CBCT in evaluating the upper airway changes and respiratory functions in patients with OSAHS

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Abstract

Objectives: To evaluate the upper airway changes before and after the use of Mandibular Advancement Device (OAm) of the patients with mild to moderate obstructive sleep apnoea hypopnea syndrome (OSAHS) using Cone Beam Computed Tomography (CBCT). Design: Prospective study recruiting patients from February 2015 to January 2017 Settings: Department of Stomatology at Yan'an Hospital Affiliated to Kunming Medical University, China. Participants: PSG confirmed Chinese OSAHS patients. Main outcomes measures: CBCT scans were done before and after the use of OAm to assess the change in the sagittal and coronal diameter, volumetric changes and the change in Minimal Cross-sectional Area (MCA) of different segments of upper airway. Results: A total of 30 patients were included with an average age of 49.53 ± 6.62 years. A significant increase in sagittal and coronal diameter of the lower margin of soft palate and the upper epiglottis was observed except the hard palate plane after OAm ($P>0.05$). MCA and volume of the posterior soft palate, lingual, epiglottis area and total airway were significantly increased with the use of OAm ($P<0.001$). Conclusion: OAm is a beneficial device in OSAHS patients as it increases the upper airway area and the volumetric changes thereby reducing the effects of OSAHS.

INTRODUCTION

Obstructive sleep apnoea hypopnea syndrome (OSAHS) is a clinical disorder characterized by complete or partial collapse of upper airway during sleep resulting in cessation or reduction of respiratory function and abnormal sleep[1]. Apnoea refers to cessation of airflow for more than 10 seconds, while hypopnea is the reduced airflow below 50% for a minimum of 10 seconds or longer with a 3% blood oxygen saturation[2].

A recent systematic review reports the overall prevalence of OSAHS ranged from 9-38% in the general adult population with a prevalence of 13-33% in adult men and 6-19% in adult women[3]. However, many OSAHS patients remain undiagnosed due to lack of identical clinical symptoms and lack of accurate diagnosis. The risk factors for OSAHS includes, higher BMI, increased neck circumference, smoking, alcohol use and family history[4]. The Apnoea-Hypopnea index (AHI), which is the total number of apnoea and hypopnea per hour of sleep is used to diagnosis the severity of OSAHS. AHI of 5-15 per hour is regarded as mild, between 15-30 as moderate, and greater than 30 as severe OSAHS[5].

As a result of disturbed sleep, the OSAHS patients are at greater risk of motor vehicle accidents, cardiovascular, pulmonary diseases, insulin resistance and metabolic syndrome[6]. Also, the OSAHS patients are affected by adverse health consequences including excessive day time sleepiness, frequent nocturnal arousal, mood disturbance, cognitive impairment and decreased quality of life[7].

Continuous Positive Airway Pressure (CPAP) remains the gold standard treatment for OSAHS[8]. However, poor patient compliance limits the effectiveness of CPAP[9]. Currently, oral appliances are used as an alternative to CPAP, as they help in forward movement of the tongue and mandible and prevents collapse of upper airway. Mandibular Advancement Device (OAm) are commonly used oral appliances and evidence suggests that these devices are highly acceptable due to its portability, effectiveness and cost[10].

Traditionally 2-dimensional (2D) lateral cephalograms have been used for the evaluation of the upper airway changes in OSAHS patients. However, 2D imaging results in superimposition of adjacent structures and provides only a 2D view of the upper airway space, thereby decreasing the accuracy of diagnosis and prognosis. In order to overcome these shortcomings of 2D imaging, a 3-dimensional (3D) imaging technique is recommended[11].

Currently 3D imaging techniques, especially the Cone Beam Computed Tomography (CBCT) has proven its accuracy in easy visualization of volumetric measurements of complex maxillofacial structures. It aids in the assessment of cross-sectional areas of the coronal, sagittal and axial planes of the airway anatomy[12]. The ability to assess 3-Dupper airway structures along with the reduction in patient exposure to radiation compared to convention CT, larger field of vision (FOV), improved image quality with short scanning time[13] has made CBCT an potential tool for the assessment of OSAHS patients[14].

CBCT has proven its efficacy in the evaluation of upper airway especially in relation to the hard tissue structures of the skull[14,15]. However, a recent systematic review reported that further research is needed to establish the reliability in assessment of upper airway volume using CBCT[5]. Whereas, the results of several other studies have reported the use of CBCT in upper airway measurement was fairly accurate[16].

Even though CBCT has been used in the evaluation of upper airway, there is paucity of literature pertaining to the use of CBCT in assessing treatment outcomes in OSAHS patients in Asian population, especially in the Chinese population. Hence, the aim of the study was to evaluate the upper airway changes before and after the use of OAm of the patients with mild to moderate OSAHS using CBCT in Chinese population and to serve as a reference for providing theoretical guidance for the clinical diagnosis and treatment of OSAHS.

MATERIAL AND METHODS

Study Design and Subjects

This was a single center, prospective study conducted at the '[removed for blind peer review]'. All the consecutive patients with a diagnosis of OSAHS who were treated with OAm in the Stomatology department from February 2015 to January 2017 were included in the study.

Patients aged [?]20 years were included in the study if they had polysomnographic (PSG) diagnosis of mild to moderate OSAHS. Patients were referred to the Stomatology department, by the Respiratory Medicine specialist after performing PSG examination and confirming the diagnosis of mild to moderate OSAHS. The other inclusion criteria included presence of at least 10 teeth with no mobility in each arch so as to ensure device retention and those willing to wear the device continuously for more than 5 hours every night. Patients with history of craniomaxillofacial trauma and operation, active periodontal disease, TMD and nocturnal bruxism and those who were mentally unfit were excluded from the study.

Following a CBCT scan, all the included patients were instructed to wear OAm (SCHEU, Germany) at night and were monitored till they were adapted with the device [figure 1]. The mandibular advancement achieved with OAm was 75% of maximum protrusion.

The study protocol was approved by the institutional review board while confirming to the standards of the Declaration of Helsinki and its subsequent revisions. The patients were explained about the study and informed consent was obtained.

CBCT Analysis

All CBCT examinations were performed using i- CAT 17-19 CBCT (KaVo 3D eXam). All the patients underwent two CBCT examinations, one before wearing the OAm and the other while wearing the device.

During imaging procedure, the patients were positioned upright with Frankfurt plane perpendicular to the floor. The scanning parameters were as follows: field-of-vision: 16 cm x 13 cm, tube current 5mA, tube voltage 120kV, scanning time 25 seconds, exposure time 3.6 seconds and the reconstruction <2 minutes.

To obtain a standardized respiratory phase during CBCT scanning, all the patients were asked to hold the breath at the end of the expiration (Muller breathing) and then breathe in. Scanning data were stored in workstations and converted to DICOM (Digital Imaging and Communications in Medicine). The CBCT images of patients were imported into InVivo Dental 5.2 software for three-dimensional airway reconstruction.

Study Outcomes

The study outcomes include assessing the sagittal and coronal diameters of the hard palate plane, the soft palate lower edge plane and the epiglottis upper edge plane [figure 2]. We also assessed the volume of posterior soft palate area, posterior lingual area, posterior epiglottis area, total airway volume, and the minimum cross-sectional area (MCA). Furthermore, sleep related indicators such as snoring frequency, AHI and minimum oxygen saturation (SaO_2) before and during the use of OAm were also assessed.

The measurement work was centralized by the same surveyor for a period of time. Each measurement item was measured three times and its average value was taken.

Statistical Analysis

The experimental data were analyzed by SPSS 21.0 software. Paired t test was used to compare the number of snoring before and after wearing. The number of snoring did not obey the normal distribution. The results were expressed by P50 (P25, P75). The difference before and after wearing OAm was analyzed by rank sum test. P value of <0.05 was considered statistically significant.

RESULTS

Study subjects

A total of thirty patients were enrolled in this study, comprising of 21 males and 9 females, with a mean age of 49.53±6.62 years, and average body mass index (BMI) of 24.82 ± 2.13 kg/m^2. Minimum oxygen saturation observed was 0.78 ± 0.08 (Supplementary table 1).

Primary outcomes

Sagittal and coronal diameter of the different planes in OSAHS patients were analyzed before initiating and during OAm treatment [figure 3]. There was a statistically significant increase (P <0.001) in the sagittal diameter of the lower margin of soft palate from 7.01±1.43 to 14.78±1.36 and the upper epiglottis margin plane from 9.58±0.95 to 13.75±0.77 after wearing OAm. However, there was no significant increase in the diameter of hard palate plane after wearing OAm (P >0.05). Similar to the sagittal diameter, the coronal diameter has statistically significant improvement in the lower margin of the soft palate from 20.46±1.24 to 28.35±1.85 and the upper epiglottis margin planes from 19.86±2.06 to 26.72±2.25 with the use of OAm and no statistically significant improvement (P >0.05) was observed in the diameter of the hard palate plane [figure 4] (Supplementary table 2).

The MCA of the posterior soft palate, the posterior lingual, and the posterior epiglottis area showed an increase after the OAm treatment with a statistically significant difference (P <0.001) [figure 5 & 6]. A statistically significant difference (P <0.001) was also observed with the increase in the volume of the upper airway segments and total airway volume (Supplementary table 3) [Supplementary figure 1].

Objective indicators of OSAHS

PSG monitoring indexes including AHI and SaO2 had shown a significant improvement with reduction in AHI from 20.61±5.19 to 10.86±4.31 and increase in oxygen saturation from 78±8 to 92±3 after the use of OAm (P <0.001). A significant reduction in snoring frequency was also observed after wearing OAm (Supplementary table 4).

DISCUSSION

Since the introduction of CBCT in 1998 [17] for dental and maxillofacial diagnosis and treatment, the popularity of this 3D imaging technique has increased due to low cost, shorter acquisition time and less effective radiation dose compared to conventional CT[11].

As CPAP treatment is intolerant and non-compliant in OSAHS patients[18], OAm being non-invasive, cheap and portable has proven its effectiveness in treating OSAHS with good patient compliance.

All the patients in our study had an overnight PSG confirmed diagnosis of OSAHS. In our study, a significant reduction in AHI, improvement in blood oxygen saturation and also decreased frequency of snoring was observed after the use of OAm. Our finding are comparable with the RCT's conducted to assess the effect of OAm on OSAHS patients on symptoms associated with OSAHS with a significant improvement in sleep latency test, Epworth Sleepiness Scale (ESS) scores, both frequency and intensity of snoring, along with enhanced arterial oxygen saturation, reduction in AHI, arousal index and Rapid Eye Movements (REM) sleep[19]. OAm enhances the upper airway diameter by traction of soft tissues achieved by mandibular protrusion. Despite the growing debate on its effectiveness, device design, side-effects and patients preferences for OAm treatment, the clinical practice guidelines recommend the applicability of OAm[20].

In our study, upper airway CBCT imaging showed, significant increase in the MCA and volume of each airway segment after using OAm. Similar results have been reported by Abi-Ramia et al., wherein they observed the increase in mean airway volume from 7601$\pm$26 to 8710$\pm$28 as a result of mandibular protrusion after the use of OAm[21]. Various studies have suggested unusual upper airway anatomy as a key factor for OSAHS[16]. Other risk factors include, male gender, older age and upper airway dimensions of $<$17mm[22].

Controversy exist between the supine and upright position of patients during CBCT. Due to limited availability of supine position CBCT assessment units, upright position CBCT is currently used for the 3-D imaging for OSAHS patients. However, the upright position cannot mimic the exact morphology of upper airway as in a normal sleeping position.

In our study CBCT was done in upright position for the evaluation of OSAHS. A study conducted by Wun Eng Hsu et al.[23] to evaluate the change in upper airway measurements comparing lateral cephalogram in upright position and CBCT in supine position suggested that, mean anterior-posterior distance in the oropharynx and mandibular plane to hyoid bone distance can be influenced by the change in the body posture[23].

Other factors which could affect the CBCT findings is the respiratory phase during the exposure. As the change in airway shape and dimensions due to variation in the breathing pattern during the exposure has already been reported[24], in our study, all the patients were instructed to hold the breath at the end of the expiration (Muller's breathing) to obtain consistency in all the CBCT scans.

In the present study, we have prospectively assessed the OSAHS patients before and after OAm, which has enabled us to maintain the relationship between the age, sex and BMI among the same patient cohort. However, most of the studies have compared the OSAHS patients with healthy individuals to assess the efficacy of OAm and failed to match the patient variables[25]. Also, many studies were retrospective in nature[23]. To the best of our knowledge, this is the first study in Chinese population that explored the feasibility of CBCT in OSAHS patients.

Strength and limitations

All the OSAHS patients were confirmed with PSG. We conducted a prospective study and effectiveness of OAm in OSAHS patients was done in the same patient cohort using CBCT. And also, we adopted Muller's breathing during CBCT exposure to standardize respiratory phase in all patients for consistent CBCT scans. Smaller sample size could be the limitations in our study, however the sample size used is in agreement with other studies.

CONCLUSION

In conclusion, based on our study finding CBCT serves as an effective tool in the assessment of OSAHA and OAm is beneficial in the treatment of mild to moderate OSAHS by significantly increasing the sagittal and coronal diameter of the airway planes along with the changes in the MCA of each airway segment and total airway volume.

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Figure legends:

Figure 1: Mandibular Advancement Device (OAm)

Figure 2: Measuring points plane (2a). Airway zoning (2b)

Figure 3: Sagittal diameter of upper airway before OAm (3a). After OAm (3b)

Figure 4: Coronal diameter of upper airway before OAm (4a). After OAm (4b)

Figure 5: Posterior lingual area before OAm (5a). After OAm (5b)

Figure 6: Posterior epiglottic area before OAm (6a). After OAm (6b)

Supplementary files

Supplementary figures

Supplementary figure 1: Total airway volume before OAm (1a). After OAm (1b)

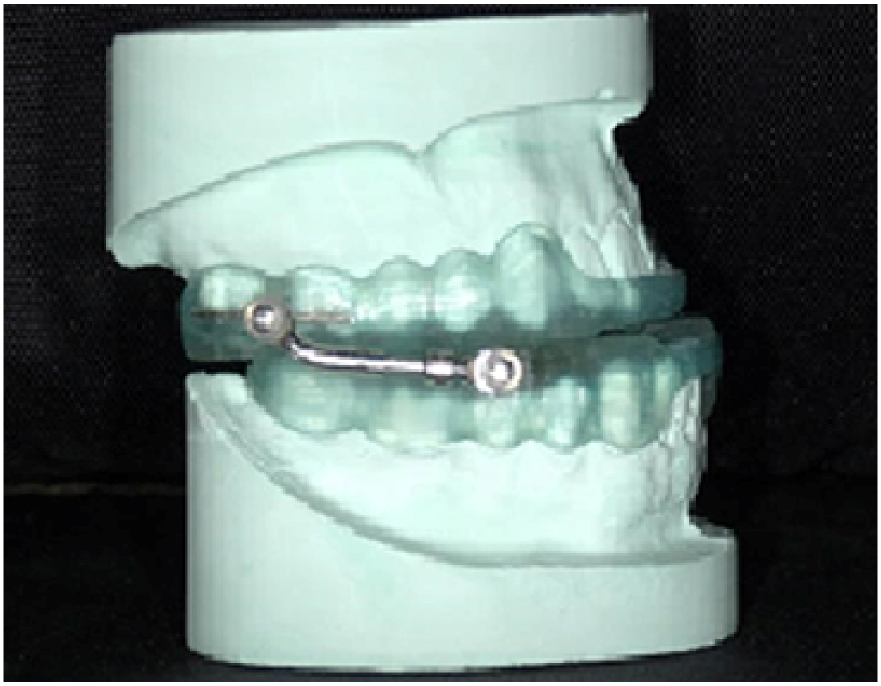
Supplementary tables

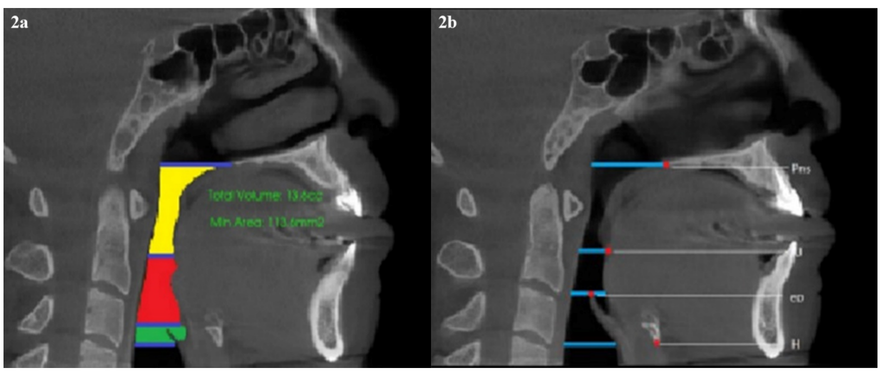
Supplementary table 1: Basic data of research subjects

Supplementary table 2: Comparison of Sagittal and Coronal Diameters of Airway Planes

Supplementary table 3: Comparisons of minimum cross-sectional area and total airway volume of each airway sections and total airway

Supplementary table 4: Comparison of PSG monitoring indicators

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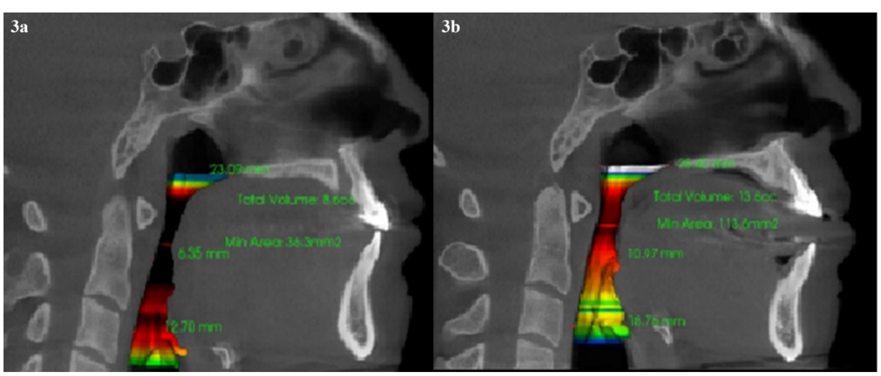
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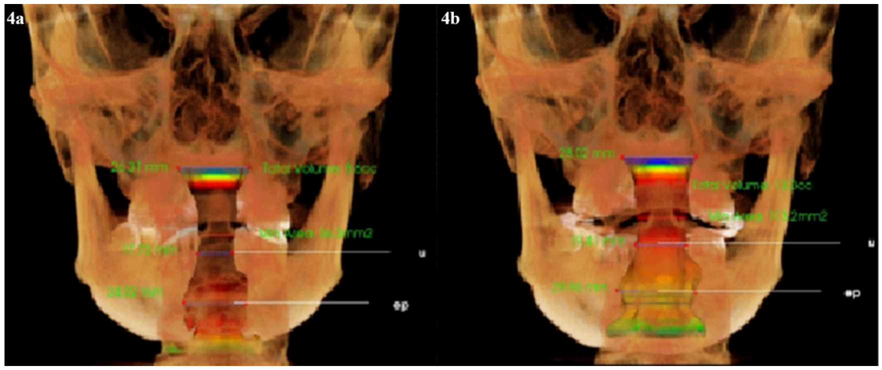
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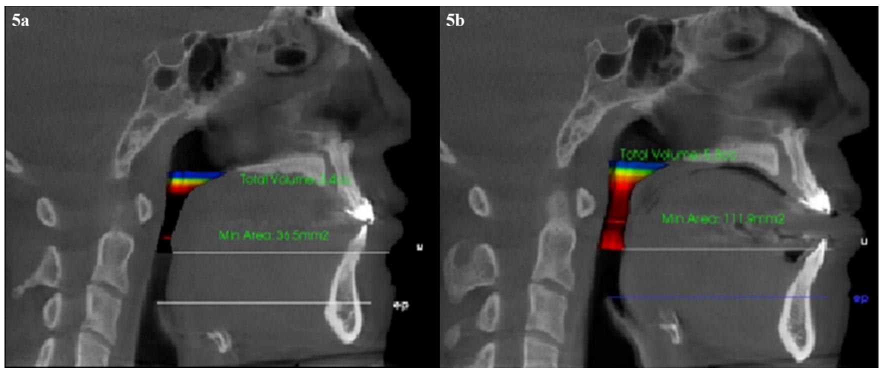
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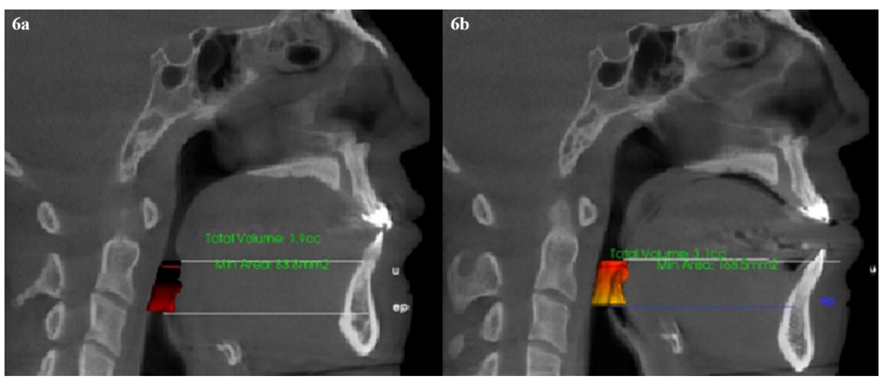
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