Original Article

Comparison of pharyngeal airway dimension, tongue and hyoid bone position based on ANB angle

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ABSTRACT

Objective: This study was undertaken to cephalometrically evaluate the pharyngeal airway dimension, tongue and hyoid position in subjects with normal nasorespiratory functions having different dentofacial patterns (A-point-nasion-B-point [ANB] >40 and ANB <40) and to find if a correlation existed. **Materials and Methods:** Class I and Class II Division I patients were selected randomly. Lateral head cephalograms were taken in normal head position within a lead foil attached to the tongue tip and a barium coating on the dorsal surface of tongue. The lateral cephalograms obtained were traced using lead acetate paper and measurements were taken. Different analyses were done for the pharyngeal airways, hyoid bone, and tongue. **Results:** The ANB angle is a significant predictor for Class I and Class II Division I malocclusion, and the mean ANB angle of Class II Division I was different and higher. The overall mean pharynx and hyoid parameters were different and lower in Class II Division I patients than in Class I patients. The mean tongue parameter almost remained the same except for the tongue position (TT-LOP), which was higher in Class II Division I. **Conclusion:** In general, there was no difference either in the pharyngeal airway anterioposterior dimension or in the position and relationship of the hyoid bone and tongue, between Class I and Class II Division I patients. These findings are consistent with the findings in studies. Anterioposterior dimension of the upper airway is usually maintained by adaptation of both the tongue and the hyoid bone. The result should be viewed in the light of the fact that only anterioposterior dimensions were taken into consideration; the vertical and transverse dimensions of these complex anatomical structures need to have newer three-dimensional (3-D) imaging technique to find if a correlation existed between them, making future studies more comprehensive.

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Introduction

The relationship of the pharynx and associated structures such as the tongue and hyoid bone with dentofacial pattern has been intensively researched.[1] Several studies have tried to correlate patients with normal nasorespiratory functions with different malocclusions and airway dimensions. Kirjavainen *et al.*[2] found a relationship of varying degree between the pharyngeal dimensions and sagittal jaw relationship. Ceylan and Oktay[3] reported no statistically significant difference between the groups based on the ANB angle and nasopharyngeal size, but they observed a negative correlation between the ANB angle and

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oropharyngeal size. The belief that the hyoid bone and tongue may be correlated with the mandibular position and morphology has led to a consideration of various skeletal types. Gobeille and Bowman,[4] Cuozzo and Bowman[5] reported variations in the position of the hyoid bone relative to the mandible within a skeletal Class I context, which led to the speculation that variability in the hyoid position is partly determined by mandibular posture.

According to Brodie (1950), the position of the hyoid bone relative to the cranial base and the mandible has been of interest specifically as an indicator of tongue posture and function, and has an important role in maintaining the airway and upright natural head position. Clinicians generally agree on a morphogenetic role of the tongue; thus, any alteration or change in the spatial relationships of the hyoid bone, tongue, and airway have wide functional significance and reciprocal consequences. According to Biorgue, the influence of the tongue on the morphology of the dental arches and on the occlusion depends not only on the lingual volume but also on its posture and mobility.[6]

Thurow proposed that the geniohyoid muscle functions to adjust the anterioposterior position of the hyoid and to maintain the airway patency throughout the various movements of the craniofacial complex.[7] The position of the hyoid bone on the genial tubercle level will 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 create a stronger opening force on the mandible, which can be of significance in the development and establishment of the dentofacial pattern and function.[8]

As of yet, there are only few studies relating the position of the pharyngeal airway, the hyoid bone and tongue to different skeletal patterns using the ANB angle. The present study aims to evaluate the pharyngeal airway dimension, tongue and hyoid position by the use of lateral cephalograms in subjects having ANB >4 and ANB <4.

Aim and Objectives

This study was undertaken to evaluate the pharyngeal airway dimension, tongue and hyoid position by the use of lateral cephalograms in subjects with normal nasorespiratory functions having ANB >4° and ANB <4°.

Materials and Methods

A total of 61 subjects (Class I, $n = 29$; Class II, $n = 32$) in an age range of 11-19 years (mean) were evaluated. The study was approved by the Ethics Committee of Career Post Graduate Institute of Dental Sciences and Hospital. The sagittal skeletal differentiation of subjects with Angle's Class I and Class II Division I molar relation was achieved with measurement of the ANB angle.[9] The subjects of this study had no history of orthodontic or dentofacial orthopaedic treatments. They could breathe comfortably through the nose and had no deleterious habits. They possessed all permanent teeth up to second molars; there was no burn/wound scar in the head and neck region.

- Lateral cephalograms were taken in the natural head position using the standard method.[10] A lead foil was placed on the tip of the tongue with glass ionomer cement (GIC) mixture and a barium paste coating was done on the tongue
- The radiographs obtained were traced using lead acetate paper and 4H pencil, and various landmarks for evaluation of the tongue, hyoid bone, and pharynx were identified and marked [Figure 1]
- ANB analysis was done for the sagittal apical base relationship on the study samples.

Tongue study

To evaluate the tongue position, the following measurements were made. The X and Y coordinates of the deepest point of the epiglottis (E) and the center of the lead disc on the tongue tip (TT) were identified.

TGL (mm) = tongue length. Linear distance between E and TT; TGH (mm) = tongue height. Linear distance along the perpendicular bisector of the E-TT line to the dorsum of the tongue; TT/LOP (mm) = tongue tip relative to lower occlusal plane. Linear distance between TT and the LOP (a line between the midpoint of the occlusal surface of the mandibular molar and incisor tip) measured

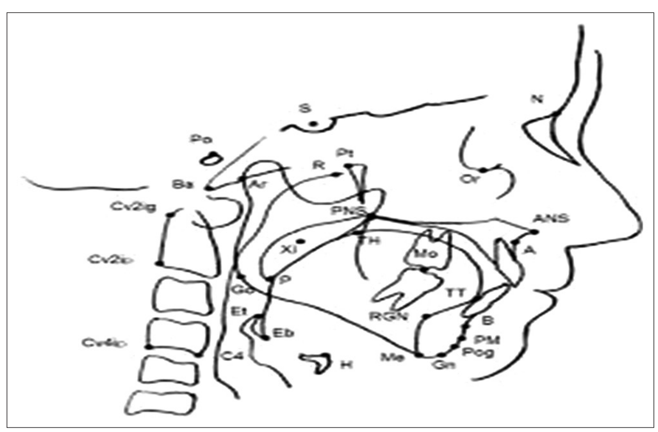

Figure 1: Different identification landmarks

perpendicular to the LOP; TT-L1/LOP (mm) = tongue tip relative to lower incisor tip. Linear distance between TT and a perpendicular line to LOP through the incisor tip.

Hyoid bone study

The Frankfort horizontal plane and a line perpendicular to it passing through sella were taken as reference plane to evaluate the hyoid bone.

The horizontal measurements made were:
Yl; At-APH: Distance of the most anterior point of the hyoid bone (APH) from the most anterior point of the atlas (At), Y2; S-APH: Distance of APH from the center of sella turcica (S), Y3; Pog-APH: Distance of the anterior point of hyoid bone (APH) to pogonion (Pog) (measured indirectly through projections of both points on the line perpendicular to FH from S), Y4; Pog-APH: Distance measured directly from APH to Pog, Y5; A-APH: Distance of APH to point A (measured through projections of both points on the line perpendicular to FH from S), Y6; N-APH: Distance of APH to nasion (N) (measured through projections of both points on the line perpendicular to FH from S).

The vertical measurements made were:
Y7; PPH-FH: Distance of the posterior point of hyoid (PPH) to FH, Y8; APH-FH: Distance of APH to FH, Y9; GoP-APH: Distance of APH to a line drawn from gonion parallel (GoP) to FH, Y10; GoP-PPH: Distance of PPH to a line drawn from GoP to FH.

The angular measurements taken were:
Y11; LAH-MP: Angle formed by the LAH and mandibular plane, Y12; LAH-FOP: Angle formed by the LAH and the functional occlusal plane (FOP), Y13; LAH-PP: Angle formed by the LAH and the palatal plane (PP), Y14; LAH- BaN: Angle formed by the LAH and the basion-nasion (BaN) plane, Y15; LAH-FH: Angle formed by the LAH and the FH, Y16; LAH-PBR: Angle formed by the LAH and the posterior border of the ramus of the mandible (PBR).

Upper airway study

For the evaluation of the upper airway, the following measurements were made:
The length of the (presellar) anterior cranial base (S-N), the length of the postsellar part of the posterior cranial base (ba-S), the total or effective cranial base length (ba-N), the length of the palate (floor of the nasal cavity). The distance between PNS and ANS. The posterior height of the nasal cavity (SPNS). The vertical diameter of the choanal opening (ho and PNS). The length of the pharyngeal clivus (ba to ho). The length of the floor of the nasopharynx (AA to PNS). The total depth of the nasopharynx. The distance from ba to PNS. The effective length of the maxilla (TMJ to ANS). The upper anterior facial height (N and ANS), the distance from aa to hy, the distance from so to in, the distance from hy to rgn, upper pharynx, lower pharynx, ho-ad_1, ad_2-ptm, ba-ad_1, ad_1-ptm, E-pns, soft palate midpoint-pharnyx, soft palate end-pharynx, 3CV-pharynx, e-pharynx, eb-pharynx.

Angular measurement

The saddle angle included between the lines joining ba to S and S to N (ba-S-N). The angle between the anterior cranial base and point A on the maxilla. The angle between the palatal plane (PNS-ANS) and the anterior cranial base (S-N). The angle of nasopharyngeal depth. Ba-S-PNS. The vertical angle of the nasopharynx. PNS-Ba-S. The roof angle of the nasopharynx. Ba-Ho-PNS.

Area measurement

The areas of the tongue; upper, middle, and lower pharynx; soft palate; and oral cavity were calculated using ImageJ software (Freely available online).

ImageJ is an image-processing program that can calculate the area and pixel value statistics of user-defined selections. The image analysis software was set to calculate the area. The outlines of the soft tissues were traced by means of the freehand preselection tool and the computer mouse. The data so obtained were subjected to statistical analysis. All the data obtained were subjected to statistical analysis and summarized as mean ± SD. The groups were compared by independent student's *t*-test and the significance of parametric *t*-test was also confirmed by nonparametric Mann-Whitney U test. Diagnostic accuracy of different linear and angular measurements was done by receiver operating characteristics (ROC) curve analysis. A two-sided (α =2) P value less than 0.05 ($P < 0.05$) was considered statistically significant.

Results

The present cephalometric study determines and compares linear and angular parameters of the pharyngeal airway, the tongue and hyoid bone in Angle's Class II Division I malocclusion subject with ANB >4 with those with ANB <4. A total of 61 symptomatic (Class I, n = 29; Class II, n = 32) age-matched patients of either sex were recruited and evaluated. The comparative linear and angular parameters of the pharyngeal airway, tongue, and hyoid bone in subjects with the ANB angle more than 4° are summarized below respectively.

Pharynx-linear measurements

Females: The pharynx linear and angular parameters of two groups of females are summarized in Table 1, and

Table 1: Linear and angular parameters (mean ± SD) of Class I and Class II Division I females

Parameters	Variables	Class I (*n* = 7)	Class II (*n* = 18)	Mean difference (Class I – Class II)	*t* (DF = 23)	*P*
Linear (mm)	S-N	68.14 ± 4.60	65.94 ± 3.00	2.20	1.42	0.170
	ba-S	43.71 ± 3.20	43.00 ± 2.72	0.71	0.56	0.580
	ba-N	102.14 ± 5.64	99.89 ± 3.36	2.25	1.24	0.227
	ANS-PNS	50.71 ± 3.04	49.94 ± 3.98	0.77	0.46	0.650
	S-PNS	44.29 ± 3.30	42.61 ± 2.79	1.67	1.28	0.213
	ho-PNS	28.29 ± 2.81	26.17 ± 2.04	2.12	2.10	0.047
	ba-ho	30.86 ± 4.60	29.44 ± 2.20	1.41	1.05	0.304
	AA-PNS	34.00 ± 4.12	32.50 ± 4.60	1.50	0.75	0.460
	ba-PNS	44.43 ± 4.50	42.50 ± 4.09	1.93	1.03	0.314
	N-ANS	49.43 ± 3.91	46.83 ± 2.73	2.60	1.89	0.071
	AA-Hy	57.43 ± 5.97	53.17 ± 8.30	4.26	1.23	0.230
	Hy-RGN	38.86 ± 4.34	35.39 ± 5.64	3.47	1.46	0.158
	So-IN	21.43 ± 1.81	21.06 ± 1.66	0.37	0.49	0.627
	UP	15.86 ± 1.77	11.78 ± 2.32	4.08	4.19	< 0.001
	LP	9.43 ± 1.62	8.00 ± 1.57	1.43	2.02	0.055
	ho-AD2	10.71 ± 4.07	9.78 ± 2.26	0.94	0.74	0.468
	AD2-PTM	10.57 ± 5.19	10.44 ± 3.24	0.13	0.07	0.942
	ba-AD1	21.57 ± 4.58	22.11 ± 6.31	– 0.54	0.20	0.839
	AD1-PTM	20.86 ± 6.64	19.44 ± 5.24	1.41	0.56	0.579
	E-PNS	55.86 ± 6.74	53.67 ± 4.12	2.19	1.00	0.330
	SPM-P	15.14 ± 2.79	13.11 ± 1.97	2.03	2.06	0.051
	SPE-P	11.71 ± 3.20	11.39 ± 2.87	0.33	0.25	0.807
	V-P	8.43 ± 3.64	8.67 ± 2.59	– 0.24	0.18	0.855
	E-P	11.57 ± 4.24	10.11 ± 2.42	1.46	1.09	0.286
	EB-P	14.57 ± 5.71	11.28 ± 3.10	3.29	1.87	0.074
Angular (degree)	ba-S-N	131.14 ± 7.52	131.67 ± 5.96	– 0.52	0.18	0.856
	S-N-A	83.57 ± 3.60	81.28 ± 4.92	2.29	1.12	0.276
	PNS-ANS/S-N	8.29 ± 4.96	6.83 ± 1.98	1.45	1.07	0.296
	ba-S-PNS	61.00 ± 9.42	59.67 ± 5.81	1.33	0.43	0.670
	PNS-ba-S	60.00 ± 5.69	59.89 ± 4.61	0.11	0.05	0.960
	ba-ho-PNS	96.86 ± 9.26	98.11 ± 9.90	-1.25	0.29	0.775

the *t*-test revealed a significant difference between the two groups ($P < 0.05$ or $P < 0.001$) and lower ho-PNS and UP in group 1 as compared to group 2; however, other parameters ($P > 0.05$) between the two groups were found to be statistically similar [Table 1].

Similarly, in the two groups the difference in the pharynx angular parameters of females was statistically significant [Table 1].

The mean pharynx-linear parameters of males of the two groups and the *t*-test revealed significantly different ($P < 0.05$) and lower AA-H4 and AD2-PTM while significantly ($P < 0.05$) higher E-P in Class II Division I as compared to Class I; however, other parameters did not differ ($P > 0.05$) between the two groups, i.e. they were found to be statistically similar [Table 2]. Similarly, comparing the mean pharynx angular parameters of males of Class II, the *t*-test revealed that they were similar ($P > 0.05$) to the pharynx angular parameters of males between the two classes, i.e. they did not differ statistically [Table 2].

The mean pharynx-linear parameters of the two groups (females and males) and the *t*-test revealed significantly ($P < 0.05$ or $P < 0.01$) different and lower mean S-N, S-PNS, ho-PNS, AA-Hy, Hy-RGN, UP, LP, and AD2-PTM in Class II Division I subjects as compared to Class I; however, it showed no significant difference between the two groups [Table 3]. The overall mean pharynx-angular parameters of the two groups were similar ($P > 0.05$).

Tongue

Linear parameters of the tongue in the females of the two groups showed no significant difference and the *t*-test revealed significantly lower ($P < 0.05$) TGL while higher ($P < 0.01$) TT/LOP was significantly higher ($P < 0.01$) in Class II Division I as compared to Class I; however, other parameters between the two groups were found to be statistically the same [Table 4].

The mean male tongue linear parameters of Class II and *t*-test revealed significantly different ($P < 0.05$) and higher TT/LOP in Class II Division I as compared to Class I; however, the difference between the two groups was not statistically significant ($P < 0.05$) [Table 5].

The overall (male and female) mean tongue linear parameters of the two groups revealed higher TT/LOP in Class II Division I as compared to Class I; however, the difference in other parameters between the two groups was not statistically significant [Table 6].

Hyoid bone

Females: The hyoid bone linear and angular parameters of Class I and Class II Division I females are summarized in Table 7. Comparing the mean

Table 2: Pharynx linear and angular parameter (mean ± SD) of Class I and Class II Division I males

Parameters	Variables	Class I (*n* = 22)	Class II (*n* = 14)	Mean difference (Class I – Class II)	*t* (DF = 34)	*P*
Linear (mm)	S-N	69.32 ± 3.34	68.57 ± 2.93	0.75	0.68	0.498
	ba-S	43.91 ± 2.76	44.64 ± 3.79	−0.73	0.67	0.506
	ba-N	101.55 ± 4.40	103.00 ± 5.66	−1.45	0.86	0.393
	ANS-PNS	50.32 ± 4.09	51.93 ± 4.10	−1.61	1.15	0.258
	S-PNS	46.36 ± 2.32	45.43 ± 3.52	0.94	0.96	0.343
	ho-PNS	29.18 ± 3.23	28.29 ± 3.56	0.90	0.78	0.441
	ba-ho	29.09 ± 3.84	29.64 ± 4.13	−0.55	0.41	0.685
	AA-PNS	33.05 ± 3.70	33.57 ± 3.55	−0.53	0.42	0.675
	ba-PNS	43.77 ± 4.47	43.36 ± 3.75	0.42	0.29	0.775
	N-ANS	49.32 ± 4.12	50.00 ± 3.59	−0.68	0.51	0.615
	AA-H4	63.09 ± 8.06	56.93 ± 9.43	6.16	2.09	0.044
	H4-RGN	38.23 ± 6.95	34.50 ± 5.54	3.73	1.69	0.100
	So-IN	21.45 ± 2.32	21.79 ± 1.89	−0.33	0.45	0.658
	UP	14.73 ± 2.43	13.64 ± 3.84	1.08	1.04	0.305
	LP	11.18 ± 2.72	10.86 ± 2.44	0.32	0.36	0.719
	ho-AD2	8.64 ± 3.20	10.14 ± 4.99	−1.51	1.11	0.276
	AD2-PTM	13.86 ± 3.06	11.07 ± 3.85	2.79	2.41	0.021
	ba-AD1	21.27 ± 5.81	21.21 ± 5.75	0.06	0.03	0.977
	AD1-PTM	20.86 ± 6.02	20.71 ± 6.01	0.15	0.07	0.943
	E-PNS	56.77 ± 6.41	57.21 ± 6.95	−0.44	0.20	0.846
	SPM-P	13.14 ± 3.08	14.21 ± 3.33	−1.08	0.99	0.328
	SPE-P	13.00 ± 4.11	13.50 ± 3.52	−0.50	0.38	0.710
	V-P	10.68 ± 4.09	12.29 ± 3.07	−1.60	1.26	0.217
	E-P	12.27 ± 3.93	14.93 ± 2.87	−2.66	2.18	0.036
	EB-P	14.82 ± 4.34	16.29 ± 3.77	−1.47	1.04	0.306
Angular (degree)	ba-S-N	127.18 ± 4.70	129.00 ± 4.98	−1.82	1.11	0.276
	S-N-A	82.91 ± 6.34	82.43 ± 2.90	0.48	0.27	0.792
	PNS-ANS/S-N	6.55 ± 4.08	6.93 ± 1.86	−0.38	0.33	0.744
	ba-S-PNS	58.77 ± 6.10	57.29 ± 2.70	1.49	0.86	0.398
	PNS-ba-S	63.18 ± 3.92	62.43 ± 4.47	0.75	0.53	0.598
	ba-ho-PNS	97.00 ± 7.43	94.64 ± 6.50	2.36	0.97	0.337

Table 3: Pharynx linear and angular parameters (mean ± SD) of two groups

Parameters	Variables	Class I (*n* = 29)	Class II (*n* = 32)	Mean difference (Class I – Class II)	*t* (DF = 59)	*P*
Linear (mm)	S-N	69.03 ± 3.63	67.09 ± 3.21	1.94	2.22	0.030
	ba-S	43.86 ± 2.81	43.72 ± 3.28	0.14	0.18	0.856
	ba-N	101.69 ± 4.63	101.25 ± 4.70	0.44	0.37	0.715
	ANS-PNS	50.41 ± 3.81	50.81 ± 4.09	−0.40	0.39	0.696
	S-PNS	45.86 ± 2.68	43.84 ± 3.39	2.02	2.56	0.013
	ho-PNS	28.97 ± 3.11	27.09 ± 2.96	1.87	2.41	0.019
	ba-ho	29.52 ± 4.02	29.53 ± 3.13	−0.01	0.02	0.988
	AA-PNS	33.28 ± 3.75	32.97 ± 4.15	0.31	0.30	0.764
	ba-PNS	43.93 ± 4.41	42.88 ± 3.91	1.06	0.99	0.325
	N-ANS	49.34 ± 4.00	48.22 ± 3.47	1.13	1.18	0.244
	AA-H4	61.72 ± 7.90	54.81 ± 8.87	6.91	3.20	0.002
	H4-RGN	38.38 ± 6.35	35.00 ± 5.52	3.38	2.22	0.030
	So-IN	21.45 ± 2.18	21.38 ± 1.77	0.07	0.14	0.886
	UP	15.00 ± 2.31	12.59 ± 3.16	2.41	3.36	0.001
	LP	10.76 ± 2.59	9.25 ± 2.44	1.51	2.35	0.022
	ho-AD2	9.14 ± 3.47	9.94 ± 3.65	−0.80	0.88	0.385
	AD2-PTM	13.07 ± 3.85	10.72 ± 3.48	2.35	2.50	0.015
	ba-AD1	21.34 ± 5.46	21.72 ± 6.00	−0.37	0.25	0.801
	AD1-PTM	20.86 ± 6.05	20.00 ± 5.53	0.86	0.58	0.563
	E-PNS	56.55 ± 6.38	55.22 ± 5.72	1.33	0.86	0.393
	SPM-P	13.62 ± 3.09	13.59 ± 2.66	0.03	0.04	0.971
	SPE-P	12.69 ± 3.89	12.31 ± 3.30	0.38	0.41	0.684
	V-P	10.14 ± 4.04	10.25 ± 3.31	−0.11	0.12	0.906
	E-P	12.10 ± 3.94	12.22 ± 3.54	−0.12	0.12	0.905
	EB-P	14.76 ± 4.60	13.47 ± 4.20	1.29	1.15	0.256
Angular (degree)	ba-S-N	128.14 ± 5.62	130.50 ± 5.63	−2.36	1.64	0.107
	S-N-A	83.07 ± 5.74	81.78 ± 4.14	1.29	1.01	0.316
	PNS-ANS/S-N	6.97 ± 4.28	6.88 ± 1.90	0.09	0.11	0.914
	ba-S-PNS	59.31 ± 6.92	58.63 ± 4.80	0.69	0.45	0.652
	PNS-ba-S	62.41 ± 4.52	61.00 ± 4.66	1.41	1.20	0.234
	ba-ho-PNS	96.97 ± 7.73	96.59 ± 8.64	0.37	0.18	0.861

Table 4: Tongue linear parameters (mean ± SD) of Class I and Class II Division I females

Variables	Class I (*n* = 7)	Class II (*n* = 18)	Mean difference (Class I – Class II)	*t* (DF = 23)	*P*
TGL	72.00 ± 5.72	65.94 ± 6.80	6.06	2.08	0.049
TGH	30.43 ± 3.64	31.17 ± 4.02	− 0.74	0.42	0.677
TT/LOP	− 1.86 ± 2.73	2.00 ± 2.22	− 3.86	3.66	0.001
TT-L1/LOP	7.71 ± 3.09	8.78 ± 5.56	− 1.06	0.47	0.640

Table 5: Tongue linear parameters (mean ± SD) of Class I and Class II Division I males

Variables	Class I (*n* = 22)	Class II (*n* = 14)	Mean difference (Class I – Class II)	*t* (DF = 34)	*P*
TGL	68.86 ± 6.83	69.79 ± 5.37	− 0.92	0.43	0.672
TGH	30.68 ± 4.28	28.64 ± 5.02	2.04	1.30	0.201
TT/LOP	-1.32 ± 3.76	3.50 ± 4.16	− 4.82	3.60	0.001
TT-L1/LOP	8.36 ± 5.57	7.57 ± 4.55	0.79	0.45	0.659

Table 6: Tongue linear parameter levels (mean ± SD) of two groups

Variables	Class I (*n* = 29)	Class II (*n* = 32)	Mean difference (Class I – Class II)	*t* (DF = 59)	*P*
TGL	69.62 ± 6.62	67.63 ± 6.41	2.00	1.19	0.237
TGH	30.62 ± 4.07	30.06 ± 4.59	0.56	0.50	0.619
TT/LOP	− 1.45 ± 3.50	2.66 ± 3.25	− 4.10	4.75	0.000
TT-L1/LOP	8.21 ± 5.04	8.25 ± 5.10	− 0.04	0.03	0.974

Table 7: Hyoid bone linear and angular parameters (mean ± SD) of Class I and Class II Division I females

Parameters	Variables	Class I (*n* = 7)	Class II (*n* = 18)	Mean difference (Class I – Class II)	*t* (DF = 23)	*P*
Linear (mm)	AA-APH	22.43 ± 6.53	20.75 ± 5.90	1.68	0.62	0.541
	S-APH	9.00 ± 10.18	9.28 ± 5.56	− 0.28	0.09	0.930
	POG-APH	50.43 ± 4.93	44.03 ± 6.02	6.40	2.50	0.020
	POG-APH	50.43 ± 4.86	44.94 ± 6.30	5.48	2.07	0.050
	A-APH	57.57 ± 8.44	58.11 ± 6.40	− 0.54	0.17	0.864
	N-APH	58.57 ± 11.46	59.78 ± 8.12	− 1.21	0.30	0.769
	PPH-FH	91.29 ± 12.46	89.67 ± 8.77	1.62	0.37	0.716
	APH-FH	103.86 ± 6.47	103.03 ± 8.97	0.83	0.22	0.826
	GOP-APH	23.57 ± 3.15	26.00 ± 4.77	− 2.43	1.24	0.228
	GOP-PPH	10.57 ± 7.37	13.11 ± 4.99	− 2.54	1.00	0.328
Angular (degree)	LAH-MP	9.43 ± 9.14	2.83 ± 11.08	6.60	1.40	0.176
	LAH-FOP	17.86 ± 11.19	17.67 ± 10.09	0.19	0.04	0.968
	LAH-PP	26.86 ± 13.97	29.61 ± 10.38	− 2.75	0.54	0.594
	LAH-BaN	54.29 ± 14.48	54.50 ± 13.32	− 0.21	0.04	0.972
	LAH-FH	28.14 ± 16.44	29.72 ± 11.15	− 1.58	0.28	0.783
	LAH-PBr	126.86 ± 14.51	126.61 ± 12.53	0.25	0.04	0.967

hyoid bone linear parameters of females of two groups showed significantly different ($P < 0.05$) and lower mean POG-APH in Class II Division I as compared to Class I; however, other parameters did not differ significantly between the two groups [Table 7]. Similarly, comparing the mean hyoid bone angular parameters of females of the two groups and the *t*-test revealed similar ($P > 0.05$) hyoid bone angular parameters between the two groups [Table 7].

The mean hyoid bone linear parameters of males of two groups and the *t*-test revealed significantly lower POG-APH ($P < 0.01$) while significantly higher ($P < 0.05$) A-APH and N-APH in Class II Division I as compared to Class I. Other parameters between the two groups were found to be statistically similar [Table 8]. Similarly, the *t*-test revealed ($P > 0.05$) hyoid bone angular parameters between the two groups that did not differ significantly ($P > 0.05$).

Comparing the overall mean hyoid bone linear parameters of the two groups and the *t*-test revealed significantly lower AA-APH, S-APH, Pog-APH, Pog-APH, and PPH-FH while significantly higher ($P < 0.05$ or $P < 0.01$) A-APH, N-APH, and GOP-PPH in Class II Division I as compared to Class I ($P < 0.05$); however, APH-FH and GOP-PPH did not differ between the two groups ($P > 0.05$) [Table 9]. Similarly, comparing the overall mean hyoid bone angular parameters of the two groups and the *t*-test revealed that hyoid bone angular parameters between the two groups did not differ statistically ($P > 0.05$) [Table 10].

Area

The mean area of different parameters of females of the two groups and the *t*-test revealed that there was no statistically significant difference between the two groups.

The mean area of different parameters of males of the two groups and the *t*-test revealed statistically significant difference ($P < 0.05$) and higher cervical pharynx of Class II Division I as compared to Class I; however, the difference in area of other parameters was not statistically significant ($P > 0.05$) [Table 11].

Total (Females and Males)

The overall (females and males) area of different parameters of the two groups (Class I and Class II Division I) are summarized in Table 12. Comparing the overall mean area of different parameters of the two groups and the *t*-test revealed statistically significant ($P < 0.05$) difference and lower upper pharynx in Class II Division I as compared to Class I; however, area of the other parameters did not differ ($P > 0.05$) and were found to be statistically similar [Table 12].

Table 8: Hyoid bone linear and angular parameters (mean ± SD) of Class I and Class II Division I males

Parameters	Variables	Class I (*n*=22)	Class II (*n*=14)	Mean difference (Class I – Class II)	*t* (DF=34)	*P*
Linear (mm)	AA-APH	25.95±5.18	22.18±6.18	3.78	1.98	0.056
	S-APH	16.00±7.45	9.61±5.59	6.39	2.75	0.009
	POG-APH	47.86±5.18	46.21±5.66	1.65	0.90	0.375
	POG-APH	50.09±5.88	47.89±6.04	2.20	1.08	0.287
	A-APH	52.05±6.95	56.86±6.47	−4.81	2.08	0.045
	N-APH	51.82±8.42	57.96±7.32	−6.15	2.24	0.032
	PPH-FH	98.64±9.71	93.75±8.34	4.89	1.55	0.130
	APH-FH	109.95±8.40	106.00±7.44	3.95	1.44	0.160
	GOP-APH	22.36±8.63	25.79±4.77	−3.42	1.35	0.185
	GOP-PPH	18.64±12.45	14.07±5.06	4.56	1.30	0.202
Angular (degree)	LAH-MP	5.23±11.11	−1.14±9.76	6.37	1.76	0.088
	LAH-FOP	19.32±10.74	16.36±7.83	2.96	0.89	0.380
	LAH-PP	27.73±15.49	26.79±7.70	0.94	0.21	0.834
	LAH-BaN	53.41±11.38	54.29±7.98	−0.88	0.25	0.803
	LAH-FH	26.18±11.74	27.00±7.34	−0.82	0.23	0.817
	LAH-PBr	126.50±12.05	123.79±7.46	2.71	0.75	0.456

Table 9: Hyoid bone linear and angular parameter levels (mean ± SD) of two groups

Parameters	Variables	Class I (*n*=29)	Class II (*n*=32)	Mean difference (Class I – Class II)	*t* (DF=59)	*P*
Linear (mm)	AA-APH	25.10±5.62	21.38±5.97	3.73	2.50	0.015
	S-APH	14.31±8.55	9.42±5.48	4.89	2.68	0.009
	Pog-APH	48.48±5.15	44.98±5.88	3.50	2.46	0.017
	Pog-APH	50.17±5.57	46.23±6.27	3.94	2.58	0.012
	A-APH	53.38±7.57	57.56±6.36	−4.18	2.35	0.022
	N-APH	53.45±9.48	58.98±7.71	−5.54	2.51	0.015
	PPH-FH	96.86±10.69	91.45±8.69	5.41	2.18	0.033
	APH-FH	108.48±8.30	104.33±8.34	4.15	1.95	0.056
	GOP-APH	22.66±7.64	25.91±4.69	−3.25	2.02	0.047
	GOP-PPH	16.69±11.84	13.53±4.96	3.16	1.38	0.172
Angular (degree)	LAH-MP	6.24±10.67	1.09±10.55	5.15	1.89	0.063
	LAH-FOP	18.97±10.66	17.09±9.05	1.87	0.74	0.461
	LAH-PP	27.52±14.90	28.38±9.27	−0.86	0.27	0.786
	LAH-BaN	53.62±11.92	54.41±11.14	−0.79	0.27	0.791
	LAH-FH	26.66±12.73	28.53±9.63	−1.88	0.65	0.516
	LAH-PBr	126.59±12.41	125.38±10.56	1.21	0.41	0.682

Table 10: Area of different parameters (mean ± SD) of Class I and Class II Division I females

Variables	Class I (*n*=7)	Class II (*n*=18)	Mean difference (Class I – Class II)	*t* (DF=23)	*P*
Upper pharynx	41167.71±9103.33	34819.50±12032.94	6348.21	1.26	0.222
Middle pharynx	44720.00±12218.25	45197.44±9740.30	−477.44	0.10	0.919
Lower pharynx	39049.00±6108.00	38192.94±12481.57	856.06	0.17	0.865
Cervical pharynx	32941.00±8125.04	34605.61±16283.03	−1664.61	0.26	0.800
Soft palate	26519.57±5304.34	28054.94±5818.07	−1535.37	0.61	0.550
Tongue	324208.71±33162.14	297236.39±48497.20	26972.33	1.35	0.192
Oral cavity	387657.14±35077.49	355546.83±50130.62	32110.31	1.54	0.136

Table 11: Area of different parameters (mean ± SD) of Class I and Class II Division I malocclusion males

Variables	Class I (n = 22)	Class II (n = 14)	Mean difference (Class I – Class II)	t (DF = 34)	P
Upper pharynx	40311.05 ± 12546.39	33819.07 ± 7014.44	6491.97	1.76	0.087
Middle pharynx	48641.00 ± 11664.14	48128.21 ± 9356.08	512.79	0.14	0.891
Lower pharynx	50250.45 ± 19796.90	42259.64 ± 13745.19	7990.81	1.32	0.196
Cervical pharynx	27839.73 ± 11427.77	36810.00 ± 13083.50	– 8970.27	2.17	0.037
Soft palate	30381.23 ± 6035.27	28014.93 ± 6343.26	2366.30	1.12	0.269
Tongue	294468.64 ± 41738.36	310875.86 ± 37009.89	– 16407.22	1.20	0.238
Oral cavity	376615.64 ± 47456.15	370745.57 ± 35133.83	5870.06	0.40	0.693

Table 12: Area of different parameters (mean ± SD) of two groups

Variables	Class I (n = 29)	Class II (n = 32)	Mean difference (Class I – Class II)	t (DF = 59)	P
Upper pharynx	40517.83 ± 11660.02	34381.81 ± 10014.46	6136.02	2.21	0.031
Middle pharynx	47694.55 ± 11702.33	46479.66 ± 9535.10	1214.90	0.45	0.657
Lower pharynx	47546.66 ± 18047.96	39972.13 ± 12994.73	7574.53	1.89	0.063
Cervical pharynx	29071.07 ± 10817.91	35570.03 ± 14778.92	– 6498.96	1.94	0.057
Soft palate	29449.10 ± 6014.62	28037.44 ± 5952.88	1411.67	0.92	0.361
Tongue	301647.28 ± 41351.76	303203.66 ± 43720.21	– 1556.38	0.14	0.887
Oral cavity	379280.83 ± 44450.53	362196.28 ± 44209.36	17084.55	1.50	0.138

Discussion

The present study compares linear and angular parameters of the pharyngeal airway, tongue, and hyoid bone between Class I and Class II Division I subjects based on the ANB angle.[9] ROC analysis for the ANB angle revealed it to be a significant predictor for skeletal sagittal differentiation into Class I and Class II Division I, as a criterion value of 4° in both females (sensitivity: 100%, 95% Class I = 81.3-100; specificity: 85.71%, 95% CI = 42.2-97.6) and males (sensitivity: 100%, 95% CI = 76.7-100; specificity: 81.82%, 95% CI = 59.7-94). Overall the ANB angle showed 100% sensitivity (95% CI = 89-100) and 82.76% specificity (95% CI = 64.2-94.1) with 86.5% positive predictive value for Class II and 100% negative Class I predictive value. These results conform to predictive value of the ANB angle at 4° for differentiating into Class I and Class II Division I skeletal types for the Lucknow population.[8]

Cephalometric analysis of airway can permit precise measurement in saggital plane.[7] In this cephalometric study, comparison between Class I and Class II Division I females revealed similar angular pharyngeal parameters (P > 0.05) [Table 1][11] and significantly different and lower (P < 0.05 or P < 0.001) pharyngeal linear parameters of ho-PNS and UP in Class II Division I as compared to Class I [Table 1]. Similar results have also been reported by other researchers.

Ceylan and Oktay[3] found no statistically significant difference between the groups based on the ANB angle and nasopharyngeal size, but they found a negative correlation between the ANB angle and oropharyngeal size. Statistical comparison between Class I and Class II Division I males revealed similar (P > 0.05) pharyngeal angular parameters [Table 2]. The linear pharyngeal parameters, AA- Hy and AD2- PTM, were significantly lower (P < 0.05) in Class II Division I as compared to Class I and the linear parameter, E-P was significantly higher (P < 0.05) in Class II Division I as compared to Class I; however, other linear pharyngeal parameters did not differ significantly (P > 0.05) [Table 2]. Comparing the overall (males + females) mean pharynx angular parameters of the two groups and the t-test revealed similar (P > 0.05) pharygneal angular parameters [Table 3].[12]

Comparison of overall pharyngeal linear parameters revealed significantly lower (P > 0.05 or P < 0.01) S-N, S-PNS, Ho-PNS, AA-Hy, Hy- RGN, UP, LP, and AD2- PTM in Class II Division I subjects as compared to Class I; however, other parameters did not differ significantly (P > 0.05) between the two groups [Table 3]. Although significant correlations of certain linear parameters are found in this study between anterioposterior skeletal relationship and airway dimensions, the correlations are low, which is in agreement with that reported by Kerr.[13] Out of a total 25 linear measurements for the pharynx, only eight were significantly smaller in Class II Division I than in Class I subjects in overall (male and female) comparisons. Significantly lower AA-Hy measurement in Class II Division I males is an indicator of superiorly placed hyoid than that of Class I males and can probably explain higher E-P linear values in Class II Division I males in comparison to Class I males. A reduced vertical (ho-PNS) and sagittal dimension (UP) of the nasopharynx in Class II Division I females as compared to Class I females is contrary to the findings of some of the previous studies and needs to be interpreted in the light of the studies that have reported no sexual dimorphism of pharyngeal dimensions in relation to dentoskeletal patterns. This may also be a reflection of the fact that the bony nasopharygeal dimension is a relatively independent variable in relation to other dimensions of facial complex.[14] These divergent views can be explained in part by the fact that variables used to measure pharyngeal airway in the previous studies differed from those used in this investigation, which makes the comparison more difficult.

The change in anterioposterior position of the mandible on the hyoid bone position and the pharyngeal airway space is well documented.[15] The precise measurement of the position of the hyoid bone has been difficult.[16] Although cephalometrics have been the preferred research technique, slight variation in the head position in the cephalostat, postural position of the spine, and the state of function have significant effect on the hyoid bone position. The fact that the hyoid bone is supported by the soft tissue and thus lacks hard tissue reference adds to its relative instability.[17] Regarding the setting of the head position, Nakamura evaluated the head position while changing it within the range of 10^o and reported that the influence of change in the head position was negligible when the change was within 5^o. Furthermore, Fujitan *et al*. reported that the position of the tongue and the hyoid bone could be ascertained in a cephalogram taken with the head within the natural position between -5^o and + 5^o.

The position and relationship of the hyoid bone were described by Ioannis P Adamidis and Meriopi N Spyropoulos in 1992. The mean angular measures of the hyoid bone in both males and females did not differ statistically ($P > 0.05$) between Class I and Class II Division I groups [Tables 7, 8].[18] A significantly lower mean Pog-APH in Class II Division I females ($P < 0.05$) as compared to Class I was the only linear measurement to be statistically significant [Table 7]. The linear parameters to differ in the two classes of males that were significantly lower ($P < 0.01$) Pog-APH and higher ($P < 0.05$) A-APH and N-APH statistically significant values in Class II Division I males as compared to Class I males [Table 8]. These values signify a more anteriorly placed hyoid with respect to the pogonion in both males and females of the Class II Division I group and a more inferiorly placed hyoid in Class II Division I males. The overall mean angular values also were not statistically different in both Class I and Class II Division I subjects [Table 9]. The linear values in the total subjects that were statistically lower ($P < 0.05$ or $P < 0.01$) include S-APH, AA-APH, Pog- APH and PPH-FH and parameters that were statistically higher include A-APH, N-NPH, and GOP-PPH in Class II Division I as compared to Class I subjects. Other linear parameters were statistically similar [Table 9]. The greater value of distances from Point A, Point N and gonion to the anterior part of the hyoid may be interpreted as downward displacement of the hyoid in overall Class II Division I subjects as compared to Class I subjects. The statistically similar angular values in males, females, and overall subjects are indicative of no anterioposterior displacement of the hyoid in any of the classes studied.

Tongue posture and function are of interest with regard to their relationship to malocclusion and speech defects.[19] Abnormalities of either posture and/or function could possibly contribute to the development of malocclusion and *vice versa*. It is possible that malocclusion and speech defects could be the causes for the abnormal posture and function of the tongue. Clinicians generally agree on a morphogenetic role of the tongue.

Biourge (1967) stated, "The influence of tongue on the morphology of dental arches and on the occlusion depends not only on the lingual volume but also on its posture and on its mobility."[6] In this study, the tip of the tongue was made radiologically evident with attachment of lead foil to it.

The position and relation of the tongue were described by some of the parameters as described by Allan A. Lowe *et al*. in 1997.[20] In females, the linear parameter of TL was statistically lower ($P < 0.05$) in the Class II Division I group as compared to the Class I group. The linear parameter of the perpendicular distance from the TT/LOP had statistically higher positive values ($P < 0.01$) in Class II Division I group as compared to Class I group [Table 4]. These values are significantly indicative of a shorter tongue length and inferiorly positioned tongue in female Class II Division I subjects as compared to Class I female subjects. In males, the *t*-test revealed a significantly higher ($P < 0.05$) positive values for the perpendicular distance from the TT/LOP in Class II Division I males as compared to Class I males. However, other parameters did not differ significantly ($P > 0.05$) between Class I and Class II Division I males. These statistics are indicative of an inferiorly positioned tongue in Class II Division I males as compared to Class I males. The overall tongue linear measurements did not differ statistically except for the linear measurement of TT/LOP, which was significantly positively higher ($P < 0.01$) in the Class II Division I group as compared to Class I group. The inference for the tongue position and relation from these statistics are indicative of an inferiorly positioned tongue tip in relation to the lower occlusal plane in Class II Division I subjects compared to Class I subjects. When the tongue is forced to assume an altered position, adaptation occurs in an attempt to return to the structural and functional relationships which the patient has accepted as normal. In the pharynx, comparing the mean area of different parameters in males as well as females and overall between the two groups of Class I and Class II Division I subjects and the *t*-test revealed a similar ($P < 0.05$) area of all parameters, i.e. they did not differ statistically except for significantly different ($P < 0.05$) and higher hypopharyngeal area in Class II Division I males as compared to Class I males [Table 11] and significantly different ($P < 0.05$) and lower nasopharyngeal area in total Class II Division I subjects as compared to Class I subjects.

The higher hypopharyngeal area and the earlier finding of increased E-P linear distance in male Class II Division I subjects is contrary to the findings of other studies that have reported a decrease in the dimensions of hypopharyngeal area in Class II Division I subjects. This decreased nasopharyngeal area in total can be corroborated to some extent by the observation of smaller volumes of nasopharynx for Class II Division I group as compared to Class I group in a previous study. Since significant correlations could not be identified with direct comparisons of airway areas and tongue areas, there remains a possibility for future studies to evaluate area ratio variables to verify the importance of relative interaction among the different components of the pharyngeal airway and oral airway.

Conclusion

The result should be viewed in the light of the fact that only anterioposterior dimensions were taken into consideration. The importance of understanding the spatial interactions between the pharyngeal airway and the surrounding structures for diagnosing and treating patients with Class II Division I dentofacial patterns is emphasized in this study. Generally speaking, there was no difference in the pharyngeal airway anterioposterior dimension and also in the position and relationship of the hyoid bone and tongue, between Class I and Class II Division I patients. These findings are consistent with those studies in which the anterioposterior dimension of the upper airway is usually maintained by adaptation of both the tongue and hyoid bone. The vertical and transverse dimensions of the complex three-dimensional (3-D) anatomical structures need to be evaluated and correlated to arrive at a definitive conclusion. The factors brought forth in this article provide an insight with regard to the interdependence between the geometric arrangement of the pharynx, hyoid, and tongue. Given the possible clinical importance of their neuromuscular adaptations, more quantitative research on their adaptations is recommended.

With the advent of 3-D computerized tomography (CT) scans, this diagnostic modality is recommended for better evaluation in orthodontic patients for potential assessments of 3-D craniofacial structures, like the pharynx, hyoid bone, and also the tongue position between different facial types.

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