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Original Research

Correlating Condylion-Gonion-Menton angle to dentoalveolar heights in various sagittal malocclusion with different growth patterns- A Cephalometric Study

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ABSTRACT:
Introduction: The Condylion-Gonion-Menton angle is a parameter related to the mandibular structure alone and is unaffected by anterior cranial base. This angle exhibits significant variations among the diverse vertical growth patterns in various sagittal malocclusions. These parameters further influence dentoalveolar heights in an individual. Understanding the correlation between this angle and dentoalveolar heights may then provide the key insights required during orthodontic treatment planning and selection of appropriate biomechanics for maintenance of dentoalveolar heights. **Methods:** Standardized cephalometric radiographs of 240 subjects were captured in centric occlusion with relaxed lips. Subjects were categorized into sagittal classes based on Angle's classification and ANB angle) and further subdivided into normodivergent, hypodivergent and hyperdivergent growth patterns based on Jarabak's ratio, mandibular plane angle and FMA, totalling nine groups. Linear and angular parameters were obtained from lateral cephalograms using AutoCAD 2025 software. Statistical analyses included descriptive statistics, Shapiro-Wilk test, Kruskal Wallis test, Dunn Bonferroni post hoc test, Pearson correlation analysis. **Results**: Anterior dentoalveolar heights, UADH and LADH showed statistically significant differences between horizontal, average and vertical growth patterns, increasing from horizontal to average group and being highest in vertical group. Pearson correlation analysis further revealed that both upper and lower anterior dentoalveolar heights (especially lower anterior dentoalveolar height) were significant predictors of variations in the Condylion–Gonion–Menton angle in different growth patterns. **Conclusion**: Lower anterior dentoalveolar height is the parameter most strongly associated with different vertical growth patterns. The Condylion-Gonion-Menton angle is a strong predictor of growth pattern.

Keywords: cephalometry, dentoalveolar heights, mandibular divergence, facial types

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INTRODUCTION

One of the most important components of orthodontic diagnosis is to determine growth pattern and implement it for treatment planning. Apart from being of scientific importance, this information helps in the formulation and selection of appropriate treatment mechanics and modalities. Both, growth of condyles and dentoalveolar development play an important role in the form of the facial skeleton, and it is the differential growth at these sites that produce various vertical facial characteristics.[1]

The pattern of vertical facial development begins by mixed dentition as enumerated by Nanda.[2] This development is influenced by a variety of factors both, genetic and environmental, and produces three distinct growth patterns- normodivergent, hypodivergent and hyperdivergent. The type of growth pattern present affects a multitude of treatment aspects such as the extraction choice, the type of anchorage, the biomechanics to be used, and the method and duration of retention.[3] Along with understanding the distinct features which characterize each growth pattern, the knowledge of dentoalveolar heights present are key to successful treatment as orthodontic treatment mainly produces changes at the dentoalveolar level through the intrusion or extrusion of the anterior and posterior teeth.[4]

The presence of dissimilar dentoalveolar heights may either be a manifestation of underlying skeletal discrepancies or play a role in the etiology of malocclusion. Studying the relationship between the different growth patterns and dentoalveolar heights may provide the key to elaborate on the complex interactions that occur between skeletal, dental and soft tissue components of dentofacial development.

Several authors have studied the relationship between different facial types and dentoalveolar heights and have reported contrasting results.[5-11] This may be due to the variation in sample characteristics, diverse methodology and genetic differences. These authors have evaluated dentoalveolar heights and correlated them to parameters such as lower anterior facial height, basal plane angle and SN-MP angle. However, these parameters are susceptible to a wide range of influences.

Condylion-Gonion-Menton angle (Co-Go-Me) formed by condylar axis and mandibular structure is not affected by external factors and hence can give better understanding of mandibular rotation imparting accurate information than mandibular plane angle which may be affected by inclination of anterior cranial base.[12] Few studies have considered Co-Go-Me as a predictor of growth pattern and determined its correlation to dentoalveolar heights.

Thus, the aim of this study is to correlate Condylion-Gonion-Menton Angle to dentoalveolar heights in different kinds of sagittal malocclusion and growth patterns.

MATERIALS AND METHOD

The present study was carried out at the Department of Orthodontics and Dentofacial Orthopedics. It was approved by the institutional ethical committee (IEC). For this study 240 subjects in the age group of 18-25 years with Class I, Class II and Class III malocclusion were chosen.

Inclusion criteria:

- Pre-treatment lateral cephalograms of subjects in the age range of 18-25 years.
- Fully erupted permanent teeth at least up to 2nd molars.

Exclusion criteria:

- Previous history of orthodontic treatment or maxillofacial surgery.
- Patients with craniofacial syndromes or presence of systemic disorders.
- Previous history of endodontic treatment and/or presence of prosthetic crowns in permanent first molars or incisors.
- Missing teeth except third molars.

Armamentarium:

- Pre-treatment lateral cephalograms in JPEG format.
- AUTOCAD 2025 software (by AUTODESK Software, United States).

Selection Criteria:

Standardized cephalometric radiographs of 240 subjects were taken in centric occlusion with lips relaxed and Frankfort horizontal plane oriented parallel to the floor. Subjects were categorized based on Angle's classification and ANB angle as Class I (ANB=0-4 degrees), Class II (ANB > 4 degrees) and Class III (ANB < 0 degrees). These subjects were further subdivided into normodivergent, hypodivergent and hyperdivergent growth patterns based on Jarabak's ratio, FH-MP angle and FMA as follows. They were further categorized equally into males and females (Table 1).

METHOD

All lateral cephalograms were taken with Vatech PHT 30 LFO smart machine with a film to focus distance of 150 cm and a film to median plane distance of 15 cm at a voltage of 85kVP, current of 10mA and a scan time of 12.9 seconds. The parameters were measured with AUTOCAD 2025 software (by AUTODESK Softwares, United States). The reference points (Table 2), planes (Table 3), angular measurements (Table 4) and linear measurements (Table 5) were recorded for evaluation.

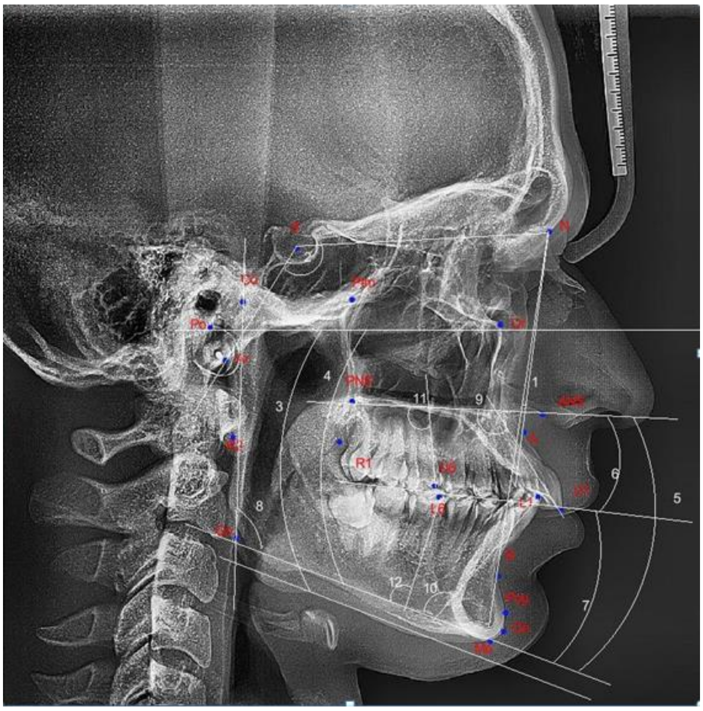

Figure 1: Angular Measurements

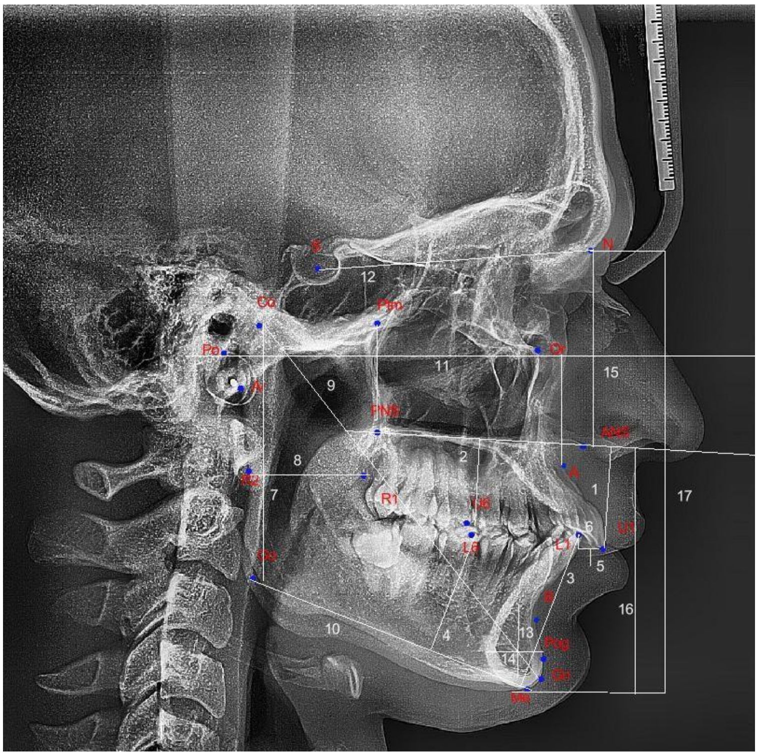

Figure 2: Linear Measurements

Measurements in AUTOCAD 2025 software

AutoCAD is a computer-aided design (CAD) software, which offers various tools for creating and editing image designs. In this study, we used AUTOCAD software for accurately measuring linear and angular values in lateral cephalometric images. All the cephalometric landmarks were traced and measured. Data was analysed by statistical package for social sciences (SPSS) 26.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p < 0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using Shapiro-Wilk test. Inferential statistics to find out the difference between the three growth patterns was done using Kruskal Wallis test followed by Dunn-Bonferroni Post hoc test. Pearson correlation test was used for correlation analysis.

S. No.	Description
Fig 1	1. ANB 2. Saddle Angle (S-N-Ar) 3. Frankfurt Mandibular plane angle (FMA) 4. Mandibular plane Angle 5. Basal Plane Angle 6. Occlusal to palatal plane Angle 7. Occlusal to mandibular plane Angle 8. Condylion-Gonion-Menton Angle 9. Upper Incisor Inclination 10. Lower Incisor Inclination 11. Upper Molar Inclination 12. Lower Molar Inclination
Fig 2	1. Upper Anterior Dentoalveolar Height (UADH) 2. Lower Anterior Dentoalveolar Height (LADH) 3. Upper Posterior Dentoalveolar Height (UPDH) 4. Lower Posterior Dentoalveolar Height (LPDH) 5. Overjet 6. Overbite 7. Ramal Height 8. Ramal Width 9. Total Mandibular Length (TML) 10. Mandibular body length 11. Maxillary Length (A-Ptm) 12. Anterior cranial base length 13. Symphyseal Length 14. Symphyseal width 15. Upper anterior facial height (UAFH) 16. Lower anterior Facial height (LAFH) 17. Total Anterior facial height (TAFH)

RESULTS

A total of 31 parameters including 12 angular parameters, 19 linear parameters were evaluated. The results were obtained using Statistical Package for Social Science (SPSS) from IBM Corp version 26 and analysed.

Table 8 (Kruskal Wallis test for inter group comparison): Highly significant differences in FMA, mandibular plane angle, basal plane angle and Co–Go–Me angle were observed among hypodivergent, normodivergent, and hyperdivergent growth patterns across Class I, Class II, and Class III malocclusions ($p < 0.001$). A consistent progression from flatter palatal and occlusal planes in hypodivergent subjects to steeper planes in hyperdivergent subjects was observed. The Co–Go–Me angle emerged as a strong indicator of vertical skeletal dysplasia in all sagittal classes.

Incisor inclinations (U1–PP and L1–MP) showed statistically significant differences only in Class III malocclusion ($p < 0.001$), highlighting their role in natural dentoalveolar compensation. In contrast, molar inclinations (U6–PP and L6–MP) differed significantly among growth patterns in Class I and Class II malocclusions ($p < 0.001$), showing progressively greater distal crown tipping from hypodivergent to hyperdivergent patterns. No significant molar inclination differences were noted in Symphyseal length and width demonstrated highly Class III subjects.

Among linear parameters (Table 9), ramal height (Co–Go) demonstrated highly significant differences across growth patterns in all three sagittal classes ($p < 0.001$), with hypodivergent subjects consistently exhibiting longer ramii. Total mandibular length (Co–Gn) varied significantly only in Class III subjects ($p < 0.001$), reflecting the characteristic mandibular excess in this group. Mandibular body length (Go–Me) showed significant differences across growth patterns in Class I, II, and III malocclusions, whereas maxillary body length (A–Ptm) differed significantly only in Class II malocclusion ($p < 0.001$). Anterior cranial base length (SN) showed no significant variation across growth patterns or sagittal classes.

Upper and lower anterior dentoalveolar heights (UADH and LADH) showed highly significant differences across growth patterns in all malocclusion classes ($p < 0.001$), increasing from hypodivergent to hyperdivergent patterns. In contrast, posterior dentoalveolar heights (UPDH and LPDH) did not show significant intergroup differences. Lower anterior facial height (LAFH) and total anterior facial height (TAFH) increased significantly from hypodivergent to hyperdivergent patterns in Class I and Class II malocclusions ($p < 0.001$).

significant differences across growth patterns in all three sagittal classes.

Pearson correlation analysis (Tables 10,11,12) identified LADH as the parameter most strongly associated with Co–Go–Me angle, showing a positive correlation in normodivergent and hyperdivergent subjects and a negative correlation in hypodivergent subjects. Posterior dentoalveolar heights showed positive correlation with Co–Go–Me angle in hypodivergent patterns and negative correlation in hyperdivergent patterns, reflecting compensatory eruption mechanism. Overall, mandibular dentoalveolar parameters exhibited stronger associations than maxillary parameters.

Table 1: Categorization of subjects

GROUP	Jarabak's ratio	FH-MP	FMA	Total	Subgroups
Class I Hyperdivergent	<62%	>36^0	>25^0	90	45 Males 45 Females
Class I Normodivergent	62-65%	28^0-36^0	20-25^0		
Class I Hypodivergent	>65%	<28^0	<20^0		
Class II Hyperdivergent	<62%	>36^0	>25^0	90	45 Males 45 Females
Class II Normodivergent	62-65%	28^0-36^0	20-25^0		
Class II Hypodivergent	>65%	<28^0	<20^0		
Class III Hyperdivergent	<62%	>36^0	>25^0	60	30 Males 30 Females
Class III Normodivergent	62-65%	28^0-36^0	20-25^0		
Class III Hypodivergent	>65%	<28^0	<20^0		

Table 2: Reference points used in the study

Sl No	Landmark	Definition
1.	Sella (S)	Geometric centre of pituitary fossa.
2.	Nasion (N)	The most anterior point of the frontonasal suture.
3.	Point A (A)	The most posterior midline point in the concavity between; the ANS and the prosthion (the most inferior point on the alveolar bone overlying the maxillary incisors).
4.	Point B (B)	The most posterior midline point in the concavity of the mandible between the most superior point on the alveolar bone overlying the mandibular incisors and Pog.
5.	Orbitale (Or)	The lowest point on the inferior margin of the orbit
6.	Porion (Po)	The superior most point of the ear rods.
7.	Gonion (Go)	The most posterior inferior point on the outline of the angle of the mandible
8.	Gnathion (Pog)	Most anterior inferior point on the bony chin in the midsagittal plane
9.	Menton (Me)	Most inferior point of the mandibular symphysis in the midsagittal plane
10.	Pogonion (Pog)	Anterior most point on the mandibular symphysis in the median plane
11.	Anterior nasal spine (ANS)	Anterior spine of sharp bony process of maxilla
12.	Posterior nasal spine (PNS)	Posterior spine of the palatine bone constituting the hard palate
13.	Condylion (Co)	The most posterosuperior point on the curvature of the average of the right and left outlines of the condylar head.
14.	Articulare (Ar)	A point at the junction of the posterior border of ramus & inferior border of posterior cranial base.
15.	Pterygomaxillary point (Ptm)	Inverted tear drop-shaped radiolucency formed anteriorly by posterior surfaces of the tuberosities of the maxilla and posteriorly by anterior curve of the pterygoid process of sphenoid bone.
16.	R1	Deepest point on the curve of the anterior border of the ramus, located

		halfway between the superior and inferior curves.
17.	R2	Located opposite to R1 on the posterior border of the ramus
18.	Cusp tip of upper Molar (U6)	Mesiobuccal cusp tip of permanent maxillary first molar.
19.	Cusp tip of lower Molar(L6)	Mesiobuccal cusp tip of permanent mandibular first molar.
20.	Tip of upper incisor (U1)	Incisal tip of most prominent permanent maxillary central incisor.
21.	Tip of lower incisor (L1)	Incisal tip of most prominent permanent mandibular central incisor.

Table 3: Reference planes used in the study

Sl No.	Landmark	Definition
1.	Frankfurt Horizontal plane	Plane formed by joining Po and Or.
2.	Mandibular plane	Plane formed by joining points Go and Me.
3.	Palatal Plane	Plane formed by joining ANS and PNS.
4.	Occlusal Plane	It is formed by a line overlapping the cusp tips of premolars and molars.

Table 4: Angular measurements used in the study

Sl No.	Landmark	Definition
1.	ANB	Angle formed by intersection of lines joining nasion to point A and nasion to point B.
2.	Saddle Angle (S-N-Ar)	It is measured by angle formed between nasion to Sella and Sella to articulare.
3.	Frankfurt Mandibular plane angle (FMA)	It is measured by angle formed between a line drawn tangent to lower border of mandible (mandibular plane) and FH plane.
4.	Mandibular plane Angle	It is the angle formed between Go-Me and FH planes.
5.	Basal Plane Angle	It is the angle formed between MP and PP.
6.	Occlusal to palatal plane Angle	It is the angle formed between OP and PP
7.	Occlusal to mandibular plane Angle	It is the angle formed between OP and MP
8.	Condylion-Gonion-Menton Angle	It is the angle measured between Co-Go and Go-Me.
9.	Upper Incisor Inclination	The angle formed between the long axis of the most prominent permanent maxillary incisor with the palatal plane.
10.	Lower Incisor Inclination	The angle formed between the long axis of the most prominent permanent mandibular incisor with the mandibular plane.
11.	Upper Molar Inclination	The angle formed by the line passing through the mesiobuccal cusp tip of the permanent maxillary first molar and the mesiobuccal root tip with the palatal plane.
12.	Lower Molar Inclination	The angle formed by the line passing through the mesiobuccal cusp tip of the permanent mandibular first molar and the mesial root tip with the mandibular plane.

Table 5: Linear measurements used in the study

Sl No.	Landmark	Definition
1.	Upper Anterior Dentoalveolar Height (UADH)	The perpendicular distance taken from the tip of the most prominent permanent maxillary incisor to the palatal plane.
2.	Lower Anterior Dentoalveolar Height (LADH)	The perpendicular distance taken from the mesiobuccal cusp tip of the permanent maxillary first molar to the palatal plane.
3.	Upper Posterior Dentoalveolar Height (UPDH)	The perpendicular distance taken from the tip of the most prominent permanent mandibular incisor to the mandibular plane.
4.	Lower Posterior Dentoalveolar Height(LPDH)	The perpendicular distance taken from the mesiobuccal cusp tip of the permanent mandibular first molar to the mandibular plane.
5.	Overjet	Distance between tips of upper and lower incisor along the occlusal plane.

6.	Overbite	Distance between tips of upper and lower incisor perpendicular to occlusal plane
7.	Ramal Height	Measured from Condylion to Gonion, parallel to the true vertical plane.
8.	Ramal Width	Measured from R1 (deepest point on the curve of anterior border of mandible located halfway between the superior and inferior curves) to R2 (located opposite to R1 on the posterior border of the ramus).
9.	Total MandibularLength (TML)	Measured from Condylion to Gnathion.
10.	Mandibular body length	Measured from Gonion to Menton
11.	Maxillary Length (A-Ptm)	Measured as the distance between point A and Ptm perpendicular to the Frankfort Horizontal (FH) plane
12.	Anterior cranial base length	Measured as the distance between Nasion and Sella.
13.	Symphyseal Length	It extends from apex of mandibular central incisor to Gnathion.
14.	Symphyseal width	Greatest diameter of the symphysis
15.	Upper anterior facial height (UAFH)	It is measured from nasion point to ANS point.
16.	Lower anterior Facial height (LAFH)	It is measured from ANS to menton point.
17.	Total Anterior facial height (TAFH)	It is measured from nasion to menton point.
18.	Jarabak's Ratio	It is calculated by ratio of posterior facial height to anterior facial height multiplied by 100.
19.	Facial Height Ratio	It is calculated by ratio of upper anterior facial height to lower anterior facial height multiplied by 100.

Table 6: Mean of Angular Parameters

Parameter	Class	Normodivergent		Hypodivergent		Hyperdivergent	
		Mean(mm)	**SD**	**Mean(mm)**	**SD**	**Mean(mm)**	**SD**
ANB	Class I	2.23	1.251	2.33	1.348	3.03	1.189
	Class II	7.23	1.382	6.1	1.062	8.4	1.632
	Class III	-2.15	3.617	-2.4	4.935	-3.3	3.342
Saddle Angle (N-S-Ar)	Class I	125.6	2.86	122.83	4.942	124.77	5.137
	Class II	124.9	5.635	127.33	4.566	123.67	2.309
	Class III	125.85	4.557	122.6	2.817	124.7	2.515
Frankfort Mandibular Plane Angle	Class I	26.03	1.732	17.93	5.356	32.73	3.14
	Class II	28.07	5.232	18.9	5.467	32.47	3.579
	Class III	22.15	2.739	18.5	1.85	29.9	1.483
Mandibular plane Angle	Class I	24.2	2.552	17.57	4.987	31	3.195
	Class II	26.8	4.536	17.53	5.178	30.57	3.702
	Class III	21.05	4.925	18.8	3.35	32.15	4.614
Basal Plane Angle	Class I	23.97	3.178	17.57	4.248	27.73	3.051
	Class II	25.2	3.377	15.93	3.151	31.33	3.177
	Class III	23.1	3.865	21.05	6.211	25.7	2.697
Occlusal Plane-Palatal plane	Class I	7.2	3.845	6.37	3.09	8.63	4.206
	Class II	11.8	4.072	6.23	3.52	14.73	3.194
	Class III	8.45	2.625	7.95	5.094	9.05	3.776
Occlusal plane-Mandibular plane	Class I	16.63	2.723	11	2.464	18.57	3.202
	Class II	13.5	2.418	9.87	3.181	16.4	3.41
	Class III	15.35	4.043	15.8	3.708	19.95	3.364
Co-Go-Me Angle	Class I	120.3	2.706	111.77	3.234	125.4	4.717
	Class II	118.63	1.938	110.37	5.048	122.57	6.932
	Class III	117	4.645	114	3.77	128.95	6.684
U1 to Palatal Plane	Class I	122.7	6.859	120.6	9.474	119.47	6.715
	Class II	115.33	9.636	115.2	8.338	116.4	7.797
	Class III	118.45	10.359	118.95	6.677	120.65	7.686

L1 to Mandibular Plane	Class I	97.63	6.931	105.4	10.546	96.73	4.934
	Class II	106.2	5.455	111.33	3.604	102.57	6.786
	Class III	87.35	10.419	93.1	3.493	80.9	12.043
U6 to Palatal Plane	Class I	92.87	6.252	90.63	5.041	86.67	7.671
	Class II	86.73	3.912	90.3	2.277	80	4.601
	Class III	89.85	0.366	94.1	3.905	84.4	3.033
L6 to Mandibular Plane	Class I	82.03	6.333	90.67	6.222	77.53	3.213
	Class II	84.7	4.388	89.93	5.291	83.9	4.802
	Class III	87.2	3.622	88.9	2.954	77.4	6.565

Table 7: Mean of Linear Parameters

Parameter	Class	Normodivergent		Hypodivergent		Hyperdivergent	
		Mean(mm)	SD	Mean(mm)	SD	Mean(mm)	SD
UADH	Class I	25.67	3.3606	21.233	4.4488	28.247	2.9384
	Class II	27.113	1.7925	24.57	2.068	27.533	2.9874
	Class III	24.02	2.1013	20.86	1.7473	25.4	2.4125
LADH	Class I	40.127	3.6539	36.667	2.5121	42.02	3.7727
	Class II	37.44	4.1094	35.123	4.0525	40.49	3.322
	Class III	36.69	0.4789	35.415	2.0841	39.73	3.5826
UPDH	Class I	21.62	2.3514	19.793	2.4253	22.29	3.3343
	Class II	20.72	2.1199	19.43	1.9146	20.92	2.1607
	Class III	20.045	1.7117	19.235	1.4572	19.635	1.2741
LPDH	Class I	30.34	3.0748	28.757	2.3757	32.657	3.4692
	Class II	28.753	1.9179	28.773	2.6893	29.363	3.8883
	Class III	26.91	1.6264	26.84	2.6025	27.62	2.7604
Overjet	Class I	4.83	2.291	3.9	1.768	3.4	1.221
	Class II	5.2	1.562	8.47	1.502	7	1.576
	Class III	-2.3	2.867	-3.7	3.358	-2.45	3.17
Overbite	Class I	3.23	1.633	3.87	2.649	2.27	1.507
	Class II	3.8	1.186	6.07	0.785	3.33	1.988
	Class III	-0.12	2.6361	2.95	2.0384	1.3	1.2074
Ramal height	Class I	55.603	3.9711	59.68	5.3323	53.953	3.6294
	Class II	52.077	4.3616	59.543	5.3284	51.493	3.6837
	Class III	59.945	3.9629	61.825	4.0087	54.085	1.7427
Ramal width	Class I	25.107	2.8853	26.917	2.5026	25.003	2.4896
	Class II	25.55	1.9002	26.333	2.1078	24.37	0.92
	Class III	23.855	3.4686	27.395	3.503	24.315	2.5471
Total Mandibular length (Co-Gn)	Class I	109.593	7.0465	109.25	7.4649	108.013	4.6187
	Class II	100.047	7.8572	103.3	4.4791	99.017	6.4605
	Class III	115.035	4.1735	108.84	3.1523	111.025	5.0784
Mandibular body length (Go-Me)	Class I	70.193	5.2902	72.34	5.0569	67.333	5.1674
	Class II	63.157	4.2501	66.857	4.8695	62.043	5.9903
	Class III	67.237	3.363	69.15	1.51049	65.205	6.22478
Maxillary body length	Class I	48.673	3.6824	49.41	4.3245	48.453	4.7599
	Class II	47.377	3.3469	50.88	2.9287	48.317	4.0336
	Class III	54.12	4.8405	52.445	8.1331	52.32	4.0968
Anterior Cranial base length (SN)	Class I	67.973	5.4145	67.15	2.9128	66.2	4.176
	Class II	67.467	3.3451	70.003	3.6091	66.553	5.074
	Class III	65.63	4.0193	66.51	2.6127	62.265	1.7367
Symphyseal length	Class I	15.797	1.4568	15.31	2.5451	18.893	2.9822
	Class II	15.727	2.2069	15.477	1.1473	18.513	2.3853
	Class III	18.81	1.6147	15.615	1.9738	18.975	1.5151
Symphyseal width	Class I	13.317	1.8852	13.313	1.0868	11.89	1.3892
	Class II	11.893	1.29	13.173	0.8781	11.427	1.0751
	Class III	13	1.026	15.515	1.798	13.125	1.53
UAFH	Class I	48.333	3.3048	47.403	2.379	47.02	2.0481
	Class II	46.753	2.8569	48.147	1.8496	47.633	1.5381
	Class III	49	3.7076	49.1	6.0481	49.405	2.4916

LAFH	Class I	60.943	5.4939	55.57	4.6511	65.24	4.1654
	Class II	57.247	4.2604	54.66	4.1265	62.39	4.2818
	Class III	61.61	3.898	57.69	6.9511	63.235	3.4835
TAFH	Class I	109.27	7.87	102.97	6.2	112.25	4.18
	Class II	104	5.5	102.8	5.28	109.95	5.48
	Class III	110.61	6.29	106.79	12.5202	112.72	5.87
Facial Height ratio	Class I	0.7965	0.0586	0.8572	0.0654	0.724	0.0608
	Class II	0.8202	0.0683	0.8847	0.0597	0.7659	0.0403
	Class III	0.7969	0.063	0.8524	0.0506	0.7815	0.01
Jarabak's Ratio	Class I	76.4695	0.64572	74.4617	3.77952	70.8103	1.01825
	Class II	58.44	1.5044	60.42	3.63909	57.7087	2.804
	Class III	64.025	1.22039	64.6167	5.0749	63.8383	3.22072

UADH: Upper Anterior Dentoalveolar Height, LADH: Lower Anterior Dentoalveolar Height, UPDH: Upper Posterior Dentoalveolar Height, LPDH: Lower Posterior Dentoalveolar Height, UAFH: Upper Anterior Facial Height, LAFH: Lower Anterior Facial height, TAFH: Total Anterior Facial Height

Table 8: Kruskal Walli test (Mean ranks) for inter-group comparison (Angular parameters)

Parameter	Class	Normodivergent	Hypodivergent	Hyperdivergent	p Value
Basal plane angle	Class I	50.13	17.4	68.97	< .001***
	Class II	46.8	16	73.7	<.001***
	Class III	26.35	25.03	40.13	<.001***
Co-Go-Me Angle	Class I	49.92	16.15	70.43	< .001***
	Class II	56.9	20.1	59.5	<.001***
	Class III	24.6	17.95	48.95	<.001***
U1 to Palatal Plane	Class I	34.48	36.08	35.93	0.356
	Class II	34.48	36.08	35.93	0.633
	Class III	33.48	28.45	29.58	<.001***
L1 to Mandibular Plane	Class I	41.72	42.8	29.98	0.956
	Class II	41.72	42.8	29.98	0.701
	Class III	29.2	43.1	19.2	<.001***
U6 to Palatal Plane	Class I	44.98	58.2	67.3	<.001***
	Class II	12.2	41.18	21.3	<.001***
	Class III	34.33	54.12	47.9	0.812
L6 to Mandibular Plane	Class I	42.48	68.57	63.22	<.001***
	Class II	11.53	26.23	34.95	<.001***
	Class III	37.5	41.7	38.33	0.343

*p <0.05 statistically significant
**p < 0.01 statistically very significant
***p < 0.001 highly statistically significant

Table 9: Kruskal Walli test (Mean Ranks) for inter-group comparison (Linear parameters)

Parameter	Class	Normodivergent	Hypodivergent	Hyperdivergent	p Value
UADH	Class I	41.62	34.3	60.58	<.001***
	Class II	51.63	27.03	54.83	<.001***
	Class III	33.25	13.8	44.45	<.001***
LADH	Class I	49.7	25.97	60.83	<.001***
	Class II	43.07	33.17	60.27	<.001***
	Class III	28.15	18.05	45.3	<.001***
UPDH	Class I	48.98	36.15	51.37	0.052
	Class II	50.2	34.37	51.93	0.651
	Class III	35	27.33	29.18	0.348
LPDH	Class I	43.5	32.33	60.67	0.056
	Class II	42.47	47.43	46.6	0.732
	Class III	29.45	26.4	35.65	0.232
Ramal height	Class I	39.73	61.42	35.35	<.001***
	Class II	37.73	66.87	31.9	<.001***
	Class III	36.15	42.65	12.7	<.001***
Ramal width	Class I	41.68	45.37	40.45	0.901

	Class II	47.03	45.57	33.9	0.514
	Class III	23.25	42	26.25	0.634
Total Mandibular length (Co-Gn)	Class I	46.82	46.75	42.93	0.804
	Class II	41.7	42.27	39.53	0.812
	Class III	42.7	21.4	27.4	<.001***
Mandibular body length (Go-Me)	Class I	45.55	56.28	34.67	.006**
	Class II	39.9	59.08	37.52	0.002**
	Class III	29.85	37.5	24.15	0.005**
Maxillary body length (A-Ptm)	Class I	44.82	47.95	43.73	0.81
	Class II	36.87	59.9	39.73	<.001***
	Class III	33.35	31.1	27.05	0.512
Anterior Cranial base length (SN)	Class I	47.85	49.28	39.37	0.282
	Class II	40.92	57.57	38.02	0.728
	Class III	25.23	30.08	16.2	0.633
Symphyseal length	Class I	37.43	34.77	64.3	<.001***
	Class II	36.5	33.73	66.27	<.001***
	Class III	37	14.78	39.73	<.001***
Symphyseal width	Class I	50.85	56.15	29.5	<.001***
	Class II	40.3	67.2	29	<.001***
	Class III	21.75	44.75	25	<.001***
LAFH	Class I	45.55	24.18	66.77	<.001***
	Class II	37.57	31.23	67.7	<.001***
	Class III	27.85	26	37.65	0.076
TAFH	Class I	47.15	26.68	62.67	<.001***
	Class II	38.87	35.7	61.93	<.001***
	Class III	28.58	28.75	34.17	0.513

UADH: Upper Anterior Dentoalveolar Height, LADH: Lower Anterior Dentoalveolar Height, UPDH: Upper Posterior Dentoalveolar Height, LPDH: Lower Posterior Dentoalveolar Height, Co-Go-Me: Condylion-Gonion-Menton Angle, LAFH: Lower Anterior Facial height, TAFH: Total Anterior Facial Height
*p <0.05 statistically significant
**p < 0.01 statistically very significant
***p < 0.001 highly statistically significant

Table 10: Pearson correlation test (Class I subjects)

Growth Pattern	Parameter		Co-Go-Me	UADH	LADH	UPDH	LPDH
Normodivergent	UADH	r value	.091	-	.121	.160	.128
		P Value	.633	-	.024*	.048*	.040*
	LADH	r value	.656	.277	-	.363	.093
		P Value	.001***	.038*	-	.049*	.026*
	UPDH	r value	-.354	.550	.162	-	.155
		P Value	.015*	.002**	.033*	-	.013*
	LPDH	r value	-.410	.459	.248	.533	-
		P Value	.017*	.011**	.017**	.002**	-
Hypodivergent	UADH	r value	-.497	-	.601	.005	.318
		P Value	.011*	-	.040*	.007**	.017*
	LADH	r value	-.714	.129	-	.037	.435
		P Value	.001**	.048*	-	.047*	.016*
	UPDH	r value	.334	.066	.504	-	.337
		P Value	.071	.035*	.045*	-	.044*
	LPDH	r value	.222	.126	.574	.032	-
		P Value	.041*	.001**	.001**	.001**	-
Hyperdivergent	UADH	r value	.061	-	.162	.039	.097
		P Value	.750	-	.002**	.037*	.009**
	LADH	r value	.318	.216	-	.093	.477
		P Value	.040*	.002**	-	.026*	.008**
	UPDH	r value	-.449	.150	.218	-	.231
		P Value	.413	.028*	.048*	-	.019*
	LPDH	r value	-.500	.060	.482	.356	-

		P Value	.055	.002**	.007**	.014*	-

UADH: Upper Anterior Dentoalveolar Height, LADH: Lower Anterior Dentoalveolar Height, UPDH: Upper Posterior Dentoalveolar Height, LPDH: Lower Posterior Dentoalveolar Height,Co-Go-Me: Condylion-Gonion-Menton Angle
*p <0.05 statistically significant, **p < 0.01 statistically very significant
***p < 0.001 highly statistically significant

Table 11: Pearson correlation test (Class II subjects)

Growth Pattern	Parameter		Co-Go-Me	UADH	LADH	UPDH	LPDH
Normodivergent	UADH	r value	.141	-	.340	.339	.289
		P Value	.459	-	.006**	.017*	.022*
	LADH	r value	.621	.283	-	.260	.131
		P Value	.001**	.029*	-	.005**	.010*
	UPDH	r value	.429	.757	.775	-	.799
		P Value	.518	.043*	.021*	-	.037*
	LPDH	r value	-.251	.693	.628	.614	-
		P Value	.004**	.042*	.018*	.023*	-
Hypodivergent	UADH	r value	-.137	-	.101	.394	.238
		P Value	.469	-	.016*	.031*	.005**
	LADH	r value	-.984	.124	-	.054	.139
		P Value	.000***	.011*	-	.009**	.004**
	UPDH	r value	.738	.070	.332	-	.570
		P Value	.700	.013*	.042*	-	.031*
	LPDH	r value	.513	.046	.257	.274	-
		P Value	.003**	.010*	.011*	.042*	-
Hyperdivergent	UADH	r value	.482	-	.117	.239	.313
		P Value	.037*	-	.039*	.003**	.022*
	LADH	r value	.546	.059	-	.175	.593
		P Value	.002**	.016*	-	.006**	.001**
	UPDH	r value	-.220	.016	.214	-	.529
		P Value	.000***	.004**	.007**	-	.003**
	LPDH	r value	-.231	.045	.095	.226	-
		P Value	.004**	.015*	.017*	.029*	-

UADH: Upper Anterior Dentoalveolar Height, LADH: Lower Anterior Dentoalveolar Height, UPDH: Upper Posterior Dentoalveolar Height, LPDH: Lower Posterior Dentoalveolar Height, Co-Go-Me: Condylion-Gonion-Menton Angle
*p <0.05 statistically significant**p < 0.01 statistically very significant***p < 0.001 highly statistically significant

Table 12: Pearson correlation test (Class III subjects)

Growth Pattern	Parameter		Co-Go-Me	UADH	LADH	UPDH	LPDH
Normodivergent	UADH	r value	.244	-	.626	.271	.650
		P Value	.042*	-	.013*	.047*	.032*
	LADH	r value	.649	.029	-	.027	.378
		P Value	.003**	.035*	-	.010*	.030*
	UPDH	r value	.543	.322	.185	-	.187
		P Value	.047*	.007**	.035*	-	.030*
	LPDH	r value	.624	.420	.452	.392	-
		P Value	.045*	.025*	.045*	.017*	-
Hypodivergent	UADH	r value	-.490	-	.081	.593	.535
		P Value	.028*	-	.034*	.006**	.015*
	LADH	r value	-.680	.366	-	.749	.545
		P Value	.007**	.012*	-	.000***	.013*
	UPDH	r value	.144	.186	.297	-	.169
		P Value	.008**	.032*	.004**	-	.027*
	LPDH	r value	.283	.169	.000	.711	-
		P Value	.037*	.026*	.009**	.000	-
Hyperdivergent	UADH	r value	.232	-	.051	.646	.579

		P Value	.325	-	.031*	.002**	.008**
	LADH	r value	.519	.019	-	.162	.134
		P Value	.001**	.038*	-	.025*	.013*
	UPDH	r value	-.127	.184	.041	-	.358
		P Value	.594	.038*	.003**	-	.021*
	LPDH	r value	-.396	.143	.042	.251	-
		P Value	.005**	.048*	.040*	.025*	-

UADH: Upper Anterior Dentoalveolar Height, LADH: Lower Anterior Dentoalveolar Height, UPDH: Upper Posterior Dentoalveolar Height, LPDH: Lower Posterior Dentoalveolar Height, Co-Go-Me: Condylion-Gonion-Menton Angle

*p <0.05 statistically significant**p < 0.01 statistically very significant***p < 0.001 highly statistically significant

DISCUSSION

The variations in dentoalveolar heights along with diverse growth patterns in different types of skeletal discrepancies affect several aspects of treatment planning such as the choice of extraction, the type of anchorage, the orthodontic biomechanics, and the method and duration of retention.[3] Different growth patterns also exhibit some atypical characteristics like hyperdivergent growth pattern with increased mandibular plane angle shows backward rotation of mandible, increased lower anterior facial height, tendency of open bite and labial incompetency. Whereas hypodivergent growth pattern with reduced mandibular plane angle results in forward mandibular rotation and tendency of deep bite.

Orthodontic treatment may require intrusion or extrusion in anterior or posterior regions of maxilla or mandible thereby altering dentoalveolar heights. Such changes must be carried out with careful consideration so as to not produce undesirable changes like mandibular rotation, incisor and gingival display, lower anterior facial height and soft tissue characteristics. Therefore, the knowledge of existing dentoalveolar heights prior to orthodontic treatment is a prerequisite for proper treatment planning. Contrasting results have been obtained so far pertaining to dentoalveolar heights in various growth patterns.

The **Condylion-Gonion-Menton (Co-Go-Me)** angle shows statistically significant differences (p < 0.001) in different types of skeletal dysplasia among all three classes. This may be attributed to association of the angle with mandibular rotational pattern and SN-GoGn angle, due to which it increases in hyperdivergent individuals with backward mandibular rotation and decreases in forward rotation as enumerated in the study by Vincenzo D'Anto et al[12] and Rosa Valletta et al.[1]

Incisor inclinations, (U1 to PP and L1 to MP) show significant difference (p < 0.001) only in Class III malocclusion highlighting their role in natural compensation mechanism. As a part of this, increased proclination of maxillary incisors and lingual inclination of mandibular incisors is noted. This is in accordance with the studies conducted by Luis Ernesto et al[13], Ishikwa et al[14] Kim et al[15], Al-Khadim et al.[16]

Molar inclination, (U6 to PP and L6 to MP) show significant differences between the three growth patterns in both Class I and Class II (both at p < 0.001). This is in accordance with the results obtained in studies by UU Hakeem et al[17,] Su Hong et al [18] and Oscar Ledesma-Peraza et al.[19]

Upper and lower anterior dentoalveolar heights (UADH and LADH) in subjects with Class I, Class II and Class III malocclusion when compared with subjects having normodivergent, hypodivergent and hyperdivergent growth patterns shows highly statistically significant difference between them (p < 0.001).

These findings are in accordance with the studies undertaken by Carla Enoki et al[9], Zafar Ul Islam et al[20], Agraj Sharma et al[21], Farah Khalifeh et al[22], and UU Hakeem et al.[17]

Whereas **upper and lower posterior dentoalveolar heights (UPDH and LPDH)** do not show significant difference among the normal, hypodivergent and hyperdivergent groups when compared with sagittal discrepancy. These findings are in accordance with those obtained in studies by Carla Enoki et al[9], Zafar Ul Islam et al[20], Agraj Sharma et al[21], Farah Khalifeh et al[22], Reinder Kuitert et al[11] and UU Hakeem et al.[17]

Above findings were further strengthened by studies of Janson et al[6], Zafar Ul Islam et al[20] and AS Kadhum[23] who observed no difference in posterior dentoalveolar heights. This could perhaps occur due to dynamic interplay of environmental or neuromuscular factors that could overpower any sagittal skeletal differences.

Statistically significant differences noted in **Ramal height, Co-Go** (p < 0.001) in all three classes among the three growth patterns. This is in accordance with studies by Roshni Mahajan et al[24], UU Hakeem et al[27], Tarek Yousry et al[25] and Danna Xiao et al.[26]

Mandibular body length (Go-Me) shows statistically significant differences between the growth pattern in Class I (p = 0.006), Class II (p = 0.002) and Class III (p = 0.005). Decreased mandibular body length has been described in hyperdivergent growers as a result of downward and backward mandibular rotation which restricts not only ramus length but also forward or anteroposterior dimensions of the mandible.[27]

Symphyseal length and **symphyseal width** show statistically highly significant difference ($p < 0.001$) for all, Class I, Class II and Class III having variable growth patterns. UU Hakeem et al[17], DM Gininda et al[28], and Abhishek Singha Roy et al[29] reported similar results. The higher masticatory muscle activity in hypodivergent group may contribute to the formation of a shorter and wider symphysis that is better at stress distribution as compared to the long and narrowed symphyseal region in hyperdivergent group.[30]

The **lower anterior facial height (LAFH) and total anterior facial height (TAFH)** both show highly statistically significant difference ($p < 0.001$) in Class I and Class II. This is in accordance with studies by UU Hakeem et al[17], Kuitert et al[11], Carla Enoki et al[9], Z Mirzen Arat et al[8], Nabila Anwar et al[4] Danna Xiao et al[26]. As a part of the internal rotation occurring about the corpus of the mandible, the symphysis swings backward. Thus, a clockwise mandibular rotation is present in hyperdivergent subjects which produces an increased LAFH and TAFH.

The findings in normodivergent and hyperdivergent groups here is similar to the findings of Martina et al[10] who found decreasing molar heights with increasing divergence of the jaws i.e., in negative association of posterior dentoalveolar heights with hyperdivergent growth pattern, especially pronounced with LPDH ($p < 0.001$) and to the findings of Valletta et al[1] who demonstrated a negative association of LPDH with Co-Go-Me angle.

All the dentoalveolar heights are correlated among each other, which occurs as a part of normal growth and development similar to the studies by Rosa Valletta et al[1] and Kuitert et al.[13]

LADH is the parameter most strongly associated with different skeletal dysplasia. This is in accordance with the studies by Nabila Anwar et al[4], Kuitert et al[11] who stated anterior dentoalveolar dimensions show stronger correlation than posterior ones. Dentoalveolar heights in the mandible showed stronger associations than maxillary ones, in accordance with the study by Buschang et al[31] which may be due to the greater susceptibility of mandibular parameters to environmental factors.

Clinical importance of the above findings is that in hyperdivergent growth pattern, molar extrusion may cause further clockwise rotation and worsen patient's existing characteristics. Whereas in the hypodivergent group, with already reduced anterior dentoalveolar heights, incisor intrusion must be cautiously carried out.

CONCLUSION

- Lower anterior dentoalveolar height (LADH) is the parameter most strongly associated with different vertical growth patterns.
- The condylion-gonion-menton angle is a reliable predictor of growth pattern. It shows strong positive association with LADH in hyperdivergent group and negative association with LADH in hypodivergent group.

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