Correlation Analysis between Airway Volume and Risk of Sleep Apnea/Periodontitis

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ABSTRACT

Objectives: Sleep apnea and periodontitis have high incidences in general population. They share common risk factors such as obesity, smoking, and aging. As cone-beam computed tomography becomes popular in dentistry, airway analysis is very accessible to dentists. However, not many studies have investigated the correlations between airway volume and risk of sleep apnea and periodontitis. The purpose of this retrospective study was to investigate the association between airway volume and the occurrence of sleep apnea and periodontitis.
Material and Methods: Overall, 258 patients were enrolled (male: 118, female: 140, age from 13 to 88). axiUm® was used to collect demographical/physical information and the status of sleep apnea and periodontitis. Invivo™ software was utilized to measure airway dimensions. One-way ANOVA followed by Tukey's HSD post-hoc test and Pearson analysis were run to determine statistical difference in airway volumes among patients with various demographic and health status, and association of airway dimensions with their sleep apnea and periodontal conditions.
Results: Sleep apnea patients had significantly higher body weight, body mass index, and significantly smaller airway compared to non-apnea patients ($P < 0.05$). Old age, male, and diabetes were found to be positively correlated with sleep apnea. No association between airway dimension and periodontal status was identified.
Conclusions: Patients with high body mass index are at higher risk of developing constricted airway and sleep apnea. There appears to be no association between restricted airway and occurrence of periodontitis. Cone-beam computed tomography plays a critical role in identifying narrow airway and necessitating proper referral.

Keywords: airway resistance; cone-beam computed tomography; periodontitis; sleep apnea.

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INTRODUCTION

The National Commission on Sleep Disorders (https://www.nhlbi.nih.gov/about/divisions/division-lung-diseases/national-center-sleep-disorders-research) estimates that sleep disorders including sleep apnea affects 7 to 18 million people in the United States, while 2 to 4 million Americans have moderate to severe systemic diseases resulting from sleep apnea [1]. National Health and Nutrition Examination Survey (https://www.cdc.gov/nchs/nhanes/) indicates that in the United States, over 47% of adults aged 30 and over have periodontitis, and for those aged 65 years and older, 64% have moderate or severe periodontitis [2]. Sleep apnea and periodontal disease share common risk factors, such as aging, obesity, smoking, and are both associated with systemic inflammation [1,3].

Narrowed airway due to palate and tongue volume, pharyngeal fat deposits, and class II skeletal profile are considered some of the contributing factors for sleep apnea [1]. In addition, narrowed airway causes mouth breathing and xerostomia during sleep, which could potentially disturbs oral microflora and increases the risk for periodontal diseases and tooth loss [4].

Recently, cone-beam computed tomography (CBCT) has established itself as a valuable imaging modality in dentistry. It generates images with superior morphologic details and dimensional accuracy, with cost and absorbed doses much lower than conventional CT [5-7]. So far, there are a plethora of studies demonstrating that CBCT is a simple, fast, effective, and reliable way to accurately analyse the airway three-dimensionally [8-11].

To date, limited information exists on the link between airway volume and occurrence of sleep apnea and periodontal disease. Thorough investigation in this area would reveal associations between airway volume and risk of developing sleep apnea and periodontal diseases. As more and more patients have CBCT scan taken for implant placement or other therapeutic purposes, dental professionals are more readily having airway data available to them than ever before. Understanding the correlation between airway anatomy and risk of developing dental disease and sleep apnea could facilitate proper referral and improve dental and overall healthcare for the patients.

The aim of the retrospective study was to evaluate correlation between airway volume and risk of sleep apnea and periodontal disease based on cone-beam computed tomography imaging analysis, so as to facilitate proper follow up and referral.

MATERIAL AND METHODS

Subjects

Two hundred and fifty-eight patients who had CBCT scan taken at the Imaging Clinic of University of Texas School of Dentistry at Houston from 2016 to 2019 were recruited consecutively (Table 1). These patients were scanned for implant placement or other therapeutic purposes. Recruited patients demonstrate loss of teeth due to a variety of reasons, including caries, periapical lesion, periodontal disease, trauma, etc.

The inclusion criteria were:

- Medium field view including both maxillary and mandibular arches;
- Clear delineation of airway from hard palate to the base of epiglottis.

The exclusion criteria were:

- Presence of imaging artifacts obscured the observation of airway;
- History of pharyngeal pathology and/or surgery.

Ethical approval was granted by the Institutional Review Board of the University of Texas Health Science Center (HSC-DB-19-0122). Among the enrolled patients, 118 were males and 140 were females, with an age range of 13 to 88 years old.

CBCT acquisition

The CBCT scans were acquired at 90 kVp, 10 mA,

Table 1. General profile of the patients (number [%])

Age	**10 - 20**	3 (1.1%)
	21 - 30	5 (1.9%)
	31 - 40	21 (8.1%)
	41 - 50	42 (16.3%)
	51 - 60	54 (20.9%)
	61 - 70	79 (30.6%)
	71 - 80	45 (17.4%)
	> 81	9 (3.5%)
Periodontal status	**Health**	50 (19.4%)
	Gingivitis	52 (20.%)
	Mild	50 (19.4%)
	Moderate	56 (21.7%)
	Severe	50 (19.4%)
Gender	**Male**	118 (45.7%)
	Female	140 (54.3%)
Diabetes	**Yes**	27 (10.5%)
	No	231 (89.5%)
Sleep apnea	**Yes**	62 (24.%)
	No	196 (76.%)

16 seconds and a 0.2 mm^3 voxel size with a Kodak 9500 Cone Beam 3D System (Carestream Health, Inc.; Rochester, New York, USA). The volumes covered maxillary and mandibular arches with a field of view (FOV) of 150 x 90 mm^2. CBCT images were reconstructed with Invivo™ software version 5.2 (Anatomage Inc.; San Jose, California, USA) at 1 mm thickness. All images were viewed on a 19-inch flat panel screen (HP Development Co.; Palo Alto, California, USA) with a 1920 x 1080 pixel resolution under a dimly lit environment.

Clinical data collection

All clinical relevant information was collected from axiUm® (Exan Corporation; Vancouver, British Columbia, Canada), the institutional electronic health record (EHR) system. For each patient, the age and gender were recorded. Body height and weight were collected from the medical/dental history form, and the body mass index (BMI) was calculated using formula:

$$\text{BMI} = \frac{\text{weight (lbs) x 703}}{\text{height (in}^2\text{)}}$$

Presence of diabetes and sleep apnea was extracted from "endocrine" and "respiratory" section of the medical/dental history form, respectively. Patients were classified as sleep apnea when they had a history of loud snores during sleep and feeling tired even after a full night's sleep as well as a prior diagnosis of "sleep apnea" from their physicians. Presence and severity of gingivitis and/or periodontitis was collected from periodontal examination and treatment planning form of EHR. Diagnosis and classification of gingivitis and periodontitis were based on the guidelines proposed by the American Academy of Periodontology based on clinical probing and radiographic examinations.

CBCT imaging analysis

Prior to airway analysis, the scan was oriented to make hard palate parallel to horizontal plane on sagittal view. The volume of oropharynx was delineated as the portion of airway between hard palate and base of epiglottis. The oropharynx airway volume and minimal surface area were automatically calculated with airway analysis tool of Invivo™ software after making several clicks on the path of the airway (Figure 1).

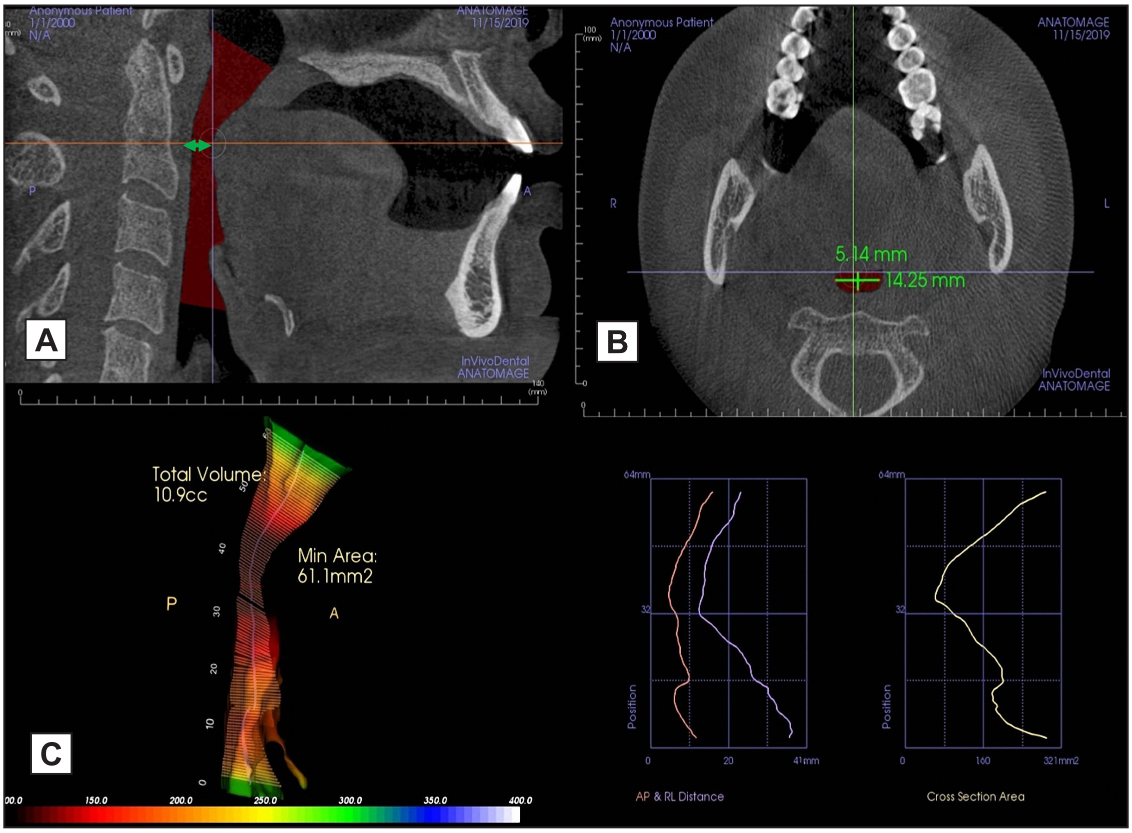

Figure 1. Airway analysis was conducted on cone-beam computed tomography scans with Invivo™ software.
A = on sagittal view, the most constricted point of oropharynx was identified manually, as marked by the green double-headed arrow.
B = on the corresponding axial view, the minimal anterior-posterior (AP) and mesial-lateral (ML) dimensions of oropharynx were measured using linear measurement tools of Invivo™ software, as AP = 5.14 mm, and ML = 14.25 mm.
C = total airway volume (10.9 ml) and minimal surface area (61.1 mm^2) were automatically calculated by the software.

On sagittal view, the most constricted point of oropharynx was identified manually, and on corresponding axial view, the minimal anterior-posterior (AP) and mesial-lateral (ML) dimensions of oropharynx were measured using linear measurement tools of Invivo™ software (Figure 1).
All the measurements were performed by one co-author (A.P.), which were repeated after 2 weeks.

Statistical analysis

The normal distribution of data was determined by Skewness analysis. One-way ANOVA followed by Tukey's HSD post-hoc test was used to determine statistical difference in airway volume and area between patients with different sleep apnea and periodontal status. Pearson analysis was run to determine the correlations among airway volume/area and the demographic profile, BMI, sleep apnea, diabetes, and periodontal conditions of the patients. Intra-class correlation coefficient (ICC) was calculated to assess intra-rater reliability and reproducibility. Parametric data were expressed as mean and standard deviation (M [SD]). The statistical difference was set at $P < 0.05$. The statistical analyses were run with SPSS® Statistics version 24 (IBM Corp.; Armonk, New York, USA).

RESULTS

Airway and demographic and physical features of the subjects

The data of airway volume and area followed normal distribution. Body weight and BMI were negatively associated with airway volume and area (Table 2 and Figure 2). Height was positively correlated with airway volume (Table 2), and male trends to have larger airway dimensions relative to females (20.06 [0.91] vs. 18.32 [0.83] ml, respectively, $P < 0.05$).

Airway and sleep apnea

Sleep apnea patients had significantly smaller minimal surface area and minimal ML dimension of airway compared to non-apnea patients ($P < 0.05$) (Figure 3). Sleep apnea was identified to be associated with higher body weight and BMI (Table 3). In addition, old age, male, and diabetes have been found to be positively correlated with sleep apnea (Table 3).

Airway and periodontitis

There was no significant difference in airway volume and area of patients with various periodontal status (Figure 4). No association between airway dimension and periodontal condition was identified (Table 3).

Intra-rater reliability

Between the two sets of measurements conducted by the same examiner (A.P.), the ICC was 0.96, which demonstrated excellent reliability and repeatability of the examiner.

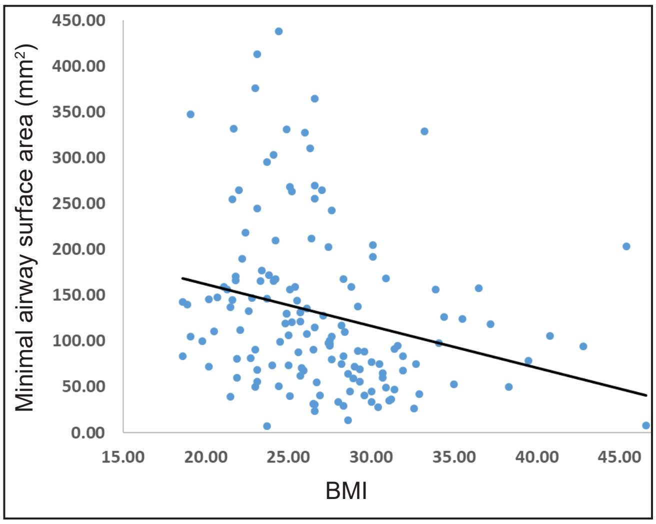

Figure 2. There was negative correlation between body mass index (BMI) and minimal airway surface area.

Table 2. Correlation coefficients between airway analysis and the demographical, physical, sleep, and periodontal status of the subjects

	Age	Gender	Height (inch)	Weight (lb)	Body mass index	Sleep apnea	Periodontal status
Airway volume (ml)	0.208	-0.231[b]	0.282[b]	-0.029	-0.219[b]	-0.043	-0.063
Airway minimum area (mm²)	-0.058	0.04	0.09	-0.106	-0.194[b]	-0.157[a]	-0.082
Minimum M-L dimension (mm)	0.006	0.051	0.079	-0.206[b]	-0.307[b]	-0.129[a]	-0.109
Minimum A-P dimension (mm)	-0.121	-0.006	0.061	0.036	0.000	-0.102	-0.054

[a]$P < 0.05$, statistically significant difference (Pearson analysis).
[b]$P < 0.01$, statistically significant difference (Pearson analysis).

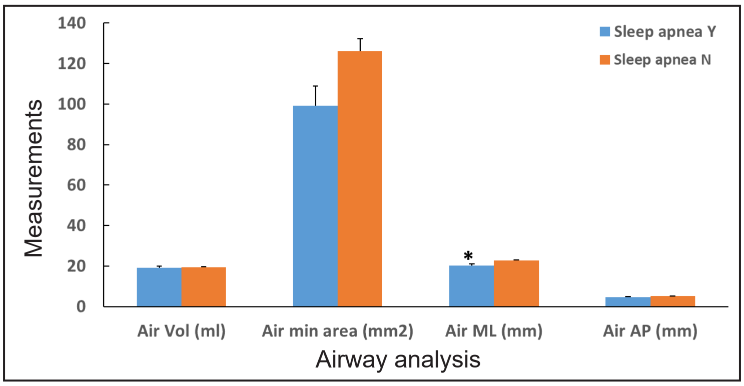

Figure 3. Sleep apnea patients demonstrated significantly smaller airway minimal surface area and minimal medial-lateral dimension compared to non-sleep apnea patients.
ML = minimal medial-lateral dimension; AP = minimal anterior-posterior dimension.
*P < 0.05 (statistically significant difference as tested by One-way ANOVA followed by Tukey's HSD post-hoc test).

Table 3. Correlation coefficients between sleep apnea and periodontal status with demographical, physical, airway and diabetic status of the subjects

	Sleep apnea	Periodontal status
Age	0.172[b]	0.1
Gender	-0.137[a]	-0.123
Height (inch)	0.083	0.078
Weight (lb)	0.255[b]	0.054
Body mass index	0.267[b]	0.007
Airway volume (ml)	-0.043	-0.063
Airway mini area (mm²)	-0.157[a]	-0.082
Airway mini M-L dimension (mm)	-0.129[a]	-0.109
Airway mini A-P dimension (mm)	-0.102	-0.054
Diabetes	0.142[a]	0.035
Periodontal status	0.095	NA
Sleep apnea	NA	0.095

[a]P < 0.05, statistically significant difference (Pearson analysis).
[b]P < 0.01, statistically significant difference (Pearson analysis).
NA = not applicable.

DISCUSSION

The presented study demonstrates that heavy patients with high BMI tend to have restricted airway and high risk of developing sleep apnea. This is consistent with what have been reported before [12-15]. Fat deposition in neck, especially in the parapharyngeal region, is considered a critical contributor to the development of sleep apnea [16-18]. The thick parapharyngeal fat pad pushes the lateral walls of the airway inwards, causes the normally elliptical shaped upper airway to be more circular and narrower, which predisposes the upper airway to collapse and results in snoring and obstructive sleep apnea [19].

Our study and several other investigations [13,20-22] demonstrate that sleep apnea is directly and strongly associated to aging and the male gender. The elderly have a greater prevalence of sleep apnea than the young [20,21],

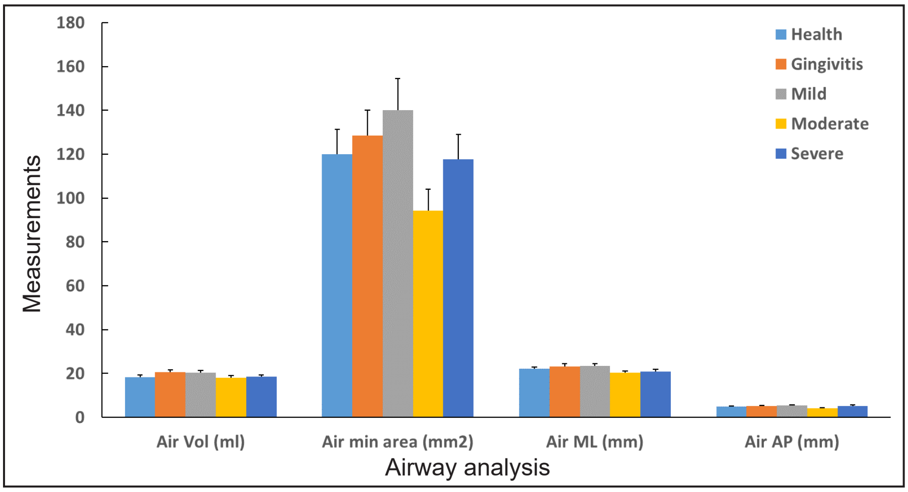

Figure 4. There was no significant difference in airway dimensions of patients with various periodontal status, including periodontal healthy, gingivitis only, and mild/moderate/severe periodontitis.
ML = minimal medial-lateral dimension; AP = minimal anterior-posterior dimension.

although the severity could be less than the young [21]. The high incidence of sleep apnea in males could be due to gender-related differences in body fat distribution and ventilatory control [23,24].

Since diabetes is one of the risk factors for periodontitis, whether it is associated with sleep apnea is investigated in the study. It is found that diabetes is positively correlated with sleep apnea with the current population. Previous cross-sectional studies also discover that sleep apnea is associated with insulin resistance and type 2 diabetes due to intermittent hypoxia [25-27].

It is speculated that constricted airway causes mouth breathing during sleep, which results in oral dryness due to saliva vaporization [28,29]. The lack of mechanical cleansing of saliva leads to accumulation of food debris and dental plaque, which promotes an aciduric and acidogenic oral microflora that stimulates gingival inflammation, pocket formation, and consequently periodontitis [30,31]. Some recent epidemiological studies support the plausibility of an association between obstructive sleep apnea and periodontitis, that the prevalence of periodontitis appears to increase with the severity of airway restriction [32-34]. Obstructive sleep apnea has been found to be associated with increased dental plaque index and risk of developing periodontitis of various stages, especially in patients with hypertension or hypertensive cardiomyopathy [35-38]. However, our study did not identify an association between airway dimensions and incidence/severity of periodontitis. The difference in sampled population, such as age, gender, race, and systemic health conditions, as well as evaluation methodologies could contribute to the discrepancy. What's more, in our study subjects, obstructive sleep apnea patients may or may not demonstrate periodontal diseases and also, they may or may not have reduced airway dimensions. Therefore, a future study focused on analysis of the correlation between obstructive sleep apnea and periodontitis may shed more light on any casual association between these two conditions. Regardless, when identified as having constricted airway, the patients need to be referred to their primary care physicians for proper evaluation and follow up.

Although designed as carefully as possible, there are limitations for the study. The demographics of the patients with various periodontal status were not perfectly match among each other, which could confound data analysis. One CBCT scanner and view software were used for the study, which limits the generalization of the observation. In addition, information on sleep apnea was largely extracted from patients' medical history, therefore, reporting errors could not be completed avoided. Future randomized controlled cohort studies with different CBCT scanners and view software will provide more in depth information on association between airway volume and risk of sleep apnea/periodontitis.

CONCLUSIONS

High body mass index is a risk factor for restricted airway and sleep apnea. No association between airway dimension and incidence/severity of periodontitis is found in the current study. Cone-beam computed tomography is a valuable tool for airway analysis, and patients with narrow airways should be identified and followed up properly.

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The authors report no conflicts of interest related to the study.

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