Research Article

Association Of Cranial Base Morphology, Hyoid Bone Position And Pharyngeal Airway Depth In Different Sagittal Skeletal Malocclusions: A Cephalometric Study

Dr. Joel Koshy Mathew[1], Dr. Gaurav Ahuja[2], Dr. Deepankar Bhatnagar[3], Dr. Meenu Vashisht[4], Dr. Arpith Ann Joseph[5], Dr. Nandini Praful.K[6]

[1]B.D.S, Postgraduate Student, M.M College of Dental Sciences and Research, Mullana, Ambala, Haryana. Email ID- jkmjoel07@gmail.com Orcid I'd - 0009-0000-9004-4223
[2]M.D.S, Professor, M.M College of Dental Sciences and Research, Mullana, Ambala, Haryana. Email ID- gauravahuja663@gmail.com Orcid I'd - 0009-0006-6087-0608
[3]M.D.S, Professor and Head, M.M College of Dental Sciences and Research, Mullana, Ambala, Haryana. Email ID- deepankarbhatnagar101@gmail.com Orcid id- 0000-0002-7260-6461
[4]B.D.S, Postgraduate Student, M.M College of Dental Sciences and Research, Mullana, Ambala, Haryana. Email ID- meenu101210@gmail.com Orcid id: 0009-0008-8385-5173
[5] B.D.S, Postgraduate Student, M.M College of Dental Sciences and Research, Mullana, Ambala, Haryana., Email ID- arpithannjoseph@gmail.com Orcid I'd - 0009-0004-5543-5201
[6]B.D.S, Postgraduate Student, M.M College of Dental Sciences and Research, Mullana, Ambala, Haryana. Email ID- nandinikhobragade99@gmail.com Orcid I'd - 0009-0004-2676-1841

Abstract

Introduction: The hyoid bone connects the cranial base, mandible, tongue, and airway. Its position changes with different craniofacial patterns and skeletal malocclusions. Since airway size is influenced by mandibular position and cranial base structure, understanding this relationship is important for orthodontic diagnosis and treatment planning. This study aimed to evaluate and compare the position of the hyoid bone and airway dimensions in Class I, II, and III skeletal patterns.
Methods: This retrospective study included 60 lateral cephalograms of subjects aged 15–30 years. They were divided equally into Class I, II, and III groups based on ANB angle and App–Bpp values. Skeletal, angular (NSAr, C3HyD, SArHy, NSHy), airway (D1–D5), and horizontal hyoid (H1–H4) measurements were recorded. Statistical analysis was done using ANOVA, t-tests, and Pearson correlation.
Results: Significant differences were found among the groups in skeletal measurements, airway dimensions (D1, D4, D5), and horizontal hyoid parameters (H1, H2). Class II subjects showed reduced airway space and a vertical growth pattern, while Class III subjects showed increased horizontal dimensions. NSHy differed significantly between groups. Gender differences were minimal. Positive correlations were found between NSAr–NSHy and SArHy–NSHy, while NSAr–SArHy showed a negative correlation.
Conclusions: Skeletal pattern affects hyoid position and airway size. Class II subjects tend to have reduced airway space, whereas Class III subjects show increased dimensions. Evaluating these relationships is important during orthodontic diagnosis.
Keywords: Cephalometrics; Hyoid bone; Pharyngeal airway; Craniofacial morphology; Skeletal malocclusion

Introduction

Malocclusion refers to improper alignment of teeth in all three planes of space. Angle's classification is widely used, but it mainly describes dental relationships and does not fully reflect skeletal differences. Skeletal Class I represents a balanced jaw relationship, Class II is usually associated with mandibular retrusion, and Class III is related to mandibular prognathism or maxillary deficiency. [1]

The hyoid bone is a small, horseshoe-shaped bone located between the mandible and cervical vertebrae. It is not directly attached to other bones but is supported by muscles and ligaments. It plays an important role in swallowing, speech, breathing, and head posture. [2] Its position depends on the tongue, mandible, and surrounding muscles. Changes in its position can affect airway space and may be associated with conditions such as obstructive sleep apnoea. [3]

The geniohyoid muscle helps maintain airway patency, and its function depends on the position of the hyoid bone. [2] the pharynx extends from the cranial base to the cricoid cartilage and is closely related to craniofacial structures. [3,4] Therefore, variations in jaw relationships can influence airway dimensions.

Previous studies have shown that Class II individuals often have reduced airway space, while Class III individuals may show increased airway dimensions. [3,6] Lateral cephalograms are commonly used to evaluate these relationships, although they provide only a two-dimensional view. Cone-beam computed tomography offers a more accurate three-dimensional assessment but is not always practical in routine clinical use. [8]

Understanding the relationship between the cranial base, mandible, hyoid bone, and airway is important for proper orthodontic diagnosis and treatment planning.

Materials And Methods

This retrospective study included 60 subjects aged 15–30 years. They were divided equally into Class I, II, and III skeletal groups based on ANB angle and App–Bpp values. This retrospective study was conducted using lateral cephalograms obtained from institutional archives. According to institutional guidelines, informed consent was waived due to the retrospective nature of the study.

Inclusion criteria:

1. Normodivergent growth pattern
2. Complete permanent dentition
3. Good-quality lateral cephalograms
4. No prior orthodontic treatment

Exclusion criteria:

1 . Craniofacial anomalies or syndromes
2 . History of trauma
3 . Missing teeth
4 . Poor-quality radiographs

All cephalograms were taken with the Frankfort horizontal plane parallel to the floor and teeth in centric occlusion. [Figure 1], [Figure 2], [Figure 3]

The following parameters were evaluated:

1. Skeletal measurements
2. Angular measurements (NSAr, C3HyD, SArHy, NSHy)
3. Airway measurements (D1–D5)
4. Horizontal hyoid measurements (H1–H4) [Figure 4]

Statistical analysis was performed using ANOVA for comparison among groups, independent t-tests for gender differences, and Pearson correlation to assess relationships between variables.

Results

The study included 60 subjects with a mean age of 19.62 ± 3.72 years, equally distributed across skeletal groups and gender. [Table 1], [Table 2]

Skeletal measurements showed clear differences among the groups ($p < 0.001$), confirming distinct craniofacial patterns. Angular parameters showed minimal variation. [Table 3]

Airway measurements (D1, D4, D5) differed significantly among groups. Class II subjects showed reduced airway space, while Class III subjects showed increased airway dimensions.

[Table 4]

Horizontal hyoid measurements (H1, H2) also showed significant differences, indicating variation in hyoid position. [Table 5] NSHy differed significantly, suggesting changes in vertical hyoid position among the groups.

Gender differences were minimal and inconsistent.

Correlation analysis showed:

1. Positive correlation between NSAr–NSHy and SArHy–NSHy
2. Negative correlation between NSAr–SArHy
3. Weak correlation with airway measurements

[Table 6], [Table 7], [Table 8], [Table 9].

Discussion

This study evaluated the relationship between hyoid position, cranial base, mandible, and airway dimensions in different skeletal patterns. The findings show that skeletal pattern influences both airway size and hyoid position.

The cranial base plays a role in jaw relationships, while the mandible and hyoid bone have a more direct effect on airway space. [9,10] The hyoid bone is adaptable due to its muscular attachments and can change position based on functional needs. [2]

The results are consistent with previous studies. Jose et al. reported a more posterior hyoid position and reduced airway space in Class II subjects. [16] Chauhan et al. found that airway dimensions vary with ANB angle. [3] Other studies have also reported reduced airway space in Class II and increased dimensions in Class III individuals. [4,6,7]

The selected age group helped reduce the influence of growth on the results. Equal distribution of subjects improved reliability.
The cranial base angle (NSAr) showed little variation among groups, suggesting a limited independent role. However, NSHy differed significantly, especially in Class II subjects, indicating altered vertical hyoid position.
Linear measurements showed increased mandibular dimensions in Class III subjects and reduced dimensions in Class II subjects. Gender differences were minimal, suggesting that skeletal pattern has a stronger influence.
Correlation analysis showed that the cranial base, mandible, and hyoid bone are interrelated. Positive correlations suggest coordinated adaptation, while negative correlation indicates the influence of cranial base on sagittal discrepancies.
Clinically, reduced airway space in Class II patients should be considered during orthodontic treatment planning. Class III patients generally show more favorable airway dimensions.

Limitations:

1. Use of two-dimensional cephalograms
2. Small sample size

Future studies using CBCT and larger samples are recommended.

Conclusion

Skeletal pattern has a clear influence on hyoid position and airway dimensions. Class II subjects show reduced airway space and mandibular retrusion, while Class III subjects show increased dimensions.
Most angular measurements remained stable except NSHy. Linear and horizontal measurements showed significant differences among groups. Gender had minimal influence.
These findings highlight the importance of evaluating airway and hyoid position during orthodontic diagnosis and treatment planning. Further studies using advanced imaging techniques are recommended.

Table 1: - Distribution of Study Participants According to Age, Gender, and Class (N = 60)

		N=60	%
AGE	15-20 Year	40	66.7%
	21-25 Year	14	23.3%
	25-30 Year	6	10.0%
Mean± SD		19.62±3.72	
GENDER	Female	31	51.7%
	Male	29	48.3%
CLASS	CLASS I	20	33.3%
	CLASS II	20	33.3%
	CLASS III	20	33.3%

Table 2: - Descriptive Statistics of Skeletal Parameters (ANB and App-Bpp)

Descriptive		SKELETAL PARAMETERS	
		ANB (Deg)	App-Bpp(mm)
Mean		3.150	2.250
95% Confidence Interval	Lower Bound	2.240	.731

for Mean	Upper Bound	4.060	3.769
5% Trimmed Mean		3.148	2.574
Median		3.000	3.500
Variance		12.401	34.597
Std. Deviation		3.5215	5.8820
Minimum		-5.0	-12.5
Maximum		11.0	13.0
Range		16.0	25.5
Interquartile Range		5.0	8.0
Skewness		-0.078	-0.989
Kurtosis		-0.292	0.303

Table 3: - Descriptive Statistics of Angular Parameters (NSAr, C3HyD, SArHy, and NSHy)

Descriptive		ANGULAR PARAMETERS			
		NSAr (Deg)	C3HyD (Deg)	SArHy (Deg)	NSHy (Deg)
Mean		127.13	160.33	125.55	88.65
95% Confidence Interval for Mean	Lower Bound	125.67	156.95	123.78	87.19
	Upper Bound	128.59	163.72	127.32	90.11
5% Trimmed Mean		127.00	160.61	125.65	88.54
Median		126.50	161.00	125.00	88.50
Variance		31.982	171.379	46.930	31.892
Std. Deviation		5.655	13.091	6.851	5.647
Minimum		117	135	105	79
Maximum		142	181	143	100
Range		25	46	38	21
Interquartile Range		9	22	10	9
Skewness		0.284	-0.262	-0.207	0.212
Kurtosis		-0.473	-0.884	0.823	-0.813

Table 4: -Descriptive Statistics of Linear Parameters (D1, D2, D3, D4, and D5)

Descriptive		LINEAR PARAMETERS				
		D1	D2	D3	D4	D5
Mean		22.7083	8.800	10.067	10.692	21.342
95% Confidence Interval for Mean	Lower Bound	21.7035	8.138	9.380	9.807	20.465
	Upper Bound	23.7131	9.462	10.754	11.576	22.219
5% Trimmed Mean		22.7407	8.741	9.981	10.472	21.231

Median	23.0000	8.750	10.000	10.000	21.500
Variance	15.130	6.561	7.072	11.730	11.530
Std. Deviation	3.88968	2.5614	2.6593	3.4248	3.3955
Minimum	13.50	3.5	4.5	5.0	15.0
Maximum	36.00	15.0	17.5	23.0	31.0
Range	22.50	11.5	13.0	18.0	16.0
Interquartile Range	4.00	2.9	3.0	5.0	4.5
Skewness	-0.006	0.411	0.479	1.030	0.475
Kurtosis	2.108	0.383	0.398	1.493	0.258

Table 5: -Descriptive Statistics of Horizontal Parameters (H1, H2, H3, and H4)

Descriptive		HORIZONTAL PARAMETERS			
		H1	H2	H3	H4
Mean		40.55	33.08	46.60	8.30
95% Confidence Interval for Mean	Lower Bound	39.12	31.88	45.25	7.76
	Upper Bound	41.98	34.29	47.95	8.84
5% Trimmed Mean		40.39	33.00	46.50	8.22
Median		40.00	32.50	46.00	8.00
Variance		30.658	21.840	27.159	4.383
Std. Deviation		5.537	4.673	5.211	2.094
Minimum		31	25	37	5
Maximum		55	43	59	15
Range		24	18	22	10
Interquartile Range		9	8	8	4
Skewness		0.375	0.273	0.194	0.584
Kurtosis		-0.450	-0.682	-0.324	0.319

Table 6: -Comparison of Skeletal, Angular, Linear, and Horizontal Parameters Between Genders in Class I

Class-I					
Test Variable		Gender	N	Mean ± SD	P-value
SKELETAL PARAMETERS	ANB (Deg)	Female	8	3.13±0.99	0.65
		Male	12	2.92±1	
	App-Bpp(mm)	Female	8	3.5±0.27	0.89
		Male	12	3.46±0.4	
ANGULAR PARAMETERS	NSAr (Deg)	Female	8	129.88±5.79	0.032
		Male	12	124.42±5.02	
	C3HyD (Deg)	Female	8	168±8.64	0.13
		Male	12	160.33±11.85	
	SArHy (Deg)	Female	8	120.75±7.52	0.12
		Male	12	125.5±5.62	
	NSHy (Deg)	Female	8	88.13±6.15	0.55
		Male	12	86.58±5.2	

LINEAR PARAMETERS	D1	Female	8	22.94±3.51	0.32
		Male	12	25.04±5.14	
	D2	Female	8	8.81±3.43	0.79
		Male	12	9.17±2.67	
	D3	Female	8	9.56±3.2	0.601
		Male	12	10.29±2.86	
	D4	Female	8	9.44±4.26	0.33
		Male	12	11.08±3.23	
	D5	Female	8	19.75±3.25	0.051
		Male	12	23.42±4.14	
HORIZONTAL PARAMETERS	H1	Female	8	37.75±4.56	0.35
		Male	12	40.17±6.04	
	H2	Female	8	30.63±2.97	0.071
		Male	12	34.17±4.69	
	H3	Female	8	42.88±4.39	0.036
		Male	12	47.42±4.38	
	H4	Female	8	8.5±2.27	0.57
		Male	12	9±1.65	

Table 7: -Comparison of Skeletal, Angular, Linear, and Horizontal Parameters Between Genders in Class II

Class-II					
Test Variable		**Gender**	**N**	**Mean ± SD**	**P-value**
SKELETAL PARAMETERS	ANB (Deg)	Female	12	7.33±1.44	0.35
		Male	8	6.63±1.92	
	App-Bpp(mm)	Female	12	7.54±0.86	0.43
		Male	8	8.06±2.03	
ANGULAR PARAMETERS	NSAr (Deg)	Female	12	128.08±5.3	0.62
		Male	8	129.25±4.92	
	C3HyD (Deg)	Female	12	156.92±16.51	0.49
		Male	8	152.25±10.91	
	SArHy (Deg)	Female	12	126.33±5.57	0.56
		Male	8	128±7.05	
	NSHy (Deg)	Female	12	91.33±5.73	0.57
		Male	8	92.75±5.01	
LINEAR PARAMETERS	D1	Female	12	22.38±2.12	0.21
		Male	8	23.81±2.9	
	D2	Female	12	8.25±1.8	0.52
		Male	8	8.88±2.56	
	D3	Female	12	9.46±2.03	0.51
		Male	8	10.19±2.8	
	D4	Female	12	9.42±1.61	0.93
		Male	8	9.5±2.58	
	D5	Female	12	19.38±2.95	0.42
		Male	8	20.38±2.26	
HORIZONTAL	H1	Female	12	38.92±5	0.92

PARAMETERS		Male	8	39.13±4.22	
	H2	Female	12	31±5.69	0.61
		Male	8	32.13±2.64	
	H3	Female	12	45.33±4.79	0.21
		Male	8	47.75±2.49	
	H4	Female	12	8.17±1.7	0.79

Table 8: -Comparison of Skeletal, Angular, Linear, and Horizontal Parameters Between Genders in Class III

Class-III					
Test Variable		**Gender**	**N**	**Mean ± SD**	**P-value**
SKELETAL PARAMETERS	ANB (Deg)	Female	11	-0.18±1.66	0.31
		Male	9	-1.11±2.37	
	App-Bpp(mm)	Female	11	-4.64±5.6	0.87
		Male	9	-4.28±4.29	
ANGULAR PARAMETERS	NSAr (Deg)	Female	11	125.18±4.75	0.39
		Male	9	127.56±7.35	
	C3HyD (Deg)	Female	11	162±9.64	0.83
		Male	9	163.22±15.99	
	SArHy (Deg)	Female	11	130.09±5.77	**0.005**
		Male	9	121.11±6.72	
	NSHy (Deg)	Female	11	89.36±3.44	**0.006**
		Male	9	83.78±4.63	
LINEAR PARAMETERS	D1	Female	11	19.82±4.59	0.13
		Male	9	22.39±1.83	
	D2	Female	11	8.95±2.65	0.88
		Male	9	8.78±2.94	
	D3	Female	11	10.45±2.24	0.99
		Male	9	10.44±3.44	
	D4	Female	11	13±4.59	0.32
		Male	9	11.22±2.71	
	D5	Female	11	22.05±3.07	0.65
		Male	9	22.61±2.4	
HORIZONTAL PARAMETERS	H1	Female	11	44.09±6.19	0.58
		Male	9	42.67±4.85	
	H2	Female	11	35.09±4.06	0.96
		Male	9	35±5.2	
	H3	Female	11	49.36±6.68	0.26
		Male	9	46.11±5.9	
	H4	Female	11	6.82±1.54	**0.041**

Table 9: -Correlation Between Angular, Linear, and Horizontal Parameters

Correlations							
Pearson Correlation		ANGULAR PARAMETERS				LINEAR PARAMETERS	HORIZONTAL PARAMETERS
		NSAr (Deg)	C3HyD (Deg)	SArHy (Deg)	NSHy (Deg)		
NSAr (Deg)	r	1	-0.136	-0.406**	0.464**	0.106	.027
	P value		0.300	**0.001**	**<0.001**	0.421	0.835
C3HyD (Deg)	r		1	-.086	-.066	0.080	0.068
	P-value			0.513	0.616	0.542	0.607
SArHy (Deg)	r			1	0.459**	-0.298*	0.074
	P-value				**<0.001**	**0.021**	0.574
NSHy (Deg)	r				1	-0.134	0.044
	P-value					0.309	0.737
LINEAR PARAMETERS	r					1	0.152
	P-value						0.248

References

1. Rothstein T, Yoon-Tarlie C. Dental and facial skeletal characteristics and growth of males and females with Class II, Division 1 malocclusion between ages 10–14 years. Am J Orthod Dentofacial Orthop. 2000;117(3):320–32.
2. Jena AK, Duggal R. Hyoid bone position in subjects with different vertical jaw dysplasias. Angle Orthod. 2011;81(1):81–5.
3. Chauhan A, Autar R, Pradhan KL, Yadav V. Comparison of pharyngeal airway dimension, tongue and hyoid bone position based on ANB angle. Natl J Maxillofac Surg. 2015;6(1):42.
4. Ceylan I, Oktay H. Pharyngeal size in different skeletal patterns. Am J Orthod Dentofacial Orthop. 1995;108(1):69–75.
5. Sheng CM, Lin LH, Su Y, Tsai HH. Developmental changes in pharyngeal airway depth and hyoid bone position. Angle Orthod. 2009;79(3):484–90.
6. Alves M Jr, Franzotti ES, Baratieri C, Nunes LK, Nojima LI, Ruellas AC. Evaluation of pharyngeal airway space in different skeletal patterns. Int J Oral Maxillofac Surg. 2012;41(7):814–9.
7. de Freitas MR, Alcazar NM, Janson G, de Freitas KM, Henriques JF. Upper and lower pharyngeal airways in Class I and II malocclusions. Am J Orthod Dentofacial Orthop. 2006;130(6):742–5.
8. Stratemann S, Huang JC, Maki K, Hatcher D, Miller AJ. Three-dimensional airway analysis using CBCT. Am J Orthod Dentofacial Orthop. 2011;140(5):607–15.
9. Dhopatkar A, Bhatia S, Rock P. Relationship between cranial base angle and malocclusion. Angle Orthod. 2002;72(5):456–63.
10. Klocke A, Nanda RS, Kahl-Nieke B. Role of cranial base flexure in sagittal discrepancies. Am J Orthod Dentofacial Orthop. 2002;122(4):386–91
11. Baik CY, Ververidou M. Beta angle for sagittal discrepancies. Am J Orthod Dentofacial Orthop. 2004;126(1):100–5.
12. Zhong Z, Tang Z, Gao X, Zeng XL. Upper airway comparison in craniofacial patterns. Angle Orthod. 2010;80(2):267–74.
13. Polat OO, Kaya B. Cranial base morphology in malocclusions. Orthod Craniofac Res. 2007;10(4):216–21.
14. Ang PK, Sandham A, Tan WC. Craniofacial morphology in obstructive sleep apnea. Semin Orthod.

2004;10(1):90–6.
15. Reddy R, Chunduri R, Mamtha T, et al. Airway evaluation in skeletal malocclusions. Int J Contemp Dent. 2011;2(5).
16. Jose NP, Shetty S, Mogra S, et al. Hyoid bone position and airway correlation. Contemp Clin Dent. 2014;5(2):187.
17. Ferros I, Mora MJ, Obeso IF, et al. Cranial base and mandible relationship. Orthod Craniofac Res. 2016;19(4):222–33.
18. Amayeri M, Saleh F, Saleh M. Hyoid bone position in facial patterns. Eur Sci J. 2014;10(15).
19. Mortazavi S, Asghari-Moghaddam H, Dehghani M, et al. Hyoid position in skeletal patterns. J Clin Exp Dent. 2018;10(4): e346.
20. Krasteva S, Zlatev S. Cranial base evaluation in Bulgarian population. Scripta Sci Med Dent. 2017;3(1):41–6.
21. Almeida KC, Raveli TB, Vieira CI, et al. Cranial base flexion and malocclusion: systematic review. Dent Press J Orthod. 2017; 22:56–66.
22. Firwana A, Wang H, Sun L, et al. Airway size and mandibular distance relationship. Indian J Dent Res. 2019;30(3):368–74.
23. Chauhan R, Bagga DK, Agrawal P, et al. Hyoid position and airway depth evaluation. Int J Clin Pediatr Dent. 2019;12(2):101.
24. Monirifard M, Sadeghian S, Afshari Z, et al. Cranial base and sagittal features. Dent Res J. 2020;17(1):60.
25. Elgadir Ahmed AA, Abuaffan AH. Cranial base morphology and malocclusion. J Dent Probl Solut. 2020;7(2):90–5.