Journal of Dental Sciences (2020) 15, 286–293

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jds.com

Journal of Dental Sciences

Original Article

Relationship between hyoid bone and pharyngeal airway in different skeletal patterns

Jung-Hsuan Cheng [a], Szu-Yu Hsiao [b], Chun-Ming Chen [c,d], Kun-Jung Hsu [d,e*]

[a] *Department of Orthodontics, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan*
[b] *Department of Dentistry for Child and Special Needs, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan*
[c] *Department of Oral and Maxillofacial Surgery, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Taiwan*
[d] *Graduate Institute of Dental Sciences, School of Dental Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan*
[e] *Department of Dentistry, Kaohsiung Municipal Ta-Tung Hospital, Kaohsiung, Taiwan*

Received 14 November 2019; Final revision received 17 May 2020
Available online 1 June 2020

KEYWORDS
Pharyngeal airway;
Craniocervical angle;
Skeletal pattern;
Hyoid bone;
Soft palate

Abstract *Background/purpose:* The hyoid bone and its attached muscles play an important role in the maintenance of the pharyngeal airway space. The aim of the present study was to investigate the correlations between hyoid bone and pharyngeal airway spaces among three skeletal patterns.
Materials and methods: Cephalograms of 90 male and 90 female were divided into skeletal patterns: Class I, Class II, and Class III. The following pharyngeal airway spaces were measured: SP, soft palate related pharyngeal airway; BP, B point related pharyngeal airway; C2P, second cervical vertebra related pharyngeal airway; and LP, laryngopharyngeal airway. The paired t-test, one-way analysis of variance, and Pearson correlation analysis were used in the statistical analyses.
Results: SP was significantly longer in Class III (12.4 mm) than in Class I (10.7 mm) and Class II (9.5 mm), and BP was significantly greater in Class III (16.3 mm) than in Class II (12.4 mm). The hyoid bone had a significantly anterior location in Class III compared to Class II, whereas vertical positions of the hyoid bone showed no significant differences among the three skeletal patterns. Among female with a Class III skeletal pattern, the horizontal position of the hyoid bone had a positive moderate, significant correlation with the C2P, whereas among male, this was not observed.

* Corresponding author. Graduate Institute of Dental Sciences, College of Dental Medicine, Kaohsiung medical university, Kaohsiung Medical University Hospital, Kaohsiung Medical University, No. 100, Shih-Chuan 1st Road, Kaohsiung, Taiwan.
E-mail address: taihen.n4545@msa.hinet.net (K.-J. Hsu).

https://doi.org/10.1016/j.jds.2020.05.012

Conclusion: The location of the maxilla (SNA) was not significantly correlated with the pharyngeal airway space. However, the more protruding the mandible (SNB) is, the more anterior the hyoid bone and the longer the pharyngeal airway will be.

Introduction

The pharynx, a conical channel, is part of the neck and connects the oral and nasal cavities to the esophagus and trachea. The pharynx is wide at the top, narrow at the bottom, and slightly flattened anteriorly and posteriorly. While the top of the pharynx corresponds to the base of the skull, its bottom corresponds to the inferior margin of the sixth cervical vertebra. Its anterior wall is incomplete and leads to the nasopharynx, oropharynx, and laryngopharynx from top to bottom. The pharynx is posteriorly connected to the prevertebral fascia by loose connective tissues.[1] The pharynx is a passage for food and air; i.e., it is an intersection between the digestive and respiratory tracts. Its primary functions include swallowing, respiratory protection, middle ear pressure adjustment, and auditory function. In addition, the pharynx is involved in resonance function because the dorsum of the tongue and the soft palate can be raised or lowered. Therefore, the pharyngeal cavity is an airway space (resonance cavity) whose size can be adjusted.[1–3]

The pharynx can be primarily Classified into three parts from the top to the bottom: the nasopharynx, oropharynx, and laryngopharynx. While the soft palate is the boundary between the nasopharynx and oropharynx, the epiglottis is the boundary between the oropharynx and laryngopharynx. The soft palate is suspended at the posterior edge of the hard palate, and its top and bottom are composed of mucosal tissues. The middle portion of the soft palate is composed of muscles, aponeurosis, blood vessels, nerves, lymph tissues, and mucosal tissues. During swallowing and suction, the soft palate posterosuperiorly develops and separates the nasopharynx and oropharynx.

The mandible is connected to the hyoid bone, tongue, and soft palate by muscles. Therefore, its location can affect the size of the pharyngeal airway space. The horseshoe-shaped hyoid bone of the neck is located between the mandible and thyroid cartilage. The hyoid bone does not form joints with any other bone, and it is connected by muscles and ligaments to the floor of the mouth, tongue, epiglottis, pharynx, throat, mandible, temporal bone, and styloid process.[4] It supports the tongue and acts as a point of attachment for some tongue muscles, primarily functioning as an anchor to aid in tongue movement and swallowing.[4,5] The different skeletal patterns have their unique structures and contents. Therefore, the present study was to investigate the correlation between the skeletal pattern and pharyngeal airway space.

Materials and methods

We investigated 180 cephalograms of 90 male and 90 female, and divided them into groups according to skeletal patterns (Fig. 1): Class I, $0° < ANB < 4°$; Class II, ANB $\geq 4°$; Class III, ANB $\leq 0°$. Each group comprised 60 patients (30 male and 30 female), with an equal number of male and female. Exclusion criteria were as follows: (1) patients with craniofacial symptoms or deformity, (2) those with previous operation for another craniofacial pathology, and (3) those with a history of facial bone trauma. All lateral cephalograms were taken in the natural head position and patients were instructed not to swallow.

The following landmarks (Fig. 2) were identified on each cephalogram: the nasion (N), sella (S), anterior nasal spine (ANS), point A, posterior nasal spine (PNS), point B, menton (Me), lower incisor (L1), upper incisor (U1), inferoanterior point on the second cervical vertebra (C2), most superior and anterior points, hyoid bone (H), B point (B), and gonion (Go). The X-axis was constructed by drawing a line through N, 7° above the SN line; the Y-axis was constructed by drawing a line through S, perpendicular to the X-axis. The linear measurement included the following: SP, shortest distance from soft palate to the pharyngeal wall; BP, B-Go line intersecting the pharyngeal airway; C2P, C2 (inferoanterior point on the second cervical vertebra) of the horizontal line to the tongue intersecting the pharyngeal airway; and LP, laryngopharyngeal airway (horizontal plane through C4, intersecting the pharyngeal wall). The angular measurement included the following: U1-PP angle, angle between the upper incisor long axis and palatal plane (ANS-PNS line); L1-MP angle, angle between the lower incisor long axis and mandibular plane (Me-Go line); and U1-L1 angle, angle between the upper incisor long axis and lower incisor long axis.

Statistical analysis

The G*Power (version 3.1.9.2; Dusseldorf University, Dusseldorf, Germany) was applied to estimate the sample size. With power ($1-\beta$) of 90% with an α of 0.05, our study recruited 180 patients to achieve sufficient power (≧ 90%). The paired t-test was used to compare various values between male and female among the groups; multiple comparisons were performed using one-way analysis of variance; and Pearson correlation analysis was used to compare correlations between variables. The study data were analyzed using SPSS 20 Statistics software (IBM Corporation, Armonk, NY, USA). A p-value <0.05 was considered statistically significant for all statistical analyses. The null hypothesis was that there were no differences among skeletal patterns in terms of pharyngeal airway dimensions. Strengths of the correlations were described as follows for the absolute value of the ratio of the compared variables: very weak (0–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), and very strong

Figure 1 Skeletal patterns from right to left: (A) Class I, (B) Class II, (C) Class III.

(0.80–1.0). This retrospective study was approved by the human investigation review committee at the Kaohsiung Medical University Hospital (KMUHIRB-E (II)-20180200).

Results

Table 1 summarizes the analysis of the different skeletal patterns. Notably, there were no significant differences among the different skeletal patterns in terms of age. Comparison of differences between the three skeletal patterns showed the following: (1) SNA angles were significantly greater in Class II than in Class III. (2) SNB angles were significantly greater in Class III than in Class I, and SNB angles were significantly greater in Class I than in Class II ($F = 54.456$, $p < 0.0001$). (3) ANB angles were significantly greater in Class II than in Class I, and those were significantly greater in Class I than in Class III ($F = 343.328$, $p < 0.0001$).

As shown in Table 1, U1-PP angles were significantly greater in Class III (122.1°) and Class I (118.6°) ($F = 10.562$, $p < 0.0001$) than in Class II (113.1°). However, there was no significant correlation of L1-MP angles among the different skeletal patterns. The U1-L1 angle (127.6°) was significantly greater in Class III than in Class II (120.4°). However, there was no significant correlation of the U1-PP and L1-MP angles among the different skeletal patterns in female (Table 2). As shown in Table 3, L1-MP angles of male were significantly greater in Classes I and II than in Class III.

As shown in Table 1, SP ($F = 12.432$, $p < 0.0001$) was significantly longer in Class III (12.4 mm) than in Class I (10.7 mm) and Class II (9.5 mm), and BP was significantly greater in Class III (16.3 mm) than in Class II (12.4 mm). There was no significant correlation of C2T and LP among the skeletal patterns. In the gender's comparison, male had larger LP than female in all skeletal patterns. The horizontal position of the hyoid bone was significantly greater in Class III (21.1 mm) than in Class I (16.9 mm), and it was significantly greater in Class I than in Class II (14.3 mm). The horizontal position of the hyoid bone was significantly greater in Class III than in Class II (Tables 1–3). Notably, there were no significant differences in any skeletal patterns for the vertical positions of the hyoid bone (Tables 1–3). Regarding the C2P and LP lengths, no significant difference was found among all the skeletal patterns.

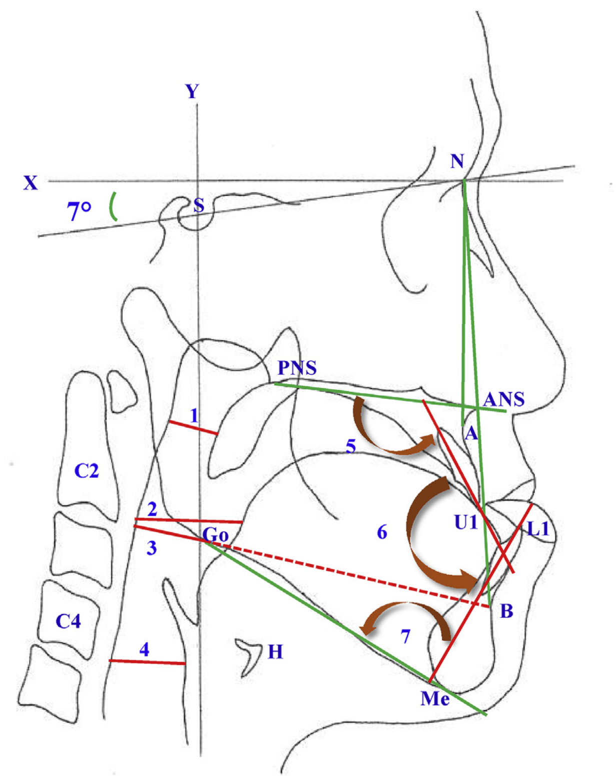

Figure 2 Cephalometric landmarks and linear measurements. Landmarks: nasion (N); sella (S); anterior nasal spine (ANS); point A; posterior nasal spine (PNS); point B; menton (Me); lower incisor (L1); upper incisor (U1); inferoanterior point on the second cervical (C2); inferoanterior point on the fourth cervical (C4); most superior and anterior point on the hyoid bone (H); and gonion (Go). The X-axis was constructed by drawing a line through the N, 7° above the SN line; the Y-axis was constructed by drawing a line through S, perpendicular to the X-axis.
Pharyngeal airway dimensions (red line): 1: SP; 2: C2P, 3: BP, 4: LP.
Angle measurement: 5: U1-PP angle, 6: U1-L1 angle, 7: L1-MP angle.

However, Class III had significantly greater pharyngeal airway dimensions (SP and BP) than Class II. Therefore, the null hypothesis was rejected.

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

Variables	Class I (F = 30; M = 30)			Class II (F = 30; M = 30)			Class III (F = 30; M = 30)			Intergroup comparison			
	Mean	SD		Mean	SD		Mean	SD		F	P value		Significant
Age	23.9	7.78	—	25.1	8.17	* (M > F)	22.7	5.96	—	1.908	0.151	—	
SNA	83.8	3.26	—	85.0	3.16	* (M > F)	82.9	3.25	—	6.357	0.002	†	Class II > Class III
SNB	82.1	3.17	—	79.3	3.27	—	85.7	3.53	—	54.456	<0.0001	†	Class III > Class I > Class II
ANB	1.8	0.73	—	5.6	1.44	—	−2.9	2.58	—	343.328	<0.0001	†	Class II > Class I > Class III
U1-PP angle	118.6	11.27	—	113.1	12.70	—	122.1	7.62	—	10.562	<0.0001	†	Class I > Class II; Class III > Class II
L1-MP angle	111.1	129.62	—	99.6	8.36	* (F > M)	87.2	10.31	—	1.496	0.227	—	
U1-L1 angle	123.1	12.46	—	120.4	12.39	—	127.6	11.65	—	5.267	0.006	†	Class III > Class II
Pharyngeal airway													
SP	10.7	3.01	—	9.5	2.48	—	12.4	3.65	—	12.432	<0.0001	†	Class III > Class I; Class III > Class II
C2P	15.5	13.57	—	12.7	3.85	—	16.4	5.17	—	2.884	0.059	—	
BP	13.7	3.75	* (M > F)	12.4	3.51	—	16.3	5.12	—	13.163	<0.0001	†	Class III > Class II
LP	16.8	3.63	* (M > F)	16.8	3.19	* (M > F)	17.9	4.03	* (M > F)	1.75	0.177	—	
Hyoid													
Horizontal	16.9	8.98	* (M > F)	14.3	7.36	* (M > F)	21.1	9.01	* (M > F)	9.874	<0.0001	†	Class III > Class I > Class II
Vertical	121.8	10.42	* (M > F)	123.4	10.25	* (M > F)	122.2	9.79	* (M > F)	0.367	0.693	—	

F: Female; M: Male.
*: Intergender comparison: Statistically significant, $P < 0.05$.
†: Intergroup comparison: Statistically significant, $P < 0.05$.
—: Not significant.

The Pearson correlation analysis (Table 4) of Class I (male and female) indicated that BP and SP had no significant correlation with related factors. Although C2P showed a positive moderate, significant correlation with the horizontal position of the hyoid bone in female ($r = 0.400$), it showed no significant correlation in male. The Pearson correlation analysis of Class II (male and female) revealed no significant correlation among all pharyngeal airway lengths and related factors. The Pearson correlation analysis of Class III (male and female) showed that the L1-MP angle had a negative moderate, significant correlation with C2P and BP. In male, ANB angles had a negative moderate, significant correlation with C2P and BP, whereas female showed no correlation. In Class III female, the horizontal position of the hyoid bone had a positive moderate, significant correlation with C2P, whereas male showed no correlation.

Table 2 The characteristics of female patients in the skeletal classification (One-way ANOVA).

Variables	Class I (n = 30)		Class II (n = 30)		Class III (n = 30)			Intergroup comparison		
	Mean	SD	Mean	SD	Mean	SD	F	P value		Significant
Age	24.6	7.55	22.8	5.23	22.8	6.52	0.727	0.486	—	
SNA	83.4	3.25	83.9	2.33	82.7	3.30	1.142	0.324	—	
SNB	81.7	3.10	78.6	2.70	85.5	3.61	34.607	<0.0001	*	Class III > Class I > Class II
ANB	1.7	0.63	5.3	1.30	−2.8	2.55	165.315	<0.0001	*	Class II > Class I > Class III
U1-PP angle	119.3	9.32	115.9	10.82	121.5	7.54	2.712	0.072	—	
L1-MP angle	127.3	181.71	101.9	6.62	88.3	10.49	1.028	0.362	—	
U1-L1 angle	125.9	11.35	117.4	13.02	125.3	10.34	4.841	0.010	*	Class I > Class II; Class III > Class II
Pharyngeal airway										
SP	10.2	3.02	10.0	2.32	12.5	3.82	5.422	0.006	*	Class III > Class I; Class III > Class II
C2P	12.2	3.17	12.4	2.73	15.5	4.22	8.586	<0.0001	*	Class III > Class I; Class III > Class II
BP	12.7	3.50	12.4	2.88	15.6	4.87	6.500	0.002	*	Class III > Class I; Class III > Class II
LP	15.2	3.46	15.7	2.75	15.8	3.12	0.269	0.765	—	
Hyoid										
Horizontal	13.9	7.46	11.5	5.37	18.6	7.94	7.737	0.001	*	Class III > Class I; Class III > Class II
Vertical	114.5	6.91	116.2	5.63	114.5	6.52	0.736	0.482	—	

n: number of patient.
*: Statistically significant, $P < 0.05$.
—: Not significant.

Table 3 The characteristics of male patients in the skeletal classification (One-way ANOVA).

Variables	Class I (n = 30)		Class II (n = 30)		Class III (n = 30)			Intergroup comparison		
	Mean	SD	Mean	SD	Mean	SD	F	*P* value		Significant
Age	24.5	5.66	25.8	7.67	23.2	5.30	3.631	0.031	*	Class II > Class III
SNA	84.7	3.49	86.1	3.24	83.6	3.05	6.22	0.003	*	Class II > Class III
SNB	82.9	3.43	80.1	3.36	85.4	2.72	21.517	<0.0001	*	Class III > Class I > Class II
ANB	1.9	0.79	6.0	1.15	−1.8	2.01	177.717	<0.0001	*	Class II > Class I > Class III
U1-PP angle	117.9	12.88	110.3	13.79	122.7	7.66	8.169	0.001	*	Class I > Class II; Class III > Class II
L1-MP angle	95.0	8.04	97.4	9.28	86.1	10.01	12.365	<0.0001	*	Class I > Class III; Class II > Class III
U1-L1 angle	120.3	12.88	123.4	10.90	129.9	12.40	4.746	0.011	*	Class III > Class I
Pharyngeal airway										
SP	11.1	2.94	11.7	4.16	15.5	5.29	8.512	<0.0001	*	Class I > Class II; Class III > Class II
C2P	18.7	18.36	13.0	4.64	17.2	5.84	1.907	0.155	—	
BP	14.8	3.70	12.5	4.04	16.9	5.28	7.529	0.001	*	Class III > Class II
LP	18.4	3.06	17.8	3.28	19.9	3.74	3.241	0.044	*	Class III > Class II
Hyoid										
Horizontal	20.0	9.30	17.0	8.02	23.7	9.30	4.084	0.020	*	Class III > Class II
Vertical	129.2	7.85	130.5	8.80	129.9	5.53	0.217	0.805	—	

n: number of patient.
*: Statistically significant, $P < 0.05$.
—: Not significant.

Table 4 Pearson test of gender in the skeletal classification.

Class I (Female = 30)	Age	SNA	SNB	ANB	U1-PP	L1-MP	U1L1	HH	HV
SP	−0.052	0.174	0.152	0.217	0.202	−0.124	0.154	0.032	0.033
C2P	0.228	−0.324	−0.323	0.014	−0.063	−0.167	−0.007	0.400*	−0.185
BP	0.038	−0.147	−0.114	−0.122	0.061	−0.200	0.079	0.320	−0.085
LP	0.366*	−0.316	−0.250	−0.358	−0.099	−0.144	−0.239	0.322	−0.235
Class I (Male = 30)									
SP	−0.049	0.051	0.087	−0.147	−0.045	0.084	−0.082	0.281	−0.140
C2P	0.130	0.205	0.169	0.141	−0.164	−0.202	0.041	0.113	0.200
BP	0.050	0.230	0.244	−0.058	0.126	−0.046	−0.177	0.259	−0.003
LP	−0.292	0.172	0.132	0.147	0.106	0.046	−0.394*	0.134	0.105
Class II (Female = 30)									
SP	−0.106	−0.066	0.015	−0.167	0.025	−0.294	−0.359	0.196	−0.226
C2P	−0.042	0.132	0.102	0.019	−0.221	−0.330	−0.016	0.080	−0.189
BP	−0.075	0.090	0.066	0.010	−0.190	−0.331	−0.137	0.157	−0.275
LP	0.170	−0.127	−0.068	−0.101	0.105	−0.248	−0.073	−0.125	0.032
Class II (Male = 30)									
SP	−0.234	0.035	0.109	−0.183	0.056	−0.099	−0.016	−0.024	0.135
C2P	−0.009	0.131	0.196	−0.169	0.008	−0.174	0.209	0.038	0.122
BP	0.033	0.206	0.277	−0.190	−0.081	−0.228	0.201	0.006	0.182
LP	−0.074	−0.086	0.038	−0.295	−0.003	−0.038	0.127	0.030	0.199
Class III (Female = 30)									
SP	−0.362*	0.072	0.203	−0.194	−0.087	−0.408*	−0.020	0.201	0.160
C2P	−0.257	−0.088	0.123	−0.288	−0.211	−0.493*	−0.196	0.440*	0.064
BP	−0.155	−0.036	0.172	−0.291	−0.318	0.510*	−0.108	0.349	0.082
LP	−0.108	0.201	0.270	−0.122	0.077	−0.339	0.038	0.387*	0.155
Class III (Male = 30)									
SP	0.236	0.080	0.174	−0.130	0.020	−0.245	0.230	−0.328	−0.062
C2P	0.126	−0.006	0.371*	−0.494*	−0.237	−0.526*	0.319	−0.049	−0.145
BP	0.191	0.054	0.400*	−0.459*	−0.199	0.575*	0.342	−0.110	−0.073
LP	0.346	−0.287	0.004	−0.357	−0.336	−0.594*	0.446*	−0.094	−0.315

HH: Hyoid Horizontal; HV: Hyoid Vertical.
*: Statistically significant, $P < 0.05$.

Discussion

Under natural circumstances such as loosening or sagging, the anterior portion of the soft palate appears concaved, whereas the posterior portion appears convexed.[1−3] Therefore, the soft palate tends to affect the size of the pharyngeal airway space. Alves et al.[6] reported that SP was significantly longer in Class I than in Class II. In the present study, SP was slightly shorter in Class II than in Class I, and there was no significant difference between SP in Class I and Class II. However, SP was significantly longer in Class III than in Class I and Class II. Abu and Al-Khateeb[7] reported that there was no sex-difference in SP among the different skeletal patterns. Our findings were similar to those of Abu and Al-Khateeb.[7] While examining the effects of the anatomic structures, only female with a Class III skeletal pattern showed a negative moderate, significant correlation between SP and L1-MP, indicating that the lower the incisor lingual inclination, the longer the SP. However, SP in Classes I and II did not have such a correlation.

The oropharynx lies between the muscles of the soft palate and epiglottis, which corresponds to the third and fourth cervical vertebrae. While the oropharynx is anteriorly connected to the oral cavity by the isthmus of the fauces and inferiorly connected to the laryngopharynx, its top portion is connected to the nasopharynx by the nasopharyngeal isthmus. The tongue is located at the floor of the mouth on the medial side of the mandible, and it protrudes into the oral cavity. It is primarily composed of smooth muscles that can be divided into intrinsic and extrinsic muscles. The origin and attachment points of muscular bundles of the intrinsic muscles are within the tongue; the extrinsic muscles are attached to the mandible, hyoid bone, and styloid process of the temporal bone, and they are connected to the soft palate. The tongue root is located at the posterior edge of the tongue, and connected to the hyoid bone and mandible by the hyoglossus and genioglossus. It is connected to the soft palate and pharynx by the glossopalatine arch and superior pharyngeal constrictor muscle, respectively.[8,9] Therefore, the tongue plays an important role in maintaining the oropharyngeal airway space. In our study, there were no differences in the C2P by skeletal patterns and sex. Compared to female with Class I and Class II skeletal patterns, Class III female showed a significantly longer C2P.

According to the Pearson correlation analysis, the lower the incisor lingual inclination (smaller L1-MP), the longer the C2P. This means more mandible protrusion, causing lower incisor lingual tipping due to dental compensation, which leads to increased C2P. The C2P in male with a Class III skeletal pattern showed a negative moderate, significant correlation, indicating that the smaller the ANB angle, the more protruding the mandible and the longer the C2P. In addition, we found that the horizontal lengths of the hyoid bones in Class I and Class III had a positive moderate, significant correlation with the C2P, suggesting that the more forward the hyoid bone is located, the longer the C2P is. This means that the hyoid position in Class II revealed no correlation with C2P (oropharyngeal airway space). Our study found that the pharyngeal airway space is the largest in patients with mandibular prognathism, followed by normal individuals and then by patients with mandibular retrognathism, indicating that the pharyngeal airway space is affected by mandibular growth patterns. Opdebeeck et al.[10] reported that the pharyngeal airway space of individuals with long faces are smaller than that of individuals with short faces; further, patients with a Class II skeletal pattern often have long faces, whereas those with a Class III often have short faces. Alves et al.[6] reported that BP was not significantly different between Class I and Class II. Our study result was similar to that of Alves et al.[6] There was no different between Class I and Class II. Abu and Al-Khateeb[7] reported that SP was not different by sex and among the different skeletal patterns (Class I, Class II, and Class III). We found that BP was significantly longer in Class III than in Class II, which is consistent with the findings of Opdebeeck et al.[10] In male and female with a Class III skeletal pattern, BP was similar to C2P and showed a negative moderate, significant correlation with L1-MP. This means that BP and C2P were significantly correlated with the anterior mandibular position in Class III.

The laryngopharynx is posteriorly located in the throat, below the epiglottis, and it connects the throat to the esophagus. The tail section of the pharynx is the laryngopharynx, whose anterior wall is the epiglottis. The superior portion of the laryngopharynx meets the upper boundary of the epiglottic cartilage, whereas the bottom portion meets the lower boundary of the cricoid cartilage, which is anteriorly located around the fourth to sixth cervical vertebrae. Our study showed that there were no differences in skeletal patterns for LP in all groups and in the female group, and that only male with a Class III skeletal pattern showed a significantly larger LP. Correlation analysis of the skeletal patterns and sexes demonstrated that LP in male with a Class III skeletal pattern showed a positive moderate, significant correlation with the mandibular position (U1-L1 and L1-MP angles), whereas male with Class I and Class II skeletal patterns did not show such a correlation.

When skeletal patterns were used to examine the correlation of the pharyngeal airway, we found that SNA angles were not correlated, suggesting that the location of the maxilla was not correlated with the length of the pharyngeal airway. Conversely, the location and shape of the mandible in Class III was moderately correlated with the pharyngeal airway length, of which L1-MP of Class III showed significant correlation with the length of the pharyngeal airway. Many researchers have reported that the position of the hyoid bone changes in accordance with that of the mandible. Therefore, the hyoid bone and its attached muscles play an important role in the maintenance of the size of the pharyngeal airway space. Adamidis et al.[11] compared the position of the hyoid bone between patients with Class I and Class III skeletal patterns and reported that the hyoid bone in Class III showed a more anterior position. Yamaoka et al.[12] found that the tongue root showed a more posterior position in patients with a Class II skeletal pattern than in those with Class III. Battagel et al.[13] found that obstructive sleep apnea (OSA) patients have significant Class II occlusion, and their hyoid bone is located at a more posterior position; therefore, their upper airway is narrower. Mortazavi et al.[14] reported that hyoid bone is positioned more superior and posterior in females than males and its location differs among different skeletal Class. Our study was similar to report of Mortazavi et al.[14] Moreover, we found that the vertical position of the hyoid bone is not correlated with the pharyngeal airway space, but the horizontal position of the hyoid bone in female with Classes I and III skeletal patterns showed a positive moderate, significant correlation with C2P, suggesting that the horizontal position of the hyoid bone chiefly affects the tongue.

In summary, the location of the maxilla (SNA) is not significantly correlated with the size of the pharyngeal airway space. The more protruding the mandible (SNB) is, the more anterior the hyoid bone and the longer the pharyngeal airway space will be. Patients with a Class III skeletal pattern had a significantly larger pharyngeal airway space (SP and BP), whereas those with a Class II skeletal pattern had the smallest pharyngeal airway space (SP, BP, and C2P).

Declaration of Competing Interest

The authors have no funding and no conflicts of interest relevant to this article.

References

1. Hiatt JL, Gartner LP. *Textbook of head and neck anatomy*, 4th ed. Lippincott Williams & Wilkins, 2010:47–9.
2. Schwab RJ, Goldberg AN. Upper airway assessment: radiographic and other imaging techniques. *Otolaryngol Clin North Am* 1998;31:931–68.
3. Berkovitz BKB, Moxham BJ. *A textbook of head and neck anatomy*. Year Book Medical Publishers, 1988:272–331.
4. Biby RE, Preston CB. The hyoid triangle. *Am J Orthod* 1981;80:92–7.
5. Lieberman DE, McCarthy RC, Hiiemae KM, Palmer JB. Ontogeny of postnatal hyoid and larynx descent in humans. *Arch Oral Biol* 2001;46:117–28.
6. Alves Jr M, Franzotti ES, Baratieri C, Nunes LK, Nojima LI, Ruellas AC. Evaluation of pharyngeal airway space amongst different skeletal patterns. *Int J Oral Maxillofac Surg* 2012;41:814–9.
7. Abu Allhaija ES, Al-Khateeb SN. Uvulo-glosso-pharyngeal dimensions in different anteroposterior skeletal patterns. *Angle Orthod* 2005;75:1012–8.
8. Du Brul EL. *Sicher's oral anatomy*, 7th ed. St Louis: Mosby, 1980:7–141.
9. Nanci Antonio. *Ten cate's oral histology: development, structure, and function*, 8th ed. St Louis: Mosby, 2012:35–41.
10. Opdebeeck H, Bell WH, Eisenfeld J, Mishelevich D. Comparative study between the SFS and LFS rotation as a possible morphogenic mechanism. *Am J Orthod* 1978;74:509–21.

11. Adamidis IP, Spyropoulos MN. Hyoid bone position and orientation in Class I and Class III malocclusions. *Am J Orthod Dentofacial Orthop* 1992;101:308—12.
12. Yamaoka M, Furusawa1 K, Uematsu TOkafuji N, Kayamoto D, Kurihara S. Relationship of the hyoid bone and posterior surface of the tongue in prognathism and micrognathia. *J Oral Rehabil* 2003;30:914—20.
13. Battagel JM, Johal A, L'Estrange PR, Croft CB, Kotecha B. Changes in airway and hyoid position in response to mandibular protrusion in subjects with obstructive sleep apnoea (OSA). *Eur J Orthod* 1999;21:363—76.
14. Mortazavi S, Asghari-Moghaddam H, Dehghani M, et al. Hyoid bone position in different facial skeletal patterns. *J Clin Exp Dent* 2018;10:e346—51.