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Novel cephalometric parameters for the assessment of vertical skeletal dysplasia

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Abstract

INTRODUCTION: The accurate diagnosis of vertical skeletal abnormalities presents several challenges. Specific cephalometric parameters can be effectively used for this purpose; however, their diagnostic utility has not been fully ascertained. This study examined the effectiveness of two novel cephalometric parameters in diagnosing vertical dysplasia.

METHODS: Orthodontic patients were divided into three study groups: average growth group (AGG), horizontal growth group (HGG), and vertical growth group (VGG). The efficacies of the sum of the angles (maxillary, mandibular, and ramal) and the height ratio (lower anterior facial height [LAFH]/upper anterior facial height [UAFH]) in identifying the different growth patterns were examined. Receiver operating characteristic curves were used to quantitatively assess diagnostic precision.

RESULTS: A total of 150 patients were included and divided equally among the 3 study groups. The ramal and mandibular angles varied across AGG, HGG, and VGG; however, the maxillary angle and the sum of these three angles did not vary significantly. There was a significant difference in LAFH, UAFH, and their ratios among the three groups. The height ratio had a sensitivity of 88% and 92% for the diagnosis of VGG and HGG, respectively, with cutoff values of 46 and 34, respectively ($P < 0.001$).

CONCLUSIONS: The height ratio values varied considerably according to facial growth patterns, suggesting its utility as a diagnostic tool for skeletal dysplasia with greater reliability for positive treatment outcomes.

Keywords:

Cephalometry, mandible, maxilla, orthodontics, ROC curve

Introduction

A combination of abnormalities in the maxilla and mandible generally leads to vertical dysplasia. The assessment of vertical growth (VG) disorders is challenging,[1,2] and to offer effective treatment for individuals with a hyperdivergent skeletal phenotype, a definitive diagnosis is necessary.[3] However, the literature regarding the diagnosis and treatment of vertical abnormalities is sparse.[4,5]

Björk examined the clinical implications of the interrelations and abnormalities among the maxillary, mandibular, and sella–nasion planes.[6] Individuals with Classes I and II malocclusion divisions were studied by Ngan *et al*.[7] to examine differences in skeletal changes. Buschang and Martins found that the vertical and anterior–posterior connections do not remain consistent during growth and vary depending on age, sex, and type of malocclusion.[8] According to Chung *et al*.,[9] who examined the skeletal and dental morphology of 85 untreated Class II patients, all patients had a decrease in mandibular plane angle and a counterclockwise rotation of the mandible; however, those with a decrease in mandibular plane angle experienced a greater rotation. Several studies have

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examined the connection between dentoalveolar heights and various facial typologies, with contradictory findings.[4,10] It was reported that male participants' Sella-Nasion to mandibular plane (SN-MP) angles had a positive relationship with either their maxillary height or mandibular molar area; however, female participants' angles had no significant relationship with any of these measurements.[11] Individuals with a large angle (SN-MP), on the other hand, had lower upper and lower posterior dentoalveolar heights according to Betzenberger *et al*.[1] Indeed, various cephalometric and non-cephalometric methodologies have been reported to examine the vertical pattern;[3,12-14] however, research does not define a single credible parameter to allow easy diagnosis of the discrepancy in the vertical plane, and different values can be obtained for some of these techniques for the same patient, resulting in difficulty in diagnosis and treatment.

In this study, we examined the diagnostic value of new indices for evaluating skeletal patterns in the vertical direction. Essentially, the validity of two cephalometric indices, the sum of the angles and the ratio of dental heights, was investigated in the diagnostic assessment of vertical development in a group of orthodontic patients.

Methods

From 2011 to 2016, patients seeking orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopaedics at Rama Dental College Hospital and Research Center in Kanpur, Uttar Pradesh, India, were recruited for this study. The sample size was estimated to be 100, using G*Power 3.1.9.4 software, and 150 people were recruited to compensate for any dropouts that could occur during the study. The inclusion criteria for the patients were those between the ages of 16 and 25 years, no known cleft or syndromic conditions, and no prior orthodontic treatment. Patients with severe skeletal malocclusion, prior orthognathic surgery, or trauma were excluded. Computer-generated random numbers were used for randomization. Each patient was informed about the procedure, and informed consent was obtained for participation in the investigation.

Cephalometric evaluation

A single examiner traced and annotated landmarks on the patient's pretreatment lateral cephalogram as a diagnostic tool for treatment planning. The cephalograms were traced and then classified into average (normal), horizontal, and vertical growers using parameters, namely, the *Y*-axis, SnGoGn, and Jaraback ratio.[15,16]

Definitions

The *Y*-axis represents the intersection of the sella–gnathion with the Frankfort horizontal plane. The angle of SnGoGn defines mandibular inclination with respect to the cranial base. The Jaraback ratio is the ratio of the posterior (sella–gonion)-to-anterior facial height (nasion–menton). Typically, a ratio of less than 62% indicates a VG pattern, whereas more than it represents horizontal growth (HG). The true vertical is the vertical plane formed perpendicular to the nasion by drawing the true horizontal 7° to the sella–nasion plane. The true vertical plane extends to the chin and can be used to measure the maxillary, mandibular, and ramal landmarks [Figure 1]. A maxillary angle is formed between the line constructed by joining the posterior nasal spine with the anterior nasal spine and the true vertical. This angle represents the maxilla with respect to the true vertical [Figure 2a]. The mandibular angle is the angle between the mandibular plane formed by joining the gonion–menton and true vertical planes. This angle depicts the rotation of the mandibular body relative to the true vertical angle [Figure 2b]. The angle of the ramal was determined by measuring the relationship between articulare–gonion–menton. This provides a high- or low-angle relationship for the mandible [Figure 2c].

The upper anterior facial height (UAFH) is a linear measurement obtained from nasion to gonion along the true vertical plane [Figure 3a]. The lower anterior facial height (LAFH) is a linear measurement taken from gonion to menton along the true vertical plane [Figure 3b].

Calculations

Generally, a combination of multiple cephalometric parameters is used to determine abnormal growth patterns. For example, the mean cranial flexure angle (N-S-Ar), articular angle (S-Ar-Go), and gonial angle (Ar-Go-Me) are correlated with vertical and HG patterns. In this study, we used the sum of the maxillary,

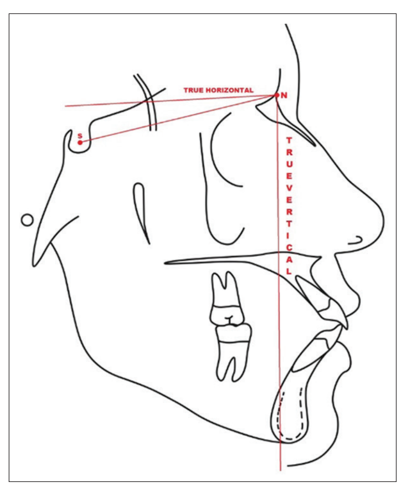

Figure 1: Diagrammatic representation of the true vertical plane (S: sella, N: nasion)

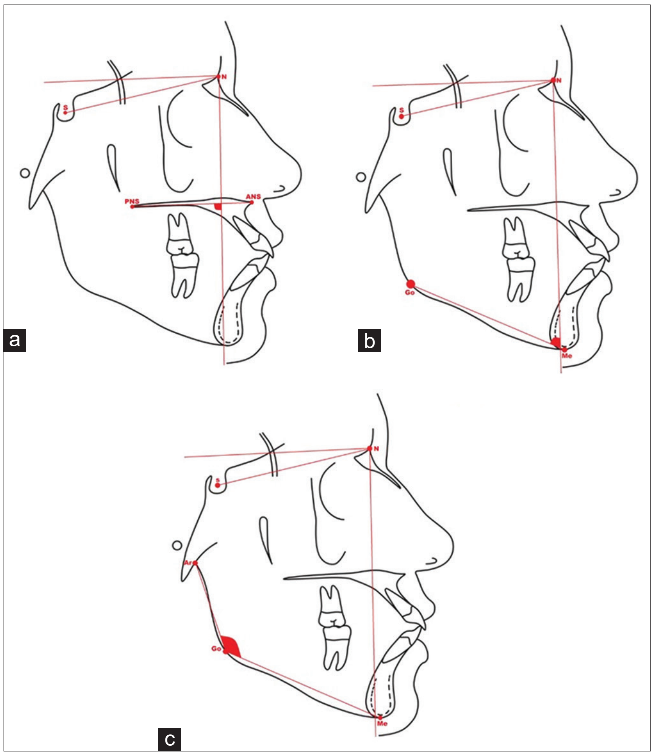

Figure 2: Diagrammatic representation of the (a) maxillary angle, (b) mandibular angle, and (c) ramal angle (ANS: anterior nasal spine; PNS: posterior nasal spine; N: nasion; S: sella; Go: gonion; Me: menton)

mandibular, and ramal angles to develop an effective index for diagnosing VG [Figure 2a–c].

$$\text{Sum of angles} = \text{Maxillary angle} + \text{Mandibular angle} + \text{Ramal angle} \quad \text{(i)}$$

Another index used to measure the VG pattern was the lower and anterior facial height ratio [Figure 2a–b]. It was expressed as %.

$$\text{Height ratio (\%)} = \frac{\text{LAFH}}{\text{UAFH}} \times 100 \quad \text{(ii)}$$

Statistical analysis

Descriptive and inferential statistical analyses were performed as part of this study. Continuous measurements are reported as mean ± SD (min–max), and categorical measurements are reported in numbers (%). Significance was measured at 5% level. The average growth group (AGG), horizontal growth group (HGG), and vertical growth group (VGG) were compared to establish a range of values for each sample group and to obtain a new parameter for identifying vertical skeletal dysplasia. The Student t-test (two-tailed, independent) was used to gauge the significance of the study variables on a continuous scale between two groups (intergroup analysis) in the metric parameters. For three groups of continuous variables, analysis of variance (ANOVA) was used to examine the statistical significance. To determine the homogeneity of variance, Leven's test was used. The Chi-square test was used to determine the significance of the research parameters on a categorical scale between two or more groups. Fisher's exact test was used when the number of samples was small. Receiver operating characteristic (ROC) analysis was used to examine the diagnostic efficacy of these parameters.

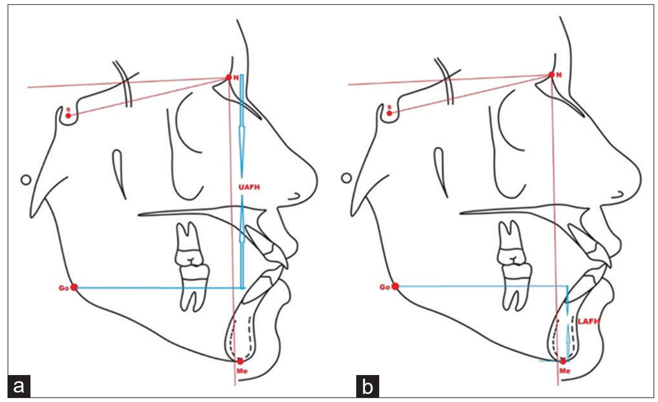

Figure 3: (a) Upper anterior facial height (UAFH) and (b) lower anterior facial height (LAFH) (N: nasion; S: sella; Go: gonion; Me: menton)

Results

Approximately 69% of participants were between 11 and 20 years of age [Table 1]. The remaining participants (31.3%) were aged 21–30 years. Among the 150 participants who participated in the study, 50 were assigned to each of the three growth pattern groups: AGG, HGG, and VGG. There were no statistically significant differences in age between the groups ($P = 0.215$, ANOVA test). As shown in Table 2, UAFH was highest in HGG and lowest in VGG ($P < 0.001$), whereas LAFH was lowest in HGG and highest in VGG, with a statistically significant difference between the groups ($P < 0.001$). The height ratio further accentuated this difference. The ratio was 51.31 ± 8.25 in VGG and just 25.80 ± 6.50% in HGG; AGG had a ratio of 41.35 ± 4.80% ($P < 0.001$).

The mean values of the maxillary, mandibular, and ramal angles in each research group are shown in Table 3. In all three groups, the maxillary angle was remarkably comparable ($P = 0.287$). In contrast, the mandibular angle varied significantly between the study groups. VGG had a mandibular angle of 54.41 ± 5.03°, whereas HGG had a much higher mandibular angle (70.68 ± 4.45°). AGG had intermediate values. The ramal angle was highest in VGG and lowest in HGG. Interestingly, there were no statistically significant differences between the study groups when the sum of the angles was considered ($P = 0.225$).

To further examine the diagnostic significance of these variables, the sensitivity and specificity were determined using a ROC curve. As expected, the sum

Table 1: Group-wise age distribution of patients included in the study

Age (years)	AGG	VGG	HGG	Total
11-20, *n* (%)	34 (68%)	31 (62%)	38 (76%)	103 (68.7%)
21-30, *n* (%)	16 (32%)	19 (38%)	12 (24%)	47 (31.3%)
Total, *n* (%)	50 (100%)	50 (100%)	50 (100%)	150 (100%)

AGG=Average growth group, HGG=horizontal growth group, VGG=vertical growth group

Table 2: UAFH, LAFH, and height ratio in different groups

	AGG	VGG	HGG	Total	P
UAFH	79.22±5.75	76.36±4.89	86.40±6.34	80.66±7.07	<0.001*
LAFH	32.53±3.23	39.47±6.40	22.21±5.28	31.40±8.76	<0.001*
Height ratio	41.35±4.80	51.31±8.25	25.80±6.50	39.49±12.44	<0.001*

AGG=Average growth group, HGG=horizontal growth group, VGG=vertical growth group, LAFH=lower anterior facial height, UAFH=upper anterior facial height.*ANOVA test

Table 3: Comparison of maxillary, mandibular, ramal, and sum of angles

	AGG	VGG	HGG	P
Maxillary angle (°)	90.69±3.46	90.91±3.04	90.00±2.38	0.287
Mandibular angle (°)	61.10±2.77	54.41±5.03	70.68±4.45	<0.001*
Ramal angle (°)	127.06±4.52	132.54±4.46	119.12±6.30	<0.001*
Sum of angle	278.73±5.54	277.78±5.25	279.62±5.11	0.225

AGG=Average growth group, HGG=horizontal growth group, VGG=vertical growth group.*ANOVA test

of the angles did not produce statistically significant diagnostic values (area under ROC curve [AUROC] = 0.53, $P = 0.605$, Table 4). In contrast, the height ratio was found to have significant ROC characteristics. The specificity for predicting VGG was 88% with a sensitivity of 76.0% (AUROC = 0.0855, $P < 0.001$). The height ratio in horizontal growers with a cutoff value of 34.14 had a sensitivity of 92.0% and a specificity of 98.0% [Table 5]. This suggests that a height ratio value between 34% and 46% falls into the category of average growers.

Discussion

This study investigated the diagnostic utility of dentoalveolar heights, as well as of the maxillary angle, mandibular angle, and ramal angles, in assessing vertical skeletal dysplasia. Our results indicated that lower and anterior facial height ratios can be used for the diagnosis of vertical skeletal dysplasia with high sensitivity and specificity.

This study involved three groups (AGG, HGG, and VGG) defined using specific criteria: *Y*-axis, SnGoGn, and Jaraback ratio.[15-17] Our findings did not show any differences in the mean maxillary angle between AGG, HGG, and VGG. Notably, in our study, the maxillary angle was measured relative to the true angle. The optimal inclination of the maxillary incisor, according to Naini *et al.*,[18] was approximately parallel to the actual vertical line. Schudy *et al.*[19] suggested that the maxillary and mandibular incisors must be adjusted to obtain a perfect interincisal angle to establish functional harmony. It may be noted that there is still much debate over the diagnostic usefulness of the metrics used in VG evaluation. It can be seen from Table 6 that sensitivity and specificity for a particular cephalometric parameter are rarely reported in the literature, and most of the time multiple cephalometric parameters are employed.[12-14]

Facial growth anomalies become increasingly noticeable with age, and the development phase stabilizes to prevent alterations in the vertical dimensions of the jaw. It has also been demonstrated that dentoalveolar bone develops and changes with age.[20] The growth of the mandible and maxilla and the alveolar processes govern the VG. VG anomalies can cause vertical malocclusions that tend to worsen over time. Our goal was to create indices that were generally applicable to a wide age range; therefore, the participants varied in age from 10 to 30 years. Our study showed a marked change in the mandibular angle between VGG and HGG. Furthermore, the ramal angle differed between VGG and HGG; however, it followed a different trend from the mandibular plane angle, with the ramal angle values in VGG being higher than those in HGG. There was insignificant variation in the growth patterns when the cumulative values of the three angles were used. ROC analysis revealed that the sum of these angles did not have discernible diagnostic utility. A few other studies have found that a large mandibular plane angle is not a strong predictor of facial maturation.[21,22] Studies also revelaed a substantial difference in different cephalometric indices, suggesting the type of mandibular development in two groups with extreme notch depths, and similar results were reported in a few additional implant investigations.[6,23] In contrast, Kolodziej *et al*.[24] found a negative association between mandibular antegonial notch depth and horizontal jaw growth. We tried using the sum of the angles to avoid these restrictions, but we did not provide any diagnostic information. Considering our results and those of other studies mentioned above, it is necessary to conduct more extensive studies involving different age groups, regions, and ethnicities to ascertain the diagnostic utility of the angles discussed above.

Individuals with horizontal development patterns had LAFHs, while those with vertical development patterns had lower posterior facial heights. In our study, UAFH was significantly higher and LAFH was significantly lower in HGG. A synergistic improvement was observed when the ratio was used, as shown by the almost double

Table 4: ROC curve analysis to predict vertical growth

Variables	ROC results to predict VG				Cutoff	AUROC	SE	*P*
	Sensitivity	Specificity	LR+	LR–				
Height ratio (%)	76.00	88.00	6.33	0.27	>46.05	0.855	0.038	<0.001
Sum of angles (°)	90.00	22.00	1.15	0.45	≤284	0.530	0.058	0.605

VG=Vertical growth, AUROC=area under the receiver operating characteristic, LR=likelihood ratio, SE=standard error

Table 5: ROC curve analysis to predict horizontal growth

Variable	ROC results to predict HG				Cutoff	AUROC	SE	*P*
	Sensitivity	Specificity	LR+	LR–				
Height ratio (%)	92.00	98.00	46.00	0.08	≤34.14	0.986	0.008	<0.001
Sum of angles (°)	52.00	66.00	1.53	0.73	>280.00	0.562	0.058	0.289

HG=Horizontal growth, AUROC=area under the receiver operating characteristic, LR=likelihood ratio, SE=standard error

Table 6: Key findings reported in the literature on cephalometric parameters for the dental anomalies

Objectives	Key parameter (s)	Sample size	Sensitivity	Specificity	Outcome	Reference
To estimate postintervention changes in hyperdivergent phenotype	The gonial angle, and upper-to-lower anterior facial height ratio (UAFH: LAFH)	38	NR	NR	The gonial angle decreased and UAFH: LAFH increased during treatment	[3]
Assessment of the true sagittal maxillomandibular relationship	Tau angle	279	96%	98%	Tau angle can be used for assessing the true sagittal skeletal relationship	[12]
	Dentoalveolar heights	270	NR	NR	Dentoalveolar heights were correlated with sella-nasion, and gonion-gnathion angle and condylion-gonion-menton angle	[13]
Mandibular incisor inclination was more closely associated with sagittal and vertical skeletal discrepancies and was not affected by the incisal relationship	SN-MP	104	NR	NR	Proclination of the maxillary incisors and flattening of the occlusal plane contributed to a positive overjet	[14]
Assessment of vertical skeletal dysplasia	Lower and anterior facial height ratio	150	92%	98%	The height ratio had a sensitivity of 88% and 92% to the diagnosis of VGG and HGG, respectively	This study

values achieved in HGG compared to VGG. When this ratio was used in the ROC analysis, both HGG and VGG showed substantial diagnostic effectiveness. A strong connection between dentoalveolar height and vertical parameters has been found in the literature.[25] However, our results suggest that using a ratio instead of a number may result in a higher diagnostic value.

This study has certain limitations. First being a retrospective study, the analysis was limited to the already collected data. Second, it is a single-center study, and since the facial features may vary in different ethnic groups and different localities, multicenter studies are necessary to generalize our findings. In addition, as cephalometric parameters may change with age, additional research is required to confirm the extent to which age affects the height ratio (LAFH/UAFH). We have excluded patients with severe skeletal malocclusion; however, in certain cases, excessive VG can manifest as severe malocclusion. Despite these limitations, the strength of this study is that it reports simple-to-measure cephalometric parameters with high sensitivity and specificity, which may be of great importance in clinical practice.

Conclusions

In orthodontic patients from North India, there was a marked variation in certain cephalometric characteristics between individuals with HG, VG, and normal development patterns. Although the ramal and mandibular angles differed substantially in the vertical, horizontal, and normal growth patterns, the maxillary angle and the sum of these three angles did not differ. The sum of the angles did not have a significant diagnostic value. In particular, the LAFH, UAFH, and their ratios differed significantly between patients with horizontal, vertical, and normal growth patterns. In fact, the height ratio was almost 90% sensitive to the identification of horizontal and vertical development patterns. The ratio demonstrated significance, with 34% considered normal, less than 34% considered horizontal, and >46% considered vertical. Further research is required to establish the relationship between these cephalometric characteristics and vertical face growth in individuals with various skeletal malocclusions.

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Ethical approval

IRB approval was waived off for this retrospective study.

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Conflicts of interest

There are no conflicts of interest.

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