Head and Neck Imaging ORIGINAL ARTICLE

Morphometric analysis and anatomical correlation of the hyoid bone and pharyngeal airway space in different skeletal patterns -a digital lateral cephalometric study

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Abstract

Background: The hyoid bone's relationship with head and neck skeletal and soft components supports the craniofacial complex. Hyoid bone and muscles support the pharyngeal airway. Airway space analysis determines skeletal pattern and craniofacial complications, so a patent airway is essential.

Methodology: This in-vitro retrospective observational study included 180 samples—60 in each of Class I, II, and III skeletal groups on digital lateral cephalogram ANB angle with equal male and female representation. The data was calculated using 5% α error and 80% study power. Pharyngeal airway space and hyoid bone in different skeletal patterns were quantified by Planmeca Romexis Viewer 2.9.2R software. SPSS 25 analysed the data (IBM Inc. Chicago). P-values < 0.05 were significant.

Result: The pharyngeal airway is wider in the Class III group than in Class II. The mandible protruded in skeletal Class III, making the hyoid bone inferior and anterior. In Class II, it was postero-superior.

Conclusion: Mandibles affect pharyngeal airway space, narrowing it and increasing sleep breathing disorders. Orthodontic and dentofacial management should include this to prevent obstructive sleep apnea and maintain global norm values.

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KEY WORDS
Airway space, Pharynx, hyoid bone, lateral cephalogram, obstructive sleep apnea, skeletal malocclusion

Introduction

Normal respiratory activity promotes harmonic maxillofacial growth. The hyoid position protects the anterior airway. Airway space analysis largely determines skeletal and craniofacial complexes. Opdebeeck et al.(1) linked the cervical spine, pharynx, tongue, hyoid bone, and mandibular movement. Hoekema et al. (2) found pharyngeal airway obstruction in OSA patients. Earlier studies showed tongue and hyoid bone locations can suggest pharyngeal airway space, although there is no unanimity. Based on this background, the current study examines the pharyngeal airway space and hyoid bone in various skeletal forms. This may help plan and manage orthodontic and dentofacial deformities associated with obstructive sleep problems and craniofacial abnormalities.

Methodology

An in-vitro retrospective observational study using digital lateral cephalograms was conducted from March 2021 to September 2022 in the Department of Oral Medicine and Radiology, JSS Dental College and Hospital, Mysuru, Karnataka, after obtaining the institutional ethical clearance JSS/DCH/IEC/32/2020. The study group comprised 180 samples, 60 samples in each skeletal group of Class I, Class II, and Class III, with an equal distribution of male and female based on their ANB angle on the digital lateral cephalogram. (Figures 1a, 1b, and 1c). The data calculated was based on 5% error and 80% power of the study.

The inclusion criteria were (i) digital lateral cephalograms that have optimum diagnostic quality and encompass the entire study area, (ii) skeletal class I group with 0°<ANB>4°, (iii) skeletal class II group with ANB ≥4° and (iv) skeletal class III group with ANB ≤0°. The exclusion criteria were (i) patients digital lateral cephalograms with craniofacial deformity and/or any central pathologies or any previous surgeries involving jaws and hyoid bone, (ii) patients' medical records with history of previous orthodontic treatment or history of any facial bone trauma and (iii) any radiographic artifacts in the area of study. The withdrawal criteria were not applicable.

The following linear measurements and angle measurements were made directly on the digital lateral cephalometric images obtained for the study subjects using Planmeca Romexis software. (Figure 2)

1. SP; shortest soft palate-pharyngeal wall distance
2. C2P; C2 of the horizontal line to the tongue intersecting the pharyngeal airway
3. BP; B-Go line intersecting the pharyngeal airway
4. LP; laryngopharyngeal airway
5. U1-PP ANGLE; angulation between palatal plane (ANS-PNS line) and long axis of the upper incisor
6. U1-L1 ANGLE; angulation of long axis of upper incisor and lower incisor long axis
7. L1-MP ANGLE; angulation of mandibular plane (Me-Go line) and long axis of the lower incisor
8. Hyoid bone Horizontal (HH): The lower most anterior point of C3 to the most superoanterior portion of hyoid bone.
9. Hyoid bone Vertical (HV): The angulation of the most superoanterior portion of hyoid bone to the mandibular plane (Me-Go line)

For statistical methods and analysis, all the data collected were analyzed in SPSS version 25 (IBM Inc. Chicago). All the continuous variables were expressed in terms of mean and standard deviation. Normality of the distribution of continuous variables were determined by Shapiro-wilks test. Measurable effect of independent variable on a dependent variable was tested using One-way ANOVA test. Using Pearson's Chi-squared test, associations between two categorical variables were obtained. Depending on the distribution of the data, the independent sample t-test or the Mann-Whitney U test were used to determine the significance level in the comparison of means. Relevant tests were made con-

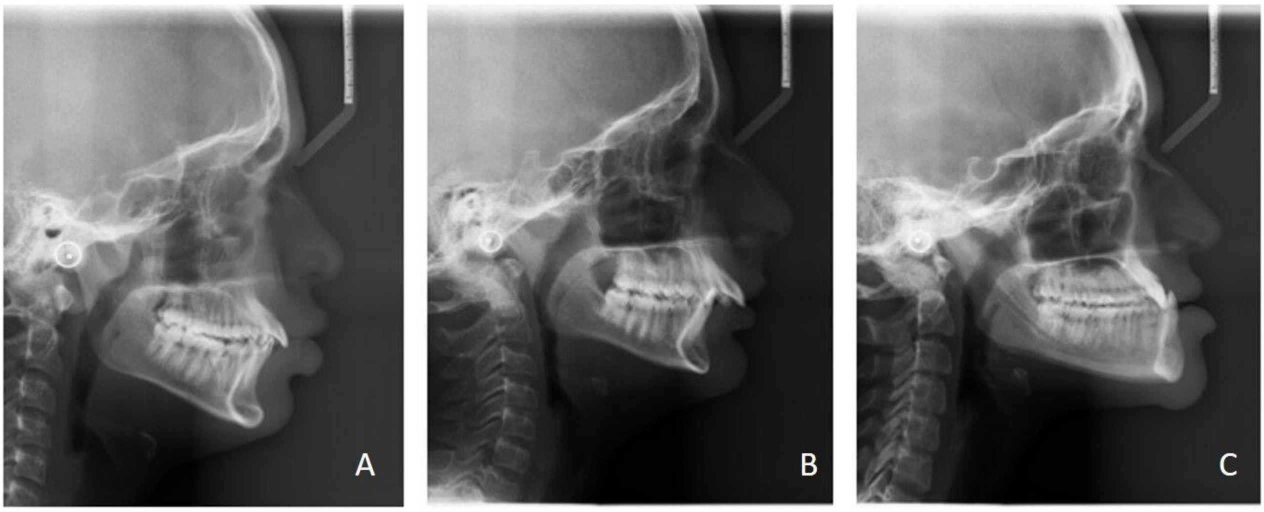

Figure 1. Skeletal patterns on lateral cephalogram (A= Skeletal Class I on lateral cephalogram, B= Skeletal Class II on lateral cephalogram, C= Skeletal Class III on lateral cephalogram)

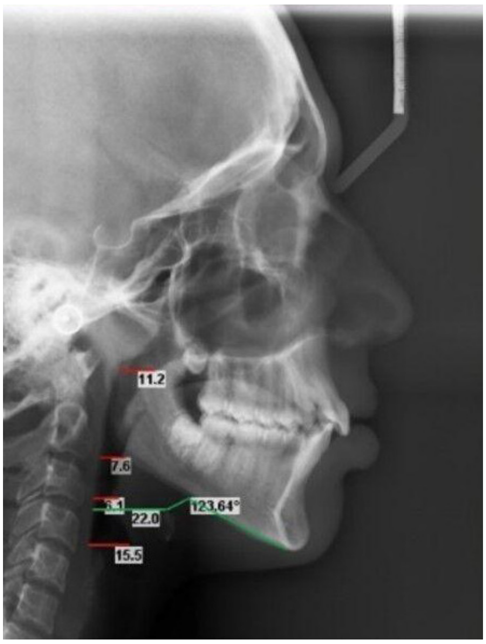

Figure 2. Measurement of pharyngeal airway space (red) and hyoid bone (green) using Planmeca Romexis software

sidering 95% of confidence interval. A P-value less than 0.05 was considered statistically significant.

Results

The mean age (years) of the Class I, Class II and Class III study group was 18.52 ±5.30, 19.45 ±5.03 and 22.45 ±5.34. Regarding age, there were no appreciable differences between the various skeletal patterns. (Table 1)

Considering the mean and standard deviation, the SNA angle was significantly higher in skeletal Class II group than Class III group (F = 10.88, P = 0.002). The SNB angle was higher in Class III than in Class I and the Class II was the least significant (F = 11.97, P = 0.001). Considering gender as a dependent variable ANB angle was significantly greater in skeletal Class II group than in skeletal Class I group (F = 8.56, P = 0.005). (Table 1)

The U1- PP angle was significantly greater in Class III group (122.64°) and Class I group (118.45°) than in Class II group (114.69°). The Class III group were significantly greater both male (t = 872.66) and female (t = 262.14). (Table 1-3)

Accordingly, the U1 – L1 angle was significantly greater in Class III (126.78°) and Class I (121.48°) than in Class II (117.69°). (Table 1). The Class III was significantly greater in both male and female. (Table 1-3) All the measurements, with the exception of L1-MP angle, were statistically significant when the mean of the three groups were taken into consideration ($P < 0.05$). (Table 1)

Table 1 summarizes the analysis of three distinct skeletal patterns. Notably the SP was significantly longer in Class III (13.64mm) than Class II (11.10mm) than Class I (10.41mm) whereas BP was significantly longer in Class III (15.14mm) than in Class I (12.82mm) than in Class II (11.60mm). There was significant correlation of C2P (F =7.825, P = 0.011) and LP (F = 7.045, P = 0.010) among the skeletal patterns. In both C2P and LP the Class III was

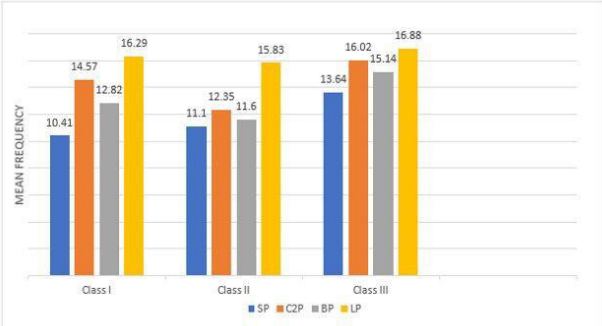

Fig 3

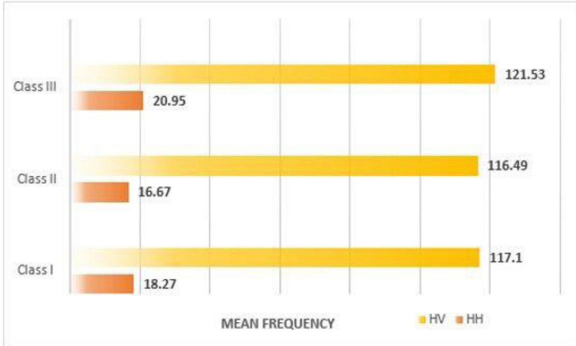

Fig 4

Figure 3. Bar chart showing intergroup comparison of pharyngeal airway spaces (SP= shortest soft palate-pharyngeal wall distance, C2P= C2 of the horizontal line to the tongue intersecting the pharyngeal airway, BP= B-Go line intersecting the pharyngeal airway, LP=laryngopharyngeal airway)

Figure 4. Bar chart showing intergroup comparison of hyoid bone (HH=hyoid bone horizontal, HV= hyoid bone vertical)

significantly more than Class I and Class II. In the gender's comparison, female had larger LP (t = 125.72mm) than male LP (t = 77.02mm) in all skeletal patterns. (Table 2,3) (Figure 3)

The hyoid bone's horizontal position was significantly greater in Class III (20.95mm) than in Class I (18.27mm) and Class II (16.67mm). Similarly, vertical positions of the hyoid bone were significantly greater in Class III than Class I and Class II. The horizontal position of the hyoid bone was more in male (t = 103.96) than in female (t = 40.15), but the vertical position was more in female (t = 126.15) than in male (t = 106.06). (Table 1-3) (Figure 4)

Table 4 summarizes the Pearson's correlation coefficient of male. Class I indicated that the hyoid bone's horizontal position was significantly correlated with C2P, BP and LP. SP was not significant with any related factors other than age. In Class II, LP (r = 0.381) had a moderate positive correlation with the hyoid bone's horizontal position. The SP, C2P and BP had no significant value with related parameters. In Class III, SP had a significant relation with U1-PP, U1 L1 and HH while there was moderate negative correlation with L1-MP. The C2P was significantly related to SNA angle only. The BP had moderate positive relation with SNA, SNB and ANB angle and strong positive relation with L1-MP (r = 0.792), U1-L1 (r = 0.603) and HH (r = 0.729). There was a negative relation between BP and U1-PP (r = -0.787). LP had positive significant relation with U1-L1 (r = 0.462) and significantly negative relation with L1-MP (r = -0.44).

Table 5 summarizes the Pearson's correlation coefficient of female. Class I indicated that BP and LP had no significant relation with any related parameters. The SP had a negative relation with SNA angle and C2P was negative relation with U1-PP (r = -0.361). In Class II SP, BP and LP had no significant relation with any related parameters. The C2P had a moderate positive significant relation with L1-MP (r = 0.423) and negative relation with U1-PP (r = -0.354). In Class III LP had no significant correlation with any other parameters. SP had positive significant relation with ANB (r = 0.472) and L1-MP (r = 0.398). The SP had negative correlation with SNA and SNB angle. C2P had strong positive correlation with U1 L1 and negative correlation with U1-PP and L1-MP. The BP had moderate positive corelation with horizontal hyoid bone (r =0.371) while strong positive corelation with L1-MP (r = 0.79). There was a negative correlation of BP with ANB, U1-PP and U1-L1.

Discussion

Given the complexity of the stomatognathic system, it is crucial to appreciate its anatomy, physiology, and theories of craniofacial growth in order to understand how the system as a whole works in various individuals. Laxmi et al. (3) specified that for a thorough under-

Table 1. Patients' characteristics in the skeletal classification (One-way ANOVA)

Variable	Class I (F = 30, M = 30)		Class II (F = 30, M = 30)		Class III (F = 30, M = 30)		Significance		Intergroup Comparison
	Mean	SD	Mean	SD	Mean	SD	*F*	*P value (<0.05)*	
AGE	18.52	±5.30	19.45	±5.03	22.45	±5.34	*2.406*	*0.126*	Non suggestive
SNA angle	83.35	±1.85	83.36	±3.05	83.41	±1.47	*10.880*	***0.002***	Class II > Class III (Considering SD in calculation)
SNB angle	81.52	±1.96	79.04	±2.72	85.62	±1.58	*11.979*	***0.001***	Class III > Class I > Class II
ANB angle	1.92	±0.66	4.70	±0.95	-5.30	±2.95	*8.560*	***0.005***	Class II > Class I
U1-PP angle	118.45	±1.36	114.69	±3.43	122.64	±1.39	*16.385*	***0.001***	Class III > Class I > Class II
L1-MP angle	97.08	±3.27	97.99	±5.26	87.78	±2.83	*2.307*	*0.134*	Not Significant
U1-L1- angle	121.48	±3.39	117.69	±6.08	126.78	±4.33	*24.458*	***0.001***	Class III > Class I > Class II
SP	10.41	±1.58	11.10	±1.48	13.64	±1.47	*12.161*	***0.001***	Class III > Class II > Class I
C2P	14.57	±2.92	12.35	±1.29	16.02	±1.13	*7.825*	***0.011***	Class III > Class I
BP	12.82	±1.64	11.60	±1.22	15.14	±1.58	*30.851*	***0.001***	Class III > Class I > Class II
LP	16.29	±1.76	15.83	±1.79	16.88	±1.49	*7.045*	***0.010***	Class III > Class II
HH	18.27	±2.50	16.67	±3.29	20.95	±1.99	*83.468*	***0.001***	Class III > Class I > Class II
HV	117.1	±10.81	116.49	±7.97	121.53	±6.09	*47.495*	***0.001***	Class III > Class I > Class II

standing of the physiology and pathophysiology of pharyngeal airway space, knowledge of the morphology and mechanical behavior of the bony and soft tissue components and their inter-relationship is crucial. Cephalometry has expanded outside the realm of dentistry, and it now serves as a crucial tool for assessing both the airway and the skull's bones. Malkoc et al. (4) demonstrated that despite cephalometric radiographs only show a two-dimensional representation of a three-dimensional object, they were accurate, consistent, and reproducible for assessing airway space.

The ANB angle, is the most frequently used cephalometric measurement for determining the sagittal relationship of the jaws. It has been shown to be a reliable indicator of skeletal malocclusion in research by Ishikawa et al (5). In the current study considering gender into account among various skeletal patterns as a dependent variable, we found that Class II male and female study groups have a substantially higher ANB angle than Class I and Class III. Ackam(6) found that increase in ANB angle did not affect the characteristic of upper airway. These findings were contrasting with the study by Elwareth et al (7) who found significant difference in airway space dimension with Class III subjects having greatest pharyngeal width and Class II subjects having the least. This may be the case since the size of the

Table 2. The characteristics of male patients in the skeletal classification (Sample T Test)

Variable	Class I (M = 30)		Class II (M = 30)		Class III (M = 30)		Significance		Intergroup Comparison
	Mean	SD	Mean	SD	Mean	SD	*t*	*P value (<0.05)*	
AGE	19.56	±5.68	20.10	±5.45	22.43	±5.13	18.85	***0.001***	*Non suggestive*
SNA angle	84.09	±1.49	82.89	±3.59	83.69	±1.31	307.52	***0.001***	*Class II > Class III*
SNB angle	82.33	±1.53	78.18	±2.98	85.35	±1.07	293.04	***0.001***	*Class III > Class II > Class I*
ANB angle	1.68	±0.34	4.76	±0.92	-7.81	±32.52	26.48	***0.001***	*Class II > Class I*
U1-PP angle	117.81	±0.73	112.90	±3.39	122.60	±0.74	872.66	***0.001***	*Class III > Class I > Class II*
L1-MP angle	96.44	±1.52	96.91	±4.01	86.74	±2.57	347.19	***0.001***	*Class III > Class I*
U1-L1- angle	119.64	±1.54	118.98	±5.27	128.79	±2.59	423.69	***0.001***	*Class III > Class I > Class II*
SP	10.66	±2.07	11.31	±1.32	15.88	±1.32	52.12	***0.001***	*Class III > Class II > Class I*
C2P	16.98	±2.07	12.63	±1.26	16.07	±1.01	61.09	***0.01***	*Class III > Class I > Class II*
BP	13.78	±1.54	11.70	±1.22	15.32	±1.87	48.98	***0.001***	*Class III > Class II > Class I*
LP	17.64	±1.25	16.42	±2.33	18.09	±1.14	77.02	***0.001***	*Class III > Class II > Class I*
HH	19.98	±1.05	19.18	±2.30	22.67	±1.22	103.96	***0.001***	*Class III > Class II > Class I*
HV	125.92	±6.50	121.79	±6.91	128.01	±2.88	106.06	***0.001***	*Class III > Class II > Class I*

bony nasopharynx is a relatively independent variable when compared to other facial complex characteristics according to Jena et al (8). The vertical component of jaw discrepancies appears insensitive on the ANB angle. ANB angle changes alone may not be sufficient to detect changes in growth patterns, which include both horizontal and vertical adaptations. However, in our study the findings were contrary to previous studies. These contentious findings from several studies recommend limiting the application of the ANB angle.

Haralabakis et al (9) detailed that the palatal plane affects the expansion of skeletal malocclusions and hyoid bone only changes in close proximity to the cervical spine, mandibular plane and the pharynx, in patients with completely distinct skeletal patterns. In our study, Class III and Class I had considerably higher U1-PP angles than Class II. In comparison to Class II, the U1-L1 angle was much higher in Class III and Class I.

When the soft palate is relaxed or drooping normally, the anterior portion appears concave and the posterior portion seems convex. Thus, the soft palate frequently has an impact on the pharyngeal airway space. The present study showed that SP in Class III was substantially longer when compared to Class I and Class II. The study by Cheng et al (10), yielded similar findings where they found significantly longer SP in Class III when compared to Class I and Class II whereas study by Alves et.al (11) obtained longer SP in Class I than in Class II. We also found that SP, U1-PP angle, U1-L1 angle and HH were significantly correlated in Class III skeletal patterns, while a moderate negative correlation with L1-MP angle. Additionally, in the current study there were no in-

Table 3. The characteristics of female patients in the skeletal classification (Sample T Test).

Variable	Class I (F = 30)		Class II (F = 30)		Class III (F = 30)		Significance		Intergroup Comparison
	Mean	SD	Mean	SD	Mean	SD	*t*	*P value (<0.05)*	
AGE	17.47	±4.7	18.80	±4.52	22.47	±5.64	22.47	**0.001**	*Non suggestive*
SNA angle	82.62	±1.91	83.83	±2.36	83.13	±1.58	193.88	**0.001**	*Class II > Class III*
SNB angle	80.71	±2.04	79.90	±2.15	85.88	±1.95	203.43	**0.001**	*Class III > Class II > Class I*
ANB angle	2.16	±0.81	4.65	±0.98	-2.79	±0.82	25.83	**0.001**	*Class II > Class I*
U1-PP angle	119.08	±1.54	116.47	±2.43	122.68	±1.84	262.14	**0.001**	*Class III > Class I > Class II*
L1-MP angle	97.71	±4.32	99.07	±6.16	88.83	±2.73	88.07	**0.001**	*Class II > Class I > Class III*
U1-L1- angle	123.31	±3.75	116.40	±6.63	124.76	±4.80	96.08	**0.001**	*Class III > Class I > Class II*
SP	10.16	±0.83	10.88	±1.62	12.31	±0.47	39.37	**0.001**	*Class III > Class II > Class I*
C2P	12.17	±1.10	12.08	±1.28	15.21	±0.84	*44.52*	**0.001**	*Class III > Class I > Class II*
BP	11.87	±1.09	11.51	±1.24	14.97	±1.23	50.73	**0.001**	*Class III > Class II > Class I*
LP	14.95	±1.01	15.24	±0.66	15.67	±0.46	125.72	**0.001**	*Class III > Class II > Class I*
HH	16.56	±2.35	14.16	±1.93	19.23	±0.71	40.15	**0.001**	*Class III > Class II > Class I*
HV	108.28	±5.89	111.19	±4.82	115.06	±1.38	126.15	**0.001**	*Class III > Class II > Class I*

tergender variations in SP between the various skeletal forms which were similar to the study by Abu and Al-Khateeb (12) and also, we found that SP was not significant with any related factors other than age. This was consistent with Taylor et al (13) findings which evaluated the dimensional alterations in oral and pharyngeal soft tissues and in bone.

Conferring to Kulshrestha et al (14) and D. Ciavarella et al (15) the maxilla's vertical position and the mandible's antero-posterior position are significantly affected by a facial development. Both the tongue and the hyoid bone adjust to maintain the anteroposterior dimension of the upper airway. Though the measurements of pharyngeal airway space were slightly smaller among skeletal Class II pattern compared to Class III pattern, these measurements were comparable among the three groups. Considering Pearson correlation analysis, the length of the C2P increases with decreasing L1-MP angulation. Increased C2P results from increased lingual tipping of lower incisor brought on by dental compensation and more mandibular protrusion. Our study demonstrated longer C2P in Class III skeletal group with prognathic mandible followed by normal individual of Class I group and then by Class II skeletal group with retrognathic mandible irrespective of gender variation indicating mandibular growth pattern affects the pharyngeal airway space. Study by Cheng et al (10) reported similar results to our study in accordance with variant gender and skeletal pattern.

Hwang et.al (16) stated that retruded mandible and maxilla are related to a constricting nasopharyngeal airway. Moreover, Abu and Al-Khateeb (12) stated that

Table 4: Pearson test of male in the skeletal classification

Parameters	Age	SNA	SNB	ANB	U1-PP	L1-MP	U1 L1	HH	HV
Class I									
SP	-0.435*	0.223	0.064	0.072	0.029	0.148	-0.145	-0.033	-0.239
C2P	0.091	-0.041	0.196	0.189	-0.154	0.058	-0.301	0.565*	0.089
BP	-0.014	0.069	0.317	0.284	-0.135	0.058	-0.213	0.440*	-0.040
LP	0.357*	0.051	0.160	0.138	-0.133	0.196	-0.213	0.627*	0.104
Class II									
SP	0.280	-0.199	-0.205	-0.104	0.064	0.185	-0.337	0.256	0.073
C2P	-0.073	0.016	0.128	0.103	0.256	0.113	-0.043	0.213	-0.118
BP	0.115	-0.231	-0.211	-0.130	0.195	-0.028	-0.061	0.032	0.068
LP	-0.025	-0.062	-0.011	-0.116	-0.282	0.019	0.087	0.381*	-0.106
Class III									
SP	0.054	0.152	0.250	-0.118	0.428*	-0.546*	0.391*	0.436*	0.244
C2P	0.172	0.585*	0.328	0.018	-0.030	-0.059	0.314	0.272	0.297
BP	-0.001	0.383*	0.593*	0.382*	-0.787*	0.792*	0.603*	0.729*	-0.360
LP	-0.028	0.339	0.244	0.216	-0.016	-0.440*	0.462*	0.233	0.323

the inferior pharyngeal airway space exhibited a slight but substantial connection with the anteroposterior skeletal arrangement. Study by Alves et al (11) and Opdebeeck et al (1) revealed in Class I and Class II there were no significance difference in BP but significantly longer in Class III pattern. Also, another study conducted by Cheng et al (10) reported identical results to our study where BP is significantly longer in Class III compared to Class I and Class II and had moderative positive correlation with of hyoid bone's horizontal position.

The laryngopharynx, has the epiglottis as its anterior wall and makes up the apical portion of the pharynx. Cheng et al (10) reported only Class III skeletal group male demonstrated considerably greater LP and no differences in other skeletal patterns or female category and also in males with Class III skeletal form, the mandibular position i.e., U1-L1 angle, L1-MP angle and LP had a positive, moderate, and significant correlation. Upon skeletal comparison in the present study, Class III subjects showed longer LP than Class I and Class II. According to the gender comparison, similar results were found to the results obtained by Cheng et al [10]. Considering C2P and LP among the skeletal patterns, a significant correlation was found and upon correlation analysis we found that in Class III both C2P and LP were significantly more in contrast to Class I and II group.

When pharyngeal airway correlation was examined using skeletal patterns, no correlation with SNA angle across the different skeletal configurations was obtained, showing that no correlation with the length of the airway space of pharynx and the position of the maxilla but there was a moderate connection with the position of the mandible (SNB) and the length of airway space of pharynx in Class III as a strong positive relation was found with L1-MP angle, U1-L1 angle.

In the literature, there are descriptions of the effects of changing the antero-posterior location of lower jaw on the location of hyoid bone and the airway space of pharynx. Although the lower jaw is further away than the cervical vertebrae it has been a reference plane for measuring the location of the hyoid bone in numerous studies. Adamidis and Spyropoulos(17) found that hy-

Parameters	Age	SNA	SNB	ANB	U1-PP	L1-MP	U1 L1	HH	HV
Class I									
SP	-0.175	-0.469*	0.127	0.179	-0.208	-0.117	0.018	-0.028	-0.135
C2P	-0.109	-0.263	-0.056	-0.027	-0.361*	-0.272	-0.025	0.035	-0.190
BP	0.074	-0.156	0.225	0.163	-0.284	-0.224	-0.056	0.294	-0.128
LP	0.151	-0.327	0.028	0.046	0.277	-0.269	-0.050	0.011	-0.119
Class II									
SP	0.206	-0.350	-0.349	-0.110	-0.139	-0.012	0.078	0.026	-0.179
C2P	0.357*	0.226	-0.054	-0.114	-0.354*	0.423*	-0.260	-0.272	-0.001
BP	0.263	0.305	0.057	-0.014	-0.275	0.350	-0.296	-0.340	0.011
LP	0.012	-0.183	-0.090	-0.091	-0.024	-0.029	0.033	0.087	0.044
Class III									
SP	0.130	-0.386*	-0.482*	0.472*	0.253	0.398*	-0.235	-0.247	-0.263
C2P	0.269	0.223	0.311	-0.215	-0.683*	-0.631*	0.685*	-0.112	0.343
BP	-0.125	0.287	0.264	-0.677*	-0.571*	0.790*	-0.463*	0.371*	-0.063
LP	-0.275	0.137	0.163	-0.179	-0.261	-0.260	0.143	-0.096	0.321

oid bone is typically positioned more anteriorly in Class III pattern rather than in Class I and Class II. Amayeri (18) noted that position of hyoid bone is more inferiorly in Class III occlusion whereas in Class II occlusion, it is positioned more superiorly. However, in our study we found that hyoid bone is placed more anteriorly in Class III skeletal form which were similar to the study by Adamidis and Spyropoulos (17).

The current study demonstrated significantly greater hyoid bone's horizontal position in Class III than in Class I and Class II. Also, on gender comparison hyoid bone's horizontal position was more in male with Class III skeletal group, whereas Cheng et al (10) stated that hyoid bone's horizontal location was more in female with Class III skeletal pattern. Interestingly, another study done by Jose et.al (19) came to the conclusion that the hyoid's horizontal position was extremely stable and that there were no statistically significant differences among the patterns.

The hyoid bone's vertical position also varies according to skeletal pattern. Jose et.al [(19)] and Duggal et.al (20) reported individuals with various forms of vertical jaw dysplasia had hyoid bones in comparable vertical position and concluded that a positive correlation was observed in the hyperdivergent group between the anteroposterior location of the hyoid bone and pharyngeal space. Mortazavi et al (21) found the placement of the hyoid bone varies depending on the skeletal class and compared to male, in female it is more superior and posterior. Our study demonstrates that HV is more in Class III subjects than compared to Class I and Class II whereas study by Cheng et al [10] reported that HV is more in Class II subjects than compared to Class III and Class I. This might be due to variable used to assess the measures of hyoid bone and may need to be accepted with some individual deviations. Another study conducted by Yamaoka et.al (22) stated that the positional assessment of the anterior-posterior location of hyoid bone and the tongue's posterior edge changed as a result of the fact that genioglossus activities that cause tongue protrusion are consistently associated to hyoid position in individuals with tongue protrusion and retrognathia. In the current study, upon Pearson correlation analysis we found that in skeletal Class I male subjects' hyoid bone's horizontal position was significantly correlated with C2P, BP, and LP in males and no significant values were obtained in case of females and none of the parameters of airway space of pharynx were linked with the vertical location of the hyoid bone. Mortazavi et al (21) and Cheng et al (10) also reported similar results to our study.

The subtle variation between the hyoid bone and airway space of pharynx may also be a result of the pharynx's ability to adapt to its surroundings during growth of the head and neck, thereby pertaining to maintain the patent airway.

CONCLUSION

The skeletal Class III sample group with mandibular protrusion have wider pharyngeal airway space whereas in Class II group the pharyngeal airway space is narrower. Due to the prominence of the mandible, the position of the hyoid bone was more inferior and anterior in skeletal Class III study group whereas in Class II it is positioned postero-superiorly which can render the individuals more vulnerable to sleep breathing disorder. Between the three different skeletal configurations, there were no apparent variations in the vertical positioning hyoid bone. Hence, these measurements of the current study can be used clinically to evaluate long-term airway space abnormalities, provide prognostications, and contribute to treatment planning, monitoring, and management of skeletal jaw pattern discrepancies through a variety of treatment modalities including orthodontic and dentofacial orthopaedic treatment protocol as well as orthognathic surgeries while maintaining the global standard value of 15-20mm and 10-12mm for upper and lower pharyngeal airway spaces respectively. **R**

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