ORIGINAL RESEARCH

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Orthodontic treatment of patients with obstructive sleep apnea syndrome (OSAS).

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Abstract

Introduction

The craniofacial skeleton in the growing child is responsive to changing functional demands and environmental factors. Orthopedic modification of facial bones through the application of constant forces over long periods of time has been a mainstay of orthodontic and dentofacial orthopedic therapy.

Aim of the study

The aim of this study was to evaluate changes in pharyngeal structures after rapid palatal expansion (RPE) and compare them with those after using a removable mandibular advancement device (MAD).

Material and methods

In order to accomplish function we modified the pattern of neuromuscular activity throught mandible forward position.

Results

This finding shows that maxillary deficiency and mandibular retrognathism have been reportedly linked to OSA as both etiologic factors and sequelae of prolonged mouth breathing during the period of growth, these illustrate the potential interaction between alteration in respiratory function and craniofacial morphology.

Conclusions

Craniofacial anatomic defects, including inferior displacement of the hyoid bone, larger gonial angle, smaller anterior cranial base, altered anterior and posterior facial heights, and mandibular deficiency, have been suggested as predisposing factors for upper airway obstruction during sleep. Cephalometry has been used extensively in the fields of orthodontics and anthropology to record craniofacial form. Recently, it has been also suggested that cephalometry could be an adjunctive procedure for assessing craniofacial patterns associated with OSAS.

Estimating efficacy of rapid maxillary expansion and mandibular advanced in the treatment of paediatric SDB. This might provide alternatives to primary treatments and/or enhance interdisciplinary treatment planning for the children suffering from OSA. The relationships between maxillofacial malocclusions and upper airway volumes were investigated. Literature studies on the association of upper airway narrowing with dento-skeletal malocclusions have been confirmed by us for the group of patients studied.

Keywords: OSA, class II anomalies, maxillary expansion, mandibular advancement.

Introduction

Nasal physiological breathing is achieved by passing the air in the laminar and swirl form through the nasal passages. During breathing in, the airflow penetrates the nasal vestibule in a vertical, oblique direction. [1,2] From an aerodynamic point of view, this air is in the form of a laminar flow. When the inspired air reaches the nasal lumen, located between the vestibule and the nasal cavity, there is a transformation of the laminar flow into a turbulent flow. [3] The direction of the airflow is influenced by air velocity and anatomy of the nasal cavity. [4] Certain anatomical changes such as nasal septal deflections, as well as functional inferior cornet hypertrophy, cause changes in nasal flow. [4,5] The obstructive sleep apnea hypopnea syndrome (OSAS) consists of episodic chains of abnormal breaths or complete upper airway obstruction. [4]

The influence of upper airways obstruction on the occurrence and perpetuation of sleeping disorders has not yet been completely understood. [6]

General dentists and orthodontists take part in the multidisciplinary management of patients with obstructive sleep apnea syndrome (OSAS) The reduction in size of the upper airway (UA) in course of sleep had been associated with many factors. [7] An aberrant anatomy of the UA, pathological and deficient reflex activation of UA dilator muscles and extended collapsibility of the passive UA have all been determined to develop and contribute to the UA collapse [7]. It has been observed that patients who suffer from OSA have hyperactive muscles during wakefulness to compensate for poor pharyngeal anatomy. Maintenance of the airway is achieved by tonic and phasic contractions of the pharyngeal dilator muscles. [5]

Increased nasal resistance has a dramatic effect on both the maxilla and the mandible, halting growth and bringing about adaptive changes in the soft tissues that are associated with a deviation in jaw posture and tongue activity. [2] A few long-term RPE studies have shown that increments in maxillary transverse dimension are relatively stable. [8] In addition, obstruction of the airways is thought to be caused by the occlusion of the lower pharynx, as the tongue settles back posteriorly against the pharyngeal wall. [9] A mandibular repositioning device changes hyoid bone position and modifies the lower airway space below the level of the base of the tongue. [10]

Objectives

The aim of this study was to evaluate changes in pharyngeal structures after rapid palatal expansion (RPE) and compare them with those after using a removable mandibular advancement device (MAD).

Material and methods

The material for this study comprised the original lateral cephalometric radiographs of 50 patients for whom long-term records were available, aged between 8 – 14 years, girls and boys, with similar Class II skeletal characteristics. Children with one or more of the following criteria were selected: narrow maxillary arch, high narrow palate, unilateral or bilateral posterior cross bite, Class II malocclusion with large overjet.

The subjects included in the studies were selected from the patients who presented for the physiological disorders, masticatory, phonetic and self-maintenance at the department of pediatrics, ENT, orthodontics and dental facial orthopedics at Faculty of Dentistry UMFST Targu Mures, during the period 2015-2018. Five patients with inadequate radiographs, of poor quality due to poor exposure, who hadn't worn the device, have been excluded.

MAD Treated Group

MAD prevent the collapse of the upper airway by protruding the mandible forward, thus altering the position of the lower jaw and tongue. These devices predominantly increase the volume of the airway at the level of the velopharynx. The airway space is mostly enlarged laterally, thought to be due to traction on soft tissue connections between the mandibular ramus and the pharynx.

The treatment objectives for OSAS address the physiological and symptomatic aspects of this disease. The physiological goals target obstructive events, oxygen desaturation and sleep fragmentation. Symptomatic goals target sleepines, snoring, quality of life and possible comorbidities.

A Frankel appliance was prescribed for the subjects in the first group (figure 1).

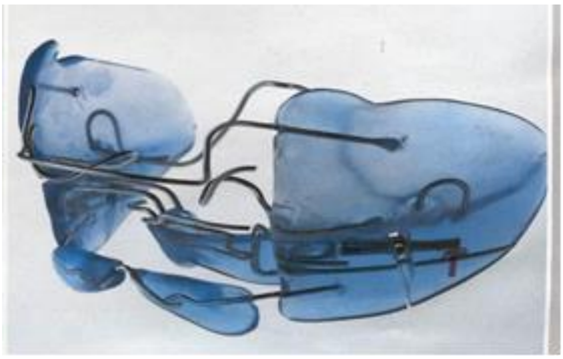

Figure 2. Customized anterior mandibular advancement device (MAD) – Frankel appliance

RPE Treated Group

The rapid palatal expander used in this study was a custom-made orthopedic appliance, bonded to the posterior upper first molars and first bicuspids. It consisted of a screw that was attached to the teeth by means of bands and a metal framework. Preformed bands were fitted on the maxillary left and right first bicuspids and first molars. These bands were transferred to a dental cast, on which the metal framework of the screw was custom bent to fit the anatomical features and the position of the bands, before being welded-together into place (figure 2).

The subjects were prescribed two turns activation of expansion every day, until the desired enlargement was obtained. The patients were seen regularly (every 10-15 days) during this activation period. Once the necessary expansion obtained, activation of the screw was stopped and the appliance was maintained in place for 12 months, to allow for bone tissue to form inside the open midline palatal suture.

Figure 2. Customized rapid palatal expander (RPE)

We performe the cephalometric measurements and there are defined in Table 1 and illustrated in Figures 3 and 4.

Lateral cephalograms were taken for the treated groups at T1 (initial records), and T2 (after treatment completion). The cephalometric points analyses were based on the methods of Tweed and Steiner. All of the cephalometric analyses were performed by the same orthodontist (ODR). The used imaging system was Vatech production Pax reve 3D type. Linear distance measurements were performed using Ceph software from Orthodontic Department.

Table 1. Definitions of the investigated cephalometric measurements

Measurement	Definition
N-S-Ba	Angle formed by the lines connecting the Nasion, Sella and Basion points
SNA	Angle formed by the lines connecting the Sella, Nasion, and A points
SNB	Angle formed by the lines connecting the Sella, Nasion, and B points
ANB	Angle formed by the lines connecting the A, Nasion, and B points
FMA	Frankfurt-mandibular plane angle
SN-GoGn	Anterior angle formed by the intersection of the Sellae-Nasion and Gonion-Gnation planes
Wits	Wits' appraisal: the distance between the projections of A and B on the occlusal plane
UPF-SPP	Distance between upper posterior pharyngeal wall and posterior nasal spine
LPF-H	Distance between lower posterior pharyngeal wall and hyoid bone

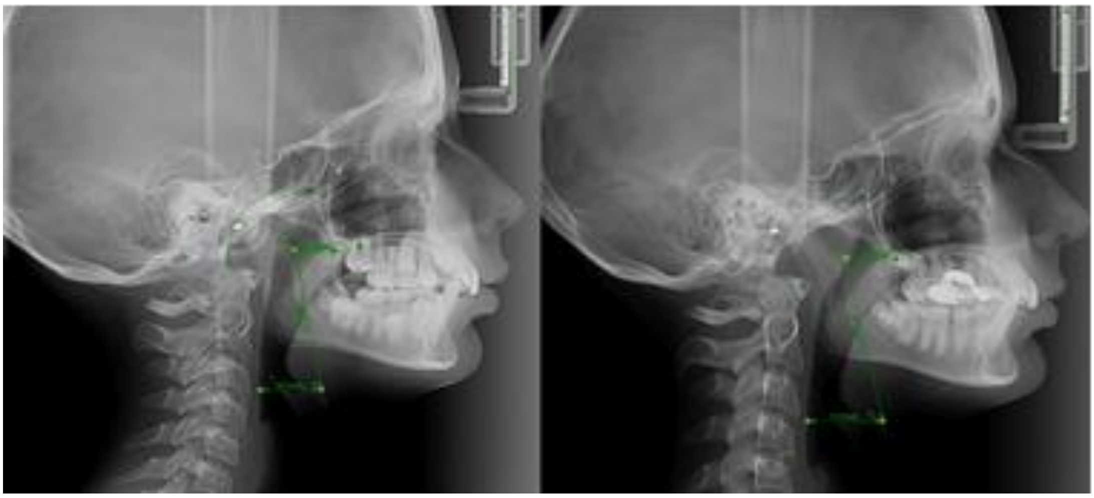

Figure 3. Measurements of the pharyngeal airways, before and after RPE

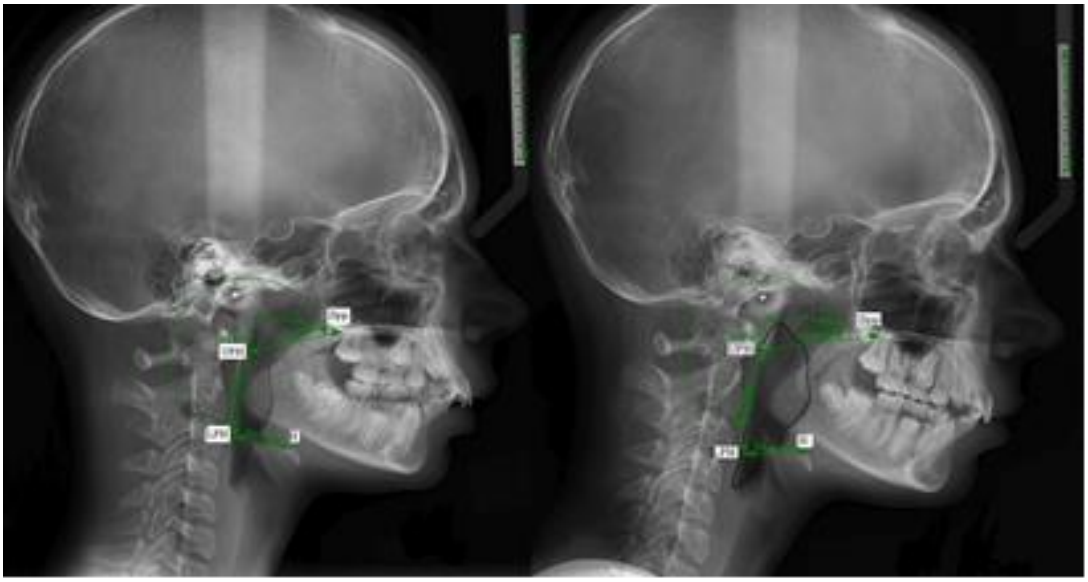

Figure 4. Measurements of the pharyngeal airways, before and after mandibular advancement device (MAD)

Two-tailed t-tests for paired samples were used to compare cephalometric measurements before vs. after treatment, for each of the two treatment groups.

Two-tailed t-tests for independent samples were used to compare the treatment-induced differences between the two treatment groups: (1) the anteroposterior position of the maxilla and mandible, (2) the size of the upper airways, between the RPE and the MAD (Twin Block) treatment groups included in the study. Fisher's Exact Test was used to investigate potential sex differences between the compared groups. For all hypothesis testing, the level of statistical significance was chosen at a threshold $\alpha=0.05$. Microsoft Excel and PSPP 0.10.2 were used to perform these analyses.

Results

The studied sample consisted of 45 subjects, divided into 2 groups, according to the main intervention and treatment plan: 25 subjects treated with rapid palatal expansion (RPE), 15 females and 10 males, with a mean age of 10.45 years (SD=2.47 years), and 20 subjects treated with a functional mandibular advancement device (MAD), 11 females and 9 males, with a mean age of 9.96 years (SD=1.28 years).

Study participants turned the expander an average of 25 turns or 6.25 mm of total rapid palatal expansion. This consisted of a range of 20-34 turns, depending on the amount of expansion needed to obtain a relationship of the maxillary lingual cusp in occlusal contact with the mandibular buccal cusp. No significant differences in respect of age or sex were found between the compared groups (RPE and MAD) ($p>0.05$ t-test for independent samples and Fisher's Exact Test).

Cranial measurements: Mandibular position in relation to the cranial base (SNB) increased less ($p=0.003$ - t-test for independent samples) in the RPE group (mean SNB change of 1.2°), when compared to the MAD functional therapy group (mean SNB change of 2.2°).

In the RPE group, the measures of lower facial height were increased by an average of 2.2°. A significant increase of the vertical dimension occurred, from a pre-treatment FMA mean angle of 24.2 ° to a post-treatment mean FMA of 26.5 ° ($p<0.001$ - Student's t-test for paired samples).

In the MAD (Frankel group,) a restraining effect of the maxilla occurred from an average pre-treatment SNA angle of 82.7° to 81.4° post-treatment, exhibiting therefore a significant decrease of 1.3° ($p<0.001$ paired t-Test). After treatment, both groups exhibited favorable and statistically significant cephalometric changes of angle and linear measurements (Tables 2 and 3). Based on both, angular values (ANB) and linear measurements (Wits appraisal), RPE was found to induce less significant sagittal advancement of the mandible compared to functional therapy using the Frankel appliance (Table 4).

Table 2. Cephalometric differences before vs. after rapid palatal expansion (RPE)

Measurement	Units	Mean before RPE	SD	Mean after RPE	SD	Difference (initial minus final)	95% CI of the Difference	p-value (paired t-Test)
N-S Ba	degrees	129.31	5.47	129.10	4.39	0.21	(-1.35, 1.76)	0.787
SNA		82.10	3.76	81.52	3.65	0.59	(-0.09, 1.26)	0.088
SNB		76.41	2.89	77.66	3.25	-1.24	(-1.73, -0.76)***	<0.001
ANB		5.90	2.13	3.86	1.92	2.03	(1.39, 2.68)***	<0.001
FMA		24.24	4.36	26.48	4.95	-2.24	(-3.34, -1.15)***	<0.001
SN-GoGn		31.97	6.98	32.41	6.26	-0.45	(-1.86, 0.96)	0.519
Wits	mm	4.90	2.48	2.83	1.56	2.07	(1.32, 2.82)***	<0.001
UPF-SPP		25.21	3.90	27.14	4.48	-1.93	(-2.5, -1.37)***	<0.001
LPF-H		28.62	3.71	31.52	4.99	-2.90	(-4.03, -1.76)***	<0.001

Legend: Measurements - see Table 1, RPE - rapid palatal expander, SD - standard deviation, CI - confidence interval

Table 3. Cephalometric differences before vs. after mandibular advancement device (MAD)

Measurement	Units	Mean before Twin Block	SD	Mean after Frankel	SD	Difference (initial minus final)	95% CI of the Difference	p-value (paired t-Test)
N-S-Ba	degrees	126.42	5.54	126.42	6.56	0.00	(-1.69, 1.69)	1
SNA		82.65	4.85	81.35	4.05	1.31	(0.65, 1.96)***	<0.001
SNB		75.65	3.87	77.85	4.25	-2.19	(-2.73, -1.66)***	<0.001
ANB		7.15	2.17	3.73	1.59	3.42	(2.56, 4.29)***	<0.001
FMA		22.77	5.15	25.31	5.40	-2.54	(-4.05, -1.03)**	0.002
SN-GoGn		28.81	5.63	29.96	5.34	-1.15	(-2.11, -0.19)*	0.021
Wits	mm	5.88	2.09	2.65	1.47	3.23	(2.39, 4.07)***	<0.001
UPF-SPP		25.15	4.76	26.46	5.30	-1.31	(-2.06, -0.55)**	0.002
LPF-H		25.42	3.08	27.96	3.63	-2.54	(-3.44, -1.64)***	<0.001

Table 4. Comparison between individual paired differences after RPE vs. MAD

Measurement	Units	Mean paired difference after RPE (N=29)	SD	Mean paired difference after MAD (N=26)	SD	Difference	95% CI of the Difference	p-value (t-Test for independent samples)
N-S-Ba	degrees	-0.07	4.12	-0.02	4.21	-0.05	(-2.31, 2.21)	0.965
SNA		-0.61	1.71	-1.16	1.60	0.55	(-0.35, 1.45)	0.227
SNB		1.16	1.26	2.22	1.25	-1.06	(-1.74, -0.37)**	0.003
ANB		-1.95	1.57	-3.26	2.06	1.31	(0.32, 2.3)**	0.01
FMA		2.35	2.87	2.60	3.66	-0.25	(-2.02, 1.52)	0.78
SN-GoGn		0.42	3.82	1.25	2.34	-0.82	(-2.56, 0.92)	0.347
Wits	mm	-2.07	1.91	-3.21	1.95	1.14	(0.09, 2.18)*	0.033
UPF-SPP		1.84	1.40	1.31	1.88	0.53	(-0.36, 1.42)	0.235
LPF-H		3.03	2.92	2.45	2.11	0.58	(-0.81, 1.98)	0.403

Discussions

Rapid maxillary expansion has been shown to be an extremely efficient and effective way of widening the maxillary bony base. In the early 1900s, Körbitz, who originally postulated the "foot in-shoe" theory showed that 92% of the treated group spontaneously improved their Class II molar relationship by one millimeter or more, and almost 50% of treated patients presented an improvement in molar relationship of 2 mm or greater, without any definitive Class II mechanics incorporated into the protocol, except for the trans-palatal arch worn during the transition to the permanent dentition. [2]

The results of the study by Guest et al indicate that spontaneous improvement of Class II malocclusion occurred equally in both half-cusp and full-cusp Class II relationships. Even Volk and co-workers found improvements of Class II relationship in 7 of their 13 subjects. [1,2]

An explanation for this conversion is that the mandible moves forward after maxillary expansion, just as a foot in a narrow shoe would move forward after the shoe was widened. [10]

The rationale for this movement is that the tongue is attached to the genial tubercles of the mandible and positioning the mandible forward will also result in the tongue being positioned in the same sense. The most common skeletal problem in orthodontics is the Class II malocclusion, characterized by mandibular retrognathia. Most subjects with this type of malocclusion also exhibit narrow maxillary arches. [10]

Abnormal narrowing in the nose, nasopharynx, oro-pharynx or hypopharynx causes abnormal air exchange during sleep, leading to clinical symptoms, which vary with age Jamieson et al (1986) described a Class II pattern as being an important factor in sleep apnea syndrome and more recent research has confirmed this observation. [10]

Concerning sagittal changes, there is a substantial amount of experimental and clinical evidence that mandibular position and length can be improved, using functional orthopedic appliances. [11] Mid-facial bone volume can be increased by targeting the craniofacial sutures, which gives the mandible a functional space to grow. Palatal expansion allows the enlargement of the upper jaw, improvement of the relationship between the jaws, and improvement of the function. Maxillary expansion makes it possible and often allows the mandible to reposition itself in a centered and forward position, thereby releasing the airway space. Several patients having undergone palatal expansion reported having easier times breathing through the nose and saw their snoring decrease

In a study by Smith et al. RPE resulted in a significant increase in nasal cavity volume, nasopharynx volume, anterior and posterior facial heights, palatal and mandibular planes and also enlarged pharyngeal airway and oro-pharyngeal space. [12]

In previous studies, RPE brought skeletal changes by maxillary sutural expansion and widening of the nasal cavity. Isaacson [13] found that forces as high as 22.5 lbs, or approximately 100 N, could be generated during RPE activation. These forces are transmitted through the teeth to the bone, and assuming the upper jaw is not rigidly attached to the rest of the skull, this causes the median palatal suture to widen.

Sleep-disordered breathing seems to have an important impact on the quality of life. Gonçalves et al. assessed the quality of life in children with sleep-disordered breathing before and after RME and concluded that the quality of life in these children improved significantly after expansion, regardless of the degree of airway obstruction. This supports the use of the rapid maxillary expansion device in reducing nasal airway resistance and reducing associated symptoms seen in pediatric sleep disorders, such as nocturnal enuresis, as proposed by Timms. [12]

In this study, the Frankel appliance group demonstrated higher skeletal changes and the ANB angle decreased. The inclined planes of the Twin-block appliance have been shown to be effective in maintaining forward mandibular posture even when the patient is asleep. [11] They achieve functional correction of Class II malocclusions by transmitting favorable occlusal forces to the inclined occlusal planes covering the posterior teeth, while the SNB angle increased significantly more compared to the RPE group. These findings are consistent with multiple studies, which noted the favorable changes in the ANB angle.

In snorers, the position of the hyoid bone was more inferiorly and posteriorly placed. This position is of interest because of its relationship to the tongue position; therefore, it could be a good prognostic indicator for mandibular advancement therapy. [13] In the vertical plane, increases in lower face height and maxillo-mandibular planes angle have been reported. In the current study, the patients treated with RPE and with MAD resulted in bilateral dental and skeletal class I Angle relationships, maxillary expansion, lower jaw advancement and the maxillary restraint, a decreased over jet, with a normal lip position, gaining a significant skeletal correction and improving the esthetics of their facial profile.

The orthopedic appliances were used to protrude the mandible, widen the maxilla, to improve jaw relationships and to correct Class II and to expand the pharyngeal airways. Such functional devices have already been proposed for pharyngeal airway expansion in the treatment of OSA. The Frankel I appliance used in this study also had palatal expansion capabilities, therefore inducing both a sutural maxillary expansion and a mandibular advancement and repositioning effect in MAD-treated study participants.

The subjects of the present study had normal height and weight for their age, they weren't obese, and no significant age or sex differences were found between the two groups.

In both groups included in this study, but mostly in the MAD group, the mandibles rotated posteriorly (the mandibular plane angle increased), which was consistent with the findings of Bondemark. As a consequence of the posterior rotation of the mandible, the FMA increased. The posterior rotation of the mandible may have been an effect of patients sleeping with their mouth open, thus allowing an extrusion of their posterior teeth.

This study did not evaluate the maxillary transverse development induced by RPE and MAD, or the mandibular growth potential of children; these aims were not in its scope. Instead, it investigated the effects of RPE and MAD on pharyngeal structures and whether these treatment options may have a potential to improve sleep apnea. The study was limited in its means by the fact that it was retrospective and only evaluated linear and angular measurements on lateral cephalograms. Cone-beam CT data were not available for the studied sample. Another limitation of the present study has been the moderate size of the available sample.

Despite this, most skeletal changes observed in the present study were found to be statistically significant, some of which may also be considered large enough to be clinically important (ANB, Wits' appraisal, LPF-H). Favorable structural changes at the pharyngeal level appeared to be triggered by both manipulations of the skeletal bases: the maxilla (RPE) and the mandible (MAD). Both RPE and MAD seem to have a clinically significant impact on the dental and skeletal systems and may be considered useful appliances for treating OSA, as previously suggested by Smith et al

More recent studies confirm the existence of significant dento-skeletal and volumetric upper airway changes induced by both RPE and MAD but are concerned by the low level of evidence regarding the long-term stability of clinically significant results following these treatments. Therefore, the clinical implications of the current retrospective study should be interpreted with caution and in light of other research on phenotypic variants of the cranial base, while also taking into consideration the role of genetic and physiologic differences between individuals.

By improving the relations between maxilla and mandible, the pharyngeal airway space seems to improve as well, however, whether all patients are suitable for RPE or MAD correction as a treatment of pediatric sleep apnea is still under debate and for the time being has not yet been well documented.

Conclusions

1. An interdisciplinary approach is needed to properly diagnose and make a predictable treatment plan for pediatric obstructive sleep apnea patients.

2. Favorable changes in pharyngeal space occurred after functional appliances and RPE treatments in growing children.

3. Early orthopedic treatment corrects the sagittal intermaxillary relation in Class II children, inducing significant pharyngeal changes that may benefit patients with mild to moderate obstructive sleep apnea syndrome.

Conflict of interest: None to declare.

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