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Evaluation of Pharyngeal Airway Space and Hyoid Bone Position in Different Skeletal Patterns: A Radiographic Study

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Introduction

The postural relationships of the head, jaws, and tongue, which are established shortly after birth with the opening of the airway, change throughout life to satisfy physiological needs and to keep the airway open(1). The intimate anatomical and functional proximity of craniofacial and upper respiratory structures influences the facial and dental growth. A healthy respiratory function is essential for the harmonious growth and development of the maxillofacial structures(2).

The upper airway is a crucial structure that supports breathing, one of the most important functions of the human body, and there has been evidence of a close relationship between the pharyngeal structures and both dentofacial and craniofacial features(3).

The past few decades have noticed a renewed interest in the interaction between form and function in craniofacial region. The growth and function of the nasal cavities, the nasopharynx, and the oropharynx are closely associated with the normal growth of skull(4). The pharynx and dentofacial structures have a strong association, and mutual interaction is expected between pharyngeal structures and dentofacial pattern. As a result, there is a difference in size and position of soft and hard tissue components of the upper airway in different skeletal patterns.

A significant relationship exists between airway space and facial morphology, also airway space may be affected by conditions such as functional anterior shifting, head posture, sagittal skeletal relation, and maxillary protraction(5).

Skeletal features such as retrognathic maxilla and mandible and vertical maxillary excess in hyperdivergent patients may lead to narrower anteroposterior dimensions of the airway. On the other hand, the oropharyngeal airway has been claimed to affect the growth of craniofacial structures(6)(7)(8).

Linder Aronson postulated that mouth breathers tip their heads backward in an attempt to increase their airway(9).

The tongue posture and function are determined by the hyoid bone's position in relation to the cranial base and the jaw, and it plays a vital role in preserving the airway and a natural upright head position. The location of hyoid bone is regulated by the tongue's position, impacting the pharyngeal airway space[(10)].

Craniofacial anomalies, including mandibular or maxillary retrognathism, short mandibular body, and backward and downward rotation of the mandible, may lead to reduction of the pharyngeal airway passage[(11)].

The hyoid bone's position on the genial tubercle level may improve the muscle's ability to move the tongue forward and retain the airway. The geniohyoid muscle is mechanically disadvantaged by its angulation due to the inferior position of the hyoid bone with lower tongue posture. Because of the requirement to raise the tongue and provide a stronger opening force on the mandible, this may increase the mandibular load, which can be important in the development and establishment of the dentofacial pattern and function[(12)].

Cheng et al[(13)] concluded that the location of the maxilla (SNA) is not significantly correlated with the size of the pharyngeal airway space. The more protruding the mandible (SNB) is, the more anterior the hyoid bone and the longer the pharyngeal airway space will be. Patients with a Class III skeletal pattern had a significantly larger pharyngeal airway space, whereas those with a Class II skeletal pattern had the smallest pharyngeal airway space.

Thus, different skeletal patterns may have distinct mandible morphologies and forms, which may be influenced by the position of the hyoid bone and the pharyngeal airway space. So, this study was to evaluatethe relation between pharyngeal airway space and hyoid bone position in different skeletal patterns.

Material and Methods

This study was performed on a total of 120 lateral cephalometric radiographs, which were divided into three groups according to skeletal patterns: Class I, Class II, Class III and were selected from the records of Department of Orthodontics and Dentofacial Orthopedics. The selected radiographs were divided into three groups of 40 samples each based on the ANB angle and β angle into skeletal Class I, Class II, and Class III, respectively. (Figure 1)

According to Steiner and Baik:

Class I: ANB angle, 0–4° and β angle 27–34°

Class II: ANB angle >4° and β angle <27°

Class III: ANB angle <0° and β angle >34°

In habitual occlusion, standardised lateral cephalometric radiographs were collected with the subject's head oriented parallel to the Frankfort horizontal plane.Exclusion criteria were subjects with no craniofacial anomalies, no cleft lip and cleft palate, no syndromes, no facial deformity or no signs and symptoms of dysfunction of the masticatory system.

All radiographs were traced and landmarkswere recorded which were used to measure 10 linear and 1 angular measurements. There were four linear measurements for the pharyngeal airway space, 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. (Table 02)

Statistical Analysis

One-way ANOVA ‘F’ test was applied to compare the mean in different skeletal patterns. Pairwise multiple comparison between all groups was assessed using Post hoc Tukey HSD test. A p-value less than 0.05 were considered as significant.

Results

One-way ANOVA analysis for BP measurement of pharyngeal airway space between the three groups shows that Class I has thehighest value of 5.68mm and Class II has the lowest value of 3.77mm. This difference is statistically significant with a P value of <0.05 (Table 3).Post hoc Tukey test comparing Class I and Class II shows statistically significant with a P value of 0.007. Comparing Class II and Class III shows statistically significant with a P value of 0.014 (Table 04). For LP measurement of pharyngeal airway spacebetween the three groups shows that Class III has the highest value of 13.72mm and Class II has the lowest value of 10.95mm. This difference is statistically significant with a P value of < 0.05 (Table 3). Post hoc Tukey test comparing Class II and Class III shows statistically significant with a P value of 0.00 .Comparing Class I and Class II shows statistically significant with a P value of 0.02. (Table 04). There was no significant correlation of SP and C2P among the skeletal patterns.

The anteroposterior hyoid bone position in Class III (H2=30.68mm, H3=46.86mm) showed statistically greater value and Class II (H2=26.95mm, H3=39.54mm) showed statistically lesser value at H2 and H3 level. At H1 & H4 level, Class III was greater but was not significant. (Table 3)Post hoc Tukey test comparing Class II and Class III at H2 & H3 level shows statistically significant with a P value of 0.00. Comparing Class I and Class II at H2 level shows statistically significant with a P value of 0.01. Comparing Class I and Class III at H3 level shows statistically significant with a P value of 0.003.(Table 05). There was no significant correlation of H1 and H4 among the skeletal patterns.

The vertical hyoid bone position at H5 level in Class III (73.90mm) showed statistically greater value and Class I (64.72mm) showed statistically lesser value. (Table 03) Post hoc Tukey test comparing Class I and Class III at H5 level shows statistically significant with a P value of 0.013. (Table 06) At H6 level, Class III (3.77mm) was shorter than Class I (4.04mm) and Class II (4.70mm) but was not significant.

Angular position of hyoid bone (H7) was significantly greater in Class III (159.9°) &shorter in Class II (144.5°). (Table 03) Post hoc Tukey test comparing Class II and Class III at H7 level shows statistically significant with a P value of 0.004. Comparing Class I and Class II at H7 level shows statistically significant with a P value of 0.016. (Table 07)

Table 01: Landmarks used in the study

	Landmarks	**Description**
1	Ptm	A bilateral teardrop-shaped area of radiolucency,the anterior shadow of which represents the posterior surfaces of the tuberosities of the maxilla.
2	Point B	The point at the deepest midline concavity on the mandibular symphysis between infradentale and pogonion
3	Me	The lowest point on the symphyseal shadow of the mandible seen on the lateral cephalogram
4	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
5	H	The anterosuperior point on the hyoid bone
6	C2	The anteroinferior point on the second cervical vertebra
7	C3	The anteroinferior point on the third cervical vertebra
8	C4	The anteroinferior point on the fourth cervical vertebra
9	E	Epiglottis

Table 02: Measurements of pharyngeal airway space and hyoid bone[13][22]

	Linear measurements for the pharyngeal airway space:	
1	**SP**	Shortest distance from soft palate to the pharyngeal wall
2	**BP**	B-Go line intersecting the pharyngeal airway
3	**C2P**	C2 (inferoanterior point on the second cervical vertebra) of the horizontal line to the tongue intersecting the pharyngeal airway
4	**LP**	Laryngopharyngeal airway (horizontal plane through C4, intersecting the pharyngeal wall)
	Linear measurements for the anterior–posterior hyoid bone position:	
5	**H1**	Horizontal linear distance between the anterosuperior point on hyoid bone and Menton
6	**H2**	Horizontal linear distance between the anterosuperior point on the hyoid bone and most anteroinferior point of the third cervical verterbra
7	**H3**	Horizontal linear distance between the anterosuperior point on hyoid bone and Point B
8	**H4**	Horizontal linear distance between the anterosuperior point on the hyoid bone and epiglottis
	Linear measurements for the vertical hyoid bone position:	
9	**H5**	Vertical distance between the anterosuperior point on the hyoid bone and Ptm
10	**H6**	The vertical distance from anterosuperior point on the hyoid bone to the plane formed by most anteroinferior point of the third cervical verterbra and Menton
	Angular measurement for the hyoid bone position:	
11	**H7**	The angle formed by epiglottis, anterosuperior point on the hyoid bone and Point B

Table 3: Comparison of Mean & SD for the pharyngeal airway space and hyoid bone position between Classes I, II & III using one way ANOVA test.

Parameters	**Class I**		**Class II**		**Class III**		**F**	**P Value**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**		
SP	7.68	1.61	7.27	1.42	8.50	2.24	2.671	.077
BP	5.68	1.96	3.77	2.67	5.54	1.14	6.091	.004**
C2P	10.86	2.45	8.59	2.30	9.95	4.92	2.428	.096
LP	12.81	2.36	10.95	0.89	13.72	2.99	8.584	.001**
H1	33.81	5.15	33.50	3.73	36.63	5.10	2.955	.059
H2	29.81	3.08	26.95	1.64	30.68	2.51	13.562	.000***
H3	41.09	5.20	39.54	6.58	46.86	4.91	10.373	.000***
H4	12.86	4.59	12.95	2.90	13.36	2.73	0.127	.881
H5	64.72	15.89	69.09	6.38	73.90	5.64	4.279	.018*
H6	4.04	2.19	4.70	2.86	3.77	2.89	.708	.496
H7	157.8	13.65	144.5	20.35	159.9	10.54	6.420	.003**

p＜0.05,*: Statistically significant; **: Very significant; ***: Highly significant

Table 4: Intergroup comparison for the pharyngeal airway space between three groups (*post hoc* Tukey's test)

Parameter	(I)Group	(J)Group	Mean diff.	Std. error	Sig.
SP	Class I	Class II	.40909	.54074	.731
		Class III	-.81818	.54074	.292
	Class II	Class III	-1.22727	.54074	.068
BP	Class I	Class II	1.90909*	.61027	.007*
		Class III	.13636	.61027	.973
	Class II	Class III	-1.77273*	.61027	.014*
C2P	Class I	Class II	2.27273	1.03814	.081
		Class III	.90909	1.03814	.658
	Class II	Class III	-1.36364	1.03814	.393
LP	Class I	Class II	1.86364*	.68227	.022*
		Class III	-.90909	.68227	.383
	Class II	Class III	-2.77273*	.68227	.000*

*. The mean difference is significant at the 0.05 level.

Table 5: Intergroup comparisonfor the anteroposterior hyoid bone position between three groups (*post hoc* Tukey's test)

Parameter	(I)Group	(J)Group	Mean diff.	Std. error	Sig.
H1	Class I	Class II	.31818	1.42025	.973
		Class III	-2.81818	1.42025	.124
	Class II	Class III	-3.13636	1.42025	.078
H2	Class I	Class II	2.86364*	.74922	.001*
		Class III	-.86364	.74922	.486
	Class II	Class III	-3.72727	.74922	.000*
H3	Class I	Class II	1.54545	1.69366	.634
		Class III	-5.77273	1.69366	.003*
	Class II	Class III	-7.31818*	1.69366	.000*
H4	Class I	Class II	-.09091*	1.05863	.996
		Class III	-.50000	1.05863	.885
	Class II	Class III	-.40909	1.05863	.921

*. The mean difference is significant at the 0.05 level.

Table 6: Intergroup comparisonfor the vertical hyoid bone position between three groups (*post hoc* Tukey's test)

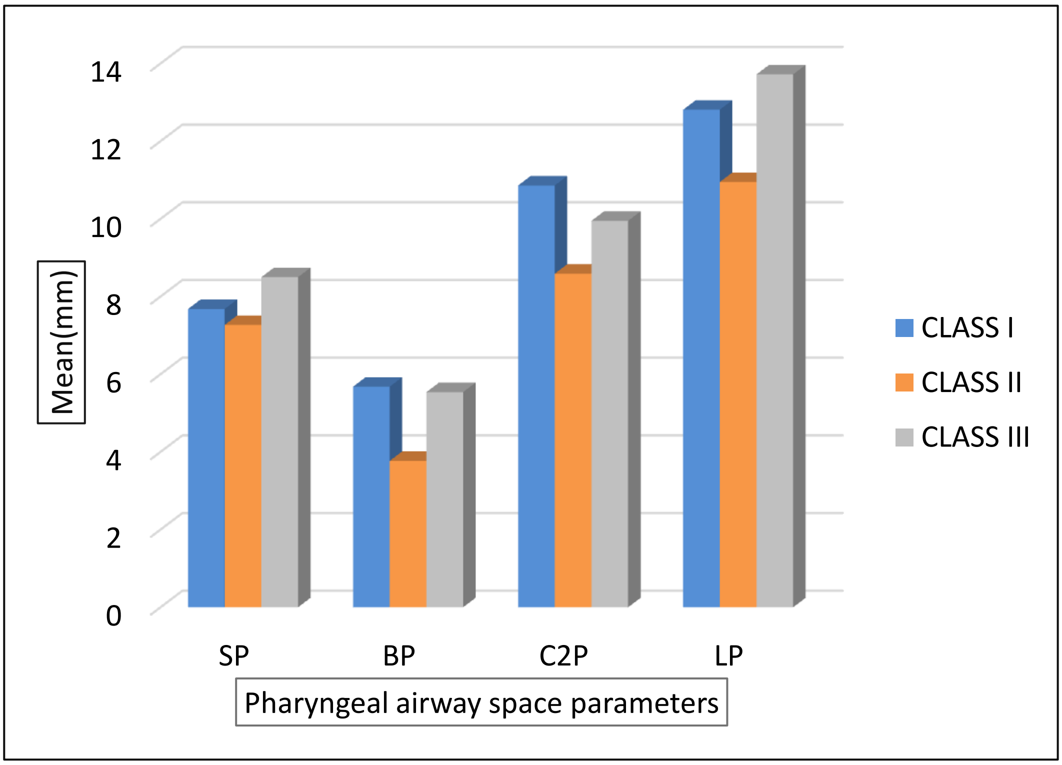
Parameter	(I)Group	(J)Group	Mean diff.	Std. error	Sig.
H5	Class I	Class II	-4.36364	3.13984	.352
		Class III	-9.18182	3.13984	.013*
	Class II	Class III	-4.81818*	3.13984	.282
H6	Class I	Class II	-.65909*	.80506	.693
		Class III	.27273	.80506	.939
	Class II	Class III	.93182	.80506	.483

*. The mean difference is significant at the 0.05 level.

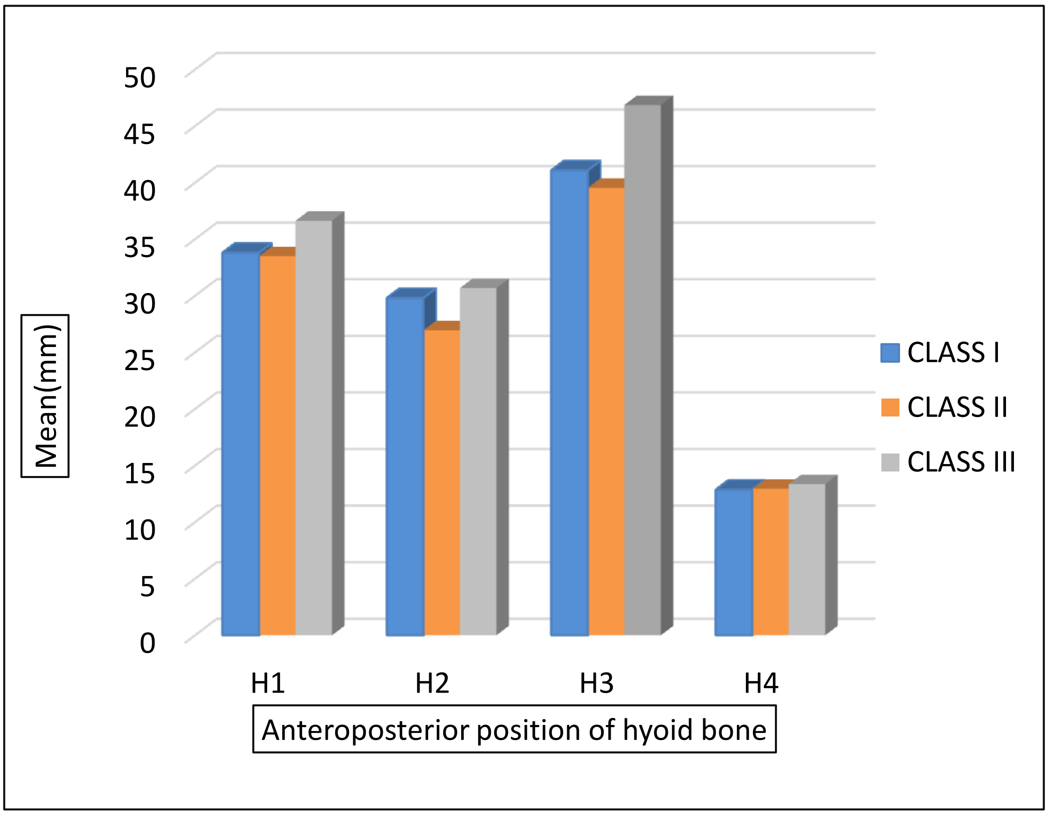
Table 7: Intergroup comparisonfor the angular hyoid bone position between three groups (*post hoc* Tukey's test)

Parameter	(I)Group	(J)Group	Mean diff.	Std. error	Sig.
H7	Class I	Class II	13.22727	4.64521	.016*
		Class III	-2.13636	4.64521	.890
	Class II	Class III	-15.36364*	4.64521	.004*

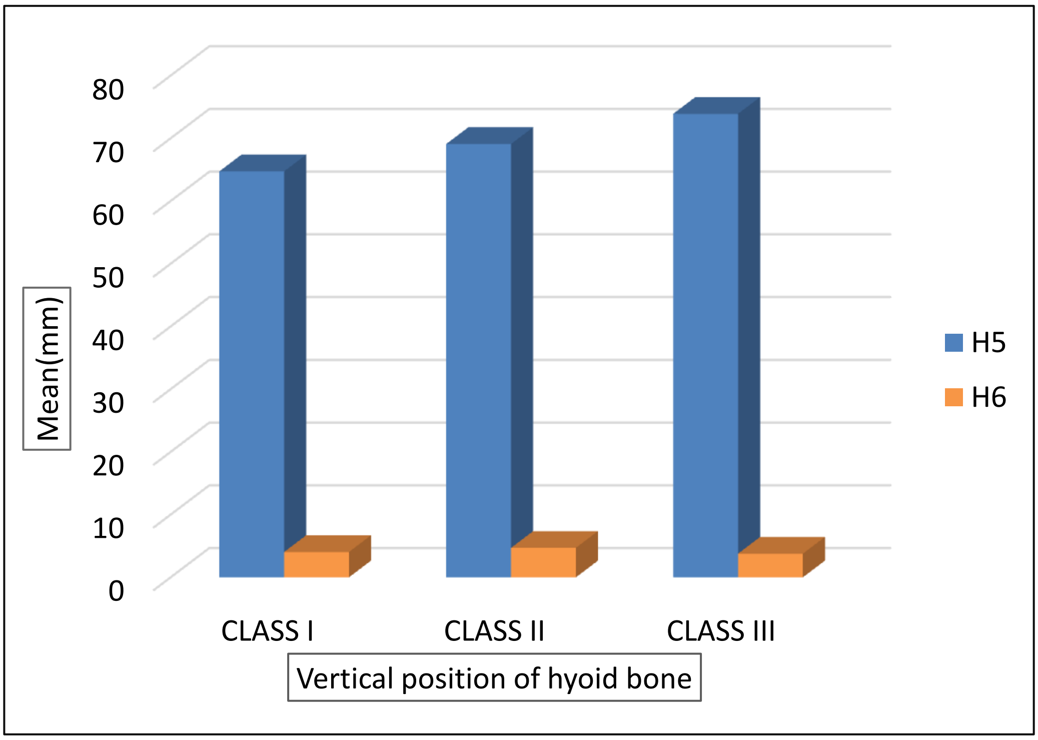
*. The mean difference is significant at the 0.05 level.



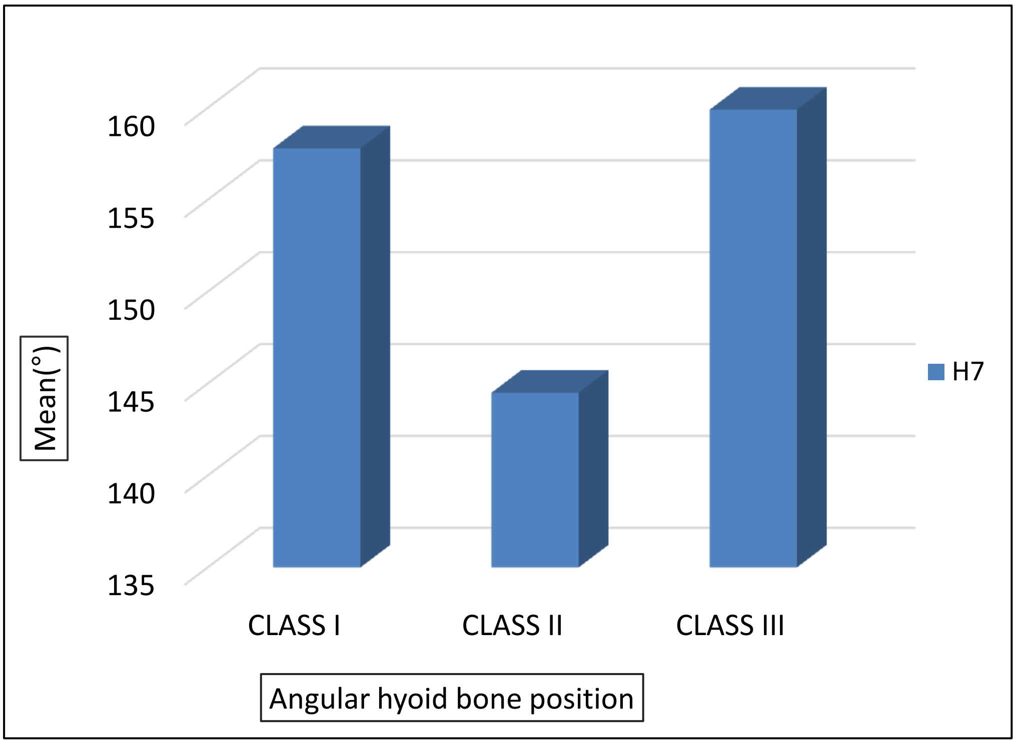
Graph no. 01: Mean measurements of pharyngeal airway space



Graph no. 02: Mean measurements of anteroposterior hyoid bone position



Graph no. 03: Mean measurements of vertical hyoid bone position



Graph no. 04: Mean angular hyoid bone position

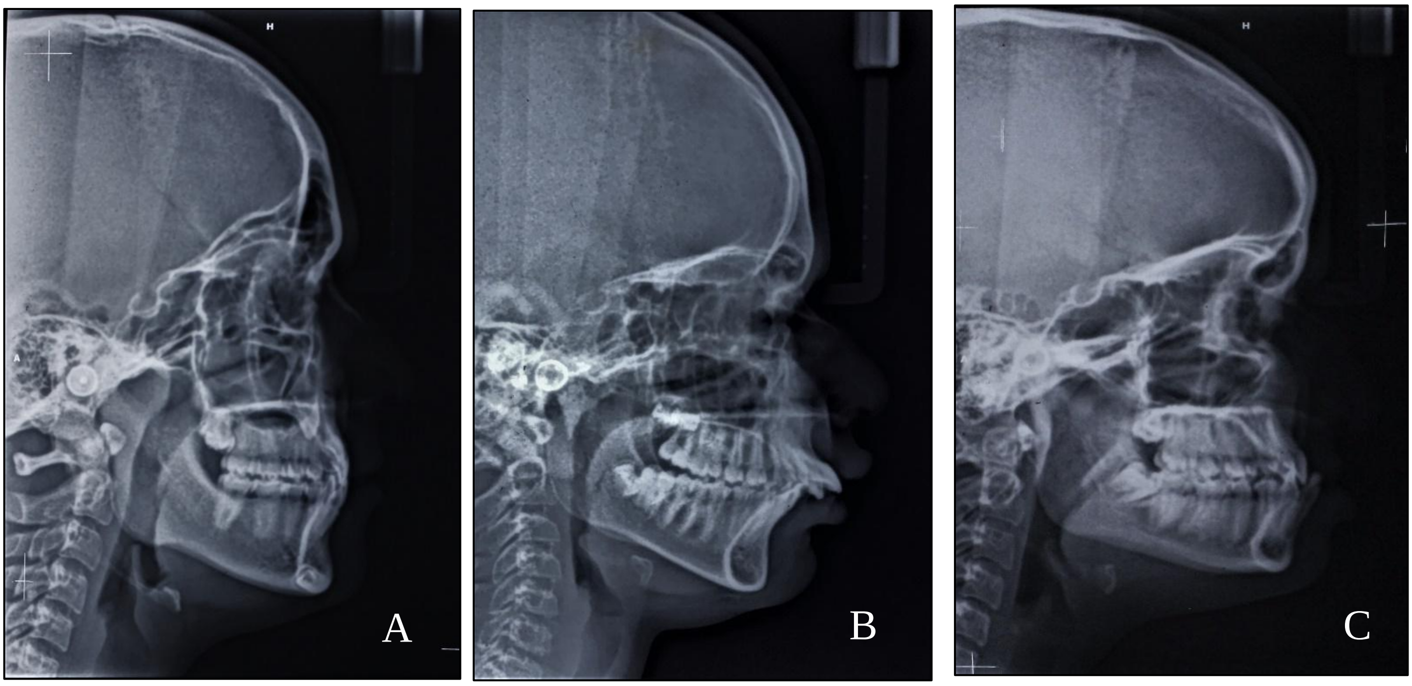


Figure 01. Skeletal patterns: (A) Class I, (B) Class II, (C) Class III

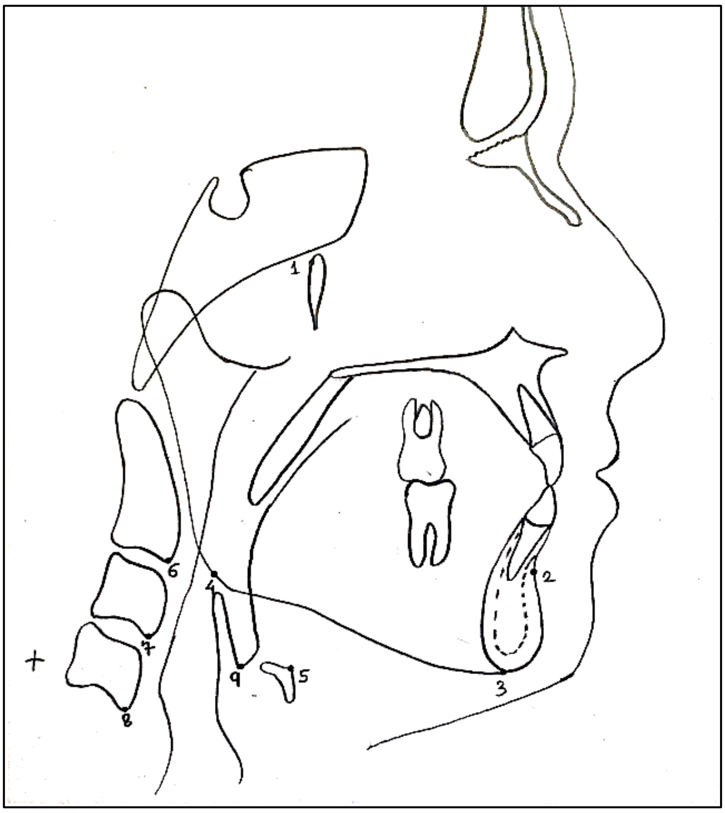


Figure 02. Landmarks used in the study.

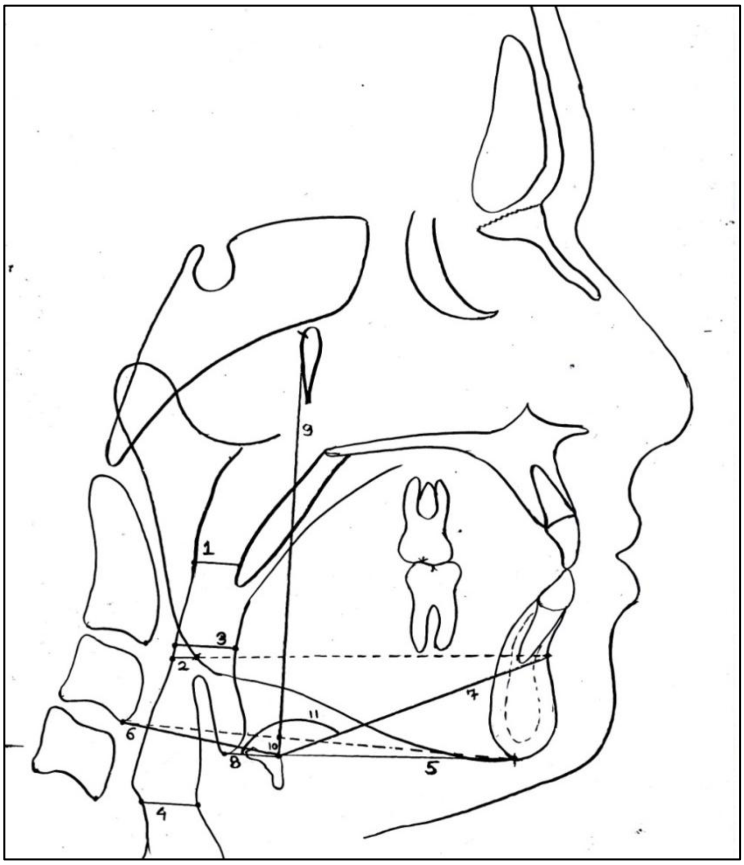


Figure 03: Measurements of pharyngeal airway space and hyoid bone (1=SP, 2=BP, 3=C2P, 4=LP, 5=H1, 6=H2, 7=H3, 8=H4, 9=H5, 10=H6, 11=H7)

Discussion

The anatomical dimensions of the nasal airway, as well as its relationship with the pharynx and its related tissues like the tongue and hyoid bone, are all necessary for a proper nasal airway. The pharynx changes position in response to changes in the hyoid bone and tongue, whereas the hyoid bone and tongue change position in response to changes in the mandibular position. As a result, alterations in skeletal patterns would have an indirect effect on the pharyngeal airway space. The present radiographic study evaluates the pharyngeal airway space as well as anteroposterior, vertical and angular position of hyoid bone in Class I, Class II & Class III skeletal patterns.

Alves et al[14] reported that SP was significantly longer in Class I than in Class II. In present study, SP was insignificantly longer in Class I than in Class II.Cheng J H et al[13] reported, SP was slightly shorter in Class II than in Class I, and there was no significant difference between SP in Class I and Class II which is similar in the present study. However, SP was significantly longer in Class III than in Class I and Class II in Cheng et al study but present study showed insignificance.

The oropharynx lies between the muscles of the soft palate and epiglottis, which corresponds to the third and fourth cervical vertebrae. While the oropharynx is anteriorly connected to the oral cavity by the isthmus of the fauces and inferiorly connected to the laryngopharynx, its top portion is connected to the nasopharynx by the nasopharyngeal isthmus. The tongue is located at the floor of the mouth on the medial side of the mandible, and it protrudes into the oral cavity. It is primarily composed of smooth muscles that can be divided into intrinsic and extrinsic muscles. The origin and attachment points of muscular bundles of the intrinsic muscles are within the tongue; the extrinsic muscles are attached to the mandible, hyoid bone, and styloid process of the temporal bone, and they are connected to the soft palate. The tongue root is located at the posterior edge of the tongue, and connected to the hyoid bone and mandible by the hyoglossus and genioglossus. It is connected to the soft palate and pharynx by the glossopalatine arch and superior pharyngeal constrictor muscle, respectively[13],[15],[16]. Therefore, the tongue plays an important role in maintaining the oropharyngeal airway space. In our study, there were no significant differences in the SP & C2P in all three skeletal patterns.

Kerr[3] reported a smaller nasopharyngeal airway area in Class II malocclusion than normal occlusion. These findings were in agreement with the present study but was insignificant. Opdebeeck et al.[17] reported that the pharyngeal airway space of individuals with long faces are smaller than that of individuals with short faces; further, patients with a Class II skeletal pattern often have long faces, whereas those with a Class III often have short faces. Alves et al[14]reported that BP was not significantly differentbetween Class I and Class II. Our study result was contrast tothat of Alves et al[14]. There was significant difference between Class I and Class II. We found that BP was significantly longer in Class III than in Class II, which is consistent with the findings of Cheng et al[13] & Opdebeeck et al[17].

The laryngopharynx is posteriorly located in the throat, below the epiglottis, and it connects the throat to the oesophagus. The superior portion of the laryngopharynx meets the upper boundary of the epiglottic cartilage, whereas the bottom portion meets the lower boundary of the cricoid cartilage, which is anteriorly located around the fourth to sixth cervical vertebrae[13]. In our study LP showed significantly longer in Class III when compared with Class II and significantly longer in Class I when compared with Class II. This means Class II skeletal pattern show narrow LP space compared to Class I & III. This result is consistent with Cheng et al in which male with a Class III skeletal pattern showed a significantly larger LP[13].

Yamaoka et al[18] found that the tongue root showed a more posterior position in patients with a Class II skeletal pattern than in those with Class III.

Battagel et al[19] found that obstructive sleep apnea (OSA) patients have significant Class II occlusion, and their hyoid bone is located at a more posterior position; therefore, their upper airway is narrower. In our study also class II patterns showed hyoid bone more posteriorly positioned and pharyngeal airway space is less. So this finding will be a diagnostic tool in OSA patients.

Adamidis et al[20] compared the position of the hyoid bone between patients with Class I and Class III skeletal patterns and reported that the hyoid bone in Class III showed a more anterior position. Mortazavi et al[21]reported that hyoid bone is positioned more superior and posterior in females than males and its location differs among different skeletal Class. Our study also showedanterior position of hyoid bone in Class III skeletal pattern at H2 & H3 level. (Table 02)

Chauhan et al[22]reported that the vertical position of the hyoid bone remained unchanged irrespective of the malocclusion groups. In this present study, Class III showed greater at H5 level (i.e. Vertical distance between the anterosuperior point on the hyoid bone and Ptm) when compared to Class I. Chauhan et al[22] reported that 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. Our study also reported lesser angulation of hyoid bone position in Class II when compared to Class I & Class III.

The data collected for the study is limited to the convenient of researchers, results would be better if the data has been collected from a wide group of patients. In our study, the cephalomertric linear and angular measurements were traced and measured manually which is the limitation of the study.

Future scope of the study

- In future studies, by using digital cephalometric softwares like Dolphin could give better accuracy in linear and angular measurements of pharyngeal airway space.
- Cone Bean Computed Tomography (CBCT) could provide three-dimensional evaluation of pharyngeal airway volumes which will give accurate and reliable results.

Conclusions

1. Patients with class II skeletal pattern had significantly smallest pharyngeal airway space at BPand LP whereas patients with Class III skeletal pattern had significantly larger pharyngeal airway space at BPand LP.
2. Patients with Class III skeletal pattern had significantly anterior position of hyoid bone at H2 and H3 level and Class II skeletal pattern had significantly posterior position of hyoid bone at H2 level.
3. Hence, the more protruding the mandible is, the more anterior the hyoid bone is positioned and greater the pharyngeal airway space.
4. Patients with Class III skeletal pattern had significantly greater hyoid bone angulation with respect to epiglottis and point B and lesser hyoid bone angulation with respect to epiglottis and point B in Class II skeletal pattern.

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