

Radiographic Evaluation of the Hyoid Bone Position and Pharyngeal Airway Depth in Anteroposterior Dysplasia

Rajat Chauhan¹, Dinesh Kumar Bagga², Poonam Agrawal³, Hiten Kalra⁴, Praful Kumar⁵, Anoop Singh⁶

ABSTRACT

Introduction: The pharyngeal airway, tongue, and hyoid bone are correlated. The hyoid bone is connected to the pharynx, mandible, and cranium through muscles and ligaments and its position with respect to them determines the tongue posture and function. It also plays an important role in maintaining the airway and upright natural head position. Different skeletal patterns have different morphologies and shapes of the mandible, which might be affected by the position of the hyoid bone and the pharyngeal airway depth. This cephalometric study was conducted to relate the pharyngeal airway depth and the hyoid bone position of different skeletal patterns in sagittal dimension, and it determines and compares the linear parameters of the pharyngeal airway depth in Class I, II, and III malocclusion groups and anteroposterior, vertical, and angular positions of the hyoid bone positions in Class I, II, and III malocclusion groups.

Materials and methods: Lateral cephalometric radiographs selected for study were divided into three groups of 30 samples each based on ANB angle and β angle into skeletal Class I, Class II, and Class III, respectively. Five linear measurements for the pharyngeal airway depth, four linear measurements for anteroposterior position, two linear measurements for vertical position, and one angular measurement for angular hyoid bone position were made.

Results: The pharyngeal airway depth was found to show no statistically significant difference between Class I and Class III malocclusions. The pharyngeal airway depth in Class II malocclusion was found to be statistically smaller at D1 as compared to that in Class I and Class III malocclusions, whereas it remained the same at the rest of the locations measured, i.e., D2, D3, D4, and D5. The Class III malocclusion group showed a significant statistical difference in the anteroposterior hyoid bone position at all levels (i.e., H1, H2, H3, and H4) as compared to the Class II malocclusion group, whereas it showed a statistically significant difference as compared to the Class I malocclusion group at H1 and H3. The angular inclination of the hyoid bone in the Class II malocclusion group showed a statistically significant difference with the Class I and Class III malocclusion group but the Class III malocclusion group showed no significant difference statistically when compared to the Class I malocclusion group.

Conclusion: The pharyngeal airway depth in the Class II malocclusion group was also found to be narrower at the superiormost level measured at the posterior nasal spine from the posterior pharyngeal wall. The hyoid bone position was variable in angular and anteroposterior dimensions among different malocclusion groups.

Keywords: Anteroposterior dysplasia, Cephalometric radiographs, Hyoid bone, Pharyngeal airway, Skeleton malocclusion.

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INTRODUCTION

The patent pharyngeal airway is mandatory for the growth and development of the craniofacial region.¹⁻⁴ The patent normal airway is maintained by the relationship of the pharynx with its associated structures, such as the tongue and hyoid bone.⁵ The hyoid bone is connected to the pharynx, mandible, and cranium through muscles and ligaments.⁶ The hyoid bone position with respect to the cranial base and the mandible determines the tongue posture and function, and it plays an important role in maintaining the airway and upright natural head position. The position of the hyoid bone is influenced by the position of the tongue, thus affecting the pharyngeal airway space.⁷ Thurow proposed that the anteroposterior position of the hyoid is maintained by the geniohyoid muscle due to which airway patency was maintained throughout the various movements of the craniofacial complex.⁸ The position of the hyoid bone on the genial tubercle level might increase the efficiency of the muscle in pulling the tongue forward and maintaining the airway. A more inferior position of the hyoid bone with lower tongue posture places the geniohyoid muscle at a mechanical disadvantage by its angulation. This may increase the mandibular load because of the need to elevate the tongue as well as to create a stronger opening force on the mandible, which can be of significance in the development and establishment of the dentofacial pattern and function.⁹

¹⁻⁶Department of Orthodontics and Dentofacial Orthopedics, School of Dental Sciences, Sharda University, Greater Noida, Uttar Pradesh, India

Corresponding Author: Rajat Chauhan, Department of Orthodontics and Dentofacial Orthopedics, School of Dental Sciences, Sharda University, Greater Noida, Uttar Pradesh, India, Phone: +91 9711762547, e-mail: rajat18chauhan@gmail.com

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Assessment of sagittal dimension has been considered by applying the ANB angle in most of the studies, but it is affected by various factors and can often be misleading. When using the ANB angle, all those factors should be considered; this makes the interpretation of this angle much more complex than previously thought.

We have additionally applied the β -angle for selection of subjects along with the ANB angle as this measurement does not depend on cranial landmarks or the functional occlusal plane.¹⁰

Thus, it may be considered that different skeletal patterns have different morphologies and shapes of the mandible, which might

be affected by the position of the hyoid bone and the pharyngeal airway depth. So, this study was conducted to relate the pharyngeal airway depth and hyoid bone position of different skeletal patterns in sagittal dimension.

MATERIALS AND METHODS

This study was performed on a total of 90 lateral cephalometric radiographs, which were randomly selected from the records of Department of Orthodontics. Subjects included in this study had natural dentition and no craniofacial anomalies, syndromes, clefting, or symptoms or signs of dysfunction of the masticatory system. Standardized lateral cephalometric radiographs were taken in habitual occlusion with subject's head oriented parallel to the Frankfort horizontal plane.

The selected radiographs were divided into three groups of 30 samples each based on the ANB angle and β angle into skeletal Class I, Class II, and Class III, respectively.

Class I: ANB angle, $0-4^\circ$ and β angle $27-34^\circ$

Class II: ANB angle $>4^\circ$ and β angle $<27^\circ$

Class III: ANB angle $<0^\circ$ and β angle $>34^\circ$

The inclusion criteria of the selected samples of the respective groups had a normodivergent growth pattern based on a Frankfort mandibular plane angle of $21-29^\circ$.

All radiographs were traced by the same researcher and 21 landmarks were recorded (Fig. 1 and Table 1), which were used to calculate 11 linear and 1 angular measurements. There were five linear measurements for the pharyngeal airway depth (Fig. 2 and Table 2), four linear measurements for the anterior–posterior hyoid bone position, two linear measurements for the vertical hyoid bone position, and one angular measurement for the angular hyoid bone position (Fig. 3 and Table 3).

Statistical Analysis

Descriptive statistics composed of calculation of means, standard deviations, minimum and maximum value, and coefficient of variance. ANOVA was used to analyze comparison in three groups. The intergroup comparison of the pharyngeal airway depth and the hyoid bone position was performed using *post hoc* Tukey's test. A value of $p < 0.05$ was considered statistically significant. All the data were analyzed by using SPSS version 21.

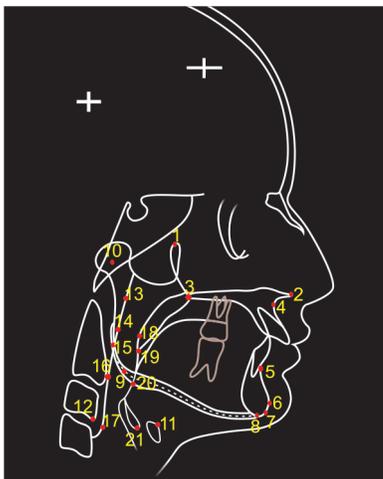


Fig. 1: Landmarks used in the study

Table 1: Landmarks used in the study

Landmark	Description
1 Ptm	A bilateral teardrop-shaped area of radiolucency
2 ANS	Anterior tip of the sharp bony maxilla at the lower margin of the anterior nasal opening
3 PNS	The posterior spine of the palatine bone
4 Point A	The point at the deepest midline concavity on the maxilla between the anterior nasal spine and prosthion
5 Point B	The point at the deepest midline concavity on the mandibular symphysis between infradentale and pogonion
6 Pog	The most anterior point of the bony chin in the median plane
7 Gn	The point located by taking the midpoint between the anterior and inferior points of the bony chin
8 Me	The lowest point on the symphyseal shadow of the mandible seen on the lateral cephalogram
9 Go	The point on the curvature of the angle of the mandible located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible
10 C	The apparent axis of the condyle
11 H	The anterosuperior point on the hyoid bone
12 C3	The most anteroinferior point of the third vertebra
13 SPU	The point on the posterior pharyngeal wall along the palatal plane
14 SPM	The point on the posterior pharyngeal wall where the distance to SAM is the shortest
15 SPML	The point on the posterior pharyngeal wall where the distance to P is the shortest
16 SPL	The point on the posterior pharyngeal wall where the distance to SAL is the shortest
17 SPLL	The point on the posterior pharyngeal wall where the distance to E is the shortest
18 SAM	The point on the soft palate where the postpalatal airway is narrowest
19 P	The tip of the soft palate
20 SAL	The point on the tongue along the mandibular lower border
21 E	Epiglottis

RESULTS

The pharyngeal airway depth was found to show no statistically significant difference between Class I and Class III malocclusions. The pharyngeal airway depth in Class II malocclusion was found to be statistically significantly smaller at D1 as compared to that of Class I and Class III malocclusion, whereas it remained the same at the rest of the locations measured, i.e., D2, D3, D4, and D5 (Table 4).

The anteroposterior hyoid bone position in the Class II malocclusion group showed statistically insignificant difference as compared to that of the Class I malocclusion group at all levels (i.e., H1, H2, H3, and H4). The Class III malocclusion group showed statistically significant difference in the anteroposterior hyoid bone position at all levels (i.e., H1, H2, H3, and H4) as compared to the Class II malocclusion group, whereas it showed statistically significant difference as compared to the Class I malocclusion group

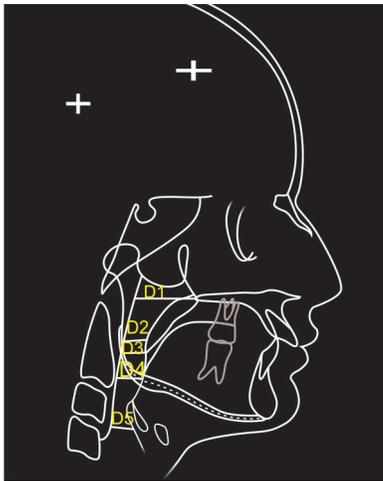


Fig. 2: Measurements of pharyngeal airway depth (in mm)

Table 2: Measurements of pharyngeal airway depth (in mm)

D1	Linear distance between the posterior spine of the palatine bone and point on the posterior pharyngeal wall along the palatal plane
D2	Linear distance between the posterior pharyngeal wall and the point on the soft palate where the postpalatal airway is narrowest
D3	Linear distance between the posterior pharyngeal wall and the tip of the soft palate where the distance is shortest
D4	Linear distance between the posterior pharyngeal wall and the point on the tongue along the mandibular lower border where the distance is shortest
D5	Linear distance between the posterior pharyngeal wall and Epiglottis where the distance is shortest

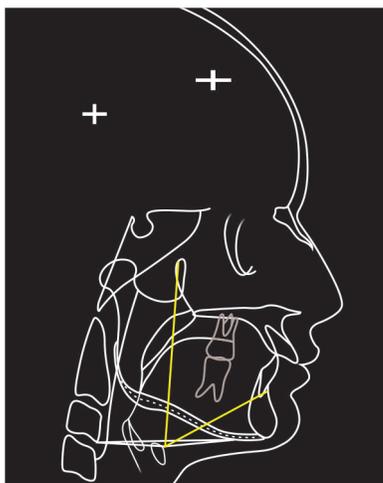


Fig. 3: Measurements of hyoid bone position (in mm)

at H1 and H3 remaining the same at the rest of the locations, i.e., H2, and H4 (Table 5).

There was no statistically significant difference in the vertical hyoid bone position in Class I, Class II, and Class III malocclusion groups (Table 6).

The angular inclination of the hyoid bone in the Class II malocclusion group showed statistically significant difference with Class I and Class III malocclusion groups but the Class III

Table 3: Measurements of hyoid bone position (in mm)

H1	Horizontal linear distance between the anterosuperior point on hyoid bone and Menton
H2	Horizontal linear distance between the anterosuperior point on the hyoid bone and most anteroinferior point of the third cervical vertebra
H3	Horizontal linear distance between the anterosuperior point on hyoid bone and Point B
H4	Horizontal linear distance between the anterosuperior point on the hyoid bone and epiglottis
H5	Vertical distance between the anterosuperior point on the hyoid bone and Ptm
H6	The vertical distance from anterosuperior point on the hyoid bone to the plane formed by most anteroinferior point of the third cervical vertebra and Menton
H7	The angle formed by epiglottis, anterosuperior point on the hyoid bone and Point B

malocclusion group showed no statistically significant difference when compared to the Class I malocclusion group (Table 7).

DISCUSSION

A normal nasal airway is dependent on sufficient anatomical dimensions of the airway and also on its relationship with the pharynx and its associated structures such as the tongue and hyoid bone. The position of the pharynx changes with the change in position of the hyoid bone and the tongue, whereas the mandibular position brings about variations in the hyoid bone and tongue. Thus, different skeletal patterns would lead to changes indirectly in the pharyngeal airway space. The present cephalometric study determines and compares the linear parameters of the pharyngeal airway depth in the Class I, II, and III malocclusion groups and the anteroposterior, vertical, and angular position of the hyoid bone in the Class I, II, and III malocclusion groups.

The pharyngeal airway depth was comparable in the Class I and Class III malocclusion groups except the Class II malocclusion group, which showed a narrower pharyngeal depth at the superiormost level measured at the posterior nasal spine from the posterior pharyngeal wall as compared to that in the Class I and Class III malocclusion groups but remained the same at the inferior part of the pharyngeal airway dimension. These findings were in agreement with a study done by Kerr, who reported a smaller nasopharyngeal airway area in Class II malocclusion than normal occlusion.¹² On the other hand, the results were in contrast to the study done by Zhe Zhong, et al., which found no significant difference in the superior part of the upper airway dimension at PNS and soft palate in Class I, Class II, and Class III malocclusion groups but the inferior part of the upper airway dimension (i.e., at the level of tip of the uvula, point of intersection of base of the tongue, and extension of line B-Go and the posteroinferior point on the base of the tongue) noted significant decrease from Class III to Class I to Class II malocclusion groups in the normodivergent facial pattern.

Alves et al. reported an increased pharyngeal airway depth in the Class III malocclusion group as compared to that of the Class I malocclusion group at the uvula in children (age 8–10 years), which is in contrast to the findings of our study as there was no significant difference in the pharyngeal airway depth between Class I and Class III malocclusion groups in our sample.^{13,14} The study conducted by Freitas et al. is also not in agreement with the

Table 4: Measurement of pharyngeal airway depth and results of statistical analysis of measurements for pharyngeal airway depth between three groups (*post hoc* Tukey's test)

Parameter	Group	Mean (mm)	SD (mm)	Minimum (mm)	Maximum (mm)	Cv	p value	Post hoc pairwise comparison by Tukey's test
D1	CI I	28.55	5.63	22	39	19.71	0.007, S	1 × 2–0.046
	CI II	25.98	1.85	23	30	7.1		1 × 3–0.796
	CI III	29.23	3.94	24	35	13.47		2 × 3–0.008
D2	CI I	10.32	0.97	8.5	12	9.39	0.735, NS	1 × 2–0.813
	CI II	9.97	3.39	4	13.5	34		1 × 3–0.992
	CI III	10.38	1.49	7	12	14.35		2 × 3–0.746
D3	CI I	11.18	1.48	8	13	13.23	0.901, NS	1 × 2–0.992
	CI II	11.08	3.21	5	15.5	28.97		1 × 3–0.960
	CI III	11.33	1.04	9.5	14	9.17		2 × 3–0.892
D4	CI I	12.37	1.65	8	14	13.33	0.260, NS	1 × 2–0.892
	CI II	12.08	3.50	5	16	28.97		1 × 3–0.486
	CI III	13.08	1.57	11	17	12		2 × 3–0.249
D5	CI I	17.90	3.66	14	26	20.44	0.313, NS	1 × 2–0.508
	CI II	16.75	5.68	2	27	33.9		1 × 3–0.933
	CI III	18.27	1.49	16	22	8.15		2 × 3–0.310

Table 5: Anteroposterior measurement of hyoid bone position and results of statistical analysis of measurements for hyoid bone position between three groups (*post hoc* Tukey's test)

Parameter	Group	Mean (mm)	SD	Min (mm)	Max (mm)	Cv	p value	Post hoc Tukey's test
H1	CI I	39.67	3.15	35	46	7.94	<0.001, S	1 × 2–0.213
	CI II	38.22	3.19	33	46	8.34		1 × 3–<0.001
	CI III	47.57	3.59	42	53	7.54		2 × 3–<0.001
H2	CI I	37.95	4.06	32	47	10.69	0.033, S	1 × 2–0.094
	CI II	35.18	6.51	28	48	18.50		1 × 3–0.933
	CI III	38.42	4.33	29	44	11.27		2 × 3–0.041
H3	CI I	51.00	4.89	44	62	9.58	<0.001, S	1 × 2–0.435
	CI II	49.62	2.77	45.5	54.5	5.58		1 × 3–<0.001
	CI III	57.27	4.98	51	64	8.69		2 × 3–<0.001
H4	CI I	14.82	4.31	10	26	29.08	0.049, S	1 × 2–0.216
	CI II	13.28	2.03	11	17	15.28		1 × 3–0.734
	CI III	15.50	3.81	10	23	24.58		2 × 3–0.044

Table 6: Vertical measurement of the hyoid bone position and results of statistical analysis of measurements for the hyoid bone position between the three groups (*post hoc* Tukey's test)

Parameter	Group	Mean (mm)	SD	Min (mm)	Max (mm)	Cv	p value	Post hoc Tukey's test
H5	CI I	87.30	11.64	78	112	13.33	0.041, S	1 × 2–0.996
	CI II	87.12	6.13	82	98	7.03		1 × 3–0.079
	CI III	92.25	7.61	78	108	8.24		2 × 3–0.066
H6	CI I	4.90	3.58	1	14	73.06	0.840, NS	1 × 2–0.991
	CI II	4.82	1.65	2	8	34.23		1 × 3–0.891
	CI III	4.53	1.87	1	7	41.28		2 × 3–0.901

present study as they found insignificant differences in the upper airway dimension among Class I and Class II malocclusion subjects with a normodivergent growth pattern.¹⁵

Ravinarayana Reddy et al. conducted a study in Class I, Class II, and Class III malocclusion groups with different skeletal patterns and reported that in Class III malocclusion with a normal skeletal pattern, upper and lower pharyngeal airway depths were significantly more than that in the Class I malocclusion group with a normal skeletal pattern, which was not in agreement with our study. Reddy et al. also concluded that in the Class I and Class II

malocclusion groups with a normal skeletal pattern, there was no statistically significant difference in the upper and lower pharyngeal airway depths and there was statistically significant difference in Class II and Class III malocclusion groups with a normal skeletal pattern in the lower pharyngeal airway depth, which was similar to our result.¹⁶

In the present study, the anteroposterior position of the hyoid bone was comparable in the Class I and Class II malocclusion groups. The anteroposterior position of the hyoid bone in the Class III malocclusion group was found to have the same distance

Table 7: Angular inclination measurement of the hyoid bone position and results of statistical analysis of measurements for hyoid bone position between the three groups (*post hoc* Tukey's test)

Parameter	Group	Mean (mm)	SD	Min (mm)	Max (mm)	Cv	p value	Post hoc Tukey's test
H7	CI I	155.20	8.05	143	172	5.18	0.002, S	1 × 2–0.016
	CI II	149.30	5.56	143	163	3.73		1 × 3–0.792
	CI III	156.57	10.09	130	165	6.44		2 × 3–0.002

from the third cervical vertebra and epiglottis as that in the Class I malocclusion group, whereas distance was increased when measured from Point B and menton.

The anteroposterior position of the hyoid bone was found to be anterior in the Class III malocclusion group than that in the Class II malocclusion group, showing increased distances between the third cervical vertebra and epiglottis posteriorly as well as between menton and Point B anteriorly.

The vertical position of the hyoid bone remained unchanged irrespective of the malocclusion groups. The angular position of the hyoid bone was comparable in the Class I and Class III malocclusion groups. The angular position of the hyoid bone in Class II malocclusion group was found to be at lesser angulation than the Class I and Class III malocclusion groups.

This result was similar to a study by Adamidis and Spyropoulos who reported a significant difference in the anteroposterior position of the hyoid bone between Class I and Class III malocclusions as the hyoid bone was laid more anteriorly in Class III than in Class I, possibly due to the muscular attachment to the hyoid bone and the mandible moving the hyoid forward in the sagittal plane. They also concluded that the vertical position remained the same in Class I and Class III malocclusions, which was similar to our study.¹⁷

Kuroda et al. conducted a study to determine the relationship between the hyoid bone, skull, and mandible by using lateral cephalograms. They concluded that in Class II samples the hyoid bone was located backward and in the Class III samples the hyoid bone was located forward in comparison with the control group. In our study, the hyoid bone was located at the same position as in Classes I, II, and III malocclusion groups except that the distance was increased when measured from Point B and menton to hyoidale in the Class III malocclusion group.¹⁸

Chauhan et al. conducted a study to compare the pharyngeal airway dimension, tongue, and hyoid bone position in Class I and Class II Division 1 and reported that there was no statistically significant difference in the pharyngeal airway anterior–posterior dimension and also in the position and relationship of the hyoid bone and tongue between Class I and Class II Division I, which was similar to our result.⁶

Our study lacks in the exclusion of samples with different types of growth pattern as we have included only normodivergent subjects but it combines the measurement of pharyngeal airway depth and hyoid bone positions in different groups of anteroposterior dysplasia having a normodivergent growth pattern, which provides an assessment tool for future comparative studies.

CONCLUSION

The pharyngeal airway depth and angular position of hyoid bone were comparable in Class I and Class III malocclusion groups. The pharyngeal airway depth in the Class II malocclusion group was also found to be the same as that in the Class I and Class III

malocclusion groups except at the superiormost level measured at the posterior nasal spine from the posterior pharyngeal wall where it was narrower in the Class II malocclusion group.

The angular position of the hyoid bone in the Class II malocclusion group was found to be at lesser angulation than the Class I and Class III malocclusion groups.

The vertical position of the hyoid bone remained unchanged irrespective of the malocclusion groups. The anteroposterior position of the hyoid bone was comparable in Class I and Class II malocclusion groups.

The anteroposterior position of the hyoid bone in the Class III malocclusion group was found to be the same as that in the Class I malocclusion group when measured from the third cervical vertebra and epiglottis posteriorly whereas it was found to be increased in the Class III malocclusion group compared to that in the Class I malocclusion group when measured from hyoidale to Point B and menton.

The anteroposterior position of the hyoid bone was found to be anterior in the Class III malocclusion group compared to that in the Class II malocclusion group, showing increased distances between the third cervical vertebra and epiglottis posteriorly as well as between menton and Point B anteriorly.

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