Differences in Volume and Area of the Upper Airways in Children with OSA Compared to a Healthy Group

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INTRODUCTION

Obstructive sleep apnea (OSA) is a respiratory sleep disorder (RSD) characterized by partial or complete upper airway (UA) obstruction that can affect children in their very early phase of development.1–6 Children between 2 and 6 years old are the most affected group for the occurrence of upper airway lymphoid tissue hypertrophy, usually presenting with the most severe aspects of OSA. Diagnostic delays of this condition may generate a negative influence on their adult life quality.3–8 The cause of obstructive sleep apnea in children is not fully known. The many risks and predisposing associated factors challenge its diagnosis and treatment. The objective of this research was to verify the differences in the volume and areas of the upper airways between children submitted to adenotonsillectomy for the treatment of OSA, but with persistent/recurrent postoperative OSA complaints, and a sex-age matched healthy control group, assisted by cone beam computed tomographic images.

METHODS

The study included a group of 20 children of both sexes, with mean age of 9.5 years, diagnosed with OSA and primary snoring (PS) by polysomnographic exam (AHI ≥ 3), angle class II, and retruded mandible, and a control group of 20 healthy children of both sexes, mean age of 7.4 years, with the same characteristics, but without respiratory complaints. Both groups were submitted to otolaryngological and orthodontic clinical examinations, and to cone beam computed tomography exam (CBCT). Areas and volumes of the nasopharynx and oropharynx and lower axial area were measured. Mean, standard deviation, confidence interval, and Student t-test with a 5% significance between these groups were analyzed.

RESULTS

The results showed a significant difference (p < 0.05) in the volume and area of the nasopharynx of patients with OSAS compared to the same parameters in healthy patients. Children with OSA (SG) showed a significant narrowing in the nasopharynx and in the lower area of the upper airway (UA) compared to the control group (CG).

CONCLUSIONS

Children with persistent OSA symptoms after adenotonsillectomy present with narrowing of the nasopharynx, and CBCT is a useful complementary test for orthodontic diagnostic and treatment planning of these patients.

KEYWORDS: apnea and hypopnea syndrome, habitual snoring, nasopharynx and oropharynx size, CBCT

METHODS

This observational case-control study was approved by the Ethics Committee of the Federal University Sao Paulo – UNIFESP under the number: 1739/11 02/12/2011, by the Ethics Committee of FOUSP-Dentistry College State University of Sao Paulo under the number 170/2010. Financed by the Research Foundation-FAPESP under the Protocol 2012/15715-2 November 2, 2012.

To accomplish this case-control study, a multidisciplinary team was enrolled. ENT examination was performed by an experienced otolaryngologist. Children suspected to have PS and OSA underwent a polysomnographic test to confirm the diagnosis, and the report was certified by a professional expert in sleep medicine. Orthodontic evaluations were carried out by 3 orthodontists in 2 different clinics. All selected patients underwent orthodontic planning examination with CBCT, and these images were evaluated by 2 imaging studies experts.

A total of 397 patients, ages ranging between 7–14 years, presenting with PS and OSA complaints were evaluated at the Oral breathing clinic at the Otorhinolaryngology Pediatric Division, Federal University of Sao Paulo (UNIFESP) from 2013 to 2014. All the patients had undergone adenotonsillectomy or had been excluded of having hypertrophic tonsils; but they all had OSA symptoms. After otorhinolaryngological and nasofibroscopic examinations, patients suspected of having OSA were referred for PSG. Patients with syndromes or obesity were excluded.

PSG was performed at the Sleep Apnea Institute-UNIFESP/SP. Patients stayed overnight and were evaluated with an electroencephalogram (EEG), electrooculogram (EOG), electromyogram (EMG) mental and/or submental muscle, electrocardiogram (ECG), airflow (nasal and oral), respiratory effort (thoracic and abdominal), other body movements (tibial EMG), oxygen saturation, and carbon dioxide concentration (precision oximeter). The parameters evaluated in PSG are described in Table 1

Twenty patients were selected for the study group (SG)—13 girls and 7 boys, with an average age of 9.5 years. The average apnea-hypopnea index of the patients included was 3.1, Angle Class II, short and retruded mandible and CMS I or II (Figure 1). Sexual dimorphism analysis in the PSG data was performed by Student t test, with 95% reliability.

The control group (CG) consisted of 12 girls and 8 boys, mean age of 7.4 years old, CVMS I or II, without respiratory complaints, Class II malocclusion, and retruded mandible, who sought orthodontic treatment at the Dentistry College, State University of Sao Paulo-FOUSP, SP for other reasons. Children of both study and control groups were referred to orthodontic planning studies (cephalometric and study models) and CBCT examinations. The selected patients and legal guardians signed the consent form.

For the CBCT, the participants were placed in the tomography room in a sitting position with their head parallel to the Frankfurt plane (FP), and the CBCT sensor was positioned

<table>
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<th>Table 1—PSG parameters.</th>
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<td>Abbreviation</td>
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<td>PMIM</td>
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<td>N3</td>
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<tr>
<td>RYM</td>
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<td>TAAS</td>
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<td>SO2 &lt; 90%</td>
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</table>

Figure 1—Bone maturation rating.
in order to cover the entire head. Patients were instructed to remain still, with relaxed lips, avoiding swallowing, and keeping a smooth breathing pattern during image acquisition.

The equipment used for CBCT was the i-Cat (Cone beam 3-D Dental Imaging System, Imaging Sciences International, Hatfield, PA). After capturing the X-rays, the tomography sensors attenuated and digitalized the images through algorithm reconstruction, converting the data in medicine digital image for communication (DICOM). After an accurate reconstructed digital image was obtained, participants were released.

The reconstruction of the primary image was performed at the workstation. The Dolphin 3D software (Imaging Dolphin/Patterson Dental, Chatsworth, CA, USA) was used for the proposed measurements. Before measuring the volume, area and lower area of the upper axial way, the pictures were standardized according to the orientation of the cranial positioning. For the orientation of the cranial positioning, the axial plane coincides with the orbital points (Or); in the lateral, the coronal plane coincides with the porion (Po) on the left and right sides, and an axial plane is superimposed on the FP; the median sagittal plane joins the nasion (N) and the anterior nasal spine (ANS) (Figure 3).

For the evaluation of the nasopharynx (NP), the upper limit of the epiglottis was seen in the coronal plane, cut at its greatest length, and its highest portion was landmarked. In the image in sagittal view, this area was limited by the union of PPINF and PAINF, and the points were created in PAIOf and PPIOF located 15 mm front and rear, respectively, of the uvula point. Sensitivity was determined using the same criteria that was used for the NP (Figures 5, 6). In Figure 7, regions of oropharynx are highlighted by software tools.

For evaluating the oropharynx (OP), the upper limit of the epiglottis was seen in the coronal plane, cut at its greatest length, and its highest portion was landmarked. In the image in sagittal view, this area was limited by the union of PPINF and PAINF, and the points were created in PAIOf and PPIOF located 15 mm front and rear, respectively, of the uvula point. Sensitivity was determined using the same criteria that was used for the NP (Figures 5, 6). In Figure 7, regions of oropharynx are highlighted by software tools.

Data from all measurements, the areas of the nasopharynx and oropharynx, the volumes of the oropharynx and nasopharynx, and lower axial area of the SG and CG, were measured with CBCT tools, and registered in a 2007 Excel table. The means, standard deviations, confidence intervals, and Student t-test with a 95% confidence level were calculated for all the obtained values.

RESULTS

No significant differences of the major values obtained in the PSG examination were observed between genders. A significant difference (p = 0.04) was only found for the hypopnea parameter (H): girls had a higher number of events than boys. The remaining parameters did not show significant differences between genders (Table 2).
Regarding the CBCT measurements, the NP volume (4,949.85 mm$^3$) and NP area (284.79 mm$^2$) were significantly lower in the SG than in the CG ($p = 0.001$ and $p = 0.002$), respectively. The OP volume and area of the SG (1,645.43 mm$^3$ and 417.87 mm$^2$) and CG (1,410.81 mm$^3$ and 100.18 mm$^2$) did not show significant
Upper Airways Dimensions and Volume in Children with and without OSA—Rossi et al.

**DISCUSSION**

Sleep apnea is a relatively well understood disorder in adults, but in children it remains controversial, particularly due to the multifactorial nature of the disease in addition to the differences in response to each child growth phase. Our results may have implications to children from 7 to 14 years of age, who had already received some treatment for OSA such as tonsillectomy in early childhood but still present with OSA complaints, as demonstrated by other authors in previous studies. Our goal was to understand which sites the upper airways could be involved with the persistence of the disease, in order to develop an effective orthodontic treatment.

The results of our study showed that the upper airway was significantly smaller in SG when compared to healthy subjects mainly at the nasopharynx. Regarding the oropharynx, we observed that healthy patients (CG) had a smaller area and volume than the OSA patients; the differences however, were not statistically significant. The axial lower area of the OSA patients was significantly lower than the CG, as already observed by many others. The CG patients did not have respiratory complaints and had no hypertrophic tonsils, despite their young age.

In addition, chronological age may not represent the real growth phase that can be best evaluated by bone age measurements. In our study, both groups were at the same stage of pubertal maturation (CVM I and II), and in the same age group (5–12 years old). Maybe OSA studies in children assessing also the real phase of growth and children development, determined by bone ossification age, could minimize the chance of erroneous conclusions.

In this study, no differences in AHI were found between males and females of the study group, and the patients were not divided by gender (Table 1). In general, male patients have shown to have increased risk for OSA; the mechanisms underlying this predisposition are unclear. At least one previous study demonstrated a difference, and proposed that to be due to the usual more enlarged UA sizes in adult males than in females, this anatomical feature could let the male UA more likely to collapse. Recent studies of CBCT, have demonstrated that patients with retruded mandible and class II tend to have the OP volume reduced when compared to patients Class I and III malocclusion, with advanced or standard mandible. According to the authors, the mandibular position may have influence on the volume of the OP. Regarding the NP, significant differences have been shown only in patients presenting with Class I and Class II malocclusion; the volume is usually lower in Class II patients. We included Class II patients with retruded mandible in both CG and the SG groups, and our results showed a greater and significantly reduced area and volume of

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**Table 3**—Mean, standard deviation, confidence interval, and student test-t between control group and study group.

<table>
<thead>
<tr>
<th>Mean</th>
<th>Age</th>
<th>AHI</th>
<th>NP Area mm²</th>
<th>NP Vol mm³</th>
<th>OP Area mm²</th>
<th>OP Vol mm³</th>
<th>Axial Area mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG</td>
<td>7.4</td>
<td>0</td>
<td>417.87</td>
<td>8,100.93</td>
<td>100.18</td>
<td>1,410.81</td>
<td>74.48</td>
</tr>
<tr>
<td>SG</td>
<td>9.5</td>
<td>3</td>
<td>284.79</td>
<td>4,949.85</td>
<td>112.88</td>
<td>1,645.43</td>
<td>44.03</td>
</tr>
<tr>
<td>p value</td>
<td>0.002</td>
<td>0.001</td>
<td>0.5</td>
<td>0.6</td>
<td>0.01</td>
<td></td>
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</tbody>
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**Figure 8**—Differences of means between CG and SG.
the NP in patients with OSA and PS. The nasopharynx is not a region of the airway particularly related to mandible retrusion, but it could be associated with class II malocclusion, oral breathing, or allergic diseases.6,19,27 The SG patients were all oral breathers, which may have caused the narrowing of NP, even after they had been submitted to a surgical ENT treatment. This agrees with some authors who have shown the influence of the breathing mode on the anatomy of the upper airways.6,19,27

The causes of the OSA disorder have not been totally established, particularly in the pediatric population, in which the growth and developmental events, and external factors, such as allergic diseases and habits, can influence the development of the sleep disorders, confusing the correct diagnosis. Due to such a complexity of OSA in children, the treatment should be planned in conjunction with various professionals simultaneously.6,14 The PSG diagnosis may not be enough for understanding the cause of disease, in order to achieve the best treatment. We should have tools to evaluate the anatomical obstructive site of the patient to plan for the possible treatment.1–7,15,16

The MRI17 and CBCT exams18–24 have shown to be of good assistance for the OSA understanding. Recent studies recommend considering the cone-beam computed tomographic (CBCT) to identify obstructions in the airways,18 due to the many advantages, including that as the 3D image is more reliable than 2D.18–22 CBCT exams15,16 are safely used for diagnosis in orthodontics because they can replace all routinely requested tests in the diagnosis and orthodontic planning, with the same or even lower ionizing radiation than tests routinely ordered.17,23,24

Our goal was to understand and build parameters that could help the diagnosis and treatment of the recurrent PS and OSAS. Our sample was just large enough for statistical analysis, but not enough for definitive conclusions. The multifactorial aspects of the disorder and aspects related to childhood growth are a great obstacle in standardizing population samples. The observation of the sites where there is a decrease in the upper airways gives us an opportunity to offer the most appropriate orthodontic treatment. Studies involving patients with all patterns of malocclusion such as class I and III angle malocclusion should also be conducted for a comparison with our results.

CONCLUSIONS

Children diagnosed with primary snoring and persistent obstructive sleep apnea after tonsillectomy showed a significant and important narrowing of the upper airway, especially at the nasopharynx region. The sagittal lower area of the upper airway also showed significant reduction. CBCT proved to be a complementary test for diagnostic and treatment planning purposes, and it is available to health professionals of many areas, avoiding the need for potentially harmful orthodontic exams.

ABBREVIATIONS

AHI, apnea-hypopnea index
ANS, anterior nasion spine
AT, adenotonsillectomy
Ba, basion
CBCT, cone beam tomography
CG, control group
DICOM, digital image for communication
FAPESP, Research Foundation of Sao Paulo State
FOUSP, Dentistry College, State University of Sao Paolo
FP, Frankfurt plane
i-Cat, cone beam 3-D dental imaging system
N, nasion
NP, nasopharynx
OP, oropharynx
OSA, obstructive sleep apnea
PAINF, pharynx anterior inferior (15 mm after the lower limit of the uvula)
PAIOF, pharynx anterior (15 mm front of the uvula point)
PNS, posterior nasion spine
PPINF, pharynx posterior inferior (15 mm after the lower limit of the uvula)
PPPOF, pharynx posterior (15 mm rear of the uvula point)
Po, porion
PS, primary snoring
PSG, polysomnography
PV, posterior vomer
RSD, respiratory sleep disorder
SG, study group
UA, upper airway
UARS, upper airway syndrome
UNIFESP, Federal University Sao Paulo

REFERENCES


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**DISCLOSURE STATEMENT**

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