertical development, such as in the long face syndrome [13]. A precise diagnosis considers the sagittal jaw-base relationship, as highlighted by Angle's classification of malocclusion in the late 19th century. This classification system, still in use, categorizes occlusion based on the relationship between the first permanent molars.

Linear measurements of the sagittal jaw-base relationship offer a more accurate diagnosis of anteroposterior discrepancies than angular measurements. Cephalometric assessments integrate both linear and angular measurements to determine treatment strategies [14]. The soft tissue paradigm, introduced in the 21st century, emphasizes the role of soft tissue in orthodontic and orthognathic treatment planning. Nadim's findings on vertical inter-maxillary correlations in the Caucasian population underscore the importance of cephalometric tests in understanding facial growth patterns. Thus, examining facial height ratios and growth patterns, as well as the relationship between the facial height ratio (FHR) and certain cephalometric angles, can help with diagnosis and treatment planning for a wide range of malocclusions [15].

Nowadays, cephalometric analysis typically uses computer-assisted analysis software to perform manual tracing. In cephalometric analysis, precise definitions of landmarks, operator calibration, and trace replication are all crucial. However, while repetitive landmark localization can save a lot of time, it does not significantly improve analytical accuracy. The experience of orthodontists, who must invest a significant amount of time in training and accumulating experience before they can perform the analysis effectively, is a determining factor in the precision, reliability, and time requirements of cephalometric analysis. Recently, researchers have conducted numerous studies on artificial intelligence (AI) to explore automated landmark locations. Artificial intelligence landmark identification exhibits higher efficiency and reproducibility compared to traditional cephalometric analysis. With the advancement of AI applications in orthodontics, practitioners still need to analyze the numerous automated cephalometric tools available. Recent advances in computer vision enable machines to recognize and process images for the purpose of detecting cephalometric landmarks once trained on a specific dataset. Artificial intelligence (AI) can evaluate images faster than traditional manual approaches, saving users time and improving the effectiveness of repetitive tasks [16].

The purpose of this study was to look into the cephalometric evaluation of FHR and growth patterns in a group of patients from Timis County, Romania, who had a wide range of malocclusions. The study's main goal was to find out if there is a link between FHR and different skull measurements, such as the y-axis to SN angle, total anterior facial height (TAFH), and total posterior facial height (TPFH). By examining these parameters, the study sought to contribute to a deeper understanding of craniofacial development and assist in the diagnosis and treatment planning of malocclusions.

2. Materials and Methods

Patients attending the Discipline of Orthodontics I, Faculty of Dental Medicine, "Victor Babeș", University of Medicine and Pharmacy Timisoara, served as the study's sample. Each and every person who participated in the study was required to provide written informed consent. The Institutional Ethics Committee of the University of Medicine and Pharmacy "Victor Babes" in Timisoara, Romania (Scientific Research Ethics Committee, CECS nr. 13/26.03.2021), granted the ethical clearance.

The study focused on investigating the cephalometric evaluation of facial height ratios and growth patterns. We needed a minimum of 94 patients in the sample. The effect size was based on a previous study [16].

We retrieved these records from consultations conducted between March 2021 and December 2022. All patients included in the study were residents of Timis County, Romania.

Edward H. Angle proposed the Angle classification in 1899 to categorize dentoalveolar malocclusion. We used pre-treatment study models, photographs, and clinical questionnaire records to evaluate malocclusion and confirm the Angle classification. We divided all 94 subjects into three groups based on Angle's dentoalveolar malocclusion, using pre-treatment study models, photographs, and clinical questionnaire records for confirmation (Table 1).

2.1. Procedure Methodology

2.1.1. Cephalometric Measurements and Protocol

The cephalometric measurements were performed by a single examiner, following a standardized measurement protocol to ensure consistency across all subjects. Lateral cephalograms were obtained using the same machine, Planmeca Promax® (Planmeca, Helsinki, Finland), with subjects positioned in a natural head posture as outlined by Beni Solow [17].

WebCeph is an orthodontic and orthognathic platform that facilitates cephalometric investigations, end-of-treatment prognosis, preparation for orthognathic surgery, management of patient records, and image preservation.

We created a free WebCeph system account, and we uploaded a prepared "jpeg" cephalometric X-ray image using www.webceph.com and a standard web browser (Google Chrome 64 bit). Each patient was given a unique ID after logging in, and the jpeg files of their cephalometric measurements were submitted. When the operator chose the AI Digitization option, the WebCeph system automatically recognized every anatomical location. After that, WebCeph (AI landmarking) automatically made all of the measurements and downloaded them to the PC. Additionally, WebCeph offered the option to manually correct anatomical landmarks. It was a 10 mm calibration.

We loaded the digital radiographs stored as jpeg files into WebCeph. The grayscale files had the following image characteristics: 2.232 × 2.304 pixels, 8 bits, and 150 dpi. We conducted the computerized analysis on a 14″ screen.

We conducted the cephalometric analysis using the WebCeph® (Korean Intellectual Property Office, Seoul, Republic of Korea, WebCeph, 1.0.0, Assemblecircle, Gyeonggi-do, Republic of Korea) software package for digital tracing and composite cephalometric analysis, incorporating two linear measures and one angular measurement.

Each digital image was downloaded and saved from a lateral cephalometric radiograph to a Lenovo IdeaPad 5 Pro computer before importing it into WebCeph.

Table 1. List of measurements and landmarks.

S. No	Measurement	Description
1	Total Anterior Facial Height	Measured along the N–Me line.
2	Total Posterior Facial Height	Measured along the S–Go line.
3	FHR	Jarabak's ratio, also known as the ratio of TPFH to TAFH multiplied by 100, is calculated. Based on FHR, we classify facial morphology into three patterns: (1) Hyperdivergent growth pattern: FHR < 59%, predominantly vertical growth pattern. (2) Neutral or normodivergent growth pattern: FHR between 59 and 63%. (3) Hypodivergent growth pattern: FHR > 63%, predominantly horizontal growth pattern [18]. According to Ahmed et al., the sum of posterior angles and the Jarabak ratio provide a more accurate measurement of the vertical relationship [19].
4	S–Gn (y-axis) Angle	The mandible's position in relation to the cranial base is defined. A mean value of 66° indicates a posterior mandibular position and a dominance of vertical growth; smaller angles indicate an anterior mandibular position and a dominance of anterior growth [20].
5	Y SN Angle	Formed by the SN plane and the y-axis, it reflects the downward and forward posture of the chin relative to the upper face [21–24].

FHR: facial height ratio; TAFH: total anterior facial height; TPFH: total posterior facial height.

The key cephalometric landmarks included are as follows:

- S (sella turcica): located in the middle of the hypophyseal and pituitary fossae.
- N (nasion): the most anterior point of the middle frontonasal suture.
- Go (gonion): the midpoint on the posterior border of each gonial angle, located mediolaterally.
- Me (menton): the lowest point on the chin's curve [25].

The planes constructed for measurement were N–Me (Nasion to Menton) and S–Go (Sella to Gonion). These landmarks and planes were used to calculate critical parameters such as FHR, which is facial height ratio, TAFH, which is total anterior facial height (N–Me line), TPFH, which is total posterior facial height (S–Go line), and Jarabak's ratio, which may be computed by multiplying the ratio of TPFH to TAFH by 100. The FHR classification categorizes facial morphology into three distinct patterns. The facial height ratio (FHR), or Jarabak's ratio, was derived from these measures, classifying facial growth patterns as follows:

1. Hyperdivergent: FHR < 59%.
2. Normodivergent: FHR between 59% and 63%.
3. Hypodivergent: FHR > 63% [18].

FHR is facial height ratio, and TAFH is total anterior facial height (N–Me line); TPFH is total posterior facial height (S–Go line); Jarabak's ratio may be computed by multiplying the ratio of TPFH to TAFH by 100. The FHR classification categorizes facial morphology into three distinct patterns [18].

2.1.2. Reliability Analysis

Since all cephalometric measurements were performed by a single examiner, intra-rater reliability was assessed. To minimize the intra-observer error, the examiner repeated the measurements on a randomly selected subset of the data (approximately 20%) after a two-week interval. The intraclass correlation coefficient (ICC) was calculated to evaluate the consistency of the repeated measurements, with an ICC value above 0.75 considered to indicate good reliability.

Radiologists oriented the skulls in three dimensions, similar to how they would place a patient's head in a cephalostat. The lateral film should properly overlay the bilateral structures on the mandibular inferior border, and the skull's central axis should run parallel to it (Figure 1).

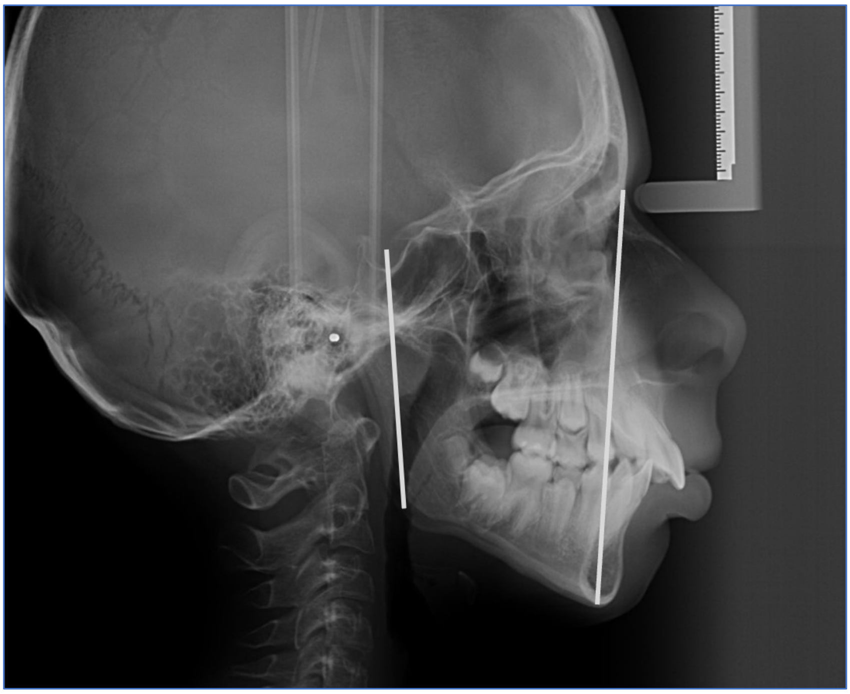

Figure 1. Constructed planes and cephalometric markers: Nasion–Menton and Sella–Gonion.

Figure 1 illustrates how we digitally drew the planes used in this study, specifically Nasion–Menton and Sella–Gonion, on a lateral cephalogram.

Figure 2a presents the WebCeph program measurements, while Figure 2b shows the corresponding outcomes from the digital version. We present in detail the mean values, standard deviation, resulting values, severity—which is noted as we observe with "*"; one "*" means the lowest degree of severity and more "*" means a greater degree of severity—polygonal charts, and their interpretations.

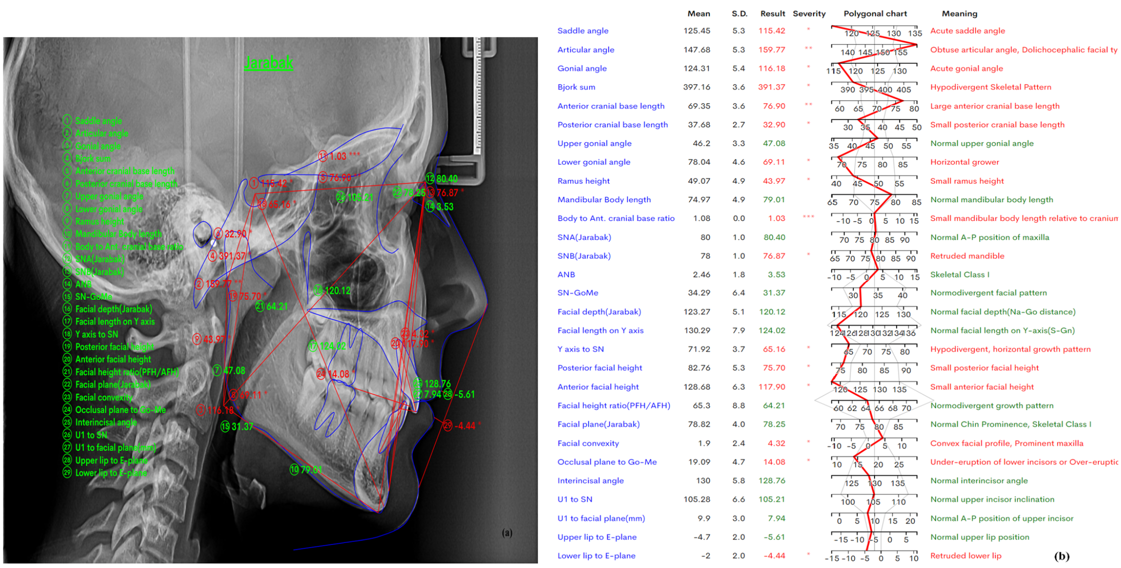

Figure 2. (**a**) WebCeph line analysis, displaying the *y*-axis to SN, anterior facial height, and posterior facial height; (**b**) WebCeph chart, presenting the mean values, standard deviation, resulting values, severity, polygonal charts, and their interpretations.

Measurements were taken based on these landmarks, and planes are presented in Table 1 above.

Figure 3 illustrates the digitally drawn *y*-axis at SN, constructed from Sella–Nasion and Sella–Gnathion. The same investigator traced and measured the radiographs, repeating the measurements after two weeks to minimize intra-observer errors. We then tabulated the parameters for analysis.

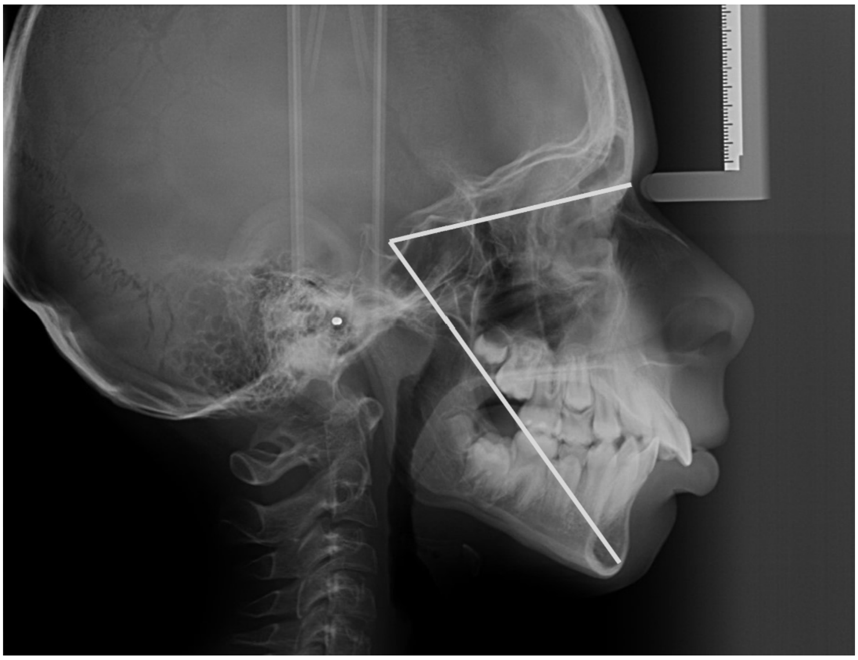

Figure 3. *Y*-axis to SN (Sella–Nasion and Sella–Gnathion) measurement (N–S–Gn).

2.2. Statistical Analysis

We conducted the statistical analysis using Python version 3.11.9. We used descriptive statistics to summarize the data. We expressed the continuous variables as means with the standard deviation (SD) for normally distributed data and as medians with the interquartile range (IQR) for nonparametric data. We presented category variables as frequencies and percentages. We assessed group differences in normally distributed continuous data using Welch's *t*-test for two groups or ANOVA (analysis of variance) for more than two groups. We used the Mann–Whitney U test or the Kruskal–Wallis test on nonparametric continuous data to find the association between the distribution of molar class and anthropometric measurements of facial size. Differences in categorical data were examined using the χ^2 test or Fisher's exact test. We employed the Shapiro–Wilk test to assess the normality of continuous data and to test the normality assumptions. Additionally, logistic regression was employed for further analysis to predict the predictors of divergence type based on anthropometric measurements. The sample size was calculated to ensure adequate power for detecting significant differences in our primary endpoint, which focused on the cephalometric evaluation of facial height ratios across growth patterns. The expected mean difference in these ratios was based on previous research findings on facial morphology in similar populations [13,26]. An alpha level of 0.05 and a beta level of 0.20 (power of 80%) were chosen to minimize type I and type II errors, respectively. References from recent research studies were used to refine and validate the sample size estimation, ensuring its relevance to the population under study. A p-value of <0.05 was considered the threshold for significance.

3. Results

3.1. Baseline Characteristics of the Included Sample

In this study, 94 patient records were analyzed, comprising 35 men and 59 women. Table 2 provides the baseline characteristics of anthropometric parameters for the study sample of 94 individuals. The median age was 21 years (IQR: 14 to 28), indicating a wide age range among participants. TPFH and TAFH had median values of 76 (IQR: 70 to 81) and 112 (IQR: 104 to 120), respectively, reflecting variation in facial dimensions within the sample. The median Jarabak's ratio, a measure of facial morphology, was 67.0 (IQR: 64.0 to 72.0). Molar class distribution revealed that the majority of individuals were in Class II (49%), followed by Class I (37%), and Class III (14%). *Y*-axis to SN angle had a median value of 65.0 (IQR: 62.0 to 69.0), indicating variation in mandibular position relative to the cranial base. Gender distribution showed that 63% were female and 37% were male within the sample.

Table 2. Baseline characteristics of the anthropometric parameters.

Characteristic	N = 94
Age [1]	21 (14, 28)
TPFH [1]	76 (70, 81)
TAFH [1]	112 (104, 120)
Jarabak's ratio [1]	67.0 (64.0, 72.0)
Molar Class [2]	
1	35 (37%)
2	46 (49%)
3	13 (14%)
Y-axis to SN [1]	65.0 (62.0, 69.0)
Gender [2]	
M	35 (37%)
F	59 (63%)

TAFH: total anterior facial height; TPFH: total posterior facial height. [1] Median (IQR); [2] n (%).

3.2. Molar Class Distribution

Additionally, using pre-treatment study models, photographs, and clinical questionnaire records, we categorized all patients into three groups based on Angle's dentoalveolar malocclusion. We examined the association between gender and molar class distribution using a chi-squared test, as Table 3 illustrates. The table indicates the distribution of molar classes among male and female participants, with a total sample size of 94 individuals. We observed no significant gender-based differences ($p = 0.223$) across the three molar class groups (Group I, Group II, and Group III), suggesting a comparable distribution of molar classes between males and females in the study population.

Table 3. Association between molar class distribution and gender.

	Male (N = 35)	Female (N = 59)	Total (N = 94)	*p* Value
Group I	13.0 (38.2%)	21.0 (35.6%)	34.0 (36.6%)	0.223 [1]
Group II	19.0 (55.9%)	27.0 (45.8%)	46.0 (49.5%)	
Group III	2.0 (5.9%)	11.0 (18.6%)	13.0 (14.0%)	

[1] Pearson's chi-squared test, n (%)—number and percentages.

Table 4 presents the association between molar class distribution and anthropometric measurements of facial size. This table presents the distribution of the *y*-axis to SN, TPFH, and TAFH measurements across three molar class groups (I, II, and III). Using Kruskal–Wallis tests, we found that there were no significant differences between the molar class distribution and the *y*-axis for SN ($\chi^2 = 0.00$, $p = 1.001$), TPFH ($\chi^2 = 0.30$, $p = 0.741$), or TAFH ($\chi^2 = 0.26$, $p = 0.771$). These findings suggest that molar class distribution did not influence the measured anthropometric facial size parameters among the study participants.

Table 4. Association between molar class distribution and the anthropometric measurements of facial size.

	N	I	II	III	Test Statistics
		(N = 35)	(N = 46)	(N = 13)	
Y-axis to SN	94	61.2, 65.0, 69.0	62.0, 65.0, 69.0	59.7, 67.0, 69.0	$F_{2,91} = 0.00$, $p = 1.00$ [1]
TPFH	94	71.2, 77.0, 81.0	69.0, 75.0, 81.1	70.7, 76.0, 78.3	$F_{2,91} = 0.30$, $p = 0.74$ [1]
TAFH	94	104.0, 112.0, 122.8	104.0, 112.0, 119.1	107.0, 113.0, 116.3	$F_{2,91} = 0.26$, $p = 0.77$ [1]

N is the number of non-missing values. [1] Kruskal–Wallis. n(%), median + IQR.

We analyzed the distribution of molar class and gender across hyperdivergent, normodivergent, and hypodivergent facial skeletal patterns. Among the ninety-four individuals included, six were hyperdivergent, thirteen were normodivergent, and seventy-five were hypodivergent. Molar Class I comprised 33.3% hyperdivergent, 61.5% normodivergent, and 33.3% hypodivergent patterns. Conversely, molar Class II exhibited 50% hyperdivergent, 30.8% normodivergent, and 52% hypodivergent patterns, while molar Class III showed 16.7% hyperdivergent, 7.7% normodivergent, and 14.7% hypodivergent patterns. We found no statistically significant association between molar class distribution and gender ($p = 0.4281$).

Females were notably more represented in the hyperdivergent group (83.3%) compared to the normodivergent (53.8%) and hypodivergent (62.7%) groups, whereas males were less represented in the hyperdivergent group (16.7%) compared to the normodivergent (46.2%) and hypodivergent (37.3%) groups. The association between gender and molar class distribution was not statistically significant ($p = 0.4661$) based on Pearson's chi-squared test.

3.3. Predictors of Gender Differentiation

The logistic regression model evaluates anthropometric measurements as predictors of gender differentiation (Table 5). TPFH did not show a statistically significant effect on gender differentiation ($p = 0.863$, OR = 0.991, 95% CI [0.897, 1.095]). The confidence intervals provide a range within which the true OR is likely to fall. TAFH showed a statistically significant positive effect on gender differentiation (estimate = 0.10096, $p = 0.022$, OR = 1.106, 95% CI [1.015, 1.206]). This indicates that for each unit increase in TAFH, the odds of being male increased by a factor of 1.106. Conversely, the *y*-axis to SN had a statistically significant negative effect on gender differentiation (estimate = −0.15276, $p = 0.041$, OR = 0.858, 95% CI [0.741, 0.994]). For each unit increase from the *y*-axis to SN, the odds of being male decreased by a factor of 0.858.

Figure 4 illustrates significant correlations among anthropometric measures. A strong negative correlation ($R = -0.72$, $p < 0.001$) between Jarabak's ratio and *y*-axis to SN indicates that as Jarabak's ratio decreases, the *y*-axis to SN angle increases. Additionally, a moderate positive correlation ($R = 0.53$, $p < 0.001$) was observed between the *y*-axis to SN and TAFH, suggesting that as the former increases, the latter tends to increase. Furthermore, a moderate correlation ($R = 0.60$, $p < 0.01$) between TPFH and TAFH can be observed. These findings emphasize the interconnectedness of different facial measurements, offering insights into craniofacial morphology.

Table 5. The anthropometric measurements serve as predictors for gender differentiation.

Model Coefficients: Gender							
						95% Confidence Interval	
Predictor	**Estimate**	**SE**	**Z**	***p***	**Odds Ratio**	**Lower**	**Upper**
Intercept	−1.30310	4.5273	−0.288	0.773	0.272	3.81×10^{-5}	1939.431
TPFH	−0.00882	0.0510	−0.173	0.863	0.991	0.897	1.095
TAFH	0.10096	0.0441	2.291	0.022	1.106	1.015	1.206
Y-axis to SN	−0.15276	0.0748	−2.043	0.041	0.858	0.741	0.994

Note. Estimates represent the log odds of "Gender = M" vs. "Gender = F".

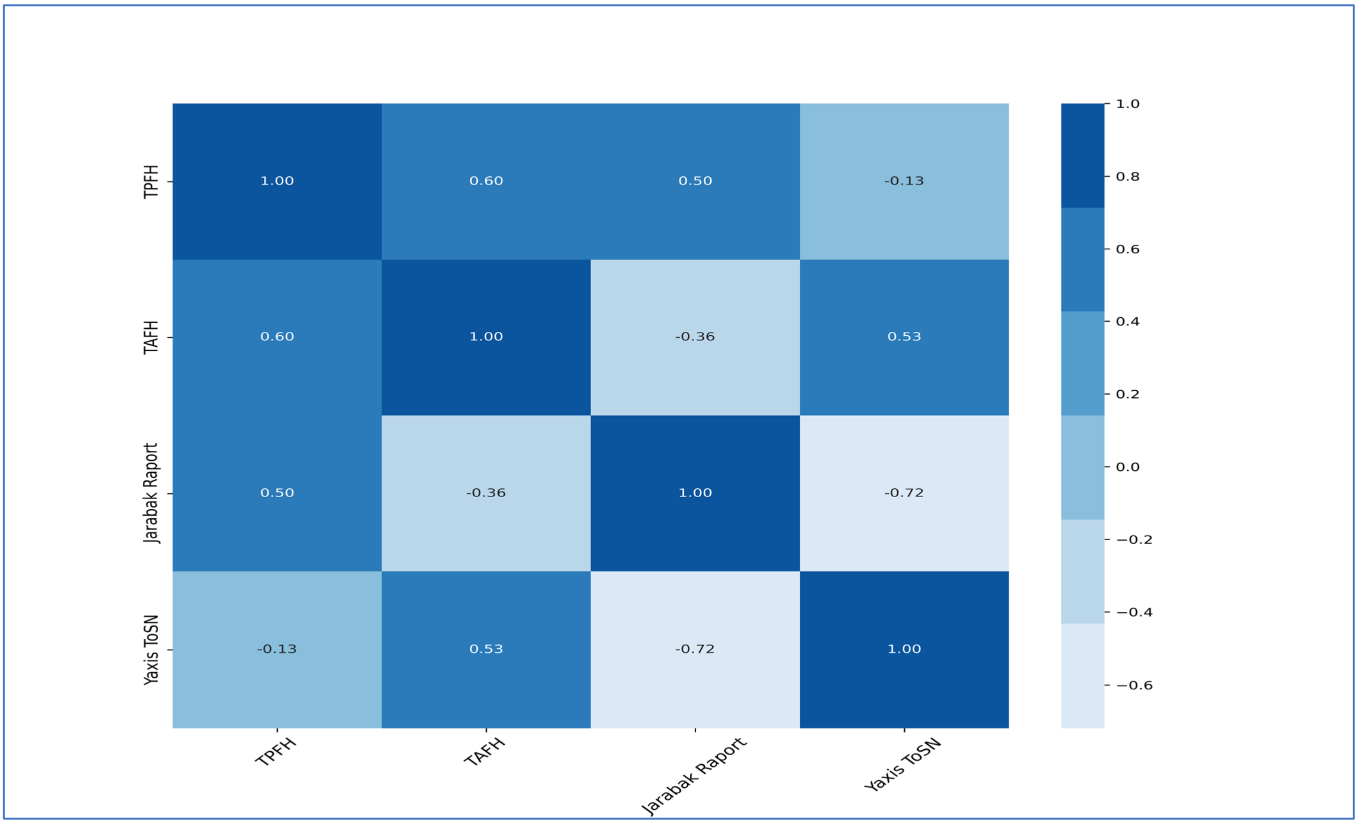

Figure 4. Correlation between the TPFH, TAFH, Jarabak's ratio, and *y*-axis to SN.

Table 6 presents the predictors of divergence types based on anthropometric measurements. There was a difference in the type of divergence between the hyperdivergent and normodivergent groups, as shown by the significant intercept estimate (estimate = 24.8994, SE = 12.1376, $p = 0.040$). Age did not have a significant effect on the odds of divergence type (estimate = −0.0564, SE = 0.1059, $p = 0.594$, OR = 0.945), but the *y*-axis to SN did (estimate = 0.3547, SE = 0.1732, $p = 0.041$, OR = 1.426). There was a difference in the type of divergence between the hypodivergent and normodivergent groups, as shown by the significant intercept estimate (estimate = 21.0955, SE = 7.1048, $p = 0.003$). Age also did not significantly impact the odds of divergence type (estimate = 0.0475, SE = 0.0468, $p = 0.310$, OR = 1.049), while *y*-axis to SN was significant (estimate = −0.3050, SE = 0.1052, $p = 0.004$, OR = 0.737). These results indicate that the *y*-axis to SN plays a crucial role in distinguishing between hyperdivergent and normodivergent, as well as hypodivergent and normodivergent facial skeletal patterns.

Table 6. Predictors of divergence type based on anthropometric measurements.

		Model Coefficients: Divergent					95% Confidence Interval	
Divergent	**Predictor**	**Estimate**	**SE**	**Z**	***p***	**Odds Ratio**	**Lower**	**Upper**
Hyperdivergent–Normodivergent	Intercept	24.8994	12.1376	−2.051	0.040	1.54×10^{-11}	7.16×10^{-22}	0.330
	Age	−0.0564	0.1059	−0.532	0.594	0.945	0.768	1.163
	Y-axis_to_SN	0.3547	0.1732	2.047	0.041	1.426	1.015	2.002
Hypodivergent–Normodivergent	Intercept	21.0955	7.1048	2.969	0.003	1.45×10^{9}	1300.356	1.62×10^{15}
	Age	0.0475	0.0468	1.015	0.310	1.049	0.957	1.149
	Y-axis to_SN	−0.3050	0.1052	−2.900	0.004	0.737	0.600	0.906

SE: standard error.

4. Discussion

In our retrospective cohort study, we aimed to explore the cephalometric parameters related to FHR and growth patterns, offering insights into the intricate relationship between various anthropometric measurements and craniofacial morphology. The vertical development of the mandible plays a pivotal role in determining facial harmony, with mandibular rotation significantly impacting facial patterns [27]. Previous studies have examined growth patterns in diverse malocclusions and populations, but it is crucial to acknowledge that the substantial differences in facial morphology prevent the indiscriminate generalization of findings across diverse racial and ethnic groups [28]. Hence, our study focused on assessing the relationships between facial height and growth patterns specifically within the population of Timis County.

Our study found an important connection between FHR and growth patterns. Based on FHR, we put people into three groups: hyperdivergent, normodivergent, and hypodivergent. This gave us useful information about how faces grow and develop. We found that the molar connection and the sagittal skeletal relationship were strongly correlated and that vertical growth patterns had a considerable impact on an individual's facial height, which is in line with the findings of Padarthi et al. [13]. By dividing participants into three main groups based on Angle's classification, we were able to assess the parameters of the vertical growth pattern more comprehensively, but an evaluation of the relationship between the anteroposterior dental arch and jaw base relationships revealed that Angle's classification of malocclusion alone cannot fully reveal the degree of dentofacial deformity [29].

Jarabak's ratio, determining anterior and posterior facial proportions, revealed intriguing insights. In our study, Class I malocclusion exhibited 33.3% hyperdivergent, 61.5% normodivergent, and 33.3% hypodivergent growth patterns, differing with findings by Sahu et al. and Padarthi et al. [13,30]. Notably, we observed a higher prevalence of normodivergent individuals in molar Class I, contrasting with a lower prevalence in molar Class II, suggesting a potential correlation between molar class and growth pattern. This emphasizes the importance of considering both dental and skeletal factors in assessing facial morphology. Our results were similar to those of Siriwat and Jarabak [18], who said that normodivergent growth patterns were common in Class I. However, our study also showed that normodivergent growth patterns were more common in skeletal Class I subjects, which could be due to differences in race. Numerous factors and demographic traits directly impact the growth of the musculoskeletal system, as noted in other types of craniofacial diseases [31].

Our study delved into gender disparities within growth pattern distributions, revealing a higher proportion of females among hyperdivergent and hypodivergent group individuals, while the normodivergent group displayed more balanced gender distributions, albeit not statistically significant. Detecting subtle gender-related differences in growth patterns may require larger sample sizes for accuracy.

In the past, research by Maskey and Shrestha [32], Taner et al. [33], and Wang et al. [26] showed that PFH and AFH are different between males and females, with females having a smaller PFH. In our study, we saw a link between PFH and Jarabak's ratio in the hypodivergent group. We also saw differences between males and females in AFH, PFH, and Jarabak's ratio in the hypodivergent group. This aligns with findings indicating the lowest sexual dimorphism in Class I malocclusion, as noted by Siriwat and Jarabak [18].

When we compared our findings with those of Siriwat and Jarabak [18], it was evident that there were disparities in PFH, AFH, and FHR among different malocclusions. We found that Class I malocclusion had a TAFH of 112.0 (IQR: 104.0 to 122.8), a TPFH of 77.0 (IQR: 71.2 to 81.0), and a *y*-axis to SN of 65.0 (IQR: 61.2 to 69.0). Class II malocclusion had a TAFH of 112.0 (IQR: 104.0 to 119.1), a TPFH of 75.0 (IQR: 69.0 to 81.1), and a *y*-axis to SN of 65.0 (IQR: 62.0 to 69.0). Additionally, Class III malocclusion displayed a TAFH of 113.0 (IQR: 107.0, 116.3), TPFH of 76.0 (IQR: 70.7.0, 78.3), and *y*-axis to SN of 67.0 (IQR: 59.7, 69.0). Notably, our study identified different distributions of malocclusions among growth patterns for females and males, showcasing variations across different classifications. While our findings broadly align with Siriwat and Jarabak's observations, discrepancies exist, highlighting potential racial variations and underscoring the need for further investigation to elucidate the underlying mechanisms.

Overall, our study adds valuable insights into the gender-specific distribution of growth patterns and further delineates the relationship between cephalometric parameters and malocclusions. Future research with larger cohorts is necessary to validate and enhance our findings, offering a comprehensive understanding of the intricate interplay between gender, cephalometric parameters, and growth patterns in craniofacial development. Additionally, it could be interesting to include the integration of recently introduced technologies such as artificial intelligence [34] and smartphone applications [35].

Our study's correlation analysis between cephalometric measurements yielded valuable insights into craniofacial relationships. We observed strong negative correlations between the Jarabak ratio and the *y*-axis to SN angle, suggesting a dynamic interplay between facial height and mandibular position. Additionally, we found moderate positive correlations between the *y*-axis to SN and TAFH, as well as between TPFH and TAFH. These findings underscore the intricate nature of craniofacial morphology, emphasizing the importance of employing comprehensive assessment methods.

Our findings align with previous research by Manish Valiathan et al., who reported *y*-axis to SN angles of $63.67 \pm 3.39°$ for Class I males and $64.74 \pm 3.61°$ for females [21]. In our study, we observed values in a similar range across the two gender groups: Group I: 65.0 (IQR: 61.2–69.0), Group II: 65.0 (IQR: 62.0–69.0), and Group III: 67.0 (IQR: 59.7–69.0). These variations may reflect inherent differences across populations and underscore the importance of considering regional factors in cephalometric analyses.

Our study sought to contribute to this understanding by assessing facial height ratios and growth patterns in individuals with various malocclusions from Timis County.

Facial traits often undergo significant variation during growth, necessitating a comprehensive assessment approach. Therefore, we selected participants aged nine to forty-eight for our study to reduce bias in interpreting facial patterns. Vertical development patterns play a pivotal role in jaw growth direction, with implications for facial height [36]. Using jaw rotation to classify facial patterns as hypodivergent or hyperdivergent helps with treatment plans and shows how useful Angle's classification is for describing vertical development patterns [37].

Furthermore, growth projections are essential for estimating future growth and predicting outcomes in orthodontic treatment. Understanding the volume and direction of growth aids in achieving accurate forecasts and guiding treatment decisions [38]. Orthodontic problem databases commonly record both hypodivergent and hyperdivergent facial forms, underscoring the clinical significance of our findings [39]. Overall, our study contributes valuable insights into the complex relationship between cephalometric measurements, growth patterns, and facial morphology, with implications for orthodontic treatment planning and patient care.

If there are several variables that contribute to malocclusion, the orthodontist should favor and consider using fixed and functional appliances in tandem during a certain growth stage as this can generate better outcomes than using fixed and functional appliances separately [40,41]. The goal of orthodontic treatment is to restore normal vertical proportions for better aesthetics. This shows how important it is to thoroughly examine the dentofacial complex in both the front and back parts. Using both fixed and functional appliances together during certain stages of growth may be more effective than using them separately, which shows that treatment strategies need more research [6,42]. Other types of craniofacial diseases have noted that a number of factors and demographic traits directly impact the growth of the musculoskeletal system [31]. Landmark detection on cephalometric radiographs remains challenging and is quite difficult for raters with little experience. Orthodontic diagnostic and treatment planning heavily relies on the analysis of lateral cephalograms. The relationships between the skeleton, teeth, and soft tissues are counted and the effects of the treatment are evaluated [43].

Limitations of our study include the use of lateral cephalograms from patients in Timis County, which may not represent the entire population. A broader study encompassing all skeletal malocclusions would provide a more accurate understanding of how different malocclusions impact growth patterns. Furthermore, although our investigation illuminates the connection between cephalometric measurements and growth patterns, we did not thoroughly examine other factors that contribute to malocclusion, including changes in muscle and bone. Future research could benefit from considering these factors comprehensively. Also, this study has some limitations that need to be considered when interpreting the results. In the present study, one of the limitations is the absence of two examiners taking the cephalogram measurements. Another limitation pertains to group allocation based on Angle's classification using plaster models; this is a risk of bias as dental and skeletal configurations can be quite different. Another limitation involves the use of AI software for cephalogram interpretation. A final limitation pertains to the possibility of considering a larger number of patients. Future studies with a larger sample will be conducted. It is important to evaluate these issues and resolve them in future research.

5. Conclusions

This study revealed significant associations between FHR and craniofacial development, emphasizing the importance of recognizing gender differences and investigating the impact of skeletal malocclusions on growth patterns. Treatment planning should integrate both hard and soft tissue alterations, considering the prevalent hypodivergent growth pattern observed in participants. The strong negative correlation between FHR and the y-axis to the SN angle underscores the need for comprehensive treatment strategies. We recommend the use of computers for cephalometric analyses in orthodontic education. Cephalometric measurements are virtually perfectly collected by automatic analytic tools, making them suitable for use in clinical settings.

Overall, our results help us understand facial harmony and plan orthodontic treatment for the best possible outcomes in terms of both aesthetics and function. This highlights the importance of using cephalometric evaluation to make personalized plans.

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