ORIGINAL ARTICLE

CONTENTS

Diagnostic value of lateral cephalometric parameters in determining vertical and horizontal maxillofacial growth patterns

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ABSTRACT

Aim: To assess the diagnostic value of qualitative and quantitative lateral cephalometric parameters in determining vertical, horizontal, and neutral maxillofacial growth patterns in patients with orthodontic pathology.

Materials and Methods: The study included 292 lateral cephalograms of patients aged 5 to 50 years who sought orthodontic consultation. Eleven quantitative cephalometric parameters were analysed in the full sample. In a randomised subgroup of 160 cephalograms, seven additional qualitative parameters were assessed. Growth pattern determination was performed using an integrated approach based on the absolute majority of diagnostic signs. In addition, 134 cephalograms were independently evaluated by 34 orthodontic trainees using qualitative characteristics only. The diagnostic performance of each parameter was assessed using balanced accuracy, sensitivity, specificity, and positive predictive value.

Results: Among 292 patients, 121 had a neutral growth pattern, 103 a vertical pattern, and 68 a horizontal pattern. Evaluation based only on qualitative signs resulted in correct classification in 60.45% of cases on average. Among quantitative parameters, ∠N-Go-Me demonstrated the highest diagnostic performance, with a positive predictive value of 82.9%, followed by ∠Ar-Go-Me and ∠Pn-MP. Among qualitative parameters, the mandibular angle, condylar process height, and contour of the lower mandibular border showed the highest diagnostic value.

Conclusions: Quantitative cephalometric parameters, particularly ∠N-Go-Me, are more diagnostically reliable than isolated qualitative assessment for determining maxillofacial growth patterns. A combined approach may improve diagnostic accuracy in orthodontic treatment planning.

KEY WORDS: orthodontics, cephalometry, craniofacial growth, vertical dimension

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INTRODUCTION

Orthodontic diagnostics is a fundamental basis for successful treatment [1]. In this context, cephalometric analysis is a unique method for accurately determining the differentiation of the level of pathology (skeletal or dentoalveolar) [2], the dimensions and relationships of the jaws to each other and to the anterior cranial base [3], as well as jaw convergence or divergence (maxillofacial growth pattern).

A correctly determined maxillofacial growth pattern not only influences the choice of treatment strategy but also helps prevent complications during orthodontic treatment and relapses afterwards [4–6].

When assessing facial aesthetics, vertical parameters are considered significant. The face is perceived as attractive when its upper, middle, and lower thirds are proportional. However, in cases of impaired development of the anterior cranial base [7, 8], taking into account hereditary factors [9], under the influence of general muscular [10] and postural imbalance [11], or abnormal functioning of oral cavity functions such as mastication [12, 13], swallowing [14], and breathing [15], the maxillofacial growth develops according to two pathological patterns: horizontal, leading to the formation of a short face, and vertical, leading to the formation of a long face.

The qualitative characteristics of the maxillofacial growth pattern were defined by A. Björk and J. Jarabak [16, 17]. However, in the early mixed dentition period or in doubtful cases of determining the growth pattern, it is impossible to base clinical decisions and orthodontic treatment objectives solely on qualitative features. Moreover, the accuracy of determining the growth pattern significantly depends on the clinician's qualification and experience, and is largely subjective. Therefore, a considerable number of

Table 1. Qualitative parameters analysed in the assessment of the maxillofacial growth pattern

Qualitative feature	Maxillofacial growth pattern	
	Vertical	Horizontal
Contour of the lower border of the mandible (lower jaw)	Concave in the region of the antegonial notch	Convex in the chin region
Shape of the mandibular symphysis	Elongated in the vertical plane	Elongated in the sagittal plane
Height of the mandibular condylar process	Greater height	Lower
Rotation of the dentoalveolar complex	Clockwise rotation	Counterclockwise rotation
Line connecting the mandibular head with the condylar process	Deviated from the midline	Deviation toward the midline
Mandibular angle	Increased	Markedly reduced
Height of the lower third of the face	Enlarged	Reduced

Source: compiled by the authors of this study

Table 2. Quantitative parameters analysed in the assessment of the maxillofacial growth pattern

Author	Parameter symbol	Parameter description
A.M. Schwarz [27]	∠B	Angle between the maxillary base (SpP) and the mandibular base (MP)
	∠Pn-MP	Angle between the perpendicular (Pn) to the anterior cranial base (NSe) and the mandibular base (MP)
	∠I	Angle between the perpendicular (Pn) to the anterior cranial base (NSe) and the maxillary base (SpP)
	∠Pn-OcP	Angle between the perpendicular (Pn) to the anterior cranial base (NSe) and the occlusal plane (OcP)
J.R. Jarabak [17]	∠NSAr	Angle between the NS and S–Ar planes
	∠Ar-Go – Me	Angle between the mandibular ramus and the mandibular base
	∠N-Go-Ar	Upper gonial angle
	∠N-Go-Me	Lower gonial angle
	(∠N-Go-Ar/∠N-Go-Me)×100	Ratio of the upper gonial angle to the lower gonial angle, reflecting not only the growth pattern type but also its degree
	∠NSGn	Y-axis angle
Downs W.B. [28], Arne Björk [16] – J.R. Jarabak [17].	S-Go	Posterior facial height
	N – Gn	Anterior facial height
	(SGo)/(NMe)×100	Ratio of posterior to anterior facial height

Source: compiled by the authors based on [16, 17, 27, 28]

prominent orthodontic researchers, in particular R. Ricketts [18], J. McNamara Jr. [19], and C. Steiner [20], have investigated quantitative parameters that allow for a more objective assessment of the maxillofacial growth pattern.

As a rule, the maxillofacial growth pattern is determined based on lateral cephalograms by considering the simple majority of qualitative and quantitative parameters [21–26]. However, in the available literature, there are no assessments of the degree of significance of each quantitative parameter's influence on the expert conclusion regarding the maxillofacial growth pattern. Moreover, there is no such analysis for partial combinations of qualitative and quantitative parameters, which would make it possible to substantially reduce the number of measurements required on lateral cephalograms for decision-making.

AIM

The aim of the study was to determine the diagnostic significance of qualitative and quantitative parameters of lateral cephalograms for assessing the maxillofacial growth pattern in patients with orthodontic pathology and to compare the results of an integrated assessment with expert determination of the maxillofacial growth pattern based solely on qualitative features.

FRAMEWORK

This study was conducted at the Department of Orthodontics of the P.L. Shupyk National Medical Academy of Ukraine as part of the research project "Develop and test an integrated approach in the diagnosis and treatment of orthodontic patients with comorbidities" (State registration number 0121U111023; duration: 2021–2025; extended to 2027).

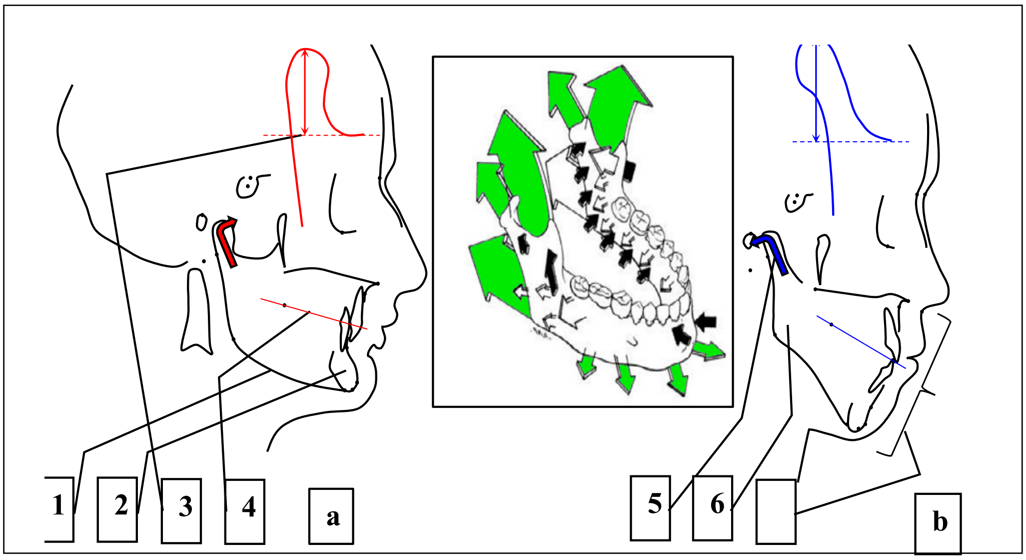

Fig. 1. Qualitative features of pathological types of maxillofacial growth (based on A. Björk and J. Jarabak [16, 17]): (a) horizontal maxillofacial growth pattern; (b) vertical maxillofacial growth pattern. 1) contour of the lower border of the mandible; 2) shape of the chin prominence; 3) height of the condylar process; 4) rotation of the dentoalveolar complex; 5) line connecting the mandibular head and condylar process; 6) mandibular angle; 7) height of the lower third of the face

Source: compiled by the authors based on [16, 17]

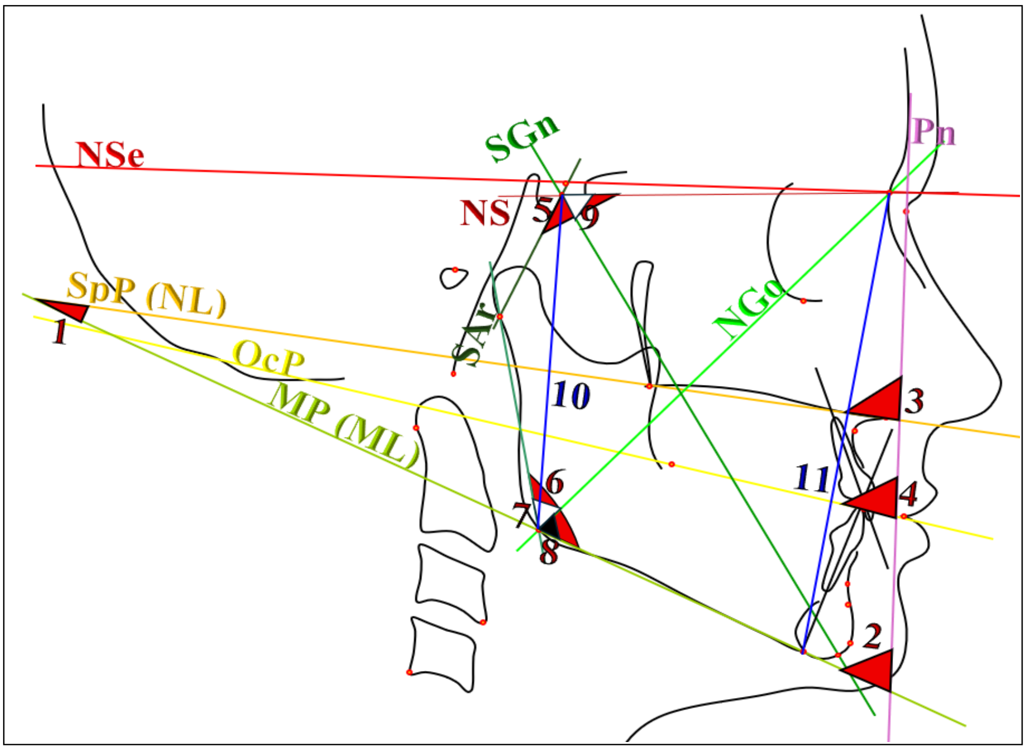

Fig. 2. Quantitative parameters analysed in the assessment of the maxillofacial growth pattern – cephalometric landmarks on lateral cephalograms (A. M. Schwarz [27]; J. R. Jarabak [17]; W. B. Downs [28]; A. Björk [16]): 1) ∠B; 2) ∠Pn–MP; 3) ∠I; 4) ∠Pn–OcP; 5) ∠NSAr; 6) ∠Ar–Go–Me; 7) ∠N–Go–Ar (upper gonial angle); 8) ∠N–Go–Me (lower gonial angle); 9) ∠NSGn (Y-axis angle); 10) posterior facial height (S–Go); 11) anterior facial height (N–Gn)

Source: compiled by the authors based on [16, 17, 27, 28.]

MATERIALS AND METHODS

Lateral cephalograms of patients with orthodontic pathology who sought consultation at the Department of Orthodontics, Shupyk National Healthcare University of Ukraine (Kyiv, Ukraine) were analysed. The maxillofacial growth pattern was determined in the vertical plane using an integrated method based on both qualitative and quantitative parameters (Table 1, Table 2, Fig. 1, Fig.2).

For the horizontal maxillofacial growth pattern (other terms: counterclockwise growth rotation, short face, low angle, anterior mandibular rotation, convergent type), the following features are characteristic: a convex contour in the chin region (mandible); an elongated symphysis in the sagittal (horizontal) plane; a low condylar process; counterclockwise rotation of the dentoalveolar complex; medial deviation of the mandibular head relative to the neck (towards the midline); an acute mandibular angle; and a reduced lower third of the face (Table 1, Fig. 1).

For the vertical maxillofacial growth pattern (clockwise growth rotation, long face, high angle, posterior mandibular rotation, divergent type), the following features are characteristic: a markedly concave contour in the antegonial notch region of the mandible; an elongated symphysis in the vertical plane; a high (elongated) condylar process; clockwise rotation of the dentoalveolar complex; distal deviation of the mandibular head relative to the neck (away from the midline); an obtuse mandibular angle; and an increased lower third of the face (Table 1, Fig. 1).

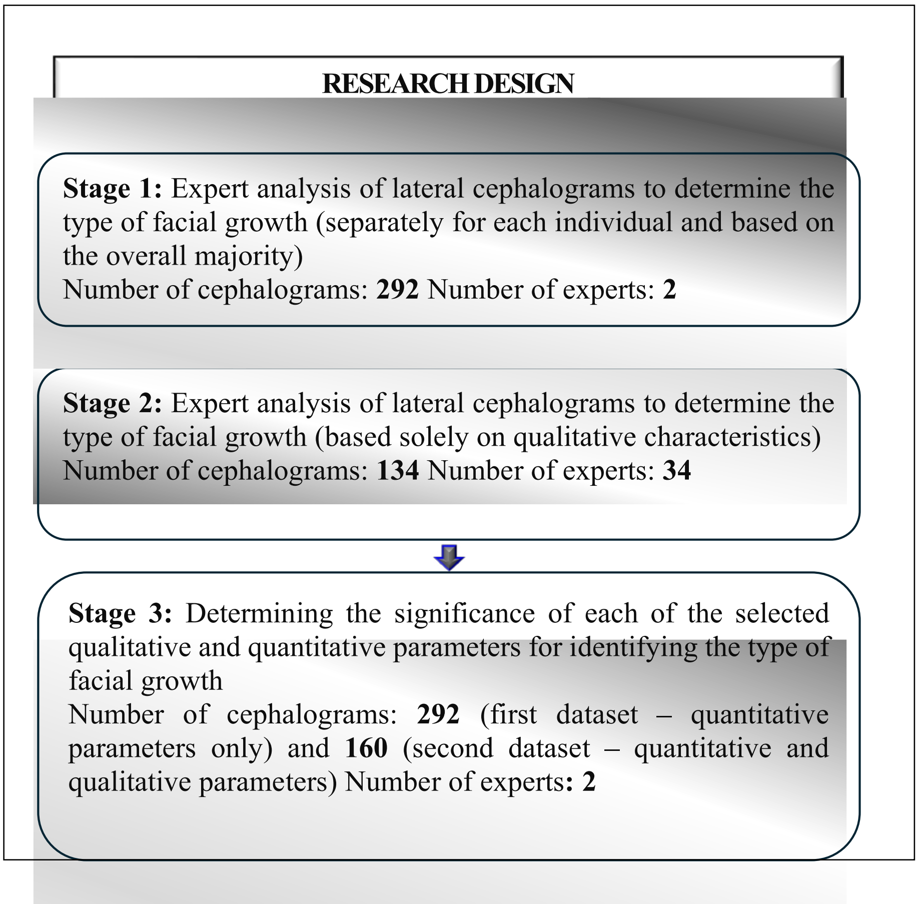

Fig. 3. Research design
Picture taken by the authors

For the neutral maxillofacial growth pattern, a balanced relationship between the vertical and horizontal components of growth is characteristic. The contour of the lower border of the mandible demonstrates a smooth, uniform course without a pronounced concavity in the antegonial notch region or excessive convexity in the chin region. The mandibular symphysis has a rounded, proportionate shape without a predominant deformation in either the vertical or sagittal plane. The height of the condylar process corresponds to average age-related and morphological characteristics.

Rotation of the dentoalveolar complex is balanced, without a pronounced tendency toward clockwise or counterclockwise rotation. The line connecting the mandibular head with the condylar process has a straight direction. The mandibular angle remains within normative values, approximating 123°, without a tendency toward marked reduction or increase. The height of the lower third of the face is proportional to the middle and upper thirds of the face. The quantitative parameters used for determining the maxillofacial growth pattern are presented in Table 2 and Fig. 2.

In the first stage of the study (Fig. 3), two datasets were formed. The full dataset included 292 lateral cephalograms of patients of both sexes: 124 males and 168 females (Fig.4a). For all these cephalograms, values of eleven quantitative parameters were obtained.

In the first (second) dataset, there were 70 (31) lateral cephalograms of patients aged 5 to 8 years (early mixed dentition period), 60 (24) cephalograms of patients aged 9 to 12 years (late mixed dentition period), and 162 (105) cephalograms of patients in both the developing permanent dentition and the fully established permanent dentition period, aged 13 to 50 years (Fig. 4b). All individuals with permanent dentition were grouped.

The second dataset is a random subset of the first and contains 160 lateral cephalograms (73 males and 87 females), for which qualitative parameters were additionally considered (a total of seven parameters).

In the first (second) dataset, there were 70 (31) lateral cephalograms of patients aged 5 to 8 years (early mixed dentition period), 60 (24) cephalograms of patients aged 9 to 12 years (late mixed dentition period), and 162 (105) cephalograms of patients in both the developing permanent dentition and the fully established permanent dentition period, aged 13 to 50 years (Fig. 4b). All individuals with permanent dentition were grouped.

In the second stage of the study (Fig. 3), 134 lateral cephalograms were randomly selected from the 292 cephalograms to compare the results of maxillofacial growth pattern assessment based on the absolute majority of qualitative (Table 1, Fig. 1) and quantitative (Table 2, Fig. 2) parameters with expert evaluation based solely on qualitative parameters.

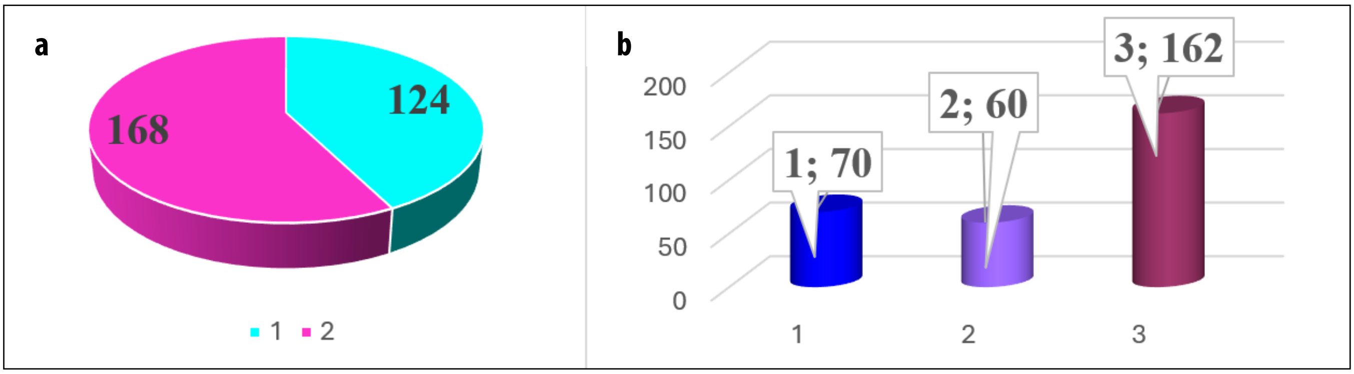

Fig. 4. Distribution of patients who's lateral cephalograms were analyzed according to: (a) sex (1 – male, 2 – female); (b) stage of dentition development (1 – early mixed dentition period, age 6–8 years; 2 – late mixed dentition period, age 9–12 years; 3 – developing and established permanent dentition period, age 13–50 years)
Picture taken by the authors

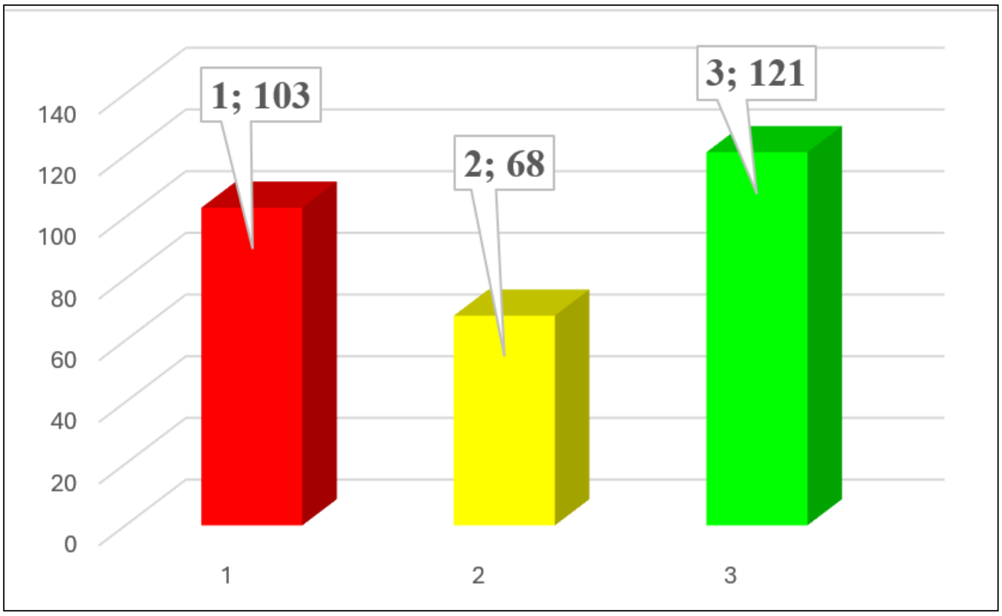

Fig. 5. Distribution of patients' lateral cephalograms according to the maxillofacial growth pattern: 1) vertical type, 2) horizontal type, 3) neutral type
Picture taken by the authors

The experts were 34 participants of an orthodontic specialization course. After studying the topic and acquiring practical skills, they were provided with links to complete a Google Form containing 134 tasks. Each task included a photographic image of one of the selected lateral cephalograms, and the respondents were required to assign one of three maxillofacial growth pattern types: neutral, vertical, or horizontal. The true growth pattern was defined as the one previously determined by the absolute majority of qualitative and quantitative parameters for each lateral cephalogram.

In the third stage of the study (Fig. 3), an analysis of 292 lateral cephalograms was performed to identify the parameters most significant for determining the maxillofacial growth pattern. The determination was based on the absolute majority of positive quantitative parameters (i.e., those corresponding to the values characteristic of a specific growth pattern). For 160 lateral cephalograms, qualitative parameters were also assessed.

Statistical data processing was performed by calculating diagnostic performance metrics for each qualitative and quantitative parameter of the lateral cephalograms. For each indicator, balanced accuracy, sensitivity, specificity, and positive predictive value were determined. Calculations were based on contingency tables using a one-vs-rest approach for each type of maxillofacial growth pattern, followed by averaging of the obtained values.

Accuracy is defined as the average probability of a correct (both positive and negative) test result across all types of maxillofacial growth patterns. Balanced accuracy accounts for the imbalance between the numbers of positive and negative cases in the overall dataset.

Sensitivity is defined as the average probability across all maxillofacial growth patterns of correctly classifying a case with a positive value of the tested parameter. Specificity is defined as the average probability across all maxillofacial growth patterns of correctly classifying a case with a negative value of the tested parameter. Positive predictive value is defined as the average probability of correct identification of the maxillofacial growth pattern among all cases classified as such based on a given cephalometric parameter.

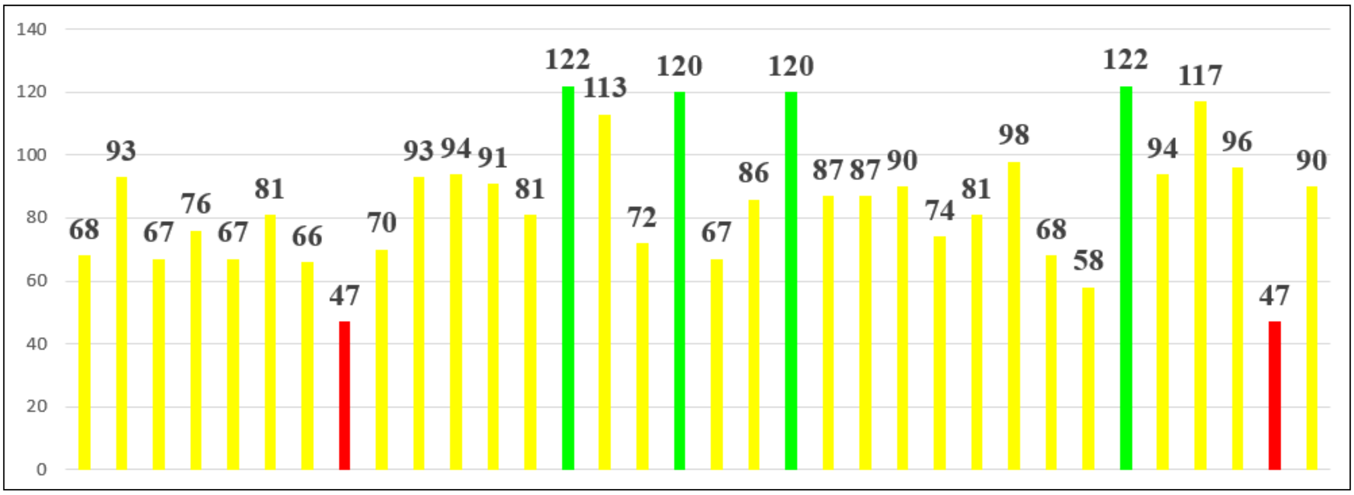

Fig. 6. Number of correctly identified maxillofacial growth patterns based on qualitative parameters. The assessment was performed by 34 experts (participants of a specialization course)
Picture taken by the authors

The 95% confidence interval (CI) limits were calculated using the Wald method; differences were considered statistically significant at $p<0.05$.

ETHICS

The study was conducted in accordance with the principles of the Declaration of Helsinki. All patients or their legal representatives provided written informed consent for the use of diagnostic materials for scientific purposes. All lateral cephalograms included in the study were anonymised in advance; only the patients' age and sex were recorded in the database. The study protocol was reviewed and approved by the local bioethics committee.

RESULTS

As a result of the first stage of the study, it was established that, among 292 patients of both sexes aged 5 to 50 years, 121 had a neutral maxillofacial growth pattern, 103 had a vertical growth pattern, and 68 had a horizontal growth pattern (Fig.5).

The analysis of expert responses based solely on qualitative parameters (second stage) to the proposed tasks showed that the correct maxillofacial growth pattern was identified in an average of only 81 out of 134 cases, corresponding to 60.45% (Fig. 6).

The lowest number of errors in determining the maxillofacial growth pattern was made by four experts. They correctly identified the growth pattern in 120–122 out of 134 cases (89.6%–91.0%). The highest number of errors in determining the growth pattern based solely on qualitative features was made by two experts, who provided 47 correct answers each out of 134 (35.1%). The remaining 28 experts correctly identified the maxillofacial growth pattern in 47 to 120 cases (35.1% to 89.6%).

In the third stage of the study, the statistical agreement between the maxillofacial growth pattern determined by each quantitative or qualitative cephalometric parameter and the true value was analysed. The results are summarised in Table 3 (for quantitative cephalometric parameters) and Table 4 (for qualitative cephalometric parameters). The values in parentheses indicate the positive predictive value of the parameter in determining the corresponding maxillofacial growth pattern (i.e., the number of correctly identified cases among all cases classified as such based on the given parameter).

Tables 5 and 6 present the diagnostic performance indicators for the determination of the maxillofacial growth pattern by each cephalometric parameter, calculated based on the distributions obtained in Table 3 and Table 4, respectively.

As shown in Table 5, among the quantitative cephalometric parameters, the best diagnostic performance is demonstrated by ∠N–Go–Me, followed by ∠Ar–Go–Me, ∠Pn–MP, and ∠B, which show nearly identical values.

The least informative parameters are ∠I, ∠NSAr, and ∠N–Go–Ar, whose positive predictive value does not exceed 40%. When using ∠N–Go–Me as the sole parameter for determining the maxillofacial growth pattern, 17–18% misclassifications should be expected. This parameter demonstrates relatively high specificity (up to 90%) and slightly lower sensitivity (up to 82%).

It should be noted that some cephalometric parameters demonstrated an almost 100% positive predictive value for the identification of a specific maxillofacial growth pattern (e.g., ∠Pn–MP, ∠B, or ∠Pn–OcP for the identification of the horizontal growth pattern; see Ta-

Table 3. Distribution of maxillofacial growth patterns determined by each quantitative cephalometric parameter according to their agreement with the true types

	Maxillofacial growth pattern		Vertical (v)	Horizontal (h)	Neutral (n)
	Number of lateral cephalograms		103	68	121
Parameter	∠N-Go-Me	v	**82 (80.4%)***	0	20
		h	0	**59 (92.2%)***	5
		n	21	9	**96 (76.2%)***
	∠Ar-Go – Me	v	**38 (97.4%)***	0	1
		h	0	**35 (74.5%)***	12
		n	65	33	**108 (52.4%)***
	∠Pn-MP	v	**99 (64.7%)***	2	52
		h	0	**19 (100.0%)***	0
		n	4	47	**69 (57.5%)***
	∠B	v	**100 (64.5%)***	0	55
		h	0	**17 (100.0%)***	0
		n	3	51	**66 (55.0%)***
	∠NSGn угол оси Y	v	**40 (80.0%)***	0	10
		h	1	**14 (82.4%)***	2
		n	62	54	**109 (48.4%)**
	(SGo)/(NMe)×100	v	**49 (75.4%)***	2	14
		h	5	**61 (51.3%)***	53
		n	49	5	**54 (50.0%)***
	(∠N-Go-Ar)/ (∠N-Go-Me)×100	v	**60 (63.2%)***	4	31
		h	14	**37 (52.9%)***	19
		n	29	27	**71 (55.9%)***
	∠Pn-OcP	v	101 (36.4%)	55	121
		h	0	**1 (100%)***	0
		n	2	12	0 (0,0 %)
	∠I	v	41 (37.3%)	22	47
		h	0	0 (0.0%)	0
		n	62	46	74 (40.6%)
	∠NSAr	v	24 (49.0%)	5	20
		h	7	11 (28.2%)	21
		n	72	52	80 (39.2%)
	∠N-Go-Ar	v	30 (33.7%)	22	37
		h	34	23 (26.7%)	29
		n	39	23	55 (47.0%)

Note: * – cases where the positive predictive value of the parameter for the given maxillofacial growth pattern is not less than 50%
Source: compiled by the authors of this study

ble 3). However, this provides limited practical benefit, as among 68 truly horizontal cases, these parameters correctly identified only 1.5–28% of them.

Among the qualitative cephalometric parameters (Table 6), the best diagnostic performance was observed for the "mandibular angle", "height of the condylar process", and "contour of the lower border of the mandible". The least informative parameter was the "line connecting the mandibular head with the condylar process", although its positive predictive value remained not lower than 50%.

Overall, qualitative parameters demonstrated slightly lower performance compared to quantitative ones. The best-performing qualitative parameter, the "mandibular angle", when used as the sole criterion for determining the maxillofacial growth pattern, may result in up to

Table 4. Distribution of maxillofacial growth patterns determined by each individual qualitative cephalometric parameter according to their agreement with the true types

Maxillofacial growth pattern			Vertical (v)	Horizontal (h)	Neutral (n)
Number of lateral cephalograms			65	25	70
Parameter	Mandibular angle	v	**59 (77.6%)***	0	17
		h	0	**15 (83.3%)***	3
		n	6	10	**50 (75.8%)***
	Height of the condylar process	v	**34 (81.0%)***	0	8
		h	1	**16 (80.0%)***	3
		n	30	9	**59 (60.2%)***
	Contour of the lower border of the mandible	v	**49 (76.6%)***	0	15
		h	1	**15 (65.2%)***	7
		n	15	10	**48 (65.8%)***
	Rotation of the dentoalveolar complex	v	**58 (71.6%)***	0	23
		h	1	**17 (58.6%)***	11
		n	6	8	**36 (72.0%)***
	Height of the lower third of the face	v	**44 (81.5%)***	1	9
		h	1	18 (38.3%)	28
		n	20	6	**33 (55.9%)***
	Shape of the mandibular symphysis	v	**31 (75.6%)***	0	10
		h	2	12 (44.4%)	13
		n	32	13	**47 (51.1%)***
	Line connecting the mandibular head with the condylar process	v	**4 (50.0%)***	0	4
		h	4	**14 (53.8%)***	8
		n	57	11	58 (46.0%)

Note: * – cases where the positive predictive value of the parameter for the given maxillofacial growth pattern is not less than 50%
Source: compiled by the authors of this study

21–22% misclassifications. Nevertheless, this parameter shows relatively high specificity (over 87%) and slightly lower sensitivity (over 74%).

DISCUSSION

Research that exactly matches the aim and design of our work was not found, which underlines its relevance. However, individual qualitative cephalometric features, such as the contour of the lower border of the mandible [29] or the line connecting the mandibular head with the condylar process [30], are considered indicators of mandibular rotation. In contrast, recent studies confirm the importance of specific morphometric characteristics of the mandible, including the gonial angle, mandibular body angle, ramus height, and the ratio of anterior to posterior facial height, in differentiating hyperdivergent, normodivergent, and hypodivergent maxillofacial growth patterns [31].

Our results do not appear isolated; rather, they fit well within current trends. The existing literature most strongly supports three of our findings: (1) the high diagnostic value of mandibular angles; (2) the importance of condylar (ramus) height in identifying the vertical growth pattern of the maxillofacial complex [32].

What is most strongly supported in the current literature is the correlation between individual quantitative parameters and the determination of the maxillofacial growth pattern. For example, recent studies identify the mandibular angle and the inclination of the mandibular plane relative to the cranial base as the most informative parameters for distinguishing the hyperdivergent growth pattern [33]. In a large 2024 study employing machine learning (ML-NSL—an analogue of SN-GoMe / SN-GoGn in different analyses) with computer-based computation, this parameter was shown to be the most influential feature in the classification of anterior open bite and vertical skeletal imbalance [34].

Our finding regarding the high significance of angles such as ∠N–Go–Me and ∠Ar–Go–Me is well aligned with these recent data. Although contemporary authors more commonly use the notations SN-GoGn / SN-MP / ML-NSL / FMA / gonial angle rather than ∠N–Go–Me, the underlying concept remains consistent: the mandibular

Table 5. Statistical performance indicators for the determination of the maxillofacial growth pattern using different quantitative cephalometric parameters.

Parameter	Balanced accuracy (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)
∠N-Go-Me	0.859 (0.819-0.899)	0.819 (0.743-0.895)	0.899 (0.857-0.941)	0.829 (0.754-0.904)
∠Ar-Go-Me	0.691 (0.638-0.744)	0.592 (0.494-0.690)	0.789 (0.732-0.846)	0.748 (0.662-0.834)
∠Pn-MP	0.704 (0.652-0.756)	0.604 (0.507-0.701)	0.805 (0.749-0.861)	0.741 (0.654-0.828)
∠B	0.693 (0.640-0.746)	0.589 (0.491-0.687)	0.798 (0.742-0.854)	0.732 (0.644-0.820)
∠NSGn угол оси Y	0.625 (0.569-0.681)	0.498 (0.399-0.597)	0.752 (0.691-0.813)	0.703 (0.612-0.794)
(SGo)/(NMe)×100	0.693 (0.640-0.746)	0.606 (0.509-0.703)	0.780 (0.722-0.838)	0.589 (0.491-0.687)
(∠N-Go-Ar)//(∠N-Go-Me)×100	0.676 (0.622-0.730)	0.571 (0.473-0.669)	0.780 (0.722-0.838)	0.573 (0.475-0.671)
∠Pn-OcP	0.497 (0.440-0.554)	0.332 (0.238-0.426)	0.662 (0.596-0.728)	0.455 (0.356-0.554)
∠I	0.502 (0.445-0.559)	0.337 (0.243-0.431)	0.668 (0.602-0.734)	0.390 (0.293-0.487)
∠NSAr	0.512 (0.455-0.569)	0.352 (0.257-0.447)	0.673 (0.607-0.739)	0.388 (0.291-0.485)
∠N-Go-Ar	0.521 (0.464-0.578)	0.361 (0.266-0.456)	0.681 (0.616-0.746)	0.358 (0.263-0.453)

Source: compiled by the authors of this study

Table 6. Statistical performance indicators for the determination of the maxillofacial growth pattern using different qualitative cephalometric parameters.

Qualitative feature (parameter)	Balanced accuracy (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)
Mandibular angle	0.807 (0.746-0.868)	0.741 (0.623-0.859)	0.874 (0.811-0.937)	0.789 (0.679-0.899)
Height of the condylar process	0.743 (0.675-0.811)	0.669 (0.543-0.795)	0.818 (0.745-0.891)	0.737 (0.619-0.855)
Contour of the lower border of the mandible	0.757 (0.691-0.823)	0.680 (0.555-0.805)	0.835 (0.765-0.905)	0.692 (0.568-0.816)
Rotation of the dentoalveolar complex	0.767 (0.701-0.833)	0.696 (0.573-0.819)	0.838 (0.768-0.908)	0.674 (0.548-0.800)
Height of the lower third of the face	0.710 (0.640-0.780)	0.623 (0.493-0.753)	0.797 (0.721-0.873)	0.586 (0.454-0.718)
Shape of the mandibular symphysis	0.652 (0.578-0.726)	0.543 (0.409-0.677)	0.761 (0.680-0.842)	0.570 (0.437-0.703)
The line connecting the mandibular head with the condylar process	0.594 (0.518-0.670)	0.483 (0.349-0.617)	0.704 (0.617-0.791)	0.500 (0.366-0.634)

Source: compiled by the authors of this study

plane angle and gonial angle are consistently increased in hyperdivergent patients and decreased in hypodivergent patients [35].

In our study, we did not confirm the high diagnostic significance of the Y-axis (parameter 9, Fig. 2). This finding may be addressed in future research, potentially involving larger sample sizes.

Further research perspectives include the analysis of partial combinations of the examined cephalometric parameters with the aim of potentially increasing their overall predictive value.

CONCLUSIONS

1. When assessing the maxillofacial growth pattern based exclusively on qualitative parameters, incor-

rect identification is possible in an average of 37.6% of cases (range: 10.4%–64.9%).

2. Among the qualitative parameters used for determining the maxillofacial growth pattern, the highest positive predictive value was observed for the following (in descending order): mandibular angle – 78.9%; height of the condylar process – 73.7%; contour of the lower border of the mandible – 69.2%. The lowest positive predictive value was observed for the "line connecting the mandibular head with the condylar process" – 50%.
3. Among the quantitative parameters used for determining the maxillofacial growth pattern, the highest positive predictive value was observed for the following (in descending order): ∠N–Go–Me – 82.9%, ∠Ar–Go–Me – 74.8%, ∠Pn–MP – 74.1%. The lowest positive predictive value was observed for the following (in ascending order): ∠N–Go–Ar – 35.8%; ∠NSAr – 38.8%; ∠I – 39.0%.

REFERENCES

1. Lo Giudice A, Rustico L, Ronsivalle V et al. A full diagnostic process for the orthodontic treatment strategy: a documented case report. Dent J (Basel). 2020;8(2):41. doi:10.3390/dj8020041. DOI
2. Ueda A, Tussie C, Kim S et al. Classification of maxillofacial morphology by artificial intelligence using cephalometric analysis measurements. Diagnostics (Basel). 2023;13(13):2134. doi:10.3390/diagnostics13132134. DOI
3. Cutović T, Jović N, Stojanović L et al. A cephalometric analysis of the cranial base and frontal part of the face in patients with mandibular prognathism. Vojnosanit Pregl. 2014;71(6):534–541. doi:10.2298/VSP121212011C. DOI
4. Nielsen IL. Facial growth and long-term stability. Taiwanese J Orthod. 2023;35(3):107–119. doi:10.38209/2708-2636.1339. DOI
5. Moon JH, Kim MG, Hwang HW et al. Evaluation of an individualized facial growth prediction model based on the multivariate partial least squares method. Angle Orthod. 2022;92(6):705–713. doi:10.2319/110121-807.1. DOI
6. Najjar HE, Alasmari RM, Manie AMA et al. Factors affecting retention and relapse in orthodontics. Int J Community Med Public Health. 2023;10(8):2946–2950. doi:10.18203/2394-6040.ijcmph20232173. DOI
7. Liang C, Profico A, Buzi C et al. Normal human craniofacial growth and development from 0 to 4 years. Sci Rep. 2023;13:9641. doi:10.1038/s41598-023-36646-8. DOI
8. Garmash OV. Stan stomatohnatychnoi systemy osib populiatsii Kharkivskoi oblasti ta prylehlykh oblastei, yaki narodylysya makrosomamy. [State of the stomatognathic system of persons of the population of Kharkiv region and adjacent regions born with macrosomia]. Visnyk Problem Biolohii i Medytsyny. 2019;3(152):347–359. doi:10.29254/2077-4214-2019-3-152-347-359. (Ukrainian) DOI
9. Hartsfield JK Jr, Morford LA, Otero LM. Genetic factors affecting facial growth. In: Bourzgui F, ed. Orthodontics: basic aspects and clinical considerations. London: InTechOpen; 2012, p. 125–152. doi:10.5772/33804. DOI
10. Von Arx T, Nakashima MJ, Lozanoff S. The face – a musculoskeletal perspective: a literature review. Swiss Dent J. 2018;128(9):678–688. doi: 10.61872/sdj-2018-09-442. DOI
11. Kale B, Buyukcavus MH. Effect of craniofacial growth pattern on head posture. J Dent Indones. 2020;27(3):144–150. doi:10.14693/jdi.v27i3.1148. DOI
12. Drohomyretska M, Tkachenko Y. The method of assessing the degree of glossoptosis according to clinical and X-ray anthropometrical predictors: clinical guidelines. Georgian Med News. 2024;(350):57–62.
13. Fuentes R, Farfán C, Arias A. Characteristics of chewing: an update of the literature. Int J Odontostomatol. 2021;15(4):873–881. doi:10.4067/S0718-381X2021000400873. DOI
14. Shah SS, Nankar MY, Bendgude VD, Shetty BR. Orofacial myofunctional therapy in tongue thrust habit: a narrative review. Int J Clin Pediatr Dent. 2021;14(2):298–303. doi:10.5005/jp-journals-10005-1926. DOI
15. Zhao Z, Zheng L, Huang X et al. Effects of mouth breathing on facial skeletal development in children: a systematic review and meta-analysis. BMC Oral Health. 2021;21:108. doi:10.1186/s12903-021-01458-7. DOI
16. Björk A. Prediction of mandibular growth rotation. Am J Orthod. 1969;55(6):585–599. doi:10.1016/0002-9416(69)90036-0. DOI
17. Jarabak JR, Fizzell JA. Technique and treatment with light-wire edgewise appliances. 2nd ed. St. Louis: C.V. Mosby Co. 1972, p.589.
18. Ricketts RM. Planning treatment on the basis of the facial pattern and an estimate of its growth. Angle Orthod. 1957;27(1):14–37.
19. McNamara JA Jr. A method of cephalometric evaluation. Am J Orthod. 1984;86(6):449–469. doi:10.1016/S0002-9416(84)90352-X. DOI
20. Steiner CC. Cephalometrics for you and me. Am J Orthod. 1953;39(10):729–755. doi:10.1016/0002-9416(53)90082-7. DOI
21. Vakhovskyi VV, Shinkaruk-Dykovytska MM, Pogorila AV et al. Correlations of basal cranial structures characteristics determined by Bjork and Jarabak methods with teleradiographic parameters of the upper and lower jaws and tooth location in young men and young women with orthognathic occlusion. Biomed Biosoc Anthropol. 2020;(41):52–59. doi: 10.31393/bba41-2020-09. DOI
22. von Bremen J, Pancherz H. Association between Björk's structural signs of mandibular growth rotation and skeletofacial morphology. Angle Orthod. 2005;75(4):506–509. doi: 10.1043/0003-3219(2005)75[506:ABBSSO]2.0.CO;2. DOI
23. Perinetti G, Primožič J, Franchi L. Cephalometric indicators of mandibular rotation: revisiting Björk structural signs in modern orthodontics. Am J Orthod Dentofacial Orthop. 2024;165(4):480–489. doi:10.1016/j.ajodo.2023.07.018. DOI

24. Alhammadi MS, Halboub E, Al-Moraissi EA. Relationship between craniofacial morphology and vertical facial pattern: a cephalometric investigation. Angle Orthod. 2023;93(2):167–175. doi:10.2319/040522-315.1. DOI
25. Hwang S, Kim SJ, McNamara JA Jr. Assessment of vertical facial pattern using Björk structural signs in growing subjects. Angle Orthod. 2021;91(5):623–631. doi:10.2319/111720-962.1. DOI
26. Paddenberg-Schubert E, Midlej K, Krohn S et al. Machine learning models for improving the diagnosing efficiency of skeletal class I and III in German orthodontic patients. Sci Rep. 2025;15(1):12738. doi: 10.1038/s41598-025-97717-6. DOI
27. Schwarz AM. Roentgenostatics: a practical evaluation of the x-ray headplate. Am J Orthod. 1961;47(8):561–585. doi:10.1016/0002-9416(61)90001-X. DOI
28. Downs WB. Variations in facial relationships; their significance in treatment and prognosis. Am J Orthod. 1948;34(10):812–840. doi:10.1016/0002-9416(48)90015-3. DOI
29. Davidovitch M, Eleftheriadi I, Kostaki A, Shpack N. The use of Bjork's indications of growth for evaluation of extremes of skeletal morphology. Eur J Orthod. 2016;38(6):555–562. doi:10.1093/ejo/cjv084. DOI
30. Ghiz MA, Ngan P, Gunel E. Cephalometric variables to predict future success of early orthopedic Class III treatment. Am J Orthod Dentofacial Orthop. 2005;127(3):301–306. doi:10.1016/j.ajodo.2004.02.014. DOI
31. Olbrisch C, Olszewski R, Gateno J et al. Three-dimensional mandibular characteristics in skeletal malocclusion. J Orofac Orthop. 2024;85(1):66–78. doi:10.1007/s00056-022-00419-1. DOI
32. de Souza Reis A, Copello FDM, de Castro ACR et al. 3D analysis of maxillomandibular morphology in hyperdivergent and hypodivergent individuals: a cross-sectional study. Orthod Craniofac Res. 2023;26(4):687–694. doi:10.1111/ocr.12677. DOI
33. Ahmed M, Shaikh A, Fida M. Diagnostic performance of various cephalometric parameters for the assessment of vertical growth pattern. Dental Press J Orthod. 2016;21(4):41–49. doi:10.1590/2177-6709.21.4.041-049.oar. DOI
34. Abu Shahin S, Abdallah L, Midlej K et al. Open bite classification using machine learning: a cephalometric analysis. J Clin Med. 2026;15(4):1494. doi:10.3390/jcm15041494. DOI
35. Roy P, Roy P, Koley S. Comparative assessment of various cephalometric parameters used for determining vertical skeletal dysplasia. Cureus. 2024;16(2):e55101. doi: 10.7759/cureus.55101. DOI

CONFLICT OF INTEREST

The Authors declare no conflict of interest

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