The Pharyngeal Airways of Patients with Class II Malocclusion: A Cone-Beam Computed Tomography Analysis

Yazgı Ay Ünüvar
Department of Orthodontics, Faculty of Dentistry, Aydın Adnan Menderes University, Aydın 09010, Turkey,
yazgiay@hotmail.com

Fundagül Bilgiç Zortuk
Department of Orthodontics, Faculty of Dentistry, Hatay Mustafa Kemal University, Hatay 31070, Turkey,
fundagulbilgic@hotmail.com

Törün Özer
Department of Orthodontics, Faculty of Dentistry, Dokuz Eylül University, İzmir 35340, Turkey,
torunozer@gmail.com

Kadir Beycan
Department of Orthodontics, Faculty of Dentistry, Marmara University, İstanbul 34722, Turkey,
orthodonty@hotmail.com

MAKARA Journal of
Health Research

The Pharyngeal Airways of Patients with Class II Malocclusion: A Cone-Beam Computed Tomography Analysis

Yazgı Ay Ünüvar[1]*, Fundagül Bilgiç Zortuk[2], Törün Özer[3], Kadir Beycan[4]

[1]Department of Orthodontics, Faculty of Dentistry, Aydın Adnan Menderes University, Aydın 09010, Turkey

[2]Department of Orthodontics, Faculty of Dentistry, Hatay Mustafa Kemal University, Hatay 31070, Turkey

[3]Department of Orthodontics, Faculty of Dentistry, Dokuz Eylül University, İzmir 35340, Turkey

[4]Department of Orthodontics, Faculty of Dentistry, Marmara University, İstanbul 34722, Turkey

Abstract

Background: This study aimed to compare the minimum axial (min Ax) area and the volumes of the nasopharyngeal (NP) and oropharyngeal (OP) airways of patients with Class II malocclusion with different sagittal positions of the mandible and maxilla and patients with Class I malocclusion with normal jaw positions.

Methods: Airway areas and volumes of 51 patients with Class I malocclusion with normal maxillary and mandibular positions (0 < ANB < 4, 84 > SNA > 80, and 82 > SNB > 78) were compared with 21 patients with Class II malocclusion with normal maxillary and retrognathic mandibular positions (ANB>4, 84>SNA>80, and SNB<78) and 21 patients with Class II malocclusion with prognathic maxillary and normal mandibular positions (ANB>4, SNA>84, and 82>SNB>78).

Results: In the comparison of airway measurements between Class I and Class II groups, significant differences were found in the OP airway volume, total airway volume, and minimum OP axial area. Patients with Class II mandibular retrusion had smaller OP airway volume. The total airway volume and min *Ax* area were significantly lower in the Class II mandibular retrusion group than in other groups.

Conclusions: The sagittal position of the jaws affects the OP airway volume and the minimum axial airway area, but not the NP airway volume.

Keywords: cone-beam computed tomography, mandibular retrusion, obstructive sleep apnea

INTRODUCTION

Class II malocclusion is associated with skeletal discrepancy owing to the retruded position of the mandible, anterior position of the maxilla, or both.[1] According to McNamara, the single most common feature of Class II malocclusions is mandibular skeletal retrusion rather than maxillary prognathism.[2] Some researchers associated mouth breathing with Class II malocclusion.[3–6]

The narrowing of the pharyngeal airway is considered among the basic causes of the development of obstructive sleep apnea syndrome (OSAS). OSAS is a sleep-breathing disorder characterized by the interruption of the pharyngeal airway caused by periodic airway collapse during sleep and respiratory arrest.[7] Class II malocclusions with vertical growth patterns have been reported to be anatomical predisposing factors for the obstruction of the pharyngeal airway.[5,8] Most researchers have analyzed

the relationship between facial morphology and pharyngeal airway shape on two-dimensional (2D) cephalometric radiographs.[3,5,6,9–12] However, 2D radiographies do not allow assessment of the pharyngeal volumes. The human airway is a three-dimensional (3D) structure, so lateral films represent the 3D structure in 2D view. Thus, analyzing a 3D structure in 2D view was a limitation of previous studies.[13,14]

The diagnostic capacity of the airway has expanded with the development of 3D computed tomography (CT); however, the routine use of CT devices is limited by the high-dose radiation they generate. The radiation dose has been reduced, thanks to the development of cone-beam CT (CBCT). CBCT has become a well-accepted maxillofacial diagnostic imaging technique because it emits lower radiation dose and has faster image acquisition times than conventional CT.[15,16]

Several studies[4,6,17,18] have shown that patients with retrognathic mandible have decreased pharyngeal airway, but how the prognathic maxilla affects the airway is still not certain. To the best of our knowledge, only one 3D study has addressed pharyngeal airway dimensions in skeletal discrepancies considering the sagittal position of the maxilla and mandible with regard to the cranial base.[19] The present study focused

Corresponding author:
Yazgı Ay Ünüvar
Department of Orthodontics, Faculty of Dentistry,
Aydın Adnan Menderes University, Aydın, Turkey
E-mail: yazgi.ay@adu.edu.tr

on Class II skeletal discrepancy with an extended sample size of each group.

This retrospective study aimed to compare the minimum axial (min Ax) area and the volumes of the nasopharyngeal (NP) and oropharyngeal (OP) airways of patients with Class I malocclusion with normal arch position and patients with Class II with different sagittal positions of the mandible and maxilla and to investigate whether the pharyngeal airway was affected by the sagittal position of the jaw.

METHODS

The protocol of this retrospective study was approved by the local ethical committee in University Faculty of Dentistry (ADÜDHF2018/030). All patients and their parents had signed an informed consent form allowing the use of their data and records for scientific purposes. The study followed a retrospective design, and no additional radiation was given to the patients. CBCT was performed to provide accurate an diagnosis of dental problems.

In this study, 1530 CBCT scans were evaluated. Scans that met the inclusion criteria were selected from among these data sets. A total set of 93 patients (aged 16–43 years) with Class I and Class II sagittal skeletal patterns were selected from the archive of the Oral Diagnosis and Radiology Department of University, Faculty of Dentistry. All CBCT images were obtained in a single 360° rotation using a ProMax 3D scanner (Planmeca, Helsinki, Finland). All images were taken at 8 mA and 90 kV in a scanning field of 20 by 17 cm and exposure time of 13.5 seconds. The axial slice thickness was 0.3 mm, and voxels were isotropic.

The exclusion criteria for this study were as follows: detectable pathology along the upper airway, missing teeth except for the third molars, previous orthodontic treatment or orthognathic surgery, craniofacial syndrome, adenoidectomy or tonsillectomy, severe hypodivergent growth pattern (Frankfort to mandibular plane angle, FMA<19), severe hyperdivergent growth pattern (FMA>31), nasal obstruction, and incomplete visualization of the upper airway.

A total set of 93 CBCT scans were used for this study. Airway areas and volumes of 51 patients with Class I normal maxillary and mandibular positions (0<ANB<4, 84>SNA>80, 82>SNB>78) were compared with 21 patients with Class II normal maxillary and retrognathic mandibular positions (ANB>4, 84>SNA>80, SNB<78) and 21 patients with Class II prognathic maxillary and normal mandibular positions (ANB>4, SNA>84, 82>SNB>78).
Lateral cephalograms were obtained automatically from CBCT data using the Dolphin 3D Imaging program (version 11, Dolphin Imaging & Management Solutions,

LA, CA) and were traced with the same program to measure four angular (FMA, SNA, SNB, and ANB) parameters (Figure 1). All data were collected and measured by a single experienced orthodontist (Y.A.Ü.).
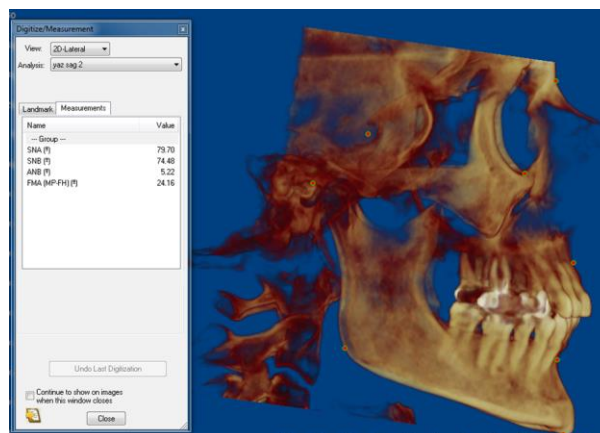

FIGURE 1. Sagittal and vertical skeletal measurements used in this study were created with the Dolphin 3D software program

The anteroposterior skeletal type was established by ANB measurements as Class I (0<ANB<4) and Class II (ANB>4). SNA and SNB angles were used to determine the maxillary and mandibular positions relative to the cranial base. Moreover, 84>SNA>80 and 82>SNB>78 were determined as the normal range of the positions of the maxilla and mandible, respectively. As a result, the patients were divided into three groups as Class I with normal maxillary and mandibular positions relative to the anterior cranial base and each other, Class II with normal maxillary and retrognathic mandibular positions relative to the anterior cranial base (ANB>4, SNB<78), and Class II with prognathic maxillary and normal mandibular positions relative to the anterior cranial base (ANB>4, SNA>84).

All skeletal and airway measurements were performed with Dolphin 3D (version 11, Dolphin Imaging & Management Solutions, LA, CA), a third-party software program. The OP airway volume was defined as the volume of the pharynx between the palatal plane (anterior nasal spine–posterior nasal spine) extending to the posterior wall of the pharynx and the plane parallel to the palatal plane passing through the most anteroinferior point of the second cervical vertebrae (Figure 2). The inferior limit of the NP airway was defined as the superior limit of the OP airway, and the superior limit of the NP airway was defined as the last slice before the nasal septum fused with the posterior wall of the pharynx. Thus, the superior border of the NP was defined on the axial slice and then reflected on the sagittal plane (Figure 3). The anterior border of the NP airway is the anterior wall of the pharynx. The superior and inferior limits of the OP and NP airways were determined from the limits used by El and Palomo.[20] In

addition to these volumetric measurements, the minimum axial (min Ax) area was calculated.

Descriptive statistics including mean, standard deviation, and minimum and maximum values for each group were calculated using SPSS for Windows (SPSS 11.0, Chicago, IL, USA). The significance level was set at 0.05. Chi-square test was performed to check the distribution of gender among groups. The Kolmogorov–Smirnov test was used to determine the normal distribution of data. Since the distribution of the variables was not normal, intergroup comparisons of age, skeletal patterns, and airway measurements were performed using the Mann–Whitney U-test and Kruskal–Wallis test. As the second step, the Mann–Whitney U-test with Bonferroni correction was used for further pairwise comparison of significant findings. Correlations between variables were tested with the Pearson correlation coefficient.
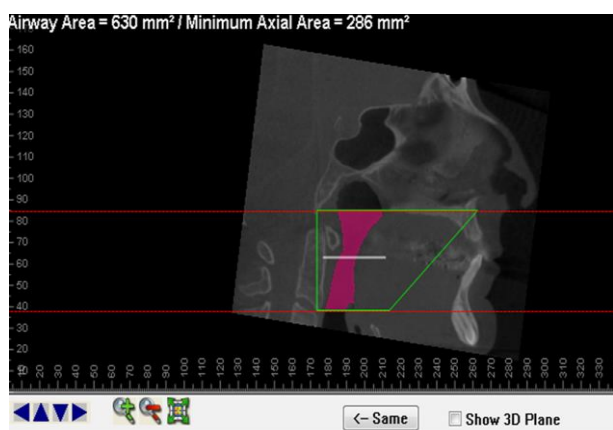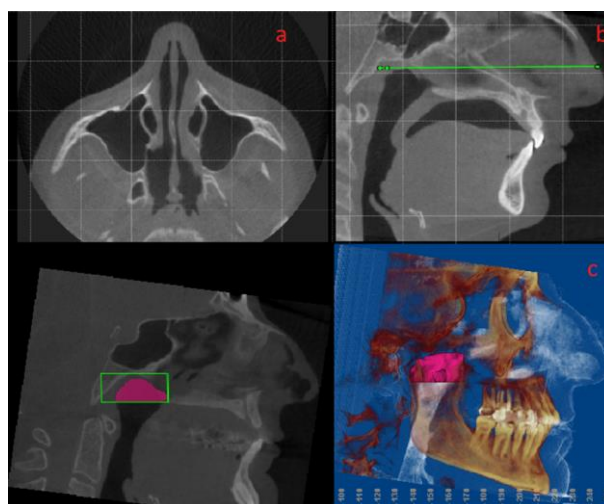

(a)
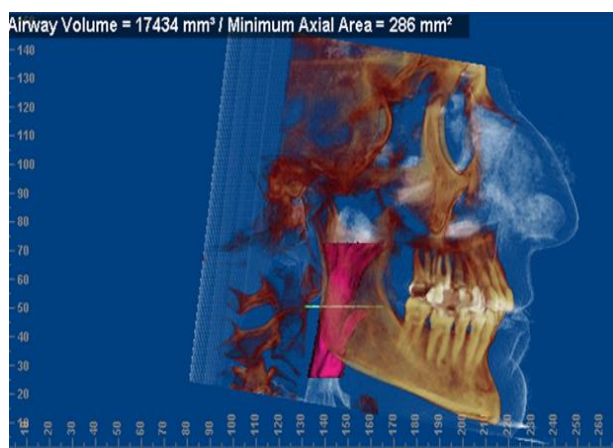
(b)

FIGURE 2. (a) Oropharyngeal minimum axial area (min Ax) and (b) Oropharyngeal airway (OP) volume rendering with the Dolphin 3D software program

FIGURE 3. Nasopharyngeal airway borders. (a) Determination of the last slice before the nasal septum fused with the posterior wall of the pharynx on the axial plane. (b) Reflection on the sagittal plane. (c) Nasopharyngeal airway (NP) volume rendering with the Dolphin 3D software program

Images were re-measured 3 weeks after the initial measurements for reliability. Dahlberg's formula ($\sqrt{\sum d^2/2n}$) for linear, areal, and angular measurements and the intraclass correlation coefficient (ICC) for volumetric measurements were used to test reliability.

RESULTS

The operator's calibration was confirmed because the ICC results were between 0.928 and 0.941 and the results of Dalhberg's formula were between 0.354 and 0.802 for all variables assessed. The gender distributions of the groups are given in Table 1. A chi-square test was used to control the distribution of gender to match the groups. No differences were found between the groups owing to the similar male-to-female composition. Data were combined because no significant difference was found.

Descriptive demographic characteristics of the groups are given in Table 2. No significant age difference was found between the groups, and the mean age was 30.57 ± 11.47 years for the Class I normal growth pattern group, 31.57 ± 11.88 for the Class II mandibular retrusion group, and 31.09 ± 10.87 for the Class II maxillary protrusion group.

TABLE 1. Male–female composition of Class I and Class II subgroups

	Class I normal	Class II mandibular retrusion	Class II maxillary protrusion	Total	*p*
Female	25	12	11	48	>0.1
Male	26	9	10	45	
Total	51	21	21	93	

TABLE 2. Descriptive statistics showing the means, standard deviations, and minimum and maximum values of the Class I group and Class II groups and results of intergroup comparisons using Kruskal–Wallis test

Variables	Class I normal (N=51)			Class II mandibular retrusion (N=21)			Class II maxillary protrusion (n=21)			P
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	
Age (years)	30.57 ± 11.47	17	40	31.57 ± 11.88	17	43	31.09 ± 10.87	17	41	NS
FMA(°)	25.54 ± 3.30	19	30.4	26.58 ± 3.10	19.9	31	23.88 ± 4.29	19.6	29.7	NS
SNA(°)	81.86 ± 1.24	80	84	82.07 ± 1.45	80	84	86.06 ± 1.16	84.4	88.6	0.000***
SNB(°)	79.14 ± 1.05	78	82	75.89 ± 1.56	72	77.9	79.88 ± 1.44	78.5	82	0.000***
ANB(°)	2.72 ± 0.74	1.5	3.9	5.99 ± 1.08	4.4	8	6.20 ± 1.79	4.2	10.8	0.000***
OP vertical length (mm)	37.84 ± 4.17	29.4	44.1	37.99 ± 4.84	25.9	45.3	36.63 ± 5.02	22.6	43.95	NS
PAS (mm)	8.47 ± 2.84	4.9	14.8	7.43 ± 2.32	3.3	13.4	8.82 ± 2.73	4.3	13.8	NS
NP volume (mm3)	15262.58 ± 5515.48	4919.5	27121.7	15092.71 ± 5473.82	6065.2	23838.5	16112.72 ± 3478.88	11542	22429.1	NS
OP volume (mm3)	14363.56 ± 3036.34	8989.8	19763.2	9509.35 ± 2305.31	4650	12455.4	14119.08 ± 4099.82	8306.7	21936	0.000***
TOTAL volume (NP+OP) (mm3)	29626.14 ± 6540.06	18791.1	42353.1	24602.07 ± 6979.79	10715.2	34484.4	30231.80 ± 4975.67	23154.4	39895.8	0.031*
OP min area (mm2)	152.00 ± 79.19	70.6	361.3	83.61 ± 59.44	47.8	233.4	111.52 ± 47.12	67.5	205	0.002**

NP, nasal passage; OP, oropharynx; PAS, posterior airway space; min Ax, minimum area of the oropharynx on the axial slice; SD, standard deviation; min, minimum; max, maximum; NS, not significant; *P < 0.05; **P < 0.01; ***P < 0.001

Since FMA, SNA, SNB, and ANB were used to form the groups, significant differences in skeletal variables were expected between the groups.

For airway measurements, the OP airway volume, total airway volume, and minimum OP axial area were significantly different among the groups, while the OP vertical length, PAS, and NP volume were not different. Further pairwise comparisons are shown in Table 3. The Class II mandibular retrusion group presented the smallest OP airway volume (9509.35 ± 2305.31 mm^3), total airway volume (24602.07 ± 6979.79 mm^3), and min Ax area (83.61 ± 59.44 mm^2), and a significant difference was observed when compared with the other groups. No significant difference was found between the Class I normal and Class II maxillary protrusion groups. The NP volume did not demonstrate a significant difference between the groups.

Bivariate correlations are shown in Table 4. The SNB, OP vertical length, PAS, total airway volume, and min Ax area were significantly positively correlated with the OP airway volume. The ANB angle was significantly negatively correlated with both the OP airway volume and min Ax area. The NP volume showed a significant positive correlation with the total airway volume but a significant negative correlation with the FMA. Stronger correlations were found with the OP data than with NP volumes and min Ax area. The strongest correlations for OP volumes were with the SNB angle and total airway volume. The comparison of the total airway among the groups showed that individuals with mandibular retrusion had smaller OP airway volumes than individuals with normal ones.

TABLE 3. Results of the pairwise comparisons with Mann–Whitney U tests with the Bonferroni adjustment

	OP volume (mm^3)	TOTAL volume (NP+OP) (mm^3)	minAx (mm^2)
Mann-Whitney U test			
Class I Normal	Class II Mand Ret***	Class II Mand Ret*	Class II Mand Ret**
Class II Mand Ret	Class I*** Class II Max Prot***	Class I* Class II Max Prot*	Class I ** Class II Max Prot*
Class II Max Prot	Class II Mand Ret***	Class II Mand Ret*	Class II Mand Ret*
Kruskal-Wallis test	0.000***	0.031*	0.002**

Mand Ret = mandibular retrusion; Max Prot = maxillary protrusion; NP = nasal passage; OP = oropharynx; PAS =

posterior airway space; min Ax = minimum area of the oropharynx on the axial slice; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

DISCUSSION

Some researchers[11,12,18,21–23] claimed that individuals with Class II mandibular retrusion had a more backward tongue position that leads to the disturbance in the cervical region. The posterior displacement of the soft palate may narrow the OP airway, resulting in mouth breathing and OSAS. Previous studies[10,12,24,25] have compared major skeletal sagittal discrepancies, but the present study compared pharyngeal airway dimensions in individuals with Class II skeletal discrepancy, taking into account the different sagittal positions of the jaws relative to the cranial base. Moreover, samples of this study have not been used in previous studies.

Several studies[4,6,12,24-30] have tried to document the association of the airway with craniofacial morphology. The relationship between facial morphology and pharyngeal airway volume and shape was mostly evaluated by lateral cephalometric radiographies.[5,6,9,12,21,23] 2D radiographs have a limited capacity for measuring airway areas. The size of the pharynx continuously changes during respiration, so static images of this dynamic structure, such as cephalometric radiographs, may not be ideal for the evaluation of the pharyngeal airway.[31] Aboudara et al.[14] found much greater inter-individual variations in the volume and area of the upper airway in cephalograms than in CT. CBCT enables the determination of the craniofacial skeleton and soft tissues in 3D. The pharyngeal airway obtained with CBCT produced anatomically correct images without magnification or distortion. It also helps us understand the real morphology of the head and airways by allowing accurate measurements in all sagittal, coronal, and axial slices.[20] Drawing the airway circumference and computer calculations of the cross-sectional areas also greatly reduce operator-dependent bias. The present study was designed on CBCT because of these advantages.

Tourne´[8] described the growth of the bony nasopharynx mainly vertically, with a slight anteroposterior increase early in life and minimal change after the growth spurt in 2D cephalometric data, but they have no 3D longitudinal data on airway changes during growth. To examine airway differences related to the growth status, the study participants were selected among individuals between age 16 and 43 years with an average of 31.07 years, so the participants had already experienced a growth spurt. As a result, the airway volume did not correlate with age.

Dolphin 3D was used to calculate the desired airway measurements in the present study. El and Palomo[20] showed that this software program is highly reliable in calculating the airway volume.

TABLE 4. Pearson correlation coefficients for OP, NP, total volumes, and min Ax area compared with the variables used for this study

		SNA(°)	SNB(°)	ANB(°)	FMA(°)	OP vertical length (mm)	PAS (mm)	NP volume (mm³)	OP volume (mm³)	TOTAL volume (NP+OP) (mm³)	min Ax (mm²)
NP volume (mm3)	Correlation coefficient	0.072	0.095	-0.018	-0.254*	-0.073	0.096		0.115	0.830**	0.028
	p	0.490	0.367	0.861	-0.014	0.482	0.408		0.272	0.000	0.788
OP volume (mm3)	Correlation coefficient	0.173	0.474**	-0.267**	-0.036	0.231*	0.564**	0.115		0.649**	0.226*
	p	0.098	0.000	0.010	0.732	0.032	0.000	0.272		0.000	0.029
TOTAL volume (NP+OP) (mm3)	Correlation coefficient	-0.152	0.339**	-0.164	-0.215*	0.217*	0.623**	0.830**	0.649**		0.148
	p	0.145	0.001	0.016	0.039	0.037	0.000	0.000	0.000		0.156
min Ax (mm2)	Correlation coefficient	-0.175	0.246*	-0.312**	0.116	0.125	0.727**	0.028	0.226*	0.148	
	p	0.094	0.023	0.002	0.266	0.134	0.000	0.788	0.029	0.156	

NP, nasal passage; OP, oropharynx; min Ax, minimum area of the oropharynx on the axial slice; sum, sum of the inner angles; Nperp, nasion perpendicular

* correlation is significant at 0.05 level (two-tailed)
** correlation is significant at 0.01 level (two-tailed)

Measurements of the pharyngeal airway area have been reported and have shed light on the evaluation of the relationship between the craniofacial growth pattern and the airway. Aboudara *et al*.[14] found that 2D measurements of the NP airway area lacked much of the structural information because the 3D structure was compressed into a 2D image. In the present study, the structures of the pharynx were obtained from 3D CBCT scans, and measurements were performed on this dynamic source.

Some researchers[5,6,24,32] claimed that patients with hyperdivergent skeletal patterns tend to have narrower upper pharyngeal airways. We excluded severe individuals with hypodivergent and hyperdivergent skeletal patterns to rule out differences caused by the severe vertical growth pattern.

In our study, no significant differences were found in the NP airway volumes when the sagittal positions of the jaws were compared among the groups. This finding corroborated those of some previous studies that were conducted with other visualization techniques.[6,12,33] However, our findings contradict those of some other studies[34,35] that found narrower NP airways in individuals with Class II malocclusion. These contrasting results might be due to the differences in sample selection, delineation of the nasal passage, or visualization technique. Our study compared individuals with Class I and Class II malocclusions, while other studies compared nasal and mouth breathers.[34,35]

Kim *et al*.[25] showed that healthy preadolescent children with retruded mandibles have reduced total pharyngeal airway volumes. Grauer *et al*.[24] and El andPalomo[19] have also found that the total airway volume of patients with retrognathic mandible was significantly smaller than those with normal mandible position. In the present study, the OP airway volume demonstrated different sagittal relationships concurrent with previous studies.[12,36,37] We found that the Class II mandibular retrusion group had the smallest OP volume. This result clarifies that the mandible is responsible for this difference in Class II cases. Retrognatic and smaller mandibles will push the tongue toward the pharynx, affecting the position of the tongue. This situation causes a decrease in the OP volume. We found a negative correlation between the OP airway volume and ANB and a positive correlation between the SNB and OP airway volume, as reported by El and Palomo[36] and Kim *et al*.[25] These correlation results support our findings.

The most constricted cross-sectional area (min Ax) of the airway has been considered an important parameter for airway evaluation. If the min *Ax* area is narrow, the air passage will be restricted and will cause more problems. Therefore, analyzing the min *Ax* area may become more important than that of the airway volume. We also found

a correlation between OP volume and min *Ax* area measurements. Tso *et al*.[38] also mentioned a high correlation between the min *Ax* area and total airway volume. El and Palomo[19] found a strong correlation between the OP airway volume and min *Ax* area, similar to our findings. As a result of our study, we thought that determining the narrow airways and the size and volume of the airways are important in clinical diagnosis and treatment plans.

Similar to the study of El and Palomo,[19] the current study presented that the PAS significantly correlated with the OP volume. We found a strong correlation between PAS and min *Ax* area. This was an expected result because the min *Ax* area is the axial representation of the PAS. However, as an advantage of 3D imaging, it is possible to determine the correct restriction zone, so that the min *Ax* area has become a more important parameter than PAS.

The development of CBCT technology provides a new perspective on volumetric airway studies. It is not sufficient to evaluate patients with orthodontic conditions only from a skeletal or dental point of view. For this reason, a detailed analysis of the airway volume and shape may provide a valuable diagnostic contribution in the field of orthodontics.

This study has several limitations. CBCT scans were taken in an upright position. As OSAS occurs during sleep, the evaluation of the pharynx in the supine position can provide more accurate information. The sample size was small, and the study design was retrospective. Further follow-up studies on pharyngeal airway volume with a larger sample size would have been more reliable. Body mass index can also help in better understanding the relationship between pharyngeal airways and skeletal patterns.

CONCLUSIONS

Patients with Class II malocclusion with mandibular retrusion had smaller OP airway volumes than those with Class I and Class II maxillary protrusions. Mandibular retrusion relative to the cranial base affected the OP airway volume. The min Ax area was the variable that best described the OP airway volume.

CONFLICT OF INTEREST

None declared.

FUNDING

None.

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