Original Article

A cone-beam computed tomography study of hyoid bone position and airway volume in subjects with obstructive and nonobstructive adenotonsillar hypertrophy

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ABSTRACT

Objectives: To investigate hyoid bone position and airway volume in subjects with adenoid hypertrophy, tonsillar hypertrophy, and adenotonsillar hypertrophy compared to subjects with nonobstructive adenoids or tonsils and to assess the correlation between hyoid bone and airway parameters.

Materials and Methods: A total of 121 subjects were grouped based on adenoid or tonsillar hypertrophy into four groups, as follows: (1) control group (C-group), (2) adenoid hypertrophy group (AH-group), (3) adenotonsillar hypertrophy group (ATH-group), and (4) tonsillar hypertrophy group (TH-group). Hyoid bone position and airway volumes were measured. The Kruskal-Wallis test was used for intergroup comparison, followed by pairwise comparison using the Mann-Whitney *U*-test. Bivariate correlation was conducted using Spearman correlation coefficients. Multiple linear regression was performed to create a model for airway volume based on hyoid bone predictive variables.

Results: No significant difference was found between subjects with isolated adenoid or tonsillar hypertrophy compared to the C-group. However, the ATH-group exhibited a significantly decreased hyoid bone vertical distance (HV), total airway volume (TA volume), and retroglossal airway volume (RG volume) compared to the C-group. HV and age had a high potential in terms of explaining the RG volume, whereas the TA volume and retropalatal airway volume (RP volume) models were not as successful as the RG volume counterpart.

Conclusions: Subjects in ATH-group were characterized by an elevated hyoid bone position and constricted TA volume and RG volume compared to those in the C-group. HV and age were predictor variables that best explained retroglossal airway volume. (*Angle Orthod.* 2023;93:467–475.)

KEY WORDS: Adenoid; Tonsils; Hyoid bone; Airway

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Accepted: February 2023. Submitted: November 2022.
Published Online: March 16, 2023

INTRODUCTION

The adenoids and palatine and lingual tonsils constitute the main component of the Waldeyer's ring, a lymphoid tissue complex around the pharynx that plays a crucial role in immunologic defense of the body. Moss' functional matrix theory states that the soft tissue directs skeletal tissue development. Consequently, nasal resistance due to adenoid or tonsillar hypertrophy is hypothesized[1] to cause developmental changes in the craniofacial complex.

The impact of mouth breathing on the dentoskeletal complex has been an area of debate and controversy for decades. Some scholars believe that mouth breathing is associated with alteration of craniofacial development and position of the hyoid bone,[2] while others disagree.[3] This is primarily because nasal airway inadequacy is subjective, and different authors judge breathing modes differently. Additionally, a recent systematic review and meta-analysis by Zhao et al.[4] concluded that mouth breathing was linked to skeletal and dental developmental changes in children.

The association between mouth breathing and craniofacial structure deformities appeared in the orthodontic literature a long time ago. However, in mouth-breathing participants, the vast bulk of previous research asserted that the site of obstruction in the airway would not be a confounding factor, which, to some extent, might explain the controversial findings. However, there is still a lack of comprehensive knowledge on the particular impact of adenoid and tonsillar hypertrophy on the stomatognathic system. Additionally, several authors[5–7] linked the position of the hyoid bone to airway adequacy, but their assumptions were speculative and debatable. Hence, this study aimed to assess hyoid bone position and airway volume in subjects with obstructive and nonobstructive adenotonsillar hypertrophy and to investigate the relationship between airway volume and hyoid bone position in subjects aged 7 to 12 years.

MATERIALS AND METHODS

This retrospective study was reviewed and approved by the Ethics Committee of Xi'an Jiaotong University. All participants' parents were informed, and signed written consent forms allowing use of their data for scientific purposes.

The sample consisted of 121 cone-beam computed tomographic (CBCT) images from Chinese children (65 females, 56 males) who were treated in the Orthodontic Department of Xi'an Jiaotong University from 2017 to 2022. Sample size was calculated using Minitab® v.18.1 software (Minitab Inc, State College, Pa), considering a power of 80%, a significance level of .05, a standard deviation of 4.2, and a 4.4-mm difference in hyoid bone vertical distance (HV) value.[8] Twenty-two subjects in each group would be sufficient for the comparison. Preoperative CBCT scans of children aged 7 to 12 years with skeletal Class I ($1 \leq$ ANB° ≤ 4.9) or skeletal Class II (ANB° ≥ 5) and a normal vertical growth pattern ($27 <$ FMA° < 37) were included. Subjects who displayed any of the following criteria were excluded: (1) previous history of adenoidectomy or tonsillectomy, (2) subjects who had undergone orthodontic treatment or had any syndromes related to the head and neck region, and (3) those with distorted CBCT scans with nonobvious landmarks.

CBCT images were taken in the natural head position. Participants were advised to remain in maximum intercuspation and to sit with a straight posture while maintaining the lips and tongue in the rest position, and they were instructed to breathe normally. All of the CBCT images were acquired with a cone-beam machine (i-Cat, Imaging Sciences International, Hatfield, Pa) using the following parameters: 120 kV, 5 mA, 14 ×17-cm field of view, 0.4-mm voxel size, and 8.9-second scan duration. The CBCT images were stored as Digital Imaging and Communications in Medicine (DICOM) files.

Dolphin Imaging Software (version 11.7, Dolphin Imaging & Management Solutions®, Chatsworth, Calif) was utilized to import the DICOM files. One investigator was responsible for all of the measurements, and this investigator was unaware of any of the participants' demographic data. To orient the CBCT images, the axial plane was adjusted to the Frankfort horizontal plane (FHP), the midsagittal plane was oriented in the midline of the patient passing through Nasion, and the coronal plane was oriented to pass through Porion, perpendicular to the axial plane.

All patients underwent clinical examination by a multidisciplinary team comprising an orthodontist and an otorhinolaryngologist. Initially, history was taken from the patients' parents to evaluate for the existence of bad sleeping habits: for instance, snoring, drooling on the pillow, and sleeping with an opened mouth. Subsequently, the Glatzel mirror test[9] was performed. Otolaryngology examination was performed by a single investigator (LL) and included a physical examination followed by endoscopy, flexible nasopharyngoscopy, and nasopharyngeal x-ray.

The level of the adenoid or tonsillar hypertrophy was computed mathematically based on the CBCT images. The percentage of adenoid hypertrophy was calculated as $AS/TNPA \times 100$; where AS indicates the linear distance extending from the posterior soft palate to the nearest point of adenoid tissues and $TNPA$ refers to the total linear distance of the nasopharyngeal airway in the sagittal section. Percentage of tonsillar hypertrophy $= TS/TOPA \times 100$, where TS is the narrowest distance

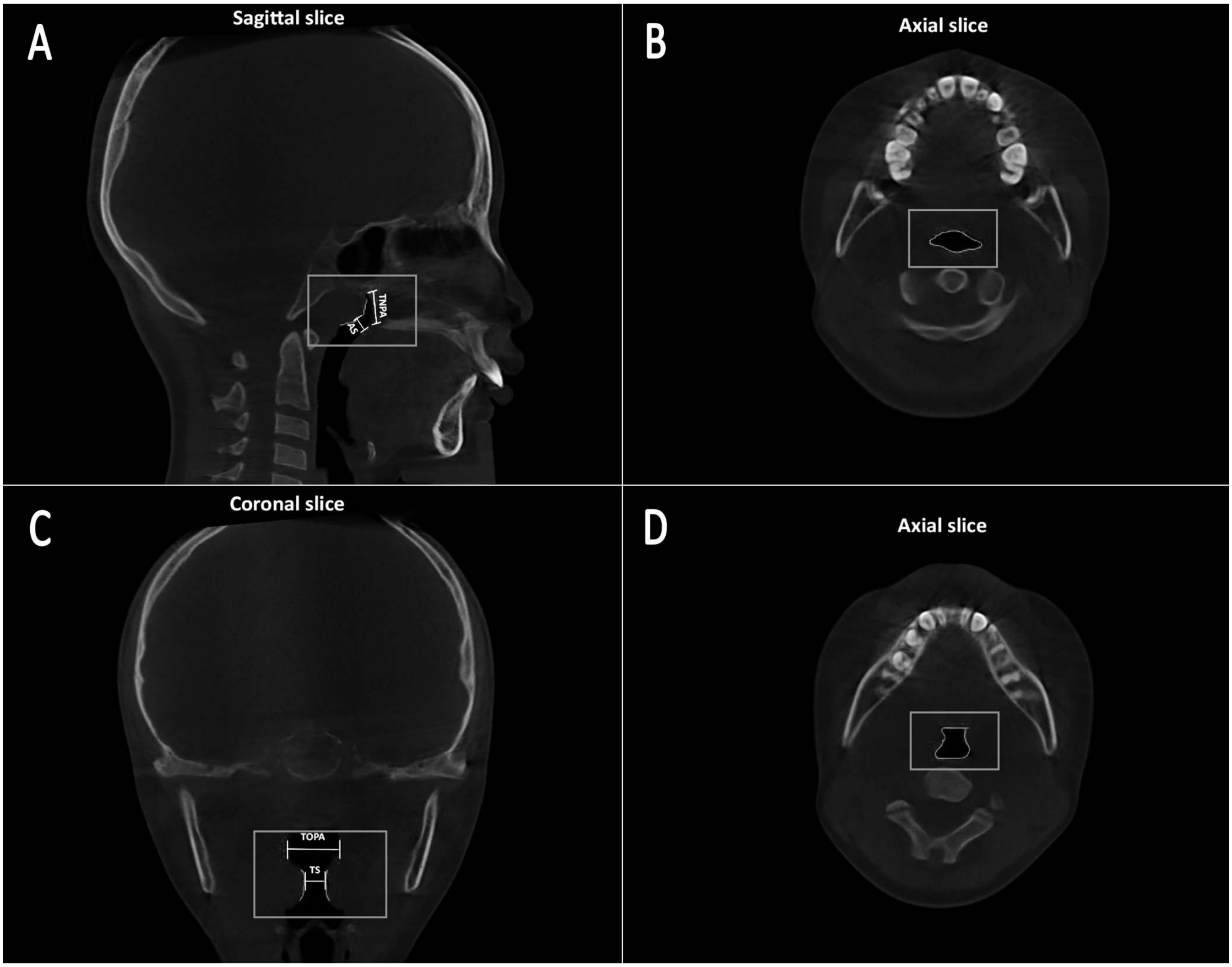

Figure 1. (A) Obstructive adenoid hypertrophy in the sagittal section. (B) Obstructive adenoid hypertrophy in the axial section at the AS plane. (C) Obstructive tonsillar hypertrophy in the Coronal section. (D) Obstructive tonsillar hypertrophy in the axial section at the TS plane.

between the tonsils in the coronal section and *TOPA* indicates the total linear distance of the oropharyngeal airway in the coronal plane (Figure 1). Subjects who displayed less than 25% of adenoid or tonsillar hypertrophy were considered nonobstructive, and those who displayed more than 50% of adenoid or tonsillar hypertrophy were considered obstructive. A similar approach was used by previous authors.[10–12] Subjects who met the inclusion criteria were divided into four groups, as follows: (1) control group (C-group) with nonobstructive adenoid or tonsillar hypertrophy, (2) adenoid hypertrophy group (AH-group), (3) adenoid and tonsillar hypertrophy group (ATH-group), and (4) tonsillar hypertrophy group (TH-group).

According to Nath et al.,[13] the superior boundary of the airway was determined as a plane that ran posterior to the nasal spine (PNS) to the posterior wall of the pharynx (P plane), and the inferior boundary of the airway was determined to be a plane that ran parallel to the P plane and passed through the most superior point of the epiglottis. Subsequently, the airway was divided into an upper (retropalatal) segment and a lower (retroglossal) segment using a plane that was parallel to the P plane and passed through the uvula. Finally, the volumes were measured using Dolphin software, and the airway sensitivity was set to 73, as recommended by Alves et al.[14] (Figure 2).

Hyoid bone linear measurements were HME, HEB, HC3, C3Me, HC3Me, HPNS, HH, and HV (Table 1; Figure 3).

Statistical Analysis

All measurements for 30 randomly selected participants were repeated 2 weeks after the first measurement, and the intraclass correlation coefficient (ICC) was calculated to check the intrainvestigator reliability

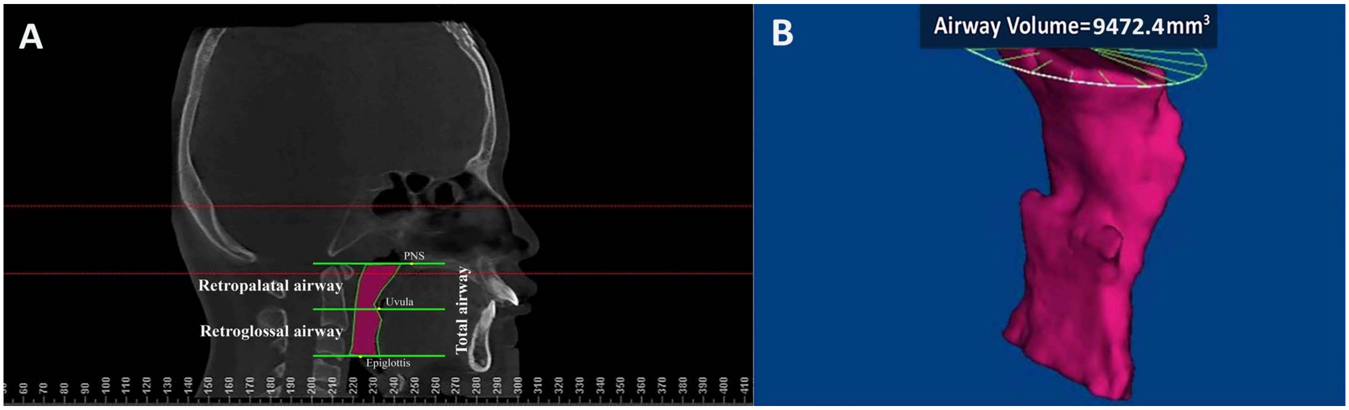

Figure 2. (A) Volumetric measurement of the airway. (B) Three-dimensional reconstruction of the airway structure.

of the measurements. Dahlberg's formula[15] was used to assess the measurement error.

The Shapiro-Wilk test was used to check the normal distribution of the data. Because the data showed nonnormal distribution, the nonparametric Kruskal-Wallis test was used for intergroup comparison, followed by pairwise comparison using the Mann-Whitney *U*-test with Bonferroni adjustment when a significant variable was detected.

Spearman correlation coefficient was performed to investigate the correlation between airway and hyoid bone parameters. Multiple linear regression analysis was used after the logarithmic transformation of the dependent variable values to build a model for the airway to identify the airway predictive parameters. SPSS software (version 25.0, SPSS Inc, Chicago, Ill) was used, and a P value $< .05$ was considered significant.

RESULTS

The ICC test revealed high intrainvestigator agreement, ranging between 0.93 and 0.99 for linear measurements and between 0.90 and 0.97 for volumetric measurements. The results of Dahlberg's formula were 0.81 to 1.60 mm and 165 to 323 mm^3 for linear and volumetric measurements, respectively.

The baseline characteristics of the selected sample are shown in Table 2. No significant difference was found in the demographic variables or in the sagittal or vertical skeletal pattern variables ($P > .05$).

The intergroup comparison is displayed in Table 3. No significant difference was found between subjects with isolated adenoid or tonsillar hypertrophy in comparison to the control group with regard to hyoid bone position and airway parameters ($P > .05$). On the other hand, subjects in the ATH-group demonstrated a statistically significant decrease in HV, total airway

Table 1. Explanation of the Landmarks and Measurements

Measurement	Definition	Interpretation
HME	The distance extending from hyoid bone most superior point (H) to Menton point, which is the most inferior point of the symphisis	The position of the hyoid bone relative to the mandible
HEB	The distance extending between H point and the epiglottis base	The position of hyoid bone relative to the epiglottis
C3H	The distance between H point and the most superoanterior point of the third cervical vertebrae	The position of hyoid bone relative to the third cervical vertebrae
C3ME	The distance extending from the third cervical vertebrae to Menton point	This line, when paired with the H-Me line and the C3-H line, forms the hyoid bone triangle
HC3ME	The perpendicular distance from H point to the C3ME line	The hyoid bone triangle's vertical height; a positive score shows that the hyoid triangle is pointing downward, while a negative value indicates that it is pointing upward
HPNS	The distance extending from H point to posterior nasal spine point	The position of hyoid bone relative to the maxilla
HH	The perpendicular distance from H point to a line extending vertically and passing through the Sella point	Hyoid bone horizontal distance
HV	The perpendicular distance from H point to a line extending horizontally and passing through the Sella point	Hyoid bone vertical distance

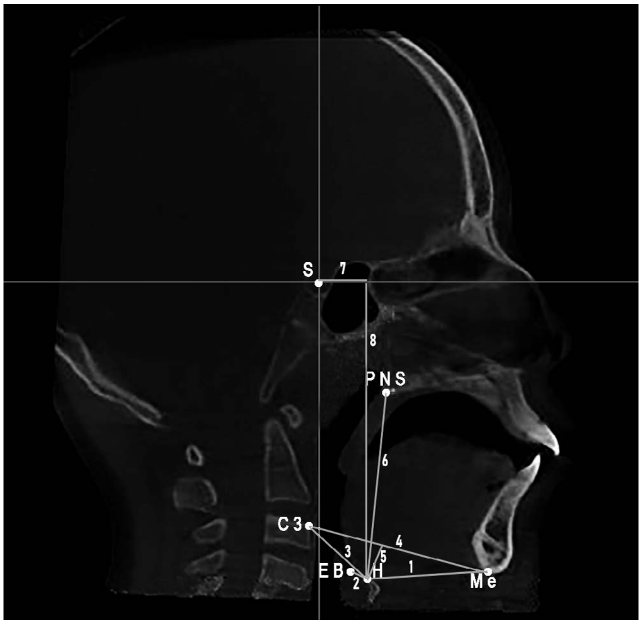

Figure 3. The landmarks and measurements of hyoid bone position. (1) hyoid bone (H) – Menton (Me); (2) hyoid bone (H) – epiglottis (EB); (3) third cervical vertebrae (C3) – hyoid bone (H); (4) third cervical vertebrae (C3) – Menton (Me); (5) hyoid bone (H) – third cervical vertebrae to Menton line (C3Me); (6) hyoid bone (H) – posterior nasal spine (PNS); (7) hyoid bone horizontal distance (HH); and (8) hyoid bone vertical distance (HV).

volume (TA volume), and retroglossal airway volume (RG volume) values when compared to those in the C-group.

The ATH-group showed significantly lesser values of HV and all airway volumetric measurements when compared to the AH-group. While the comparison between the ATH-group and the TH-group showed significantly decreased TA volume and RG volume only, no significant difference in hyoid bone variables was observed.

Bivariate correlation analysis between airway and hyoid bone parameters is shown in Table 4. The correlation results in the C-group showed a moderate to strong positive correlation. Likewise, correlation results for the AH-group revealed a moderate to strong positive correlation. Correlation outcomes showed moderate to weak positive correlations for the ATH-group and TH-group.

Multiple linear regression analysis is shown in Table 5. The TA volume and retropalatal airway volume (RP volume) models were not as successful as the RG volume model. The RG volume model had a moderate potential for explaining the RG volume, representing 40% of the variance. The variables HV and age had a significant role in explaining the RG volume (beta $= 0.4$ and 0.17; $P = .002$ and 0.037, respectively). A linear regression equation was formulated as follows: $Y = 2.099 + 0.009(X1) + 0.019(X2)$, where Y indicates the log of RG volume; $X1$ indicates the HV value; and $X2$ indicates age. The predicted and actual logs of RG volume are plotted in Figure 4.

DISCUSSION

In the current study, a collaborative approach was established between the Ear Nose and Throat and Orthodontic Departments to aid in the proper grouping of samples. Additionally, CBCT images were reported[10,12] to be a reliable and accurate tool for the assessment of adenoids and tonsils. Thus, CBCT images were used as an adjunctive tool for evaluating the extent of hypertrophy; images were only taken when they were expected to have an additive value for orthodontic diagnosis and treatment planning and following ALARA principles.[16]

The intergroup comparison revealed significantly different vertical hyoid bone position, described by the variable HV, between the C-group and ATH-group, indicating an elevated hyoid bone position in the ATH-group. This finding was similar to that of Chung et al.,[2] who found that subjects with mouth breathing were characterized by an elevated hyoid bone. In addition, Chaves et al.[7] reported that an elevated hyoid bone position was found in asthmatic patients. On the contrary, another investigation by Behlfelt et al.[6] claimed that subjects with enlarged tonsils had a lower

Table 2. Baseline Characteristics of the Samples[a]

	C-Group (n = 26)	AH-Group (n = 25)	ATH-Group (n = 38)	TH-Group (n = 32)	*P*-Value
Age, y (mean ± SD)[b]	9.96 ± 1.63	9.16 ± 2.13	9.05 ± 1.76	9.93 ± 1.38	.068
Gender, N (%)[c]					
Male	14 (24.1)	13 (22.4)	19 (32.8)	12 (20.7)	.574
Female	12 (19)	12 (19)	19 (30.2)	20 (31.7)	
ANB, ° (mean ± SD)[b]	5.25 ± 2.04	5.02 ± 2.02	4.95 ± 2.03	5.16 ± 1.91	.888
SNA, ° (mean ± SD)[b]	81.60 ± 3.74	81.63 ± 3.80	80.15 ± 3.73	80.35 ± 3.60	.286
SNB, ° (mean ± SD)[b]	76.47 ± 2.99	73.89 ± 14.47	75.34 ± 3.86	75.36 ± 3.42	.526
FMA, ° (mean ± SD)[b]	30.64 ± 2.38	30.95 ± 2.93	30.03 ± 3.02	30.80 ± 3.32	.57

[a] C-Group indicates control group; AH-Group, adenoid hypertrophy group; ATH-Group, adenotonsillar hypertrophy group; TH-Group, tonsillar hypertrophy group; and SD, standard deviation.
[b] Kruskal-Wallis test.
[c] Chi-square test.

Table 3. Kruskal-Wallis Test for Intergroup Comparison Followed by Pairwise Comparisons Using Mann-Whitney *U*-Test With Bonferroni Adjustment[a]

						Pairwise Comparisons					
	C-Group (Mean ± SD)	AH-Group (Mean ± SD)	ATH-Group (Mean ± SD)	TH-Group (Mean ± SD)	*P*-Value	C-Group vs AH-Group	C-Group vs TH-Group	AH-Group vs TH-Group	C-Group vs ATH-Group	ATH-Group vs AH-Group	ATH-Group vs TH-Group
Hyoid bone measurements											
HME	41.14 ± 5.84	40.67 ± 5.07	41.09 ± 4.47	39.88 ± 1.26	.757	NS	NS	NS	NS	NS	NS
HEB	8.99 ± 3.83	9.62 ± 3.97	8.08 ± 3.85	8.95 ± 3.61	.414	NS	NS	NS	NS	NS	NS
C3H	27.36 ± 3.12	28.34 ± 5.49	26.27 ± 3.71	25.97 ± 3.98	.29	NS	NS	NS	NS	NS	NS
C3ME	67.56 ± 5.82	67.62 ± 6.97	65.44 ± 8.03	65.10 ± 8.89	.305	NS	NS	NS	NS	NS	NS
HC3ME	3.15 ± 4.39	1.7 ± 5.71	0.20 ± 4.39	1.54 ± 4.45	.12	NS	NS	NS	NS	NS	NS
HPNS	51.75 ± 5.83	52.48 ± 6.85	48.94 ± 5.41	49.99 ± 5.33	.105	NS	NS	NS	NS	NS	NS
HH	15.38 ± 6.03	13.81 ± 8.80	13.61 ± 8.98	13.6 ± 13.28	.287	NS	NS	NS	NS	NS	NS
HV	86.76 ± 6.80	88.39 ± 9.78	81.30 ± 6.58	84.68 ± 8.92	.004**	NS	NS	NS	S	S	NS
Airway measurements											
TA volume	15,994.61 ± 6780.71	16,816.02 ± 6377.16	11,042.39 ± 4527.83	16,282.43 ± 8567.79	.001**	NS	NS	NS	S	S	S
RP volume	8607.54 ± 3933.45	8849.30 ± 3591.13	5996.05 ± 2639.45	8161.35 ± 3918.03	.007**	NS	NS	NS	NS	S	NS
RG volume	7326 ± 3006.96	7782.62 ± 2905.88	5028.67 ± 2052.18	6858.46 ± 2982.45	.0001***	NS	NS	NS	S	S	S

[a] C-Group indicates control group; AH-Group, adenoid hypertrophy group; ATH-Group, adenotonsillar hypertrophy group; TH-Group, tonsillar hypertrophy group; and SD, standard deviation; NS, not significant; and S, significant. See Table 1 for additional abbreviations.

* $P < .05$; ** $P < .01$; *** $P < .001$.

hyoid bone position. However, it is worth noting that these previous investigations used different methodologies than the current study, which, to some extent, might explain the controversial findings.

Jiang[5] highlighted that a positive correlation between airway volumes and HME and HV was found, which was in agreement with the current correlation results. This could explain the previous findings, which reported[17] airway and hyoid bone positional changes after orthodontic or orthognathic surgery treatment involving mandibular growth modification or advancement. Although the ATH-group showed the fewest correlations between airway and hyoid bone parameters, positive correlations were still found, especially in the RG volume (C3H: $r = 0.447$, HPNS: $r = 0.355$, HV: $r = 0.486$). These findings were similar to those of the previous case series performed by Riley et al.,[18] who proposed the hyoid suspension technique as a surgical approach for treatment of obstructive sleep apnea. They concluded that suspending the hyoid bone antero-inferiorly contributed significantly in increasing the hypopharyngeal airway size, and a significant decrease in the apnea-hypopnea index (AHI) was observed postsurgically.

The muscular complex around the hyoid bone mainly consists of the suprahyoid and infrahyoid muscles. The suprahyoid muscles are largely responsible for lifting the hyolaryngeal complex and opening the upper esophageal sphincter during swallowing, while the infrahyoid muscles are responsible for maintaining the hyoid bone during swallowing to provide a stable foundation for the suprahyoid muscles to assist with mandibular depression. The middle pharyngeal constrictor muscle, which inserts into the hyoid bone, plays a vital role in maintaining airway patency. When the pharyngeal constrictor muscles are activated, the airway dilates at relatively low airway volumes, but it constricts at relatively high airway volumes.[19] This suggests that alteration of hyoid bone position could affect muscle tonicity and, hence, the airway patency.

The relationship between obstructive sleep apnea and the hyoid bone has been investigated by several authors. Young and McDonald[20] found a significant correlation between all hyoid bone vertical measurements and the AHI. In addition, Chang and Shiao[21] studied the craniofacial variables that could be contributing in obstructive sleep apnea; they highlighted that a positive correlation was found between the distance extending from the hyoid bone to the mandibular plane (H-MP) and AHI. A previous investigation by Pae and Harper[22] investigated factors that could be associated with a positive response to oral appliances for the treatment of obstructive sleep apnea; their findings showed that the hyoid bone moved superiorly after oral appliance therapy in subjects who demonstrated a greater decrease in AHI, suggesting that H-MP could be a useful marker for the favorable response to oral appliance treatment.

A collection of predictor variables that best explains variations in the dependent variable can be identified using linear multiple regression analysis. For TA volume, RP volume, and RG volume, every regression analysis was carried out independently. According to the results of the linear regression models, HV was a significant explanatory variable for the variation in RG volume. Another variable in the predicted model for RG volume was age. Previous research[20] underlined the significance of the vertical position of the hyoid bone in the severity of obstructive sleep apnea syndrome. Additionally, Schendel et al.[23] illustrated the potential impact of age on airway volume. Thus, it makes sense that the predictive model was able to adequately explain the variance in RG volume. The same

Table 4. Spearman Correlation Between Airway Volumes and Hyoid Bone Parameters[a]

	HME	HEB	C3H	C3ME	HC3ME	HPNS	HH	HV
C-group								
TA volume								
Correlation coefficient	0.725**	−0.322	0.014	0.713**	0.124	0.195	0.193	0.205
P-value	<.001	.109	.946	<.001	.548	.340	.346	.315
RP volume								
Correlation coefficient	0.671**	−0.287	0.011	0.628**	0.033	0.067	0.242	0.037
P-value	<.001	.155	.956	.001	.873	.744	.234	.857
RG volume								
Correlation coefficient	0.579**	−0.322	0.024	0.530**	0.239	0.402*	−0.056	0.628**
P-value	.002	.109	.908	.005	.239	.042	.787	.001
AH-group								
TA volume								
Correlation coefficient	0.616**	0.027	0.292	0.647**	0.371	0.626**	0.112	0.438*
P-value	.001	.900	.157	<.001	.068	.001	.593	.028
RP volume								
Correlation coefficient	0.595**	−0.003	0.247	0.573**	0.355	0.531**	0.107	0.288
P-value	.002	.990	.234	.003	.081	.006	.610	.162
RG volume								
Correlation coefficient	0.542**	0.018	0.222	0.569**	0.446*	0.743**	0.160	0.625**
P-value	.005	.933	.287	.003	.025	<.001	.446	.001
ATH-group								
TA volume								
Correlation coefficient	0.094	0.088	0.366*	0.202	0.162	0.194	0.088	0.170
P-value	.575	.598	.024	.225	.332	.243	.600	.306
RP volume								
Correlation coefficient	0.118	0.170	0.298	0.211	0.085	0.091	0.145	−0.003
P-value	.481	.307	.069	.203	.613	.589	.384	.984
RG volume								
Correlation coefficient	−0.032	−0.014	0.447**	0.142	0.308	0.355*	−0.039	0.486**
P-value	.850	.934	.005	.394	.060	.029	.818	.002
TH-group								
TA volume								
Correlation coefficient	0.346	−0.031	0.209	0.355*	−0.018	0.086	−0.195	0.067
P-value	.052	.866	.250	.047	.922	.638	.284	.714
RP volume								
Correlation coefficient	0.541**	−0.158	0.166	0.507**	−0.081	0.058	−0.237	−0.025
P-value	.001	.387	.365	.003	.658	.753	.192	.891
RG volume								
Correlation coefficient	0.404*	−0.042	0.319	0.454**	0.210	0.424*	−0.177	0.451**
P-value	.022	.821	.075	.009	.250	.016	.333	.010

[a] TA volume indicates total airway volume; RP volume, retropalatal airway volume; RG volume, retroglossal airway volume; C-group, control group; AH-group, adenoid hypertrophy group; ATH-group, adenotonsillar hypertrophy group; and TH-group, tonsillar hypertrophy group. See Table 1 for additional abbreviations.

* Correlation is significant at .05; ** Correlation is significant at .01.

variables utilized for TA volume and RP volume, in contrast to the RG volume model, provided low predictive value for the variances.

Despite the fact that the cross-sectional design of this study was not capable of assessing causation principles, a longitudinal design was not used because of the possible increased radiation associated with it. Another limitation of this study was that it did not include Class III subjects because of the lack of a large enough sample size. Variations of the hyoid bone position and, thus, the angulation and the relative muscular tone of the associated muscles in subjects with different skeletal phenotypes were previously reported.[24] Therefore, further investigations with more detailed grouping and a bigger sample size are recommended to better determine the effect of adenotonsillar hypertrophy on the craniofacial complex. In addition, the results of this study were limited to Chinese patients, and future studies should consider racial differences when evaluating the findings.

CONCLUSIONS

- A significant decrease in HV, TA volume, and RG volume was found in subjects with adenotonsillar hypertrophy compared to the control group.
- HV and age were significantly positively correlated predictors for explaining the RG volume.

Table 5. Multiple Linear Regression Model for Retroglossal Airway Volume as a Dependent Variable After Logarithmic Transformation[a]

Dependent Variable:	Unstandardized Coefficients		Standardized Coefficients			ANOVA		
Log of RG Volume	Beta	SE	Beta	*t*	*P*	*F*	*P*	Adjusted R^2
Constant	2.099	0.393		5.342	.000	6.907	<.0001****	0.4
Age	0.019	0.009	0.173	2.105	.037*			
Gender	−0.038	0.029	−0.098	−1.329	.187			
ANB°	0.010	0.009	0.098	1.105	.271			
SNA°	−0.005	0.005	−0.100	−0.991	.324			
SNB°	0.002	0.002	0.079	0.865	.389			
FMA°	0.003	0.005	0.047	0.597	.551			
HME	0.004	0.005	0.113	0.839	.403			
HEB	−0.003	0.005	−0.064	−0.734	.464			
C3H	0.004	0.005	0.088	0.838	.404			
C3ME	0.004	0.004	0.174	1.144	.255			
HC3ME	−0.005	0.006	−0.111	−0.808	.421			
HPNS	0.007	0.005	0.207	1.313	.192			
HH	0.000	0.002	0.024	0.314	.754			
HV	0.009	0.003	0.399	3.151	.002**			

[a] SE indicates standard error; ANOVA, analysis of variance. See Table 1 for additional abbreviations.
* $P < .05$; ** $P < .01$; *** $P < .001$; **** $P < .0001$.

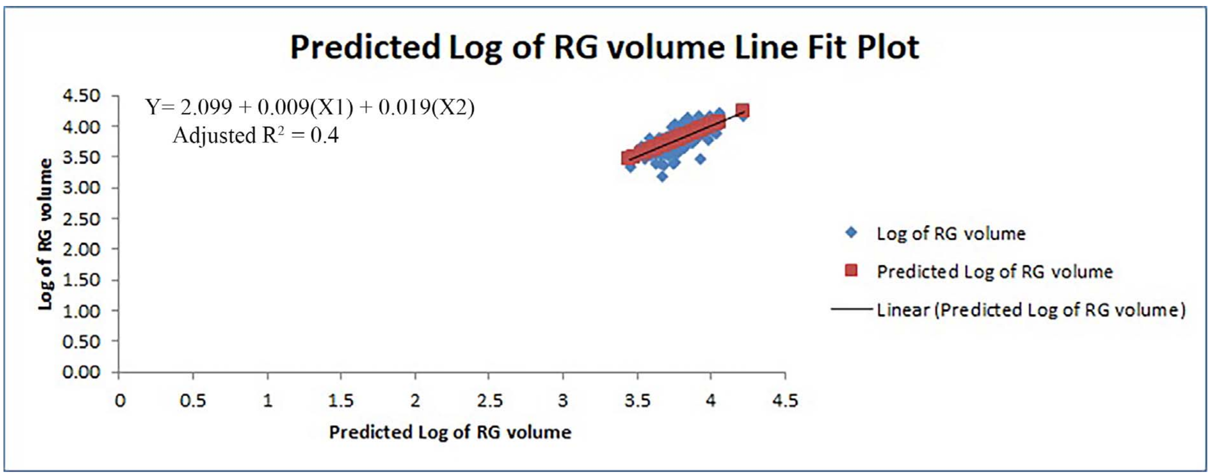

Figure 4. Multiple linear regression analysis.

ACKNOWLEDGMENTS

This project was funded by (1) a general project from the field of Social Development in the Department of Science and Technology of Shaanxi Province, grant/award 2019SF-081; (2) the Science and Technology Project of Xi 'an, grant/award 20YXYJ0010(3); and (3) Clinical New Technology from Stomatological Hospital of Xi'an Jiaotong University in 2018.

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