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**Title:**

Management of the pediatric OSAS: what about simultaneously expand the maxilla and advance the mandible? A retrospective non-randomized controlled cohort study

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**ABSTRACT:**

**Objective/Background:** This retrospective non-randomized controlled cohort study aimed to evaluate the efficiency of simultaneous maxillary expansion and mandibular advancement for the management of pediatric OSAS.

**Patients/Methods:** The sample was composed of 94 children treated with an innovative orthopedic device to correct a Class II malocclusion associated with an OSAS. Polysomnographic recordings were performed before and after the treatment. We also included a group of 113 age-matched control patients who had the same pathologies, but who did not receive the orthopedic treatment at the time they undergone polysomnographic exams. Statistical tests evaluated the significance of the evolution of these data, both in treated and untreated control patients.

**Results:** After nine months ( $\pm 3$  months) of treatment, respiratory OSAS symptoms significantly improved: the AHI significantly decreased as it became inferior to the pathological threshold ( $<1$ ) for 53% of the treated patients' sample, with a greater proportion within the youngest age group (63%). Only two patients still presented a moderate OSAS after treatment, with an AHI slightly superior to 5. This positive evolution of OSAS respiratory symptoms was not observed within the control group, highlighting the real impact of the orthopedic treatment over the children's natural growth. However, sleep remained fragmented following the treatment.

**Conclusions:** This study confirmed that simultaneous maxillary expansion and mandibular advancement induced a modification of the maxilla-mandibular anatomy, helping in the significant improvement of the respiratory OSAS symptoms. Then, considering these preliminary results, pediatric OSAS can be managed with this new orthopedic strategy, especially if it is performed early.

**Keywords:** Maxillary expansion; Mandibular advancement; Child; Obstructive Sleep Apnea Syndrome; Polysomnography.

Journal Pre-proof

## 1. Introduction

Obstructive Sleep Apnea Syndrome (OSAS) is defined as a respiratory disorder characterized by a partial (hypopnea) or complete (apnea) obstruction of the upper airways during sleep. In the pediatric population, its prevalence ranges from 1.2% to 5.8% [1–3]. This pathology leads to an oxygen desaturation and sleep fragmentation and is associated with various signs and symptoms as snoring, excessive daytime sleepiness, reduced concentration, hypertension or even cardiac arrhythmia [4,5].

In a systematic review, Caron et al. [6] highlighted that around 10 to 20% of OSAS children present a craniofacial anatomy anomaly. Indeed, the narrowness of the upper airways and reduced airflow can be the consequence of a posterior position of the mandible associated to a fallback of the tongue in the hypopharynx. Likewise, a constricted maxilla may cause a size reduction of the nasal cavities, an ogival-shape palate and lower the position of the tongue [7–9].

The American Association of Sleep Disorders recommends the use of oral appliances as mandibular advancement devices, lingual retainers, appliances acting upon the soft palate or maxillary expanders [11–14]. These devices widen the palatal vault and the nasal cavities, move the tongue outside the pharynx, and change the hyoid bone position. The result is the increase of the airway dimensions, the improvement of their patency and the relief of their obstruction [15,16].

In a previous study, we presented the innovative, custom-made oral device Ortho2D<sup>®</sup> combining maxillary expansion and mandibular advancement: see Figure 1 [17]. These preliminary results demonstrated a significant improvement of sleep breathing quality. But the need to confront them to non-treated patients remained.

In this study, we measured the respiratory status during sleep of children with OSAS and performed a retrospective non-randomized controlled cohort study by comparing patients treated with the Ortho2D® device with age-matched patients awaiting treatment. The aim of this study was to assess whether this oral device was efficient in reducing OSAS symptoms.

## **2. Material and Methods**

### **2.1. The study samples**

The patients included in this study were followed between 2013 and 2019 in a French private orthopedic practice and were diagnosed with a Class II malocclusion (mandible posterior to the maxillary arch) and OSAS (initial Apnea/Hypopnea Index (AHI)  $\geq 1$  event/hour of sleep). All these children were treated with the personalized, innovative oral appliance Ortho2D® described in a previous paper combining rapid palatal expansion and nocturnal mandibular advancement [17].

According to the French law n°2012-300 of March 5<sup>th</sup>, 2012 on researches involving human beings, because this study was retrospective and non-interventional, and because data were anonymized, no signed consent was required.

This study sample was divided into two groups: treated patients (TP), considered as cases, for whom data about the respiratory status were collected before (TP<sub>t0</sub>) and after (TP<sub>t1</sub>) the orthodontic treatment; and patients considered as control (CP) whose age matched that of the TP<sub>t1</sub> patients, and who did not yet receive the orthopedic treatment at the time they undergone polysomnographic exams. For the purpose of this study, the results were broken down into 3 age groups: “6-7y”, “7-8y” and “8-9y”.

### **2.2. The polysomnographic exams**

The respiratory status during sleep of TP<sub>t0</sub>, TP<sub>t1</sub> and CP patients were assessed with type 2 polysomnographic (PSG) exams performed with SOMNOlab® (Weinmann, Hamburg, Germany). Those sleep studies were performed at patient's home, after a detailed explanation to the parents on the way to operate it and careful instructions regarding the correct placement of the device sensors. These exams were performed according to the American Academy of Sleep Medicine (AASM) guidelines [18].

The following parameters were recording:

- The Apnea/Hypopnea Index (AHI), defined as the number of apneas and hypopneas events per hours of recorded sleep. This is the most significant OSAS parameter. In accordance with the reviewed literature, this criteria was used to assess the severity of the child's OSAS as: mild ( $1 \leq \text{AHI} < 5$ ), moderate ( $5 \leq \text{AHI} < 10$ ) or severe ( $\geq 10$ ) [19,20].
- The Oxygen Desaturation Rate (ODR), defined as the amount of time the blood oxygen saturation was  $\leq 96\%$  over the recorded sleep period. A respiratory disorder was considered when this rate was  $> 1.4\%$  [19].
- Arousals were scored according to the American Sleep Disorders Association standards [21]. An Arousal Index (AI) was computed as the number of arousals per hour of total sleep time. An  $\text{AI} \geq 11$  was considered pathological [22,23]. This index was classified as respiratory-related if the arousal occurred immediately after an apnea or hypopnea. If so, a Sleep Respiratory-Related Disorder (SRRD) was identified when this index (named  $\text{AI}_{\text{SRRD}}$ ) was  $> 1$  [23,24]. When the arousal occurred together with a series of consecutive leg movements, it was classified as related to a Periodic Limb Movement syndrome (PLM) and so was reported as  $\text{AI}_{\text{PLM}}$  [25]. It was considered pathological when it occurred  $\geq 5$  times per hours of recorded sleep [26].
- The total duration of sleep recorded (in minutes).

- The duration of REM (Rapid Eye Movement) and non-REM sleep on the total duration sleep (in percentage), as Tauman et al. reported that children with sleep-disordered breathing had a significantly increased percentage of non-REM sleep and decreased REM sleep compared with control children [27].

For the TP<sub>t0</sub> and CP samples, those parameters were collected before the treatment initiation.

For TP<sub>t1</sub>, they were collected at the end of the treatment, i.e. after approximately 9 ±3 months.

### 2.3. The statistical analyses

The statistical analysis was carried out with the R kernel (version 3.6.1) in the Rstudio environment (v 1.2.5033) [28]. Qualitative and quantitative results were presented as percentages and as mean ±standard deviation respectively. Differences were considered significant at  $p < 0.05$ . As the normality of the data distribution was assessed with Shapiro-Wilk tests, parametric analyses were performed.

To evaluate the impact of the orthopedic treatment, we compared TP<sub>t0</sub> and TP<sub>t1</sub> values using paired t tests. We also used Student's t test to highlight the effect of treatment by comparing the treated patients' group TP<sub>t1</sub> with the age-matched control group CP. Those analyses were performed for each age group. Finally, to evaluate the spontaneous evolution of the polysomnographic data in untreated patients, we compared each age group of CP with a Student's t test.

## 3. Results

The description of the treated and control samples is presented in Table 1.

### Table 1



Description of the two samples of this study: the treated patients (TP) and their TP<sub>t1</sub> age-matched control equivalent, for each age group

	Groups		N	Age (years)			
				Min	Max	Mean	SD
6-7y	Treated patients	TP <sub>t0</sub>	16	4.19	5.92	5.19	0.55
		TP <sub>t1</sub>		6.00	6.99	6.49	0.32
	Control patients	CP	54	6.00	6.99	6.50	0.30
7-8y	Treated patients	TP <sub>t0</sub>	38	5.59	6.91	6.28	0.34
		TP <sub>t1</sub>		7.07	7.98	7.48	0.28
	Control patients	CP	34	7.07	7.98	7.55	0.29
8-9y	Treated patients	TP <sub>t0</sub>	40	5.43	7.98	7.01	0.53
		TP <sub>t1</sub>		8.06	8.96	8.55	0.26
	Control patients	CP	25	8.06	8.96	8.50	0.26

The polysomnographic data for each age group are summarized in Table 2 to Table 4. We also illustrated these distributions as boxplots for the AHI which is the most significant OSAS parameter: see Figure 2. The distribution of the other PSG parameters can be found in the supplementary material. The evolution of the prevalence of OSAS children and its severity for each age group is resumed in Table 5. Finally, the results of the comparison of each age group of CP are summarized in Table 6.

**Table 2**

Summary of the polysomnographic data collected for the '6-7y' age group

	mean ± sd			<i>p-values</i>	
	Treated patients (n = 16)		CP (n = 54)	TP <sub>t0</sub> vs TP <sub>t1</sub> <sup>a</sup>	TP <sub>t1</sub> vs CP <sup>b</sup>
	TP <sub>t0</sub>	TP <sub>t1</sub>			
<b>AHI</b>	6.9 ±5.9	1.3 ±1.6	4.5 ±2.3	<b>&lt;0.01</b>	<b>&lt;0.001</b>
<b>ODR (%)</b>	2.9 ±2.3	3.7 ±4.8	2.9 ±2	0.83	0.65
<b>AI</b>					
- Total	6.8 ±3.8	7.9 ±7.4	7 ±4.5	0.61	0.64
- AI <sub>SRRD</sub>	0.5 ±0.5	0.2 ±0.3	0.5 ±0.5	<b>&lt;0.05</b>	<b>&lt;0.05</b>
- AI <sub>PLM</sub>	13 ±12.7	8.5 ±6	12.6 ±8.2	0.22	<b>&lt;0.05</b>
<b>Time sleep duration</b>					
- Total (min)	465.8 ±72.3	433.4 ±66.1	453.5 ±67.6	0.21	0.30
- REM sleep (%)	29.2 ±7.3	34.1 ±13.7	31.4 ±14.4	0.49	0.65
- Non-REM sleep (%)	24.4 ±10.5	20.8 ±11.3	23.8 ±6.1	<b>&lt;0.05</b>	0.42

**T0**: Treated patients' sample, before receiving the orthodontic treatment; **T1**: Treated patients' sample, after receiving the orthodontic treatment; **CP**: Age-matched control patients' sample. Significant *p-values* are in bold (<sup>a</sup> paired t test; <sup>b</sup> Student T test)

**Table 3**

Summary of the polysomnographic data collected for the '7-8y' age group

	mean $\pm$ sd			<i>p-values</i>	
	Treated patients (n = 38)		CP (n = 34)	TP <sub>t0</sub> vs TP <sub>t1</sub> <sup>a</sup>	TP <sub>t1</sub> vs CP <sup>b</sup>
	TP <sub>t0</sub>	TP <sub>t1</sub>			
<b>AHI</b>	4.4 $\pm$ 2.1	1.1 $\pm$ 0.7	4.7 $\pm$ 3	<b>&lt;0.001</b>	<b>&lt;0.001</b>
<b>ODR (%)</b>	2.7 $\pm$ 1.8	1.7 $\pm$ 1	2.8 $\pm$ 3.1	0.38	0.08
<b>AI</b>					
- Total	6.6 $\pm$ 3.3	8.1 $\pm$ 4.8	7.8 $\pm$ 5.8	0.10	0.82
- AI <sub>SRRD</sub>	0.5 $\pm$ 0.4	0.2 $\pm$ 0.3	0.5 $\pm$ 0.5	<b>&lt;0.05</b>	<b>&lt;0.001</b>
- AI <sub>PLM</sub>	13.3 $\pm$ 9.5	19.2 $\pm$ 24.6	11.5 $\pm$ 7.8	0.18	0.08
<b>Time sleep duration</b>					
- Total (min)	457.2 $\pm$ 57.1	438.8 $\pm$ 63.4	450.9 $\pm$ 66.2	0.10	0.43
- REM sleep (%)	33.3 $\pm$ 16	31.9 $\pm$ 13.2	27.7 $\pm$ 12.5	0.60	0.31
- Non-REM sleep (%)	24.1 $\pm$ 6.8	25.9 $\pm$ 8.9	25.4 $\pm$ 8.5	0.74	0.85

**T0:** Treated patients' sample, before receiving the orthodontic treatment; **T1:** Treated patients' sample, after receiving the orthodontic treatment; **CP:** Age-matched control patients' sample. Significant *p-values* are in bold (<sup>a</sup> paired t test; <sup>b</sup> Student T test)

**Table 4**

Summary of the polysomnographic data collected for the '8-9y' age group

	mean $\pm$ sd			<i>p-values</i>	
	Treated patients (n = 40)		CP (n = 25)	TP <sub>t0</sub> vs TP <sub>t1</sub> <sup>a</sup>	TP <sub>t1</sub> vs CP <sup>b</sup>
	TP <sub>t0</sub>	TP <sub>t1</sub>			
<b>AHI</b>	5 $\pm$ 3	1.7 $\pm$ 1.3	6.3 $\pm$ 5.7	<b>&lt;0.001</b>	<b>&lt;0.001</b>
<b>ODR (%)</b>	3.4 $\pm$ 3.1	2.5 $\pm$ 2.2	5.1 $\pm$ 9.3	0.24	0.22
<b>AI</b>					
- Total	8.6 $\pm$ 6.6	7 $\pm$ 4.2	6.6 $\pm$ 3.4	0.23	0.68
- AI <sub>SRRD</sub>	0.6 $\pm$ 0.6	0.4 $\pm$ 0.7	0.5 $\pm$ 0.5	0.19	0.41
- AI <sub>PLM</sub>	12.4 $\pm$ 7.2	13.8 $\pm$ 8.6	14.4 $\pm$ 10.3	0.32	0.80
<b>Time sleep duration</b>					
- Total (min)	450.1 $\pm$ 73.8	427.1 $\pm$ 86.9	401.6 $\pm$ 70.5	0.20	0.20
- REM sleep (%)	26.7 $\pm$ 10.3	31.6 $\pm$ 9	26 $\pm$ 9.2	0.38	0.11
- Non-REM sleep (%)	24.5 $\pm$ 5	24.8 $\pm$ 8.5	29.6 $\pm$ 11.3	0.67	0.11

**T0:** Treated patients' sample, before receiving the orthodontic treatment; **T1:** Treated patients' sample, after receiving the orthodontic treatment; **CP:** Age-matched control patients' sample. Significant *p-values* are in bold (<sup>a</sup> paired t test; <sup>b</sup> Student T test)

**Table 5**

Prevalence of pathological patients for each age group, defined according to the pathological thresholds for each PSG parameter (see chapter 2.2 of the Materials and Methods section)

	6-7y			7-8y			8-9y		
	TP <sub>t0</sub>	TP <sub>t1</sub>	CP	TP <sub>t0</sub>	TP <sub>t1</sub>	CP	TP <sub>t0</sub>	TP <sub>t1</sub>	CP
	(n=16)	(n=16)	(n=54)	(n=38)	(n=38)	(n=34)	(n=40)	(n=40)	(n=25)
<b>AHI &gt;1</b>	100%	37.5%	100%	100%	44.8%	100%	100%	67.5%	100%
<b>1 <math>\leq</math> AHI &lt;5</b>	62.5%	31.2%	72.2%	73.7%	50%	64.7%	62.5%	67.5%	60%
<b>5 <math>\leq</math> AHI &lt;10</b>	12.5%	6.2%	24.1%	21.1%	0%	29.4%	32.5%	2.5%	28%
<b>AHI <math>\geq</math>10</b>	25%	0%	3.7%	5.3%	0%	5.9%	5%	0%	12%
<b>ODR</b>	56.2%	31.2%	55.6%	37%	21%	55.9%	65%	42.5%	68%

<b>&gt;1.4%</b>									
<b>AI <math>\geq</math>11</b>	12.5%	25%	11.1%	13.2%	21%	20.6%	20%	7.5%	8%
<b>AI<sub>SRRD</sub> &gt;1</b>	18.7%	6.2%	7.4%	5.3%	0%	8.8%	10%	2.5%	12%
<b>AI<sub>PLM</sub> <math>\geq</math>5</b>	75%	81.2%	79.6%	71%	78.9%	70.6%	82.5%	85%	76%

**TP<sub>t0</sub>**: Treated patients' sample, before receiving the orthodontic treatment; **TP<sub>t1</sub>**: Treated patients' sample, after receiving the orthodontic treatment; **CP**: Age-matched control patients' sample.

**Table 6**

Summary of the *p-values* get from the Student T tests comparing the polysomnographic data collected for each age group of the control patients' group (CP). Significant *p-values* are in bold

	<i>p-values</i>	
	'6-7y' vs '7-8y'	'7-8y' vs '8-9y'
<b>AHI</b>	0.77	0.20
<b>ODR (%)</b>	0.85	0.28
<b>AI</b>		
- Total	0.46	0.31
- AI <sub>SRRD</sub>	0.99	0.93
- AI <sub>PLM</sub>	0.52	0.24
<b>Time sleep duration</b>		
- Total (min)	0.86	<b>&lt; 0.05</b>
- REM sleep (%)	0.30	0.63
- Non-REM sleep (%)	0.39	0.16

As it was an inclusion criterion, at the beginning of the study, all children presented an initial pathological AHI ( $\geq 1$ ). The global prevalence of moderate ( $5 \leq \text{AHI} < 10$ ) and severe OSAS ( $\text{AHI} \geq 10$ ) in TP<sub>t0</sub> children were 24% and 8% respectively. About the same proportions were found within the CP group. Following the treatment, regardless of age, only 7 patients (i.e. 7%) did not have a reduction of their initial AHI after the treatment. Among those whom AHI did decreased, 53% had a normalization of their OSAS ( $\text{AHI} < 1$ ), 45% had a residual mild OSAS ( $1 \leq \text{AHI} < 5$ ) and only 2 children had a residual moderate OSAS, even though the AHI remained close to 5 ( $\text{AHI} = 6.1$  in the '6-7y' age group and  $\text{AHI} = 5.7$  in the '7-8y' age group respectively). A greater proportion of TP<sub>t1</sub> patients with an  $\text{AHI} < 1$  was found within the "6-7y" age group (62.5%) versus the "8-9y" age group (32.5%). Besides this significant decrease of the AHI values, their spread also decreased, assessing a normalization of this parameter.

The most significant result of the study was the lower AHI observed in TP<sub>t1</sub> patients compared to their controls, regardless of age.

The ODR decreased after the treatment only until the age of 7 years, but not significantly. Still, this parameter became inferior to the pathological threshold (<1.4 %) for 68% of the TP<sub>t1</sub> sample, compared to 48% and 42% in the TP<sub>t0</sub> and CP samples respectively. No difference was observed across the age groups.

The Arousal Index following a Sleep Respiratory-Related Disorder (AI<sub>SRRD</sub>) significantly decreased after the orthopedic treatment in age groups “6-7y” and “7-8y”. After the age of 8 years old, this evolution was no longer significant. Similar discrepancies have been observed when comparing TP<sub>t1</sub> and CP samples. Moreover, this index remained superior to the pathological threshold (>1) at the end of the treatment for only 2% of the TP<sub>t1</sub> sample. These proportions were greater for the TP<sub>t0</sub> and CP groups, though they were quite low (10% and 9% respectively).

Despite these improvements, the sleep of TP<sub>t1</sub> patients under 8 years of age remained fragmented or worsened following the treatment: while about 13% of TP<sub>t0</sub> patients had a pathological AI ( $\geq 11$ ), this proportion almost doubled after the treatment (22% of the TP<sub>t1</sub> sample). As arousals related to respiratory stress disorders (AI<sub>SRRD</sub>) do significantly decreased after treatment, we may hypothesize that the increase of pathological AI was more due to the sleep study itself as it implies several sensors all over the child’s body, which may impair its sleep quality. Regarding the control group, there was no difference between its proportions and those observed in the ‘6-7y’ age group of the TP<sub>t0</sub> sample, and then doubled like the age-matched TP<sub>t1</sub> groups. For the “8-9y” age group, these proportions of pathological subjects finally decreased, whether they received the orthopedic treatment or not.

A discrepancy was found concerning the Arousal Index associated with a Periodic Limb Movement syndrome ( $AI_{PLM}$ ): this parameter was first smaller in the  $TP_{t1}$  sample compared to  $TP_{t0}$  and CP patients of the age group “6-7y”, then became greater. The only significant difference was found between the  $TP_{t1}$  and CP samples of the age group “6-7y”. The proportions of patients with an index superior to the pathological threshold ( $>5$ ) remained constant in the study sample.

We also observed a significant decrease of the duration of non-REM sleep between  $TP_{t0}$  and  $TP_{t1}$  patients in the age group ‘6-7y’.

Finally, regarding the comparison of each age group of the CP sample, significant differences were only observed for the total time sleep duration which decreased between ‘7-8y’ and ‘8-9y’.

#### **4. Discussion**

Numerous cephalometric studies demonstrated that for most of the OSAS pediatric population, the airway obstruction is related to a craniofacial anomaly: a constricted maxillary dental arch and a retrusive position of the mandible are considered as common characteristics in the pediatric OSAS [8,29]. Oral appliances can be used to correct these transverse or sagittal orofacial deficiencies and relieve respiratory problems, as those observed in the pediatric OSAS. Rapid maxillary expansion and mandibular advancement devices are one of the main dentofacial orthopedic treatment procedures commonly accepted in the current practice, usually carried out separately [30,31].

With the present study, we confirmed that simultaneously expand the palate and advance the mandible with the Ortho2D® device – presented in a previous paper [17] – was associated

with a significant improvement of the respiratory status during sleep. More specifically, at the end of the treatment, the AHI significantly decreased below the severity threshold ( $<5$ ). There was even a complete recovery for 53% of the sample ( $<1$ ), with a greater proportion within the youngest age group (63%).

This residual OSAS for some treated patients was in accordance with previous studies focusing on rapid maxillary expansion or jaw-positioning separately: Villa et al. also observed that 85% and 64% of the AHI fell by at least 20% to 50% [13,14]. According to this definition ( $\Delta\text{AHI TP}_{t1}-\text{TP}_{t0} > 20\%$  or  $>50\%$ ), the Ortho2D® device used in the present study achieved a success rate of 90% and 79% respectively, without significant difference according to the age group.

AHI values of  $\text{TP}_{t0}$  and CP samples were not significantly different, for any age group, suggesting they could be considered as part of the same population. Yet, CP were  $15.7 \pm 7.6$  months (mean  $\pm$ sd) older than  $\text{TP}_{t0}$ . This suggests that AHI did not evolve during growth, when children were not treated. On the contrary,  $\text{TP}_{t1}$  patients exhibited significantly lower AHI values than CP, assessing that the treatment can be considered as a real opportunity to relieve OSAS symptoms.

In comparison with both the untreated groups ( $\text{TP}_{t0}$  and CP), we also observed a significant decrease of the  $\text{AI}_{\text{SRRD}}$ . A large majority of  $\text{TP}_{t1}$  patients exhibited  $\text{AI}_{\text{SRRD}}$  values below their pathological threshold ( $<1$ ).

Thus, this study supported the recent findings demonstrating the efficiency of rapid maxillary expansion and mandibular advancement when applied simultaneously for the management of OSAS children [11,17,32]. The comparison of the treated patients' outcomes with those of age-matched untreated patients allows us to assert the real impact of this therapeutic strategy.

This was also supported by the comparison of each age group of the untreated patients' sample as none significant spontaneous evolution was observed, except for the total time sleep duration which decreased between '7-8y' and '8-9y'. However, this result should be considered with caution as it represents the transversal evolution of the data. Still, during the CHAT trial, Marcus et al. highlighted that 46% of untreated pediatric OSAS patients had a normalization of their OSAS (i.e. AHI <2) after 7 months of watchful waiting [33]. If we consider the same threshold (AHI <2), 74% of the TP<sub>t1</sub> sample had a normalization of their OSAS. Here again, a lesser prevalence was observed in the older age group: 81% of the '6-7y' group, 87% of the '7-8y' group and 70% of the '8-9y' group.

To really assert the therapeutic efficiency of simultaneous rapid maxillary expansion and mandibular advancement for the management of OSAS children, longitudinal study of untreated patients should be performed: to compare the same two sleep studies separated by the same amount of time between treated and control groups. As our study was a retrospective observational one, this would have implied to not treat the control children group, even though OSAS symptoms were identified. It is for these ethical reasons that only pre-treatment data were collected for the not-yet-treated control group.

Anyway, these results also highlighted the benefit of acting at early ages: to reduce the length of intervention ( $9 \pm 3$  months versus 12 months in the study of Villa et al. on rapid maxillary expansion therapy in 4-10 years old patients [14] or 13 to 15.4 months in the study of Wey et al. on mandibular advancement in 10-13 years old patients [34]). We hypothesized that this reduction in treatment period and this improvement of clinical outcomes may be explained by the bone plasticity and maximal growth observed during this period.

Despite these respiratory improvements, one should remark that sleep remained fragmented at the end of treatment. Likewise, AI<sub>PLM</sub> were still omnipresent following the treatment. As

previously suggested, this emphasizes the importance of a multidisciplinary approach in the management of the pediatric OSAS as a complete resolution of the disease can only be achieved if the cause of the airway obstruction is well understood [35]. This may also highlight the importance of a long-term follow-up, as the pediatric OSAS symptoms may not improve as soon as a few months after the end of the treatment. Further studies should be carried out to assure these effects in the long run.

Finally, as noticed by Tauman et al., treated patients spent significantly less time in non-REM sleep after the treatment, whereas no such difference was found in our study [27].

Regarding the stability of the treatment over time and if there was any relapse: most of the patients tolerated the oral appliance well, as the device was worn during the entire treatment period. Despite this good compliance, some children may have expressed discomfort early on, but no pain was reported. Slight dysphonia may have also been observed. This emphasizes the importance of the close collaboration between the orthopedist, the myofunctional rehabilitation specialist, the child and the family.

Still, longitudinal studies should be performed to observe the evolution of the sleep parameters several years after the end of the treatment.

## **5. Conclusions**

This retrospective non-randomized controlled cohort study confirmed the orthopedic impact of the Ortho2D® device on the respiratory status of OSAS children during sleep. Expand the oral space in its three dimensions helped to prevent airflow obstruction by enlarging the upper airways, and by promoting the lingual advancement during the night [11–13]. These present



outcomes highlight the importance of an early management and demonstrated the important role of the orthodontists in the management of pediatric OSAS.

Future studies should focus on the definition of the phenotypes and risk factors to better target responders. We may also consider to perform a case-control study with the comparison of longitudinal data get both for treated and untreated patients to better assess the therapeutic effect of the investigated oral appliance.

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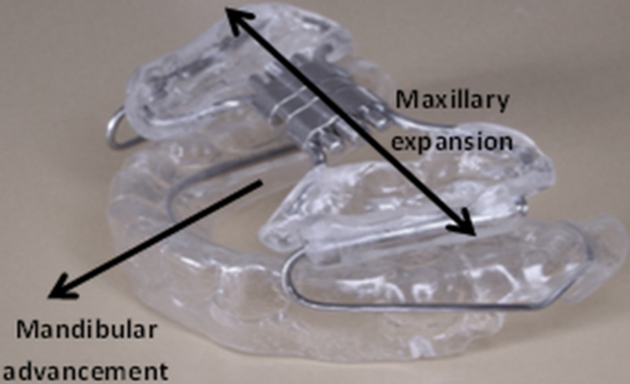
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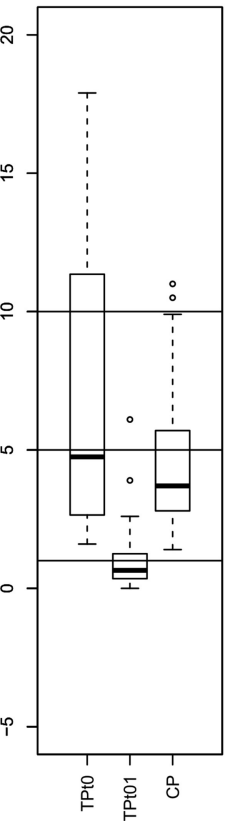
**Figures caption:**

**Fig. 1** Presentation of the custom-made oral device

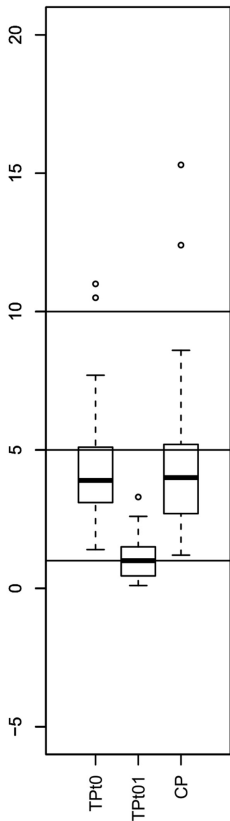
**Fig. 2** Values dispersion of the Apnea/Hypopnea Index collected for each age group within the treated patients' group, before and after the orthodontic treatment ( $TP_{t0}$  and  $TP_{t1}$  respectively), and the control patients' group (CP). The three horizontal lines highlight the pathological thresholds defining the OSAS severity: mild when  $1 \leq AHI < 5$ , moderate when  $5 \leq AHI < 10$ , or severe when  $AHI \geq 10$ .



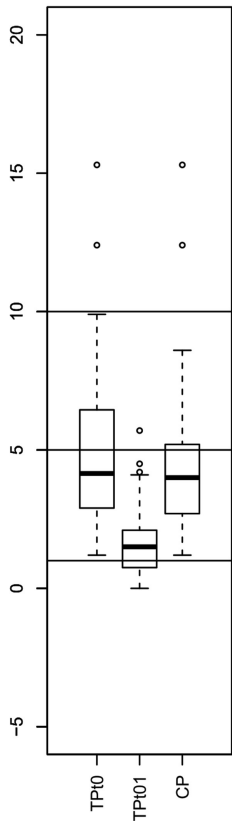
6-7y age group



7-8y age group



8-9y age group



**Highlights:**

- Management of OSAS with simultaneous maxillary expansion and mandibular advancement
- Treated and age-matched untreated patients were compared
- The orthopedic treatment induced a significant decrease of the AHI
- Better results were found within the treated patients' groups
- The improvement of OSAS symptoms was greater when patients were treated earlier