Increase in upper airway volume in patients with obstructive sleep apnea using a mandibular advancement device

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Abstract

Introduction: Diagnosis, treatment and monitoring of patients with obstructive sleep apnea syndrome (OSAS) are crucial because this disorder can cause systemic changes. The effectiveness of OSAS treatment with intraoral devices has been demonstrated through cephalometric studies. **Objective:** The purpose of this study was to evaluate the effect of a mandibular advancement device (Twin Block, TB) on the volume of the upper airways by means of Cone-Beam Computed Tomography (CBCT). Sixteen patients (6 men and 10 women) with mild to moderate OSAS, mean age 47.06 years, wore a mandibular advancement device and were followed up for seven months on average. **Methods:** Two CBCT scans were obtained: one with and one without the device in place. Upper airway volumes were segmented and obtained using Student's paired t-tests for statistical analysis with 5% significance level. **Results:** TB use increased the volume of the upper airways when compared with the volume attained without TB ($p<0.05$). **Conclusion:** It can be concluded that this increased upper airway volume is associated with the use of the TB mandibular advancement device.

Keywords: Obstructive sleep apnea syndrome. Mandibular advancement device. Cone-Beam Computed Tomography.

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INTRODUCTION

With the increase in respiratory sleep disorders, such as snoring, upper airway resistance syndrome (UARS) and obstructive sleep apnea syndrome (OSAS), the need for better diagnostics and treatment of these disorders became apparent.[4,11] Treatment of OSAS is important[11,15,21,25] as it is considered a high morbidity, progressive disease.[11,28]

The effectiveness of mandibular protrusion appliances has been demonstrated in several studies.[13,25] Although cephalometric radiography is a simple method, widely used in dentistry and in studies of obstructive sleep apnea,[2,3,4,5,10,13,25,26] this method generates two-dimensional images of three-dimensional structures, which limits the validity and reproducibility of airway measurements.[14,16,24]

Three-dimensional studies[14,21] to determine the effectiveness and action mechanism of oral appliances have shown that such appliances can modify pharyngeal geometry,[21] significantly enlarging the minimum pharyngeal area.[14]

The aim of this study was to evaluate, using Cone-Beam Computed Tomography (CBCT), the effects of mandibular advancement, performed with a modified Twin Block type appliance, on the volume of OSAS patients' upper airways.

MATERIAL AND METHODS

This research was submitted to the Ethics Committee of Pedro Ernesto University Hospital and approved under number 1366-CEP/HUPE.

Patients were referred to the Orthodontics postgraduate clinic, School of Dentistry, Rio de Janeiro State University (FO-UERJ) by specialists in Sleep Medicine after undergoing a nocturnal polysomnography examination and being diagnosed with mild to moderate OSAS (AHI<30).

Other inclusion criteria were used: Only patients with a body mass index (BMI) of less than 27; having at least ten teeth in each arch to ensure adequate device retention; having an overjet of at least 4 mm so as to enable mandibular advancement.

Sixteen patients, 6 men and 10 women, mean age of 47.06 years, received modified Twin Block (TB) type oral appliances for mandibular advancement (Fig 1). They were instructed to wear the appliance at night and were monitored for an average period of seven months. The mandibular advancement achieved with TB was approximately 75% of maximum protrusion.[12] To participate in the sample the patients signed a form of free and informed consent after being given information about the research.

At the end of the follow up period each patient underwent two CBCT scans (NewTom 3G, Verona, Italy) with field of view of 9 inches and slice thickness of 0.2 mm. Both scans were performed on the same day, one without and one with the mandibular advancement appliance in place. The patients were awake, lying supine, with the Frankfort plane perpendicular to the floor.[24]

The scanning method was standardized with the aid of an acrylic positioner (Fig 2) and the

FIGURE 1 - Modified Twin Block appliance in place: **A**) right lateral view, **B**) front view and **C**) left lateral view.

NewTom 3G laser beam itself, to position the facial midline. Moreover, the distances between patient and scanner, and the height of the stretcher were recorded in the first examination to ensure that the two scans were as similar as possible. This position was verified on the computer with the aid of a scanogram before the start of the second examination.

After the primary reconstruction of the projections in the three orthogonal planes (axial, coronal and sagittal) and images of the entire craniofacial complex volume were obtained in DICOM format (Digital Imaging Communications in Medicine), the images were manipulated with ITK SNAP 1.8.0[30] software to obtain volumetric reconstructions of the relevant structures. The software allows semiautomatic segmentation[6,7] of the area of interest, which was limited in the anterior and superior regions by the posterior nasal spine (PNS)[24,27] while in the inferior region, the limits were the anterior-most and inferior-most regions of the third cervical vertebra (C3)[13] (Fig 3). The volume in mm^3 of the three-dimensional model of the upper airway (Fig 4) was obtained with the software.

The statistical data were tabulated in a statistical program (Biostat 2.0, Belém, Pará State, Brazil). Method error was used only to

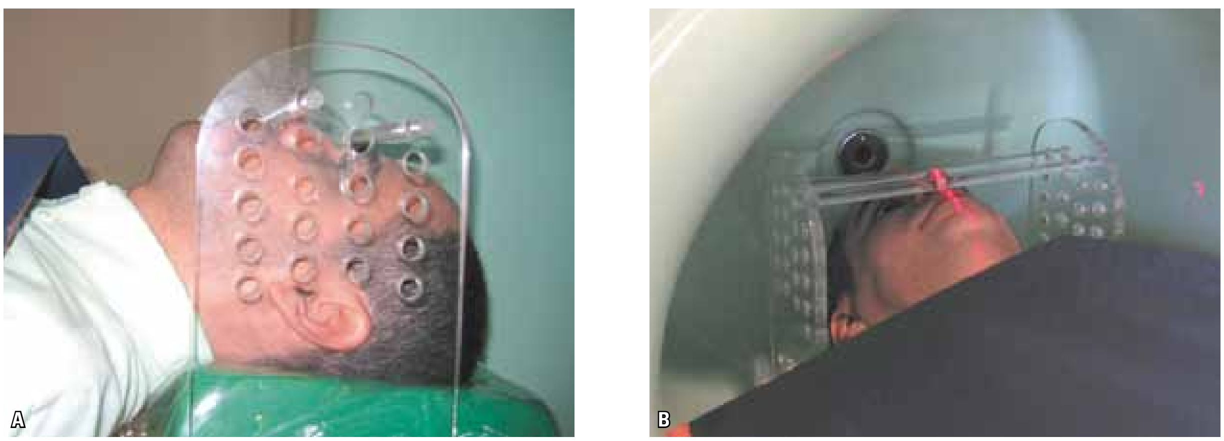

FIGURE 2 - Cone-Beam Computer Tomography scans: **A**) Patient positioned at NewTom 3G with acrylic positioner and Frankfort horizontal plane perpendicular to the floor; **B**) Using the laser beam to position the facial midline.

FIGURE 3 - Points used to determine upper airway volume. PNS (posterior nasal spine), C3 (anterior-most and inferior-most portions of the third vertebra).

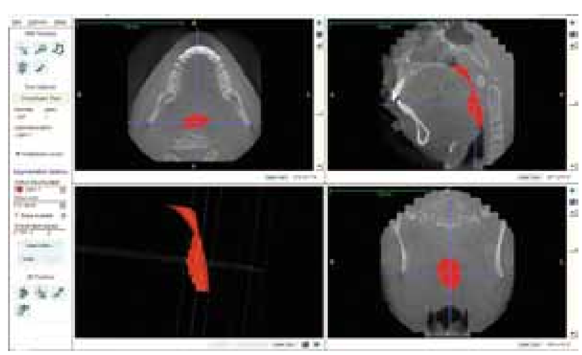

FIGURE 4 - Segmentation of a three-dimensional model. The upper airways are in red. The segmented areas are shown both in CT slices and in the three-dimensional model.

circumscribe the structure because it is a semi-automatic method. Two examiners delimited the area of interest twice at intervals of two days, and the intraclass correlation coefficient (ICC) for nominal or quantitative variables was utilized to assess the correlation between repeated measurements in the same patient. The ICC showed excellent intra and interexaminer repeatability, which allows the authors to assert that the method used to segment and obtain upper airway volume is reliable (p<0.0001).

After using the Shapiro-Wilk normality test, the paired t-test was applied to compare the volumes with and without TB. To be considered significant, p value was set at 0.05.

RESULTS

The mean airway volumes with and without TB were 8710±2813 mm^3 and 7601±2659 mm^3, respectively (Fig 5). There was a statistically significant difference (p=0.0494) in airway volume between patients with and without TB (Table 1), demonstrating that TB was successful in increasing upper airway volume in the TB patients.

DISCUSSION

Upper airway three-dimensional assessment was performed using CBCT given its low radiation dose.[16,27] According to Aboudara et al,[1] although CBCT is not usually indicated for evaluating soft tissues the contrast between the airway lumen and the soft and hard tissue enhances segmentation accuracy when quantifying airway volume. The NewTom 3G scanner used in this study enabled the assessment of the upper airways while the patient was lying down and, although it failed to reproduce the exact sleeping position, positioning the pharyngeal tissues is important in determining the severity of the syndrome.[18] How to position the patient during follow-up examinations is a much debated issue, since air flow is influenced by changes in head position,[8,29] which

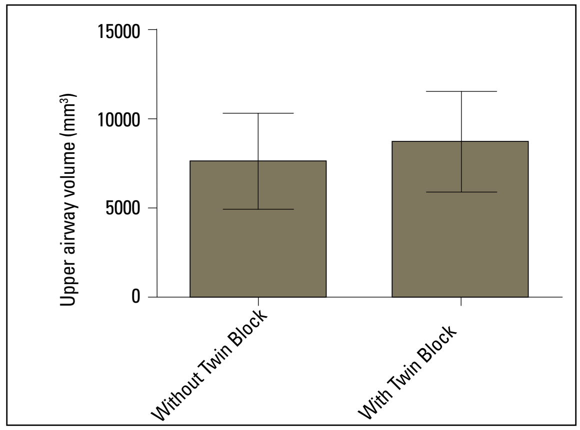

FIGURE 5 - Volume values of upper airway (mm^3) of patients without and with TB.

TABLE 1 - Mean, standard deviation and p value for comparing airway volume (in mm3) between patients with and without TB.

	Mean	Standand deviation	P value
Volume without TB	7601	2659	p=0.0494
Volume with TB	8710	2813	

may result from the reduced dimensions of the upper airways in the retropalatal region.[1]

While assessing the images in the three planes of space with ITK-SNAP software reference points were selected for defining the area of interest according to previous studies.[24,27] The reference points used in this study were the ENP[1,4,13,24,27] and the most anterior and inferior point of the third cervical vertebra.[13]

The statistically significant difference found in this study between patients with and without TB in place (p<0.05) shows that the upper airways expanded as a result of the mandibular advancement caused by the TB. This mechanism is still under debate. It is believed, however, that the more anterior position of the mandible and hyoid bone and the consequent stimulation of the pharyngeal muscles and tongue are responsible for increasing airway volume.[30] According to the cephalometric study by Fransson et al[13], the increase in pharyngeal area occurred because of the more anterior position of the hyoid bone as a result of increased activity in the genioglossus and lateral pterygoid muscles.

Only two patients had lower airway volume with TB than without TB, which may be explained by the amount of mandibular advancement in these patients or the width of their soft palate. The amount of mandibular advancement varies widely between different studies, ranging from 2.0 mm[20] to 9.5 mm.[12,13] Despite the differences, a protrusion of 75% of each patient's maximum capacity is very often used by researchers.[9,10,13,14,15,17,19,22,23,25] This advancement yields adequate success rates and can usually be endured by most patients.

CBCT comparison between healthy patients and patients presenting with OSAS has shown that the anteroposterior dimensions and minimum oropharyngeal dimensions of patients with OSAS were significantly lower compared to patients who did not have this syndrome.[24]

Three-dimensional studies in patients with SAOS[14,21,30] have shown increased upper airways, predominantly in the oropharyngeal[21] and velopharyngeal[30] regions. However, most of these studies[21,30] assessed the airways using linear measurements only, i.e., using two-dimensional data obtained through three-dimensional examinations. According to Zhao, Liu, Gao[30] and Kyung, Park, Pae,[21] airway augmentation is achieved at the expense of an increase in transverse diameter. Gale et al[14] found an increase in the pharyngeal area using a mandibular advancement device but with substantial individual variability.

In the present study, preference was given to conducting two CBCT scans on the same day after the monitoring period due to image acquisition standardization, since each patient's ideal position is unique. Moreover, there could be changes in patients' BMI and health status during follow-up, as well as climate changes. These factors would render impracticable any comparisons between soft tissues and upper airway volumes at different times.

OSAS studies using Cone-Beam Computed Tomography and three-dimensional models require further research and improved standardization of assessment methods, in addition to a better understanding of the action mechanisms underlying mandibular advancement devices and their results, if these devices are to become the treatment of choice for OSAS patients.

CONCLUSIONS

Based on the results of upper airway volume comparisons (in mm^3) of OSAS patients treated with a mandibular advancement device, the authors have grounds to conclude that the TB significantly changed upper airway volume.

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