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Comparison of Upper and Lower Pharyngeal Airway Dimension And Hyoid Bone Position in Subjects with Normodivergent and Hyperdivergent Facial Patterns in Class I and Class II Malocclusions –A Cephalometric Study

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Abstract:
Introduction: *The upper and lower pharyngeal airways play an eminent role in the normal growth and development of craniofacial structures. The hyoid bone and its related musculature are also implicated in maintenance of the airway patency. Thus, present study is designed to compare the upper and lower pharyngeal airway dimension and hyoid bone position in subjects with normodivergent and hyperdivergent facial patterns in Class I and Class II malocclusions.*
Materials and Methods: *The study was conducted on lateral cephalometric radiographs of 80 subjects. The subjects were divided into 4 groups, 20 subjects in each group, based on normodivergent and hyperdivergent facial patterns. Group 1: Skeletal Class I jaw relationship and normal growth pattern; Group 2: Skeletal Class I jaw relationship and vertical growth pattern, Group 3: Skeletal Class II jaw relationship and normal growth pattern, Group 4: Skeletal Class II jaw relationship and vertical growth pattern. The lateral cephalograms were taken in a natural head position. The upper and lower pharyngeal airway dimension was measured according to method described by McNamara and the hyoid position was measured according to Ashok Kumar Jena and RituDuggal.*
Results:*A highly significant intergroup difference in the upper pharyngeal width was found between Groups 1 and 2, Groups 1 and 4, Groups 2 and 3, Groups 3 and 4. No significant intergroup differences were found for the lower pharyngeal airway. Anteroposterior position of the hyoid bone in subjects from skeletal Class I malocclusion was significantly forward as compared to the subjects from skeletal Class II malocclusion.*
Conclusion:*The upper pharyngeal airway passage in subjects with vertical growth pattern is narrow as compared to the average growth pattern. Also, the position of hyoid bone is more posterior in Class II vertical grower as compare to Class I normal growers.*
Keywords:*Pharyngeal space, Hyoid bone, Cephalogram.*

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I. Introduction

Upper and lower pharyngeal airway is an important factor for the normal growth and development of craniofacial structures.Nasorespiratory function and its relation to craniofacial growth are of great interest today not only for an orthodontist but for the paediatrician, otorhinolaryngologist, allergist, speech physiologist and other members of health care community as well.[1]

Pharyngeal space size is primarily determined by relative growth and size of the soft tissue surrounding the dentofacial skeleton. Craniofacial malformations including mandibular and maxillary retrognathism, short mandibular body and backwards and downwards rotation of mandible may lead to reduction of pharyngeal airway passages.[2,3]

Relationship between pharyngeal structures and dentofacial patterns has been intensely researched[4]. Mergen and Kerr et al[5,6] associated mouth breathing and Class II malocclusions and Tourne and McNamara et al[1,4] reported association of vertical growth pattern with obstruction of upper and lower pharyngeal airway concurrently with mouth breathing.

According to Battagelet al[7] Class II malocclusion are consequences of backward positioning of tongue, disturbing the cervical region.Thus, in Class II malocclusion the respiratory function is impeded in the region of pharynx and there is a faulty deglutition and mouth breathing.

Opdebeeck and associates[8] compared the position of the hyoid bone in subjects with short face and long face syndrome and noted the movement of hyoid bone in harmony with the movement of the mandible, tongue, pharynx, and cervical spine. Thus, the position of the hyoid bone and the tongue has considerable implication on pharyngeal airway dimensions.

The patients with Class II malocclusions and vertical growth patterns might have narrower airway passages than patients with normal occlusions and growth pattern, or Class I malocclusion. Also, the position of the hyoid bone and the tongue are changed, with consequent narrowing of the pharyngeal airway space. Therefore, the positions of the hyoid bone, tongue and the facial types can be considered as indicators of patency of pharyngeal airway passage.[9]In the past only few studies have been done for the comparison of pharyngeal airways and hyoid bone position. Therefore, the present study is designed to compare the upper and lower pharyngeal airway dimension and hyoid bone position in subjects with normodivergent and hyperdivergent facial patterns in Class I and Class II malocclusions.

II. Material and Methods

SOURCE OF DATA:

The data was obtained from lateral cephalograms of subjects with Class I and Class II malocclusion with normodivergent and hyperdivergent facial patterns in the Department of Orthodontics and DentofacialOrthopaedics, Himachal Institute of Dental Sciences, Paonta Sahib, Himachal Pradesh, India.

METHOD OF COLLECTION OF DATA:

The inclusion criteria consisted of subjects with 16 to 25 years of age, subjects with Class I and Class II skeletal malocclusion with normodivergent and hyperdivergent facial pattern,subject with no pharyngeal pathology and no clinical signs and symptoms of nasal obstruction.

The exclusion criteria consisted of subjects with horizontal growth pattern, subjects with Class III malocclusion, subjects with anomaly of cervical vertebra and history of any orthodontic treatment.

After the subjects were analyzed only 80 subjects fulfilled the above criteria.

METHODOLOGY:

The subjects were divided into 4 groups according to their ANB angles and growth patterns (FMA) with 20 subjects in each group:

Group 1: Class I malocclusion and normal growth patterns (ANB 0^{o} - 4^{o} & FMA 20^{0} - 30^{0})

Group 2: Class I malocclusion and vertical growth patterns (ANB 0^{o} - 4^{o}& FMA > 30^{0})

Group 3: Class II malocclusion and normal growth patterns (ANB > 4^{o}& FMA 20^{0} - 30^{0})

Group 4: Class II malocclusion and vertical growth patterns (ANB > 4^{o}& FMA > 30^{0})

The lateral cephalograms were taken with a standard “ROTOGRAPH PLUS” cephalostat, manufactured by VILLA MEDICAL SYSTEM (Italy). Lateral cephalograms (8 × 10 inches) were obtained for each subject in natural head position as described by Cooke and Wei[10].The cephalometric tracings, landmark identification and measurements were performed on acetate paper (0.003 inches thick, 8 × 10 inches) using 3H pencil in a dark room using X-ray viewer by one investigator.

For the measurement of the linear distances, scale to the nearest of 0.5 mm and angles to the nearest of 0.5 degree was used.

Measurements on lateral cephalograms:

Upper pharyngeal airway width: measured from point on posterior outline of soft palate to closest point on posterior pharyngeal wall (PPW), taken on anterior half of soft palate outline.

Lower pharyngeal airway width: measured from intersection of posterior border of tongue and inferior border of mandible to closest point on posterior pharyngeal wall. (Figure 1)

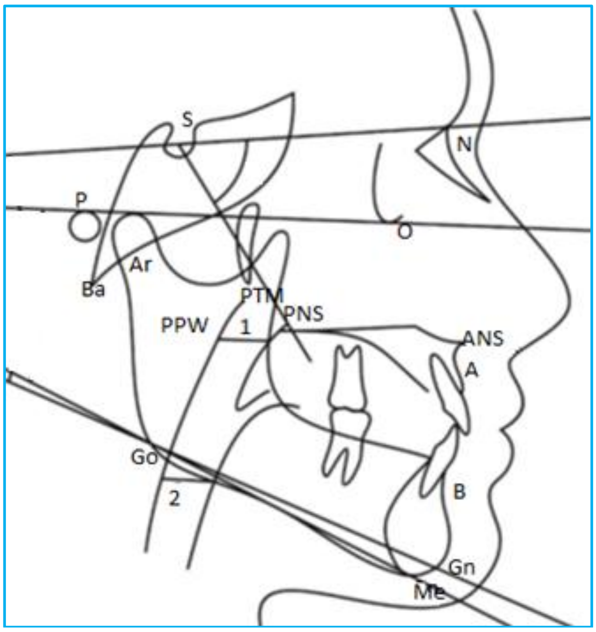

Figure 1: Upper and lower pharyngeal width (point 1 and 2 respectively).

Frankfort mandibular plane angle: measuredasan angle between the mandibular plane (tangent to lower border of mandible) and the Frankfort horizontal plane.

Sella perpendicular (Sper) and PTR perpendicular (PTRper) planes were used as vertical reference planes and C3C horizontal (C3Chor) plane was used as the horizontal reference plane for evaluation of anteroposterior and vertical positions of the hyoid bone, respectively.

The perpendicular distances from H-point to PTRper plane (H-PTRper distance) and from H-point to Sper plane (H-Sper distance) was used to evaluate the anteroposterior position of hyoid bone, whereas the perpendicular distances from H point to C3Chor plane (H-C3Chor distance) and from G-point to C3Chor plane (G- C3Chor distance) was used to evaluate the vertical position of the hyoid bone.

The angle between H-axis and PTRper plane (Haxis-PTRper angle) and the angle between H-axis and C3C horizontal plane (Haxis-C3Chor angle) was considered as angular parameters for evaluating the axial inclination of hyoid bone.(Figure 2)

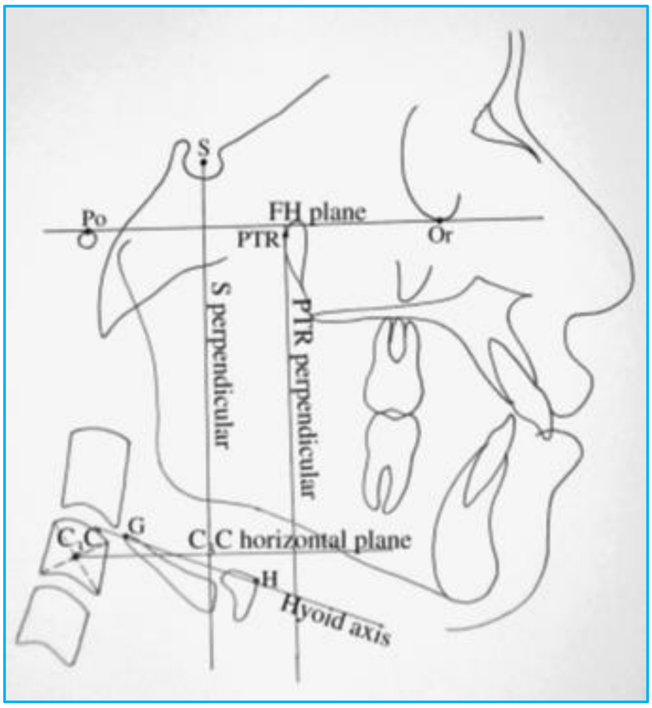

Figure 2: Hyoid bone position

When the position of the H-point was anterior to the PTRper and Sper planes, values for the perpendicular distances were considered as positive; values were considered as negative when the position of the H-point was posterior to the reference planes.

When the positions of the H-point and the G-point were superior to the C3C horizontal plane, values for the H-C3Chor and G-C3Chor distances were considered as positive; when the positions of the H-point and the G point were inferior to the C3C horizontal plane, values for the H-C3Chor and G-C3Chor distance were considered as negative.(Figure 3)

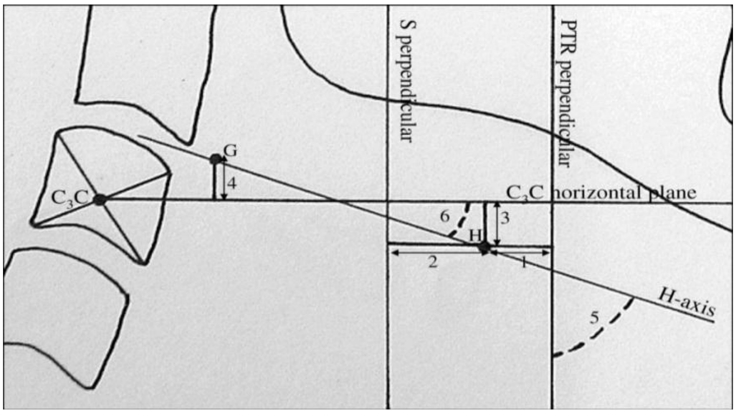

Figure 3: Linear and angular parameters used for the evaluation of hyoid bone position. 1: H-PTRper distance; 2: H-Sper distances; 3: H-C3Chor distance; 4: G-C3Chor distance; 5: Haxis-PTRper angle; and 6: Haxis-C3Chor angle

STATISTICAL ANALYSIS:

A master file was made and data was statistically analyzed on a computer with the Statistical Package for the Social Sciences (SPSS) software version 17. A data file was created under dBase and was converted into a microstat file. The data were subjected to descriptive analysis for mean, range, and standard deviation of all variables. One-way ANOVA was used for analysis of variance, unpaired-t test to compare two variables and a post hoc test (Tukey) was used for multiple comparisons. A p value ≤ 0.05 was considered to indicate statistical significance.

III. Results

Table 1 shows the mean age, ANB and FMA angle among the four groups of subjects are.

Table 1. Comparison of Age, ANB and FMA among four groups.

PARAMETERS	GROUP 1 (n = 20) Class I with normal growth pattern Mean ± SD	GROUP 2 (n = 20) Class I with vertical growth pattern Mean ± SD	GROUP 3 (n = 20) Class II with normal growth pattern Mean ± SD	GROUP 4 (n = 20) Class II with vertical growth pattern Mean ± SD
Age years	19.65 ± 3.021	18.95 ± 2.259	18.8 ± 2.130	18.15 ± 3.201
ANB degrees	3.00 ± 1.02	2.73 ± 1.057	6.90 ± 1.651	6.60 ± 1.501
FMA degrees	24.20 ± 3.205	32.50 ± 8.319	25.30 ± 2.130	36.25 ± 3.683

FMA indicates Frankfort mandibular plane angle; SD, standard deviation

Table 2 shows the mean UPA (upper pharyngeal airway width) andLPA (lower pharyngeal airway width).

Table 2. Means and standard deviations of upper and lower pharyngeal airway dimension among four groups.

PARAMETERS	GROUP 1 Class I with normal growth pattern Mean ± SD	GROUP 2 Class I with vertical growth pattern Mean ± SD	GROUP 3 Class II with normal growth pattern Mean ± SD	GROUP 4 Class II with vertical growth pattern Mean ± SD	Sig P ≤ .05
Upper Pharyngeal Airway UPA (mm)	16.90 ± 2.125	12.95 ± 3.576	16.85 ± 2.231	12.65 ± 2.207	0.00***
Lower Pharyngeal Airway LPA (mm)	9.75 ± 2.149	9.75 ± 1.832	9.65 ± 3.675	9.25 ± 2.337	0.917

* The mean difference is significant at the * < .05 level, ** < .01 level *** < .001 level

A highly significant intergroup difference in the upper pharyngeal width was found between Groups 1 and 2, Groups 1 and 4, Groups 2 and 3, Groups 3 and 4 (*p* value ≥ 0.00). A non-significant intergroup difference in the upper pharyngeal width was found between Groups 1 and 3, Groups 2 and 4.No significant intergroup differences were found for the lower pharyngeal airway width between the groups as shown in Table 3.

Table 3. Intergroup comparison of upper and lower pharyngeal airway dimension and hyoid bone position among four groups.

Variables	1 v/s 2		1 v/s 3		1 v/s 4		2 v/s 3		2 v/s 4		3 v/s 4	
	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05
Upper Pharyngeal Airway UPA (mm)	3.95	0.00***	0.05	1.00	4.25	0.00**	-3.90	0.00**	0.30	0.98	4.20	0.00***
Lower Pharyngeal Airway LPA (mm)	0.00	1.00	0.10	0.99	0.50	0.92	0.10	0.99	0.50	0.99	0.40	0.96

* The mean difference is significant at the * < .05 level, ** < .01 level *** < .001 level

Whena total of skeletal Class I and Class II malocclusion were compared irrespective of the growth pattern, the mean differences in the UPA (upper pharyngeal airway width) and the LPA (lower pharyngeal airway width) was found to be non-significant (Table 6).

Table 4 shows the mean H-PTR per distance and H-S per distance. A highly significant intergroup difference in the H-PTR per distance and H-S per distance was found between Groups 1 and 4 (*p* value ≤ 0.01).

Table 4. Means and standard deviations of hyoid bone positionamong four groups.

PARAMETERS	GROUP 1 Class I with normal growth pattern Mean ± SD	GROUP 2 Class I with vertical growth pattern Mean ± SD	GROUP 3 Class II with normal growth pattern Mean ± SD	GROUP 4 Class II with vertical growth pattern Mean ± SD	Sig P ≤ .05
H-PTR per distance mm	1.38 ± 5.318	-1.30 ± 7.277	-2.23 ± 6.701	-4.95 ± 5.652	0.021*
H-S per distance mm	17.50 ± 6.262	14.05 ± 8.338	13.25 ± 7.622	10.83 ± 6.808	0.042*
H-C_3C hor distance mm	-13.65 ±7.393	-17.00 ± 6.928	-12.65 ± 8.261	-13.30 ± 10.579	0.367
G-C_3C hor distance mm	-3.00 ± 6.905	-7.20 ± 4.753	-4.00 ± 5.058	-3.95 ± 4.729	0.087
H axis- PTR per angle	70.30 ± 7.948	71.60 ± 9.185	71.35 ± 7.051	68.45 ± 7.089	0.577
H axis- C_3C hor angle	19.70 ± 7.948	18.40 ± 9.116	18.65 ± 6.991	21.50 ± 7.112	0.588

* The mean difference is significant at the * < .05 level, ** < .01 level *** < .001 level

A non-significant intergroup difference in the H-PTR per distance and H-S per distance was found between Groups 1 and 2, Groups 1 and 3, Groups 2 and 3, Groups 2 and 4 and Groups 3 and 4 (Table 5).

Table 5. Intergroup comparison of hyoid bone position among four groups.

Variables	1 v/s 2		1 v/s 3		1 v/s 4		2 v/s 3		2 v/s 4		3 v/s 4	
	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05	M.D.	Sig P ≤ .05
H-PTR per distance Mm	2.67	0.53	3.60	0.27	6.32	0.01*	0.925	0.96	3.65	0.26	2.72	0.52
H-S per distance mm	3.45	0.44	4.25	0.26	6.67	0.02*	0.80	0.98	3.22	0.50	2.42	0.72
H-C_3C hor distance mm	3.35	0.59	-1.00	0.98	-0.35	0.99	-4.35	0.36	-3.70	0.50	0.65	0.99
G-C_3C hor distance mm	4.20	0.07	1.00	0.93	0.95	0.94	-3.20	0.25	-3.25	0.24	-0.05	1.00
H axis- PTR per angle	-1.30	0.95	-1.05	0.97	1.85	0.87	0.25	1.00	3.15	0.58	2.90	0.65
H axis- C_3C hor angle	1.30	0.95	1.05	0.97	-1.80	0.88	-0.25	1.00	-3.10	0.59	-2.85	0.66

* The mean difference is significant at the * < .05 level, ** < .01 level *** < .001 level

Whena total of skeletal Class I and Class II malocclusion were compared irrespective of the growth pattern, the differences in the mean H-PTR per distance and H-S per distance was found to be statistically significant.(Table 6).

Table 4 shows the mean H-C3C hor distance,G-C3C hor distance and the mean H axis–PTR per angle, H axis-C3C hor angle.A non-significant intergroup differenceswere found between all the groups.(Table 5)

Whena total of skeletal Class I and Class II malocclusion were compared irrespective of the growth pattern, the difference in the mean H-C3C hor distance, G-C3C hor distanceand the mean H axis–PTR per angle, H axis-C3C hor angle was found to be statistically non-significant. (Table 6)

Table 6. Comparison of variables between skeletal Class I and Class II malocclusion.

Variables	Skeletal Class I Malocclusion (n=40)	Skeletal Class II Malocclusion (n=40)	Std. Error	Significance
Age	19.30 ± 2.48	18.48 ± 2.83	0.595	0.169
ANB	2.863 ± 1.03	6.75 ± 1.565	0.297	0.001***
FMA	29.08 ± 6.01	30.78 ± 6.29	1.385	0.224
Upper Airway width (mm)	14.93 ± 3.53	14.75 ± 3.05	0.737	0.813
Lower Airway width (mm)	9.75 ± 1.97	9.45 ± 3.05	0.574	0.602
H-PTRper distance (mm)	0.038 ± 6.43	-3.588 ± 6.273	1.421	0.012**
H-S per distance (mm)	15.775 ± 7.485	12.038 ± 7.238	1.646	0.020*
H-C_3C hor distance (mm)	-15.33 ± 7.27	-12.98 ± 9.37	1.876	0.214
G-C_3C hor distance (mm)	-5.10 ± 6.23	-3.98 ±4.83	1.246	0.369
H axis- PTR per angle(deg)	70.95 ± 8.50	69.90 ± 7.13	1.755	0.551
H axis- C_3C hor angle(deg)	19.05 ± 8.47	20.08 ± 7.11	1.748	0.559

* The mean difference is significant at the * < .05 level, ** < .01 level *** < .001 level

IV. Discussion

The upper airway is a structure responsible for one of the main vital functions in the human organism i.e. breathing. There exists a close relationship between the pharynx and the dentofacial structures, thus a mutual interaction is expected to occur between the pharyngeal structures and the dentofacial pattern, justifying orthodontic interest.[11]

According to the Balter's philosophy[12], Class II malocclusions are a consequence of backward positioning of the tongue. The respiratory function is impeded in the region of pharynx leading to faulty deglutition and mouth breathing. Clinically, this knowledge might be useful to diagnose the developing Class II malocclusions. Therefore, consideration of the pharyngeal airway should be included in the orthodontic diagnosis and treatment planning.

King[13] and Tourne[14] stated that nasopharyngeal depth is established in the early ages of life, and after which it usually remains the same. Furthermore, it has been reported that the nasopharyngeal airway increases rapidly until 13 years of age, and after this period the growth slows down.[15] Therefore, to rule out the influence of growth, the sample used in this study consisted of subjects from 16 to 25 years of age.

The **upper pharyngeal width** is measured from a point on the posterior outline of the soft palate to the closest point on the pharyngeal wall as described by Mc Namara.[16] This measurement is taken on the anterior half of the soft palate outline because the area immediately adjacent to the posterior opening of the nose is critical in determining upper respiratory patency. According to himthe average upper airway measurement for adults of both sex is approximately 15 to 20 mm in width.

According to the results of the present study, the upper airway width was 16.9 ± 2.12 mm in normodivergent individuals which was comparable to the values as reported by McNamara(Table 2). The present study revealed a significant narrow upper pharyngeal width of 12.95 ± 3.57 mm in patients with hyperdivergent growth pattern as compared to normodivergent growth pattern.

Similar results were found by Freitas et al[17] (2006) also reported narrow upper pharyngeal airway width in individuals with vertical growth pattern (9.33± 3.92 mm) as compared to the individuals with normal growth pattern (12.58 ± 2.04 mm).

However, W. John and S. Kerr[5] (1985) andChester S. Handelman[18] (1976) found no relationship between growth pattern, facial morphology, and nasopharyngeal airway. They reported that size of the nasopharynx was not influenced by the growth pattern and facial morphology. Probably, this is because these studies evaluated the influence of the nasopharyngeal airway on facial form and occlusion and not on the skeletal jaw bases.

The **lower pharyngeal width** is measured from the point of intersection of the posterior border of the tongue and the inferior border of the mandible to the closest point on posterior pharyngeal wall.The average value for this measurement is 11to14 mm and does not change appreciably with age. An obstruction of the lower pharyngeal area because of posterior positioning of the tongue is rare however greater than average lower pharyngeal width on the other hand, suggests a possible anterior positioning of tongue, either due to habitual posture or due to tonsillar enlargement.[16] According to the results of present study, the lower airway width of 9.75 ± 1.97mmwas comparable to the values as reported by McNamaraand was found to be statistically non-significant (*p* value ≥ 0.91) i.e. no association of lower pharyngeal airway space with craniofacial growth pattern and malocclusion type was found.

This was in agreement with the earlier study done by Freitas et al[17] (2006) who compared the width of the lower pharyngeal airways in patients with skeletal Class I and Class II malocclusions and found no difference in the width of the lower pharyngeal airways, suggesting that the anteroposterior dimension of the lower airway is usually maintained by adaptation of both tongue and hyoid bone.

However, Linder-Aronson and Leighton[19] (1983) suggested that oropharyngeal space appears to be larger than normal when the nasopharyngeal airway is smaller, although they did not evaluate this correlation directly.

Comparison of Hyoid Bone Position

The anteroposterior position of the hyoid bone was evaluated from the H-PTR per distance and the H-S per distance. In the present study, the position of the hyoid bone was found to be significantly anterior in subjects with normodivergent facial pattern with a mean value of as compared to the subjects with hyperdivergent facial pattern.

Similar findings were reported by Jena and Duggal[9] (2006) who compared hyoid bone position in subjects with different vertical jaw dysplasias and found that the position of the hyoid bone in subjects with short face syndrome was more anterior than in subjects with long face syndrome.

Also, the position of the hyoid bone was found to be significantly anterior in subjects with skeletal Class I malocclusion as compared to the subjects with skeletal Class II malocclusion. Thus, the anteroposterior position of the hyoid bone followed the anteroposterior position of the chin. When the mandible was rotated in an upward and forward direction, the suprahyoid muscles pulled the hyoid bone to move into a more anterior position, and when the mandible was rotated in a downward and backward direction, the hyoid bone tends to move posteriorly.

The vertical position of the hyoid bone in subjects with normal growth pattern was slightly upward i.e. -13.65 ±7.393 mm as compared to the subjects with vertical growth pattern i.e. -17.00 ± 6.928 mm. This could be the result of pull from the suprahyoid muscles, which occurs as the mandible is rotated in an upward and forward direction. In subjects with long face syndrome, the mandible was rotated in a downward and backward direction, resulting in slightly downward positioning of the hyoid bone.

The axial inclination of the hyoid bone was evaluated in relation to both vertical (PTRper) and horizontal (C3C horizontal) reference planes. The values of the axial inclination of the hyoid bone were found to be non-significant among the groups.

Thus, the present study demonstrates that the pharyngeal airway passage in subjects with vertical growth pattern is narrower as compared to the average growth pattern. This may be due to the backward rotation of the mandible in vertical growers along with backward positioning of the tongue which could lead to the narrowing of pharyngeal airway. Moreover, the position of hyoid bone is more posterior in skeletal Class II vertical grower as compared to skeletal Class I normal growers. The hyoid bone being an important element for the functioning of both the suprahyoid and infrahyoid groups of muscles, has a pivotal role in contributing to a specific orientation and function of these muscles which might be influential in the establishment of specific structural elements of the jaws and the occlusion of the teeth.

V. Conclusion

According to the methods used in this study we can comprehend that:

- Patients with skeletal Class I and Class II malocclusions and vertical growth patterns have significantly narrower upper pharyngeal airways than those with skeletal Class I and Class II malocclusions and normal growth patterns.
- However, malocclusion type does not influence upper pharyngeal airway width, and malocclusion type and growth pattern do not influence lower pharyngeal airway width.
- The anteroposterior position of the hyoid bone in subjects with skeletal Class I malocclusion was more anterior than in subjects with skeletal Class II malocclusion.
- The vertical position of the hyoid bone was comparable among subjects in skeletal Class I malocclusion and skeletal Class II malocclusion with different growth pattern.
- The axial inclination of the hyoid bone closely followed the axial inclination of the mandible.

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