Original article

Rapid maxillary expansion in OSA children: Cone Beam CT skeletal and nasomaxillary complex airway volume changes evaluation and correlation

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Abstract

Objective: **evaluate the correlation between skeletal changes in 2D dimensions and volume changes of the upper airways before and after rapid maxillary expansion (RME) therapy in children with obstructive sleep apnoea (OSA) by Cone Beam computed tomography (CBCT) and between volume of the upper airways and clinical data.**
Methods: **23 children with OSA and malocclusion underwent CBCT scans with a Dentascan and 3D reconstruction program before (T0) and 4 months after (T1) RME. Patients underwent an ENT visit with auditory and respiratory tests, including a daytime sleepiness questionnaire, a 19-channel polysomnography, and an orthognatodontic examination.**
Results: **in all cases opening of the mid-palatal suture was demonstrated. Nasal osseous width, volume of the total upper airways, nasal cavity and nasopharynx and oropharynx increased significantly (P, .05), and enlarged nasopharyngeal volume was correlated to increased nasal width at the PNS plane (P, .05). Posterior suture, pterygoideus process, maxillary width and Nasal cross-sectional width (PNS) (W-PNS) have an excellent and statistically significant correlation coefficient with Total upper airway volume (V-TA) Nasal cavity volume (V-NC) (Nasopharyngeal airway volume (V-NPA) Oropharyngeal airway volume (V-OPA), while Anterior and middle suture have an excellent and statistically significant correlation coefficient only with Oropharyngeal airway volume (V-OPA).**

Keywords: Rapid Maxillary Expansion, OSA children, Computed tomography.

Conclusion

Enlarged Posterior suture, pterygoideus process, maxillary width and Nasal cross-sectional width (PNS) showed a direct correlation to increased airways volume, bringing a functional improvement. The increase in volume of the nasal cavity and nasopharynx, with expansion of the nasal osseous width and maxillary width causing by RME treatment had a positive effect on children affected by chronic snoring and OSA. The results show that the RME therapy can restore and improve a normal nasal airflow with disappearance of obstructive sleep breathing disorder.

Introduction

The Orthodontic treatment options in OSAS children have emerged in the past decade for children with OSAS (1-3). The nasomaxillary complex provides anterior bony support for the upper airways, and orthodontic treatment affects these structures, causing changes in the airways to some extent. RME can help to increase nasopharyngeal and oropharyngeal space for children with upper jaw restriction. This means that orthodontists have the responsibility to understand the physiology of upper airways (2-3). Katyal et al (4) showed how children with narrow dentoalveolar transverse width and reduced nasopharyngeal and oropharyngeal sagittal dimensions had a high risk for sleep-disordered breathing. Many studies have reported the influence of RME on the upper airways, though the results were different due to various subjects and expansion methods (5).
Imaging 3D software programs have been extremely useful in assessing the benefits of RME. In recent times a three-dimensional method of investigation (3D-CT) has been used to study the effects of RME treatment (6-8) using low dose protocol (9). The same author (9, 10) studied the treatment and post-treatment skeletal effects of RME, using low dose CT in growing subjects.
The CBCT systems are operated at a lower patient dose than the MDCT systems, which are used for wide ranges of exposure protocols in dental clinics (11) and have become a standard technique for dentomaxillofacial CT imaging (12-14).
They have also proven vital for structural comparisons between pre and post-clinical treatment and for the evaluation of the morphological changes caused by the treatment, because they improved the visualization of anatomical structures by rendering unnecessary the superimposition of conventional radiographs (15). Furthermore, these programs enhance the accuracy of research findings, besides improving the effectiveness of

any techniques applied, while facilitating the use of computer tools for 3D image manipulation, be it by itself or associated with other software (14, 15).

The purpose of this study was to evaluate the correlation between skeletal changes in 2D dimensions and volume changes of the upper airways before and after rapid maxillary expansion (RME) therapy in children with obstructive sleep apnoea (OSA) by Cone Beam computed tomography (CBCT) and between volume of the upper airways and clinical data.

Materials and methods

Subjects

78 children were selected from a sample of 120 patients presenting malocclusion (45 boys and 33 girls) with the average age of 8.5 years (range: 5-12 years) presenting oral breathing, snoring and OSA symptoms. Patients presenting adeno-tonsillar hypertrophy and body mass index more than 24 kg/m^2 were excluded from this sample. Furthermore, a subsequent selection excluding the younger population was made: in order to reduce the probabilistic effects of ionizing radiation —the stochastic radiation effect— children between 5 and 9 years of age were excluded. Moreover, only patients with a good polysomnography were selected, and patients who did not undergo second CT control or who had image artifacts in the first or second control were excluded. At the end of the screening the selected sample for the study consisted of 23 patients with mixed dentition, an average age of 10.5 years (range 9 e12 years), an average apnoea/hypopnea index (AHI0) of 14.1 (±2.4), and an average minimum oxygen saturation of 75.8 (±8.3) %.

Selection criteria included: malocclusion with upper jaw contraction, oral breathing, snoring and OSA symptoms (documented by polysomnography), no adenotonsillar hypertrophy, body mass index less than 24kg/m^2.

Patients underwent an ENT visit with auditory and respiratory tests, including a daytime sleepiness questionnaire, a 19-channel polysomnography, an orthognatodontic examination and CB CT scans with a Dentascan and 3D reconstruction program, before (T0) and 4 months after (T1) RME. All the clinical investigations were carried out before orthodontic therapy (T0), after 2 months (T1) with the device still on, and 4 months after the end of the orthodontic treatment (T2).

This study was approved by Ethical Committee and the informed consent was obtained from the parents or guardians of all patients.

Specific evaluations were made regarding the following parameters: maxillary suture width at anterior, middle and posterior level; nasal width; right and left molar angulation and pterygoid processes distance. Vertical and horizontal dimensions and volume of the nasal cavity, nasopharyngeal, oropharyngeal and the total pharyngeal airway volume were compared before and after RME. Correlations between changed volume and dimensions were explored.

Data collection

CBCT scans examinations (Newtom 5GXL) were performed before expansion (T0) and after 4 months' retention (T1) by the same operator.

The patients were scanned in orthostatic position with the Frankfurt plane perpendicular to the floor, keeping the teeth in centric occlusion and the tongue in the position at the end of swallowing (against the palate), breathing smoothly, and no swallowing. The digital imaging and communications in medicine (DICOM) data were imported into Dolphin Imaging software (Chatsworth, CA, USA) and used for the measurements described. Volumetric measurements were carried out with the aid of Dolphin® Imaging v. 11.7 software, using the "Airways Volume" tool, and density was set at 55 for all patients.

The images were evaluated in three views (sagittal, coronal and axial), thus delimiting the nasomaxillary complex, and then calculating the volume in cubic millimetres.

Numerical evaluation of the various parameters was based on the identification and registration of a group of reference points, identified on the CT images reformatted on different planes.

Before landmark identification, the three-dimensional volumetric images were oriented with the Dolphin imaging software as follows: coronal plane (horizontal line through orbital bilaterally), sagittal plane (Frankfurt horizontal), and axial plane (Crista galli to basion). The Dolphin software allowed automatic volume calculation after segmenting the area of interest by setting the threshold value of 55.

The material was measured twice by the same author, with at least one week interval between T0 and T1.

The following parameters were measured in millimetres:

(1) Suture opening was measured at three levels on the axial plane: anterior edge, middle and posterior nasal spine. At T0 the measurement of the midpalatal suture at three different levels was considered equal to 0 in order to level the different values before RME treatment that were in the range of 0-0.3.
(2) Maxillary base width was calculated on the axial plane between the vestibular border of buccal cortical plate (left and right respectively). The points were joined using a line tangent to the dental root of the first molar.
(3) The distance between the apices of the pterygoid processes (left and right) was calculated on the axial plane.
(4) Nasal cross-sectional (ANS) height (H-ANS): The height of nasal cavity at the cross-section passing through ANS on Coronal plane reconstruction.
(5) Nasal cross-sectional (ANS) width (W-ANS): The greatest width of nasal cavity at the cross-section passing through ANS on coronal plane reconstruction.
(6) Nasal cross-sectional height (midpoint) (H-mid): The height of nasal cavity at the cross-section passing though the midpoint between ANS and PNS on coronal plane reconstruction. (Fig. 1)
(7) Nasal cross-sectional width (midpoint) (W-mid): The greatest width of nasal cavity at the cross-section passing through the midpoint between ANS and PNS on coronal plane reconstruction. (Fig. 1)
(8) Nasal cross-sectional height (PNS) (H-PNS): The height of nasal cavity at the cross-section passing through PNS on coronal plane reconstruction.
(9) Nasal cross-sectional width (PNS) (W-PNS): The greatest width of nasal cavity at the cross-section passing through ANS on coronal plane reconstruction.

The cavity volume was measured in mm^3 by 3D images

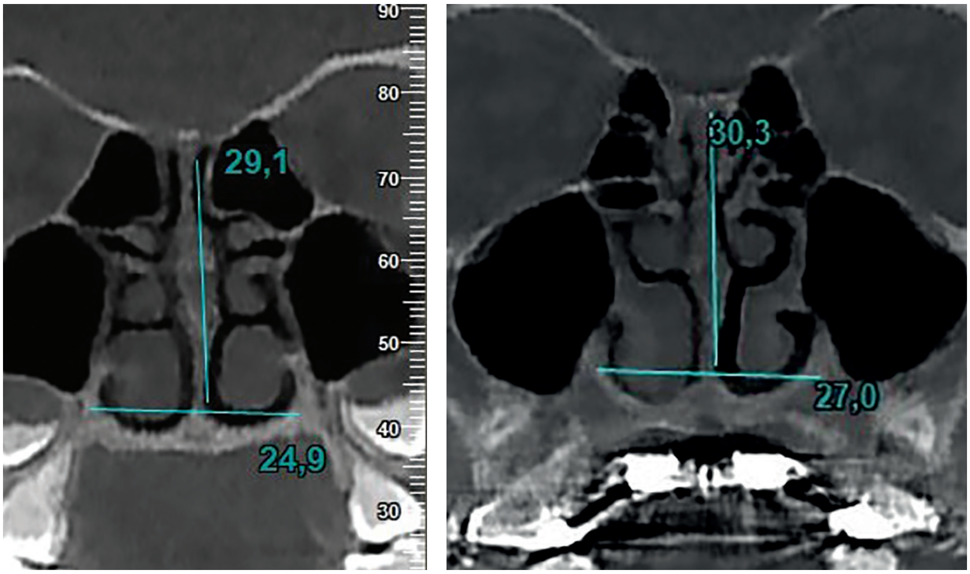

Figure 1.

(1) Nasal cavity volume (V-NC) bound by lines connecting the anterior nasal spine (ANS) to the tip of the nasal bone, then to nasion (N), then to sella (S), then to posterior nasal spine (PNS).
(2) Nasopharyngeal airways volume (V-NPA): The line passing through PNS and S is its anterior border, the line parallel to the Frankfurt horizontal plane (FHP) passing through PNS point is the inferior border, pharyngeal posterior wall is the posterior border.
(3) Oropharyngeal airways volume (V-OPA): The line parallel to FHP passing through the tip of the uvula is the inferior border pharyngeal anterior wall is the anterior border and pharyngeal posterior wall is the posterior border.
(4) Total upper airway volume (V-TA): The line passing through PNS and S is its anterior border, the top of the epiglottis is its inferior border, pharyngeal anterior wall is the anterior border and pharyngeal posterior wall is the posterior border added to nasal cavity volume (V-NC).

Rhinomanometric and polysomnography was performed before, after 2 and 4 months from RME.
The following parameters of the polysomnography test were evaluated: Obstructive AHI Range, Nadir SPO2 (%), Duration of Longest Obstructive Apneas, Duration of Desaturation (S302<92%) ass% TST and Sleep Efficiency (%).

Statistical Analysis

The normality of the data was evaluated using the Shapiro-Wilk test. Measurements for each patient before and after treatment were compared with Wilcoxon's paired matched test. Values are expressed as mean ± standard deviation. As a threshold of statistical significance, a value of p _ 0.05 was used.
The Spearman coefficient, ρ, was calculated for interrelationships between 2D and 3D measures.
The statistical treatment of the data was performed with the Statistical Package for the Social Sciences (SPSS), version 22 for Windows.

Results

The table 1 summarizes the results.
In all the 23 cases, an opening of the midpalatal suture was obtained, with resulting effects at different levels.

Midpalatal suture

In all cases we obtained the opening of the midpalatal suture. The increase at the anterior level of the suture showed an average opening of 4.1 mm. This increase is evident with the appearance of an interincisive space, the hallmark of the midpalatal suture opening that was always present in all cases; 3.1 mm at the medium level of the suture; 1.95 at the posterior level of the suture. (Fig. 2)

Maxillary width

RME therapy is responsible for the expansion of the maxilla with an average cross-sectional increase of 3.5 mm. There were individual variations, although all values showed clear differences between T0 and T1, indicating that, in all patients, the manoeuvre had an expansive effect.

Pterygoid processes

From the study of the pterygoid processes distance, we found an average increase of 2.6 m.
W-ANS, W-mid, W-PNS, H-ANS, H-PNS and H-mid
We found an average increase respectively of 6.3mm, 2.43mm, 3.1mm, 3.9mm, 0.5mm and 1.7mm.
In summary, the midpalatal suture was opened in all patients. A statistically significant difference was observed between the measurements of the maxillary, nasal cavities, and pterygoid processes distance width, performed before and after treatment.
W-ANS, W-mid, W-PNS, showed a significant increase, while H-ANS, H-PNS and H-mid showed a non-statistically significant increase.

Table 1. Changes in the Volumes and Dimensions of the Upper Airway and Changes of Skeletal Widths Before (T0) and After (T1) Rapid Maxillary Expansion.

Parameters	T0 Mean (SD)	T1 Mean (SD)	(T1-T0) Mean (SD)	P value*
Anterior suture	0	4,1	4,1	<.001*
Middle suture	0	3,1	3,1	<.001*
Posterior suture	0	1,95	3,1	<.001*
Pterygoideus processes	51,7	54,3	2,6	<.001*
Maxillary width	51,6	55,1	2,6	.021*
Total upper airway volume (V-TA)	60.8 (11.5)	70.3 (11.5)	9.4 (5.4)	.012*
Nasal cavity volume (V-NC)	32.3 (6.1)	39.5 (6.3)	7.2 (6.3)	.014*
Nasopharyngeal airway volume (V-NPA)	8.8 (4.2)	10.8 (4.1)	2.0 (4.3)	.003*
Oropharyngeal airway volume (V-OPA)	11.37 (2.4)	14.94 (2.9)	3.57 (5.1)	.004*
Nasal cross-sectional height (ANS) (H-ANS)	24.8 (6.3)	28.7 (6.5)	3.9 (6.1)	.062*
Nasal cross-sectional width (ANS) (W-ANS)	15.4 (6.2)	21.7 (6.4)	6.3 (6.3)	.008*
Nasal cross-sectional height (midpoint) (H-mid)	29.2 (2.1)	30.9 (2.2)	1.7 (2.3)	.082*
Nasal cross-sectional width (midpoint) (W-mid)	29.7 (2)	31.5 (2)	1.8 (2)	.006*
Nasal cross-sectional height (PNS) (H-PNS)	19.4 (2.4)	19.9 (2.6)	0.5 (2.2)	.078*
Nasal cross-sectional width (PNS) (W-PNS)	20.7 (4.4)	23.8 (4.7)	3.1 (4.2)	<.001*

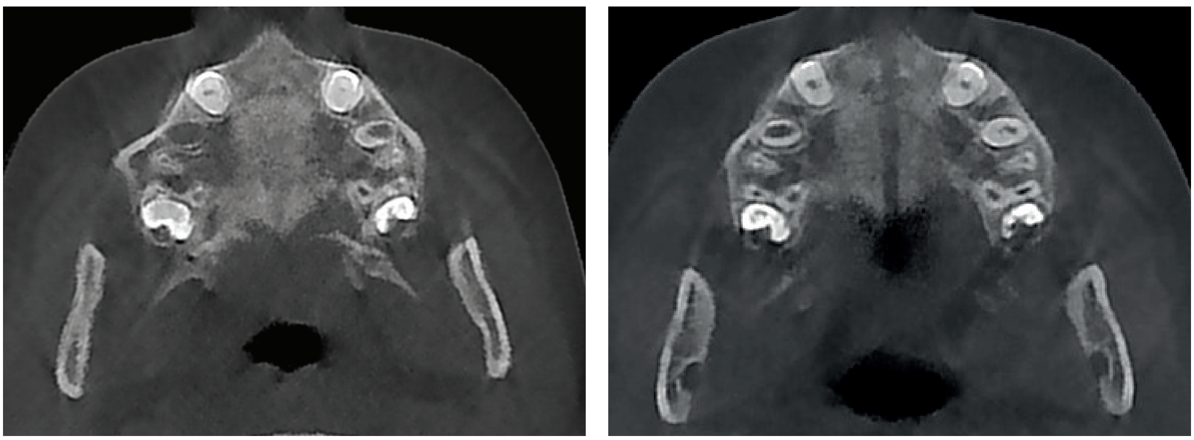

Figure 2.

The increased V-NPA was closely linked to the enlarged W-PNS.

At T0 the mean total upper airways volume was 60.8 mm^3 (SD = 11,5 mm^3), the mean nasal volume was 32.3 mm^3 with a standard deviation of 6,1mm^3, the mean nasopharynx volume was 8.8 mm^3 (DS = 4.2 mm^3), the mean oropharynx volume was 11.3mm^3, with a standard deviation of 2.4 mm^3.

At T1 the mean total upper airways volume was 70.3 mm^3 (SD = 11,5 mm^3), the mean nasal volume was 39.5 mm^3 with a standard deviation of 6,3mm^3, the mean nasopharynx volume was 10.8 mm^3 (DS = 4.1 mm^3), the mean oropharynx volume was 14.9 mm^3, with a standard deviation of 2.9mm^3.

The study shows an increase T0/T1: the total upper airways volume of 9.4mm^3 (SD = 5.4 mm^3), the nasal volume of 7.2 mm^3 with a standard deviation of 6,3mm^3, the nasopharynx volume of 2.0 mm^3 (DS = 4.3 mm^3), the oropharynx volume of 3.5 mm^3, with a standard deviation of 5.1mm^3.

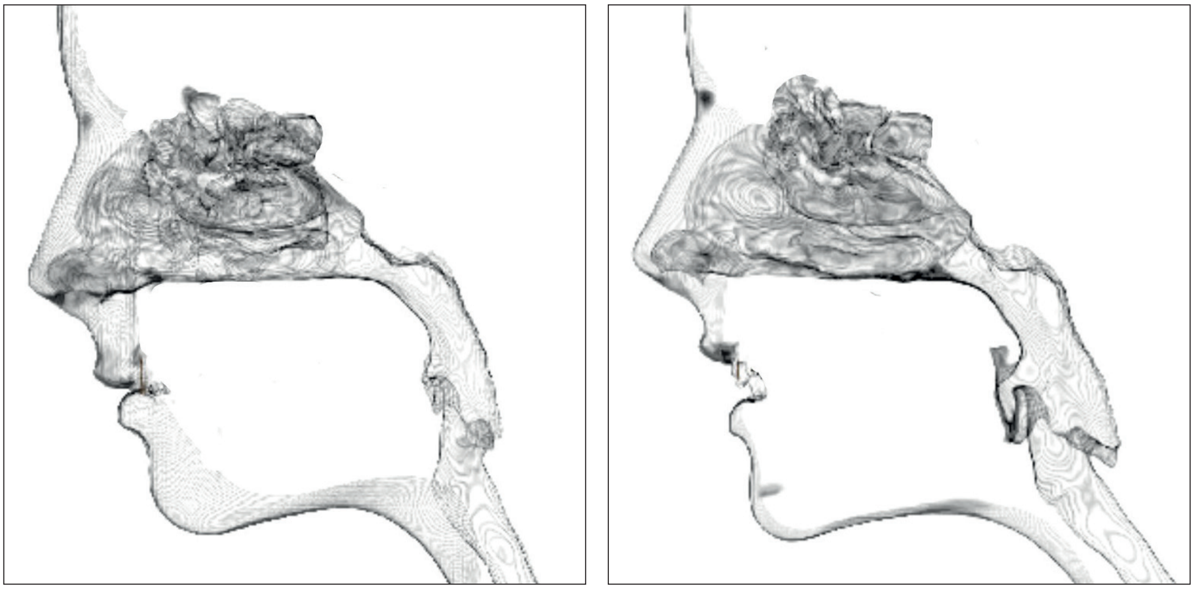

Figure 3.

The results confirmed the evidence obtained in the descriptive analyses, meaning that the increase in total upper airways volume ($p < 0.05$), nasal volume ($p < 0.05$), nasopharynx volume ($p < 0.05$) and oropharynx ($p < 0.05$), were statistically significant. (Fig. 3)
Enlarged nasopharyngeal volume was correlated to increased nasal width at the PNS plane (P, .05). Posterior suture, pterygoideus process, maxillary width and Nasal cross-sectional width (PNS) (W-PNS) have an excellent and statistically significant correlation coefficient with Total upper airway volume (V-TA) (respectively p .014,.023, .033, .038; ρ.84,.87,.78,.78), Nasal cavity volume (V-NC) (respectively p .018,.027, .034, .032; ρ.82,.86,.81,.87), Nasopharyngeal airway volume (V-NPA) (respectively p .018,.038, .036, .031; ρ.89,.88,.82,.91), and Oropharyngeal airway volume (V-OPA) (respectively p .021,.042, .039, .039; ρ.87,.89,.81,.72). While Anterior and middle suture have an excellent and statistically significant correlation coefficient only with Oropharyngeal airway volume (V-OPA) (respectively p .047,.031; ρ.78,.75). (Table 2)

Table 2. Correlation Coefficient Between Significant Changes of Upper Airway Volume and Other Variables.

PARAMETERS	Total upper airway volume (V-TA)		Nasal cavity volume (V-NC)		Nasopharyngeal airway volume (V-NPA)		Oropharyngeal airway volume (V-OPA)	
	p value*	ρ	p value*	ρ	p value*	ρ	p value*	ρ
Anterior suture	0.676	.37	0.721	.42	0.684	.43	0.047	.78
Middle suture	0.564	.46	0.642	.41	0.691	.38	0.031	.75
Posterior suture	0.014	.84	0.018	.82	0.018	.89	0.021	.87
Pterygoideus processes	0.023	.87	0.027	.86	0.038	.88	0.042	.89
Maxillary width	0.033	.78	0.034	.81	0.036	.82	0.039	.81
Nasal cross-sectional height (ANS) (H-ANS)	0.326	.24	0.289	.27	0.295	.31	0.542	.12
Nasal cross-sectional width (ANS) (W-ANS)	0.321	.52	0.332	.58	0.298	.57	0.284	.52
Nasal cross-sectional height (midpoint) (H-mid)	0.415	.26	0.435	.22	0.447	.21	0.479	.14
Nasal cross-sectional width (midpoint) (W-mid)	0.124	.54	0.147	.57	0.165	.58	0.197	.56
Nasal cross-sectional height (PNS) (H-PNS)	0.235	.25	0.224	.22	0.264	.24	0.297	.18
Nasal cross-sectional width (PNS) (W-PNS)	0.038	.78	0.032	.87	0.031	.91	0.039	.72

* Represents a significant correlation, P, .05.

Table 3. Polysomnographic data. Note the significant improvement in all the functional parameters achieved at T2. All data are displayed as mean _ standard deviation. Abbreviations: TST, total sleep time; T0, before any orthodontic therapy; T1, after 4 weeks with the device; T2, 4 months after the end of the orthodontic treatment.

	T0	T1	T2
OBSTRUCTIVE AHI	Range 6.1-22.4 Averange 16.3 2.5	Range 0-9.1 Averange 8.3 2.3	Range 0-26 Averange 0.8 1.3
Nadir SPo2 (%)	77.9 ± 8.4	90.2 ± 5.7	95.4 ± 1.4
Duration of longest obstructive apneas	39.8 ± 17.2	24.3 ± 12.3	12.1 ± 6.5
Duration of desaturation (S302 < 92%) ASS % TST	18.5 ± 3.2	5.8 ± 1.3	1.3 ± 1.4
Sleep efficiency (%)	88.5 ± 9.1	88.9 ± 5.7	89.8 ± 8.5

These CBCT changes were associated with changes in PSG findings with an AHI ¼ 0.5 (±1.3) and lowest saturation ¼ 96.1 (±1.8) %.

The Table 3 shows polysomnography data in terms of average of obstructive AHI Range, Nadir SPO2 (%), Duration of Longest Obstructive Apneas, Duration of Desaturation (S302<92%) ass% TST and Sleep Efficiency (%) at T0, after 2 and 4 months from RME.

Polysomnography presents a normalization of recording in the AHI in all patients at the end of 4 months.

The baseline rhinomanometric data showed a statistically significant difference between those measured at 2 and 4 months (Wilcoxon Z 5–4.86, P5 .000; Wilcoxon Z 5 –5.39, P 5 .000, respectively). The difference between rhinomanometric data at 2 and 4 months was also statistically significant (Wilcoxon Z 5 –4.86, P 5 .000).

The difference between baseline AHI and that at 2 and 4 months was statistically significant (Wilcoxon Z 5 –4.0, P 5 .000; Wilcoxon Z 5 –5.15, P 5 .000, respectively).

The difference between AHI at 2 and 4 months was also statistically significant (Wilcoxon Z 5 –2.0, P 5 .046).

Four months after the end of the orthodontic treatment (T2), all tests showing a normalization of functional examinations were confirmed.

Discussion

A lot of studies have demonstrated the accuracy of the CBCT and its low radiation dose on pediatric patients (14-16). The need to reduce the radiation dose also arose to fully adhere to both the Italian regulatory framework and the European dosimetric levels, reported by the International Commission on Radiological Protection, for which the use of ionizing radiation in the health field must be justified by the advantages that can derive from it. This meant that exposure had to be be kept as low as reasonably possible, consistently with diagnostic needs (17, 18) (a principle of primary importance in particular in the pediatric patients). Usage of 3D-CB CT is not new when considering changes in upper-airways morphology following RME. DiCarlo et al. (18) performed a systematic review for coherent protocols with CBCT to measure airways dimensions and morphology. In recent times a three-dimensional method of investigation (3D-CT), has been used to study the effects of RME treatment (19) and imaging software programs have been extremely useful in assessing the benefits of RME (20, 21).

Respiratory problems associated with transverse maxillary deficiency have been widely discussed by orthodontists and otolaryngologists, given the relation between causes, effects and treatment.

RME anchored on teeth is performed more and more in young children with OSA, as the presence of an abnormal narrow palate is frequently noted with or without enlarged adenotonsils (22), particularly after the demonstration of incomplete results of tonsillectomy and adenoidectomy (T&A) surgery and reoccurrence of abnormal breathing during sleep post T&A (23, 24).

Today, rapid maxillary expansion is regarded as an important method to correct maxillary deficiency and this technique has been validated by many other authors as it makes the splitting of the midpalatal suture possible while producing certain changes in the nasal cavity, which improves breathing (25-27).

Increases in nasal width and height, and changes in nasal volume between pre and post-RME, assessed by Cone Beam computed tomography, have been observed by several authors (28, 29). This was also among the goals of this study, which were confirmed by the results.

It is no doubt that an improved breathing pattern is an important clinical achievement, as observed in this study immediately following RME. Our patients showed an increase in nasal cavity volume after RME, with this outcome being confirmed by an image manipulation program with 3D images, and by quantification of the measured areas.

The same results were observed in all measures of the nasomaxillary complex.

We found clear orofacial skeletal modifications related to RME, including the changes of the pterygoid processes in our subjects.

Imaging is only a part of a sleep-disordered-breathing investigation, and had to be integrated into the overall results, including those obtained during sleep with nocturnal polysomnography; but the 3D-CT provided valid information on the skeletal changes obtained with treatment.

The results we obtained show that the RME therapy widens nasal fossa, thus restoring a normal nasal airflow with disappearance of obstructive sleep-disordered breathing.

The improvement can be clearly linked to the skeletal expansion caused by the manoeuvre performed on the suture.

CBCT images before and after RME therapy confirm that the expansion occurs not only in the maxillary arch but also in the nasal cavity. This anatomic change brings about an increased patency of the upper airways, restoring normal airflow. This patency is the basis for the positive effects induced by the manoeuvre, and it acts on air exchange, with a net improvement of breathing disorders during sleep (30-32).

Increasing of upper jaw cross section also clearly affects the nasal cavities, and it is a true anatomic change that brings about an increased patency of the upper airways. This increase is also the basis for the positive effects induced by the RME manoeuvre on the respiratory function. Associated orthodontic movements can also indirectly improve the oropharyngeal space by modifying the resting posture of the tongue. (20)

Several (33, 34) studies demonstrate an increase in the volume of the upper airways as a result of lateral displacement of the walls of the nasal cavity, caused by the rapid expansion of the palate. Over the past decade the volumetric airways analysis with CBCT was investigated as well as the effects of RME on respiratory function.

In our series volume of the total upper airways, the nasal cavity, the nasopharynx and the oropharynx showed significant increases, consistent with some previous studies (29-32). Kim et al (35) demonstrated that volume of the nasal cavity increased continuously from pre-expansion to immediately after expansion, and to 1 year after expansion. They reported that nasopharyngeal volume showed a significant increase 1 year after expansion, compared with the initial volume.

In addition, we found a correlation between increased nasal osseous width at the PNS plane and expansion of nasopharyngeal volume: in fact the cross-sectional area of the upper airways at the PNS plane enlarged with the increase of maxillary width. we also demonstrated in our study how enlarged nasopharyngeal volume was correlated to increased nasal width at the PNS plane (P, .05), how posterior suture, pterygoideus process, maxillary width and Nasal cross-sectional width (PNS) (W-PNS) was correlated to increased total upper airway volume (V-TA), Nasal cavity volume (V-NC), Nasopharyngeal airway volume (V-NPA) and Oropharyngeal airway volume (V-OPA) , while Anterior and middle suture was correlated to increased Oropharyngeal airway volume (V-OPA).

Referring to a previous study, the upper airways were divided into more segments in this study, resulting in significant changes in all its parts.

Kim et al (35) also showed no changes in volumes of the inferior section of the upper airways and MCA, in accordance with the data reported in the literature.

Many studies agree that the expansion of the nasal cavity and the increased distance between the side walls and the septum caused a reduction in air resistance (36-40), facilitating physiological breathing. In our series, polysomnography presented a normalization of recording in the AHI in all patients at the end of the 4 months, and the baseline rhinomanometric data showed a statistically significant difference between those measured at 2 and 4 months.

Several methods have been proposed to evaluate changes in respiratory efficiency as a result of RME.

De Filippe et al (36), through the use of morphometric 3D analysis and acoustic rhinometry, showed an increase in cross sectional in the area of the nasal cavities, followed by a 34% decrease in nasal resistances. In fact a follow-up to 60 months confirms the stability of the treatment.

Enoki et al (37) evaluated changes in respiratory function in 29 children through the use of three otolaryngology examinations: nasofibroscopy, acoustic rhino-metria and rhinomanometry, carried out before, immediately after and 90 days after rapid expansion. Rhinonomanometry showed a progressive decrease in resistance to both inhalation and extraction.

Iwasaki et al. (38) investigated the effects of RME on nasal respiratory flow in terms of pressure and speed in 22 subjects of average age of 9 years. Eighteen patients treated with RME benefitted from a 66.7% reduction in nasal resistance and a 46.5% decrease in blood pressure. In 2015 Fastuca et al (39) evaluated respiratory response following RME on 15 subjects (average age 7.5) and observed a significant correlation between respiratory volume and blood oxygen saturation level (spO2). These results correlate the expansion of the jaw to an increase in the diameter of the airways, a decrease in respiratory resistance, and an improvement in the patient's respiratory pattern. Through polysomnography (PSG) the same authors found an improvement in the Apnea-Hypopnea Index (AHI) with a reduction in apneic episodes of 4.2 per hour.

In the same year Ghoneima (40) showed how RME had positive effects in terms of pressure reduction, speed and airway resistance, and these changes were capable of changing the airflow pattern from turbulent to laminar.

All the effects on respiratory function mentioned above make RME the therapy of choice in the case of patients with OSAS without obvious upper airways obstructions. In fact, under physiological conditions, the nose contributes 50% of respiratory resistance, and RME is able to significantly decrease these resistances (37).

The authors suggest careful evaluation of the maxillary skeleton base status as a possible common cause of OSAS and recommend resorting to RME therapy.

RME can improve nasal airflow, leading to better ventilatory function through increased upper airways volume, so it could be a therapeutic option for nasal obstruction.

Orthodontists may play an important role in the interdisciplinary treatment of OSAS because a high percentage of patients with OSAS suffer from maxillary narrowness. The authors' experience shows that RME treatment has a positive effect on children affected by chronic snoring and OSA (41, 42). By changing the anatomic structures, RME brings a functional improvement. It is always important to assess the condition of the upper jaw to consider RME therapy in the multidisciplinary treatment of OSAS in children.

Conclusions

Enlarged Posterior suture, pterygoideus process, maxillary width and Nasal cross-sectional width (PNS) showed a direct correlation to increased airways volume, bringing a functional improvement. The increase in volume of the nasal cavity and nasopharynx, with expansion of the nasal osseous width and maxillary width causing by RME treatment had a positive effect on children affected by chronic snoring and OSA. The results show that the RME therapy can restore and improve a normal nasal airflow with disappearance of obstructive sleep breathing disorder and 3D reformatting CBCT confirmed the real remodeling of craniofacial structure and nasomaxillary complex airway volume,

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