Orthod Fr 2022;93:47-60

https://doi.org/10.1684/orthodfr.2022.86

Original article

Persistent pediatric obstructive sleep apnea treated with skeletally anchored transpalatal distraction

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KEYWORDS:
OSA / TPD / RPE / EASE / RME / MARPE / Sleep apnea / Maxillary expansion / Nasomaxillary expansion

ABSTRACT – Introduction: *The aim of this study was to evaluate the impact of nasomaxillary expansion using skeletally anchored transpalatal distraction (TPD) in children without transverse maxillary deficiency that were previously treated by rapid palatal expansion (RPE).* **Materials and Methods:** *Twenty-nine consecutive children were treated by TPD. Twenty-five children, aged 10-16 years completed pre- and post-operative clinical evaluations, questionnaires (OSA-18), cone beam computed tomography (CBCT), and polysomnography (PSG). The pre- and post-operative CBCT data were used to reconstruct the 3-dimensional shape of the upper airway. Two measures of airflow function (pressure and velocity) were simulated by using computational fluid dynamics (CFD) at four different airway segments (nasal, nasopharyngeal, oropharyngeal and hypopharyngeal).* **Results:** *Twenty-three patients (92%) experienced improvement based on PSG. The apnea hypopnea index (AHI) improved from 6.72±4.34 to 3.59±5.11 ($p<0.001$) events per hour. Clinical symptoms based on OSA-18 scores were improved in all patients. Twenty-five patients (100%) had successful expansion defined as separation of the midpalatal suture at least 1 mm from anterior nasal spine (ANS) to posterior nasal spine (PNS). The nasal sidewall widening was 2.59±1.54 mm at canine, 2.91±1.23 mm at first molar and 2.30±1.29 mm at PNS. The ratio of dental expansion to nasal expansion was 1.12:1 (2.90 mm:2.59 mm) at canine and 1.37:1 (3.98 mm:2.91 mm) at first molar. The nasal airflow pressure reduced by 76% (-275.73 to -67.28 Pa) and the nasal airflow velocity reduced by over 50% (18.60 to 8.56 m/s).* **Conclusions:** *Nasomaxillary expansion by skeletally anchored TPD improves OSA in children without transverse maxillary deficiency that were previously treated by RPE. A nearly parallel anterior-posterior opening of the mid-palatal suture achieves enlargement of the entire nasal passage with improvement of the airflow characteristics in the nasal and pharyngeal airway. The improved airflow characteristic is significantly correlated with the improved polysomnographic findings, thus demonstrating that nasomaxillary expansion in previously expanded patients is a viable treatment option.*

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1. Introduction

Rapid palatal expansion (RPE) is a widely performed orthodontic procedure to treat unilateral or bilateral crossbites due to maxillary constriction. RPE separates the mid-palatal suture and pushes the maxilla's two halves apart, resulting in a wider maxilla and lateral nasal wall, yielding nasomaxillary expansion[35]. It was adapted as a treatment of obstructive sleep apnea (OSA) in children with narrow hard palates (transverse maxillary deficiency) with numerous studies reporting improvement of OSA using RPE as a primary or secondary treatment[6,31,32,36]. A review of 17 maxillary expansion studies found consistent improvement in the apnea hypopnea index (AHI) and lowest oxygen saturation, but with residual OSA after expansion[4].

One major limitation utilizing RPE in treating OSA is the change in occlusion. Expansion in the absence of a skeletal or dental crossbite results in an excessively wide maxilla and uncoordinated dental arches, and in these cases bimaxillary expansion has been utilized with some improvement[32]. However, expansion is discontinued when the maxilla is no longer narrowed, or when dental crowding or the crossbite is corrected, thus limiting the nasal airway expansion. Moreover, the widening of the lateral nasal wall is less than the maxillary widening as there is some lateral displacement of the alveolus from teeth tipping buccally rather than sole separation of the mid-palatal suture[11,12]. Indeed, it has been shown that most of the maxillary widening in RPE is dentoalveolar changes instead of skeletal widening[5,13,20,38], and the pattern of mid-palatal suture opening is inconsistent[25].

Skeletally anchored palatal expansion with miniscrews has been advocated to improve the skeletal effect and reduce the undesirable dental impact in RPE[3,16,34]. This approach is usually advocated in late adolescent or young adult patients when surgery is likely necessary to facilitate successful expansion. Limited case studies report improvement in OSA in young adults[3,16].

Since the early 2000s, we evaluated children with persistent or recurrent OSA previously treated by RPE and adenotonsillectomy[14,15]. Due to the scarcity of treatment options, we attempted further expansion of the maxilla in an effort to gain more space in the nasal cavity to reduce nasal resistance. A skeletally anchored transpalatal distractor (TPD)[28] was used in order to maximize nasal airway expansion while minimizing the dentoalveolar widening in an already expanded maxilla. This study aimed to evaluate the outcome of nasomaxillary expansion using TPD based on polysomnographic data and clinical symptoms. Skeletal, dental and airway changes based on cone beam computed tomography (CBCT) and computational fluid dynamics (CFD) were also analyzed.

2. Materials and Methods

2.1. Subjects

This retrospective study was approved by Institutional Review Board (#15494). Informed consent was obtained from the parents for transpalatal distraction (TPD) treatment as well as discussion for the need for orthodontic treatment post-expansion. Twenty-nine consecutive children (ages 10-16) with persistent OSA who were previously treated by RPE underwent TPD to expand the nasomaxillary complex. All children had the absence of narrow hard palates (transverse maxillary deficiency) or crossbite, had prior adenotonsillectomy or had small tonsil size (grade 1 and 2) where adenotonsillectomy was not warranted. Data evaluated included: clinical records, polysomnography (PSG) records, OSA-18 questionnaire by the caretaker, cone beam computed tomography (CBCT), and computational fluid dynamics (CFD) results.

2.2. Surgical Procedure: transpalatal distraction

The same surgical procedure was applied to all patients and performed by the same surgeon. Due to the extended head position necessary for device placement as well as the decision to take extra precaution in managing pediatric patients during the operation, the procedure was performed under either general anesthesia or intravenous sedation. The distractor (TPD, KLS Martin Group, Jacksonville, FL) was inserted onto the palate at the second premolar/first molar region. Incisions were made at the proposed footplate sites for the TPD. Limited subperiosteal dissection was performed to create a pocket that allowed the footplate to be inserted. A single screw was used to stabilize each footplate, and the TPD was expanded so the footplates fully engaged the palatal bone. All patients were discharged the same day.

2.3. Expansion process

TPD was activated between 3-5 days following surgery at 0.1-0.3 mm per day. The expansion process was deemed completed either when the patient experienced no further clinical improvement with continual expansion, or when the occlusion was altered so that further alteration would result in orthodontic difficulties. The TPD was locked at the completion of the expansion and removed under local anesthesia three months later.

2.4. Polysomnography (PSG)

PSG was performed usually within one year before surgery, and postoperative PSG was performed at most 12 weeks after the TPD was removed. The in-lab study included electroencephalogram, eye movements, chin electromyogram, leg electromyogram. The respiration was monitored with a nasal cannula, a mouth thermistor, thoracic and abdominal uncalibrated inductive plethysmograph bands, a snore microphone, a position sensor and a finger pulse oximeter. PSG scoring was based on the 2012 American Academy of Sleep Medicine (AASM) recommendations[2].

2.5. Questionnaires

OSA-18 questionnaire is a subjective questionnaire of 18 items to evaluate the quality of life (QOL). The questions were divided into six domains: sleep disturbance, physical suffering, emotional distress, daytime problems, care-giver concerns, and total quality of life. OSA-18 is a valid, reliable, and sufficiently discriminative to measure QOL in children with OSA[10]. The questionnaire was administered at the preoperative appointment (1-3 weeks prior to surgery) and between 3-4 months postoperatively just before TPD removal.

2.6. Cone Beam Computed Tomography (CBCT)

The use of CBCT is now widely utilized in routine orthodontic practice and is gradually replacing pre- and post-treatment plane radiograph including panoramic and cephalometric radiographs for documentation purposes. Additionally, CBCT has been utilized to assess treatment outcomes in maxillary expansion in the pediatric population[18,19]. Therefore, all patients underwent CBCT preoperatively and within six weeks postoperatively. CBCT scans were acquired in the supine position in extended field modus (FOV: 16 x 22 cm, scanning time 2 x 20 s, voxel size 0.4 mm, NewTom 3D VGI, Cefla North America, Charlotte, NC). Data from CBCT were exported in Digital Imaging and Communications in Medicine (DICOM) format. Data from CBCT were exported in Digital Imaging and Communications in Medicine (DICOM) format into InVivo5© software (Anatomage, San Jose, CA, USA) and were reoriented with the palatal plane parallel to the floor in the sagittal and coronal planes. The following measurements were recorded by dental radiology technicians blinded to the study: intercanine width, lateral nasal wall width at canine, intermolar width, nasal sidewall width at first molar, lateral nasal wall width at posterior nasal spine (Fig. 1).

2.7. Simulation of Airway Ventilation Conditions with Computational Fluid Dynamics (CFD)

Volume-rendering software (INTAGE Volume Editor, CYBERNET, Tokyo, Japan) was used to generate 3D volume data for the upper airway. Using mesh-morphing software (DEP Mesh Works/Morpher, IDAJ, Kobe, Japan), the 3D models were subsequently converted to a smoothed model without losing the patient-specific airway shape. CFD was used to simulate ventilation of the upper airway models (Fig. 2)[18,19]. The models were exported to fluid dynamics software (PHOENICS, CHAM-Japan, Tokyo, Japan) in stereolithographic format, and the fluid was assumed to be Newtonian, homogeneous, and incompressible. Elliptic-staggered equations and a continuity equation were used in the analysis. The CFD of the upper airway models was analyzed under the following conditions: volumetric flow rate of 7 ml/s/kg no-slip condition at the wall surface, and 300 iterations to calculate mean values. Convergence was judged by monitoring the magnitude of the absolute residual sources of mass and momentum, normalized to their respective inlet fluxes. The iteration was continued until all residuals fell below 0.2%. Simulation of estimated airflow pressure and velocity was performed at the nasal airway, nasopharyngeal airway (NA), oropharyngeal airway (OA), and hypopharyngeal airway (HA).

2.8. Statistical Analysis

Descriptive statistics and frequency distributions were performed on all demographic and clinical characteristics. Summary measures were calculated as means, and standard deviation for continuous

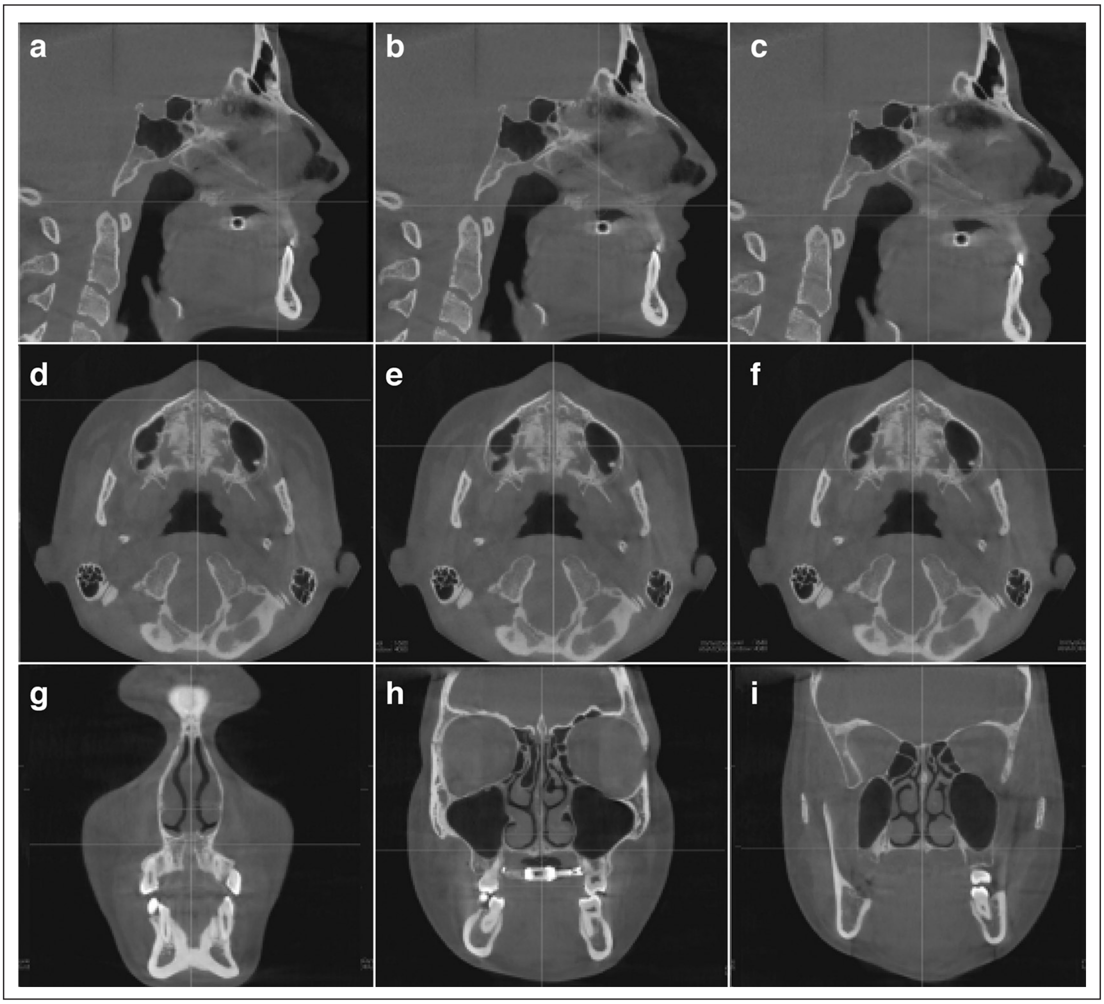

Figure 1
CBCT measurements. (a) Sagittal view at the location of anterior measurement at canine. (b) Sagittal view at the location of measurement at first molar. (c) Sagittal view at the location of posterior measurement at PNS. (d) Axial view at the location of the anterior measurement at canine. (e) Axial view at the location of measurement at the first molar. (f) Axial view at the location of the posterior measurement at posterior nasal spine (PNS). (g) Frontal view of intercanine width and nasal sidewall width measurement. (h) Frontal view of intermolar width and nasal sidewall width measurement. (i) Frontal view of nasal sidewall width measurement at PNS.

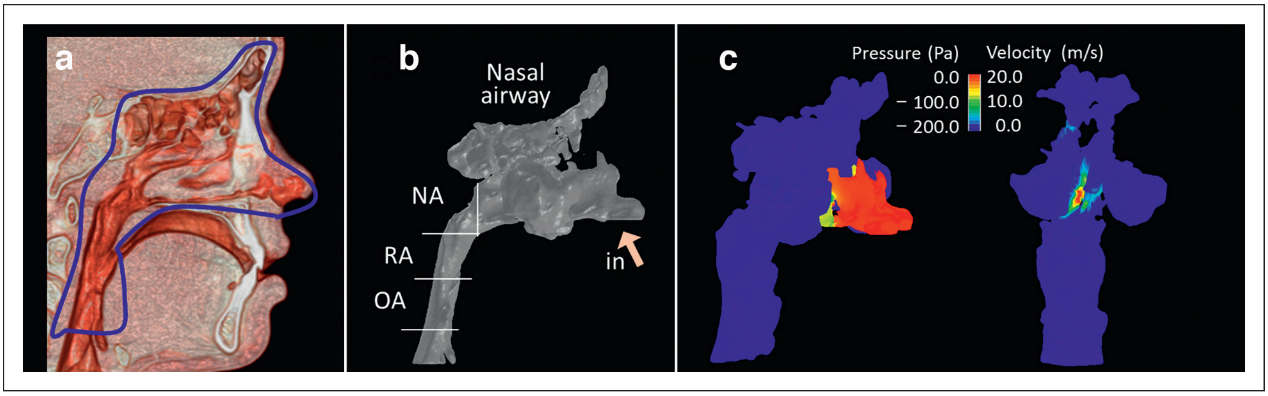

Figure 2
Evaluation of upper airway ventilation using computed fluid dynamics. (a) Extraction of the upper airway. (b) Construction of three-dimensional upper airway model and numeric simulation (inspiration air mass flow: 7 ml/s/kg), at nasopharynx (NA), oropharynx (RA), hypopharynx (OA). (c) Evaluation of the upper airway pressure (left) and velocity (right).

variables or counts and proportions for categorical variables were also calculated. Paired sample Wilcoxon signed-rank test was used to compare preoperative and postoperative parameters due to the small sample size and skewed distribution of some measures. The data was evaluated for extreme or implausible values and a 2-sided P value less than 0.05 was used to indicate statistical significance. All analyses were performed using R Studio version 1.1.383.

Table 1. Respiratory data, symptoms, pressure and velocity changes before and after transpalatal distraction (TPD).

n = 25	Preoperative	Postoperative	Treatment change	p-value*
	Mean ± DS	**Mean ± DS**	**Mean ± DS**	
AGE	13.16 ± 1.46			
BMI	17.51 ± 3.38	17.56 ± 3.38		**0.44**
AHI	6.72 ± 4.34	3.59 ± 5.11		**< 0.001**
OSat	92.72 ± 2.21	93.89 ± 1.20		**< 0.001**
Sleep disturbance	10.12 ± 3.17	5.48 ± 0.92		**< 0.001**
Physical suffering	10.12 ± 4.02	6.40 ± 2.12		**< 0.001**
Emotional Distress	9.36 ± 3.41	6.32 ± 2.42		**< 0.001**
Daytime Problems	13.56 ± 3.57	7.16 ± 2.03		**< 0.001**
Caregiver Concerns	12.80 ± 4.93	8.04 ± 2.88		**< 0.001**
QOL (0-10)	5.32 ± 0.90	7.64 ± 0.76		**< 0.001**
Pressure (Pa)				
HA	-285.542 ± 248.60	-73.472 ± 95.13	212.062 ± 229.01	**< 0.001**
OA	-282.472 ± 249.90	-68.722 ± 95.87	213.742 ± 229.32	**< 0.001**
NA	-281.332 ± 249.26	-67.212 ± 97.61	214.122 ± 227.40	**< 0.001**
Nasal	-275.732 ± 246.42	-67.282 ± 97.75	208.452 ± 224.86	**< 0.001**
Velocity (m/s)				
HA	1.932 ± 1.05	2.252 ± 1.29	0.322 ± 0.88	0.205
OA	1.732 ± 0.69	1.952 ± 1.11	0.222 ± 1.03	0.534
NA	2.032 ± 1.23	1.782 ± 1.08	-0.252 ± 1.67	0.663
Nasal	18.602 ± 8.23	8.562 ± 5.03	-10.042 ± 5.74	**< 0.001**
Nasal Width (mm)				
Canine	20.522 ± 2.00	23.112 ± 2.53	2.592 ± 1.54	< 0.001
First Molar	31.352 ± 3.13	34.252 ± 2.89	2.912 ± 1.23	< 0.001
PNS	20.31 ± 2.61	31.61 ± 3.17	2.30 ± 1.29	**< 0.001**
Dental Width (mm)				
Canine	24.60 ± 1.73	27.37 ± 2.45	2.90 ± 1.63	**< 0.001**
First Molar	38.25 ± 2.24	42.22 ± 2.22	3.98 ± 2.23	**< 0.001**

**p-values determined using Wilcoxon signed-rank test.*

2.9. Polysomnography and OSA-18 Symptoms

Four of the 29 patients were excluded from the analysis due to the lack of post-treatment PSG. Twenty-five patients (16 males) completed pre- and post-treatment polysomnography (PSG) and the OSA-18 questionnaire (Tab. 1). All patients were previously treated by RPE with tooth anchored expanders. Sixteen patients had prior adenotonsillectomy. Nine of the patients that did not undergo adenotonsillectomy were deemed to have small tonsils (grade 1 or 2) that did not warrant surgery. The mean age was 13.16±1.46 years (range 10-16). The AHI improved from 6.72±4.34 to 3.59±5.11 ($p<0.001$) events per hour. The mean AHI reduction was 47% (range 20-79%). The minimum oxygen saturation increased from 92.72±2.21% to 93.89±1.20% ($p<0.05$). The interval between the preoperative PSG to TPD insertion was 9 months (range 2-24 months). Twenty-three of the twenty-five patients (92%) showed improvement based on PSG. In addition to improvement of PSG results, quality of life improvement was evident based on OSA-18 questionnaires (Tab. 1). All patients returned to school and regular activities within three days.

There were no adverse events related to the insertion of the TPD. Over-the-counter analgesics were used for pain control. Two patients had minor transient bleeding from the wound during the first week post-surgery, and the bleeding ceased spontaneously without intervention. During the expansion phase, displacement of the TPD was evident in two patients as one side of the TPD had migrated occlusally. The TPD was adjusted in the office setting under local anesthesia, and expansion continued without complications. All patients had a routine TPD removal in the office under local anesthesia.

2.10. Lateral Nasal wall and Dental width Changes

Nasomaxillary expansion was evident in all patients with separation of the midpalatal suture, nasomaxillary sutures, and the frontonasal sutures (Figs. 3 to 6). All of the patients had near parallel expansion pattern along the length of the nasal floor with sutural separation from ANS to PNS. The nasal sidewall widening was 2.59±1.54 mm at canine, 2.91±1.23 mm at first molar and 2.30±1.29 mm at PNS. The ratio of dental expansion to nasal expansion was 1.12:1 (2.90 mm:2.59 mm) at canine and 1.37:1 (3.98 mm:2.91 mm) at first molar.

2.11. CFD Pressure and Velocity

The mean airflow velocity in the nasal cavity significantly decreased by over 50% from 18.60±8.23 to 8.56±5.03 m/s (Tab. 1, Fig. 7). The airflow velocity did not change significantly in other parts of the pharyngeal airway. The mean negative pressure improved in the nasal airway (from -275.73±246.42 to -67.28±97.75 Pa), nasopharyngeal airway (from -281.33±249.46 to -67.21±97.61 Pa), oropharyngeal airway (from -282.47±249.90 to -68.72±95.87 Pa), and hypopharyngeal airway (from -285.54±248.60 to -73.47±95.13 Pa).

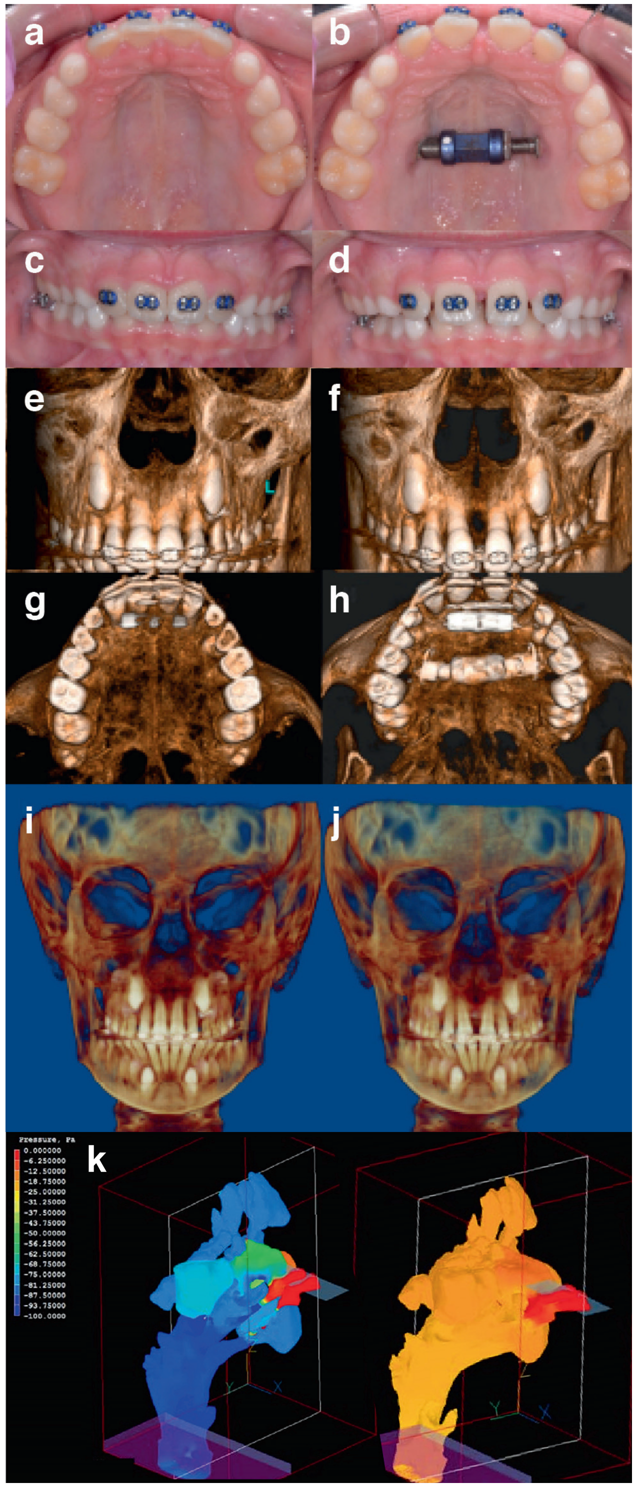

Figure 3

Nine-year-old patient's expansion photos, CBCT and CFD images. (a) Preoperative palatal view. (b) Postoperative palatal view showing the TPD in place at the completion of expansion. (c) Preoperative frontal view. (d) Postoperative frontal view. (e) Preoperative frontal view. (f) Postoperative frontal view at the completion of expansion showing widening at ANS. (g) Preoperative palatal view. (h) Postoperative palatal showing a parallel expansion at the mid-palatal suture from ANS to PNS. (i) Preoperative frontal skull view. (j) Postoperative frontal skull view showing the expanded maxilla. Note the widening between the roots of the central incisors with minimal to no teeth tipping, expanded nasal aperture and modulation of the sutures at the nasofrontal region. (k) Pre- and postoperative CFD demonstrating airway pressure changes.

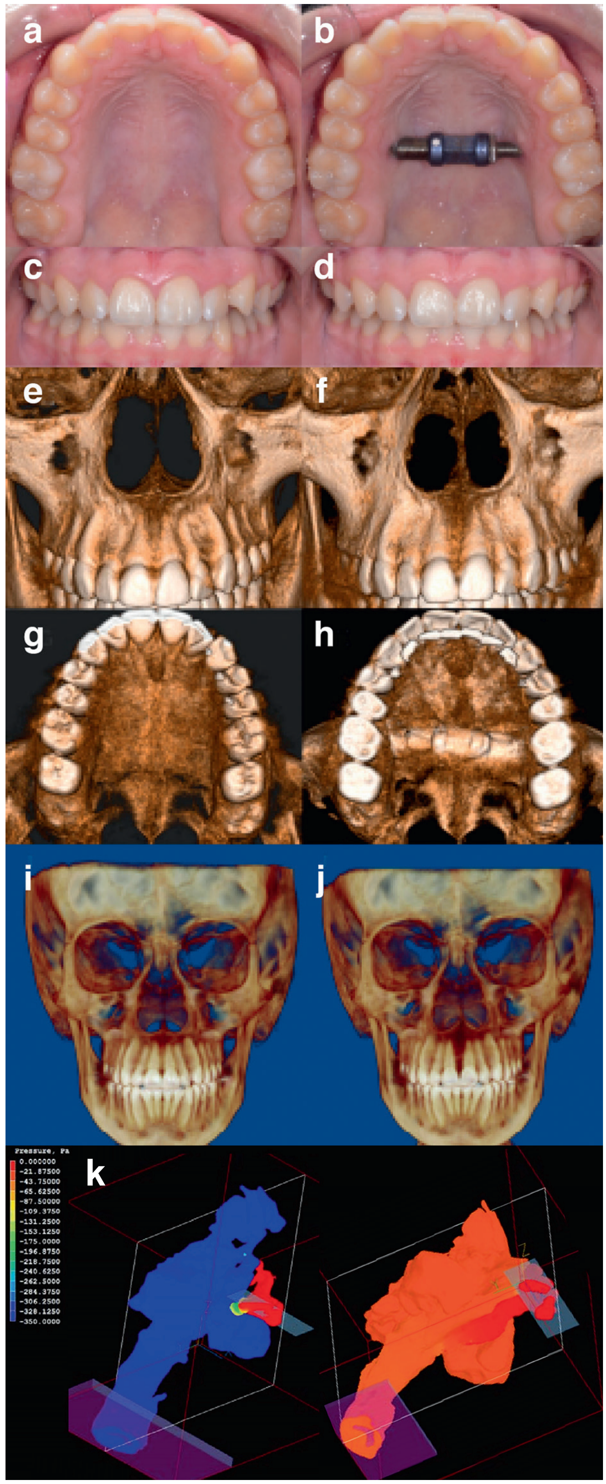

Figure 4

Twelve-year-old patient's expansion photos, CBCT and CFD images. (a) Preoperative palatal view. (b) Postoperative palatal view showing the TPD in place at the completion of expansion. (c) Preoperative frontal view. (d) Postoperative frontal view. (e) Preoperative frontal view. (f) Postoperative frontal view at the completion of expansion showing widening at ANS. (g) Preoperative palatal view. (h) Postoperative palatal showing a parallel expansion at the mid-palatal suture from ANS to PNS. (i) Preoperative frontal skull view. (j) Postoperative frontal skull view showing the expanded maxilla. Note the widening between the roots of the central incisors with minimal to no teeth tipping, expanded nasal aperture and modulation of the sutures at the nasofrontal region. (k) Pre- and postoperative CFD demonstrating airway pressure changes.

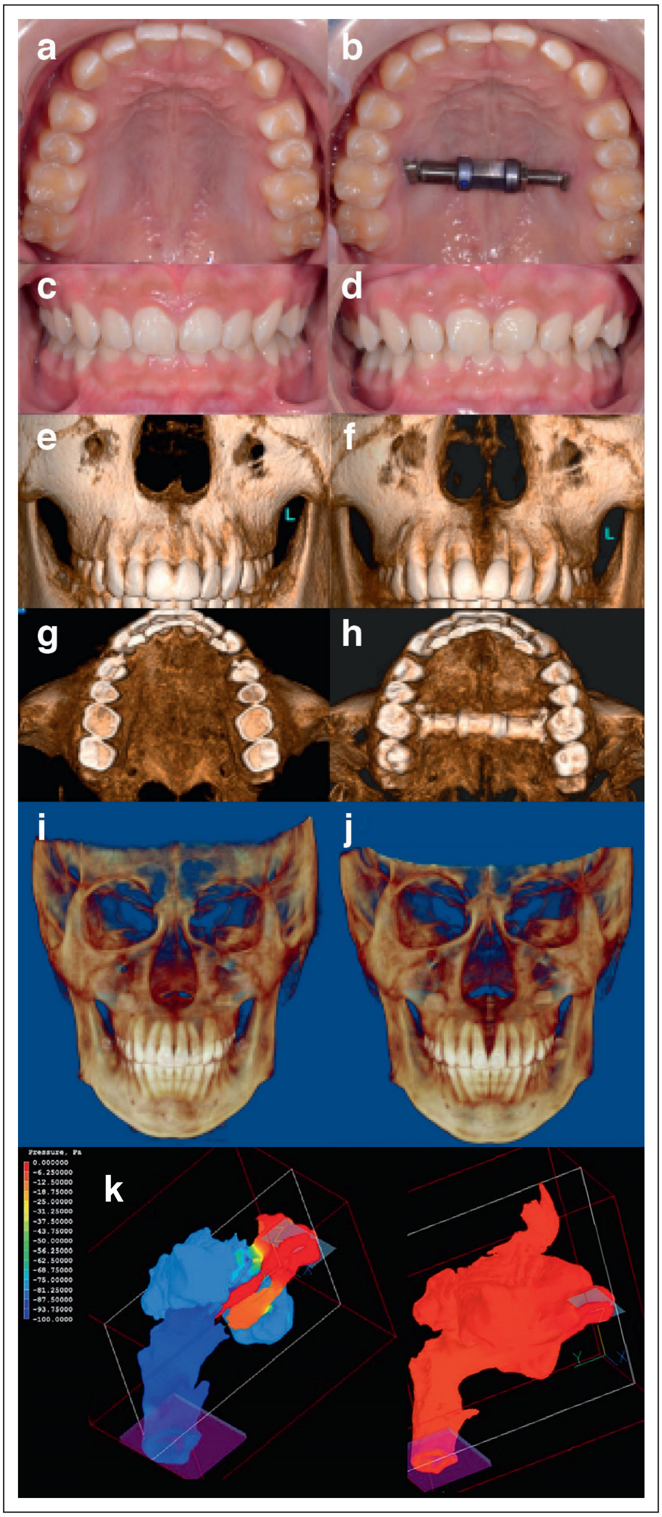

Figure 5

Thirteen-year-old patient's expansion photos, CBCT and CFD images. (a) Preoperative palatal view. (b) Postoperative palatal view showing the TPD in place at the completion of expansion. (c) Preoperative frontal view. (d) Postoperative frontal view. (e) Preoperative frontal view. (f) Postoperative frontal view at the completion of expansion showing widening at ANS. (g) Preoperative palatal view. (h) Postoperative palatal showing a parallel expansion at the mid-palatal suture from ANS to PNS. (i) Preoperative frontal skull view. (j) Postoperative frontal skull view showing the expanded maxilla. Note the widening between the roots of the central incisors with minimal to no teeth tipping, expanded nasal aperture and modulation of the sutures at the nasofrontal region. (k) Pre- and postoperative CFD demonstrating airway pressure changes.

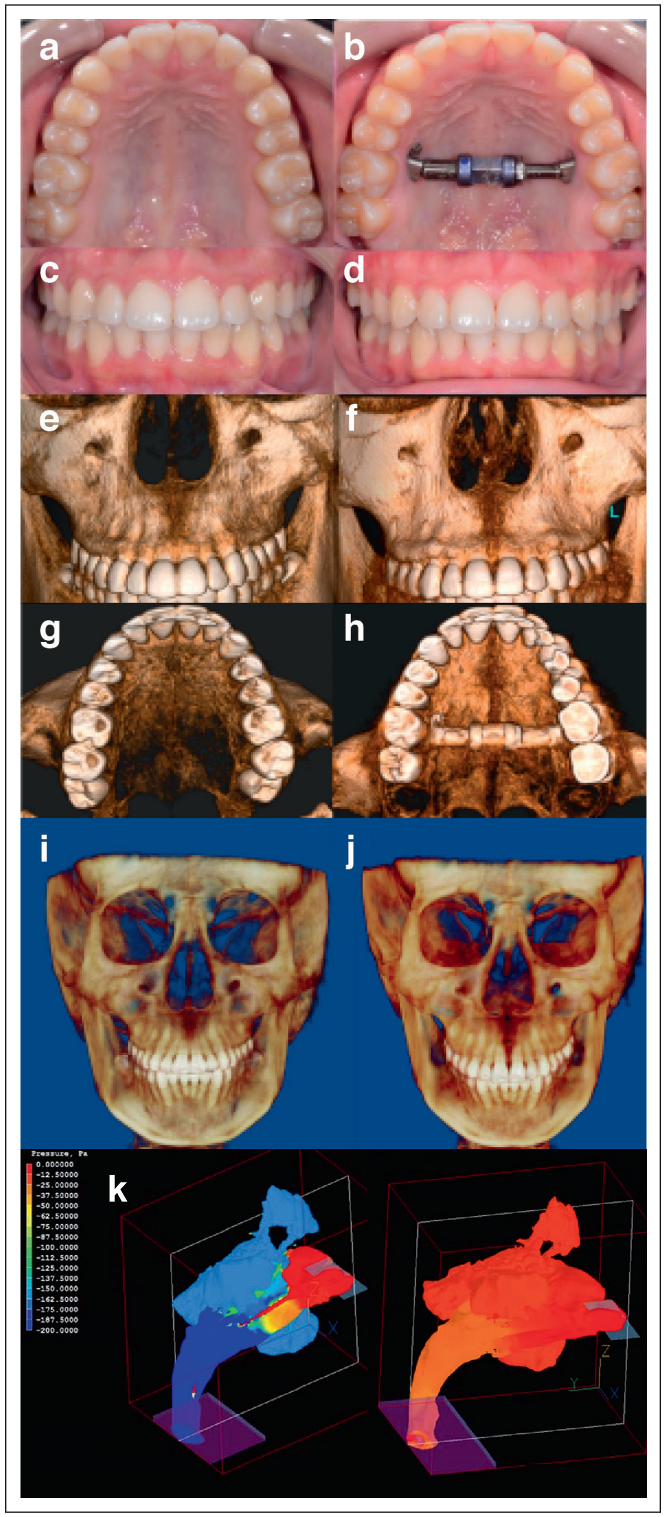

Figure 6

Fifteen-year-old patient's expansion photos, CBCT and CFD images. (a) Preoperative palatal view. (b) Postoperative palatal view showing the TPD in place at the completion of expansion. (c) Preoperative frontal view. (d) Postoperative frontal view. (e) Preoperative frontal view. (f) Postoperative frontal view at the completion of expansion showing widening at ANS. (g) Preoperative palatal view. (h) Postoperative palatal showing a parallel expansion at the mid-palatal suture from ANS to PNS. (i) Preoperative frontal skull view. (j) Postoperative frontal skull view showing the expanded maxilla. Note the widening between the roots of the central incisors with minimal to no teeth tipping, expanded nasal aperture and modulation of the sutures at the nasofrontal region. (k) Pre- and postoperative CFD demonstrating airway pressure changes.

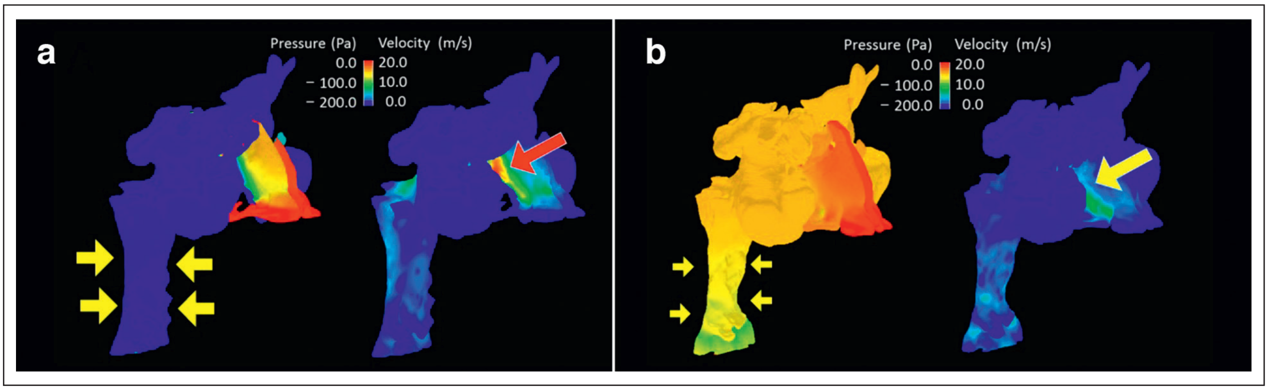

Figure 7

Change in upper airway ventilation modeled during inspiration by TPD. (a) Before TPD. *Right:* Computational fluid dynamics showing high nasal airway velocity (red arrow, more than 20m/s). The high velocity showed airway obstruction. *Left:* Maximal negative pharyngeal airway pressure is very high, resulting in a strong tendency to collapse the pharyngeal airway (large yellow arrow). (b) After TPD. *Right:* Computational fluid dynamics showed that nasal airway velocity is low (yellow arrow, less than 10 m/s). The airway obstruction site was improved. *Left:* The high negative pressure disappeared, resulting in improved airway collapsibility and corresponding reduced AHI values.

3. Discussion

This study highlights the persistence of OSA in a treated pediatric population as it is well recognized that OSA often remains with continual symptoms despite undergoing treatment such as adenotonsillectomy[1,14,15]. The children in this study are challenging to treat because commonly available treatment options such as adenotonsillectomy and RPE have already been utilized. Positive airway pressure therapy has limitations because it can be difficult to tolerate, but more importantly, long-term use can result in midface hypoplasia[22,37] which can potentially exacerbate or perpetuate airway resistance. Maxillofacial jaw advancement surgery is a later stage option that is not appropriate until jaw growth has ceased. Additionally, many families do not want to consider such an invasive procedure. Due to the lack of good remaining treatment options, we elected to treat these children with further maxillary expansion to improve nasal airflow, despite the lack of maxillary narrowing. While watchful waiting has shown an improvement of OSA in some primarily nonobese pediatric cohort (AHI< 5)[26], we are describing a different pediatric group that still present with residual mild OSA after therapies, and significant symptoms that prompted the families to seek further treatment.

Pediatric OSA treatments can be directed to decrease nasal resistance and establish nasal respiration because nasal resistance accounts for 50% of total airway resistance in both children and adults[9]. We elected to treat these patients with further maxillary expansion, despite the lack of maxillary narrowing and no other overt anatomical deficiencies. Orthodontic maxillary expansion has been a commonly employed pediatric treatment by our group to enlarge the upper airway. A clear distinction must be made as to what part of the upper airway is targeted and where the expansion actually occurs. Nasomaxillary expansion for OSA targets nasal cavity expansion. Intraoral dental expansion without nasal widening does not reduce nasal resistance. The ideal expander design would widen the lateral nasal walls to enlarge the nasal airway and the nasal widening would at least equal to, if not to a greater extent than the intraoral dentoalveolus. This is especially important in patients without maxillary constriction or crossbite, such as in patients previously treated with RPE, where the creation of a large diastema with excessive dental widening may lead to periodontal compromise and compromised esthetics and a significant malocclusion.

Airflow modeling based on CFD demonstrated elevated nasal airway velocity and negative pressure that suggest increased nasal resistance despite prior maxillary expansion. Higher nasal airway velocities have been described in cases of nasal blockage[21] as airway obstruction will create higher airflow velocities. Airflow modeling further demonstrated a dynamic change in nasal airway pressure and velocity after TPD expansion. We postulate that the reduction of nasal airway resistance from expansion can render the airway less collapsible to the negative intraluminal pressure on inspiration, leading to reduced OSA severity, and this was reflected in improved negative airway pressure in the oropharyngeal and hypopharyngeal airway.

Numerous expanders are currently used, either skeletally anchored, tooth anchored or hybrid devices. A fundamental difference is emphasized between the types of maxillary expansion and the age at the time of expansion. Tooth anchored expanders are routinely used in RPE in young children for dental crowding and now for OSA. A review of 17 pediatric expansion studies showed that RPE is done at a mean age of 7.6 years for OSA treatment[4]. Enlarging the nasal airway by maxillary expansion becomes more difficult in older children due to maturation of the midpalatal suture where ossification occurs with resultant mineralized bridges[30], causing increased resistance to suture separation[27]. The concomitant dental widening precludes further skeletal expansion as the teeth move at a faster rate than the maxillary skeleton, in a ratio of about 3:1 in older adolescents and 2:1 in younger children during the deciduous or mixed dentition[7]. In patients without maxillary constriction or crossbite, such as in patients previously treated with RPE, the creation of a large diastema with excessive dental widening may lead to periodontal problems, compromised esthetics and a significant malocclusion. Skeletally anchored devices bypass the dentition with less tooth tipping because forces are directly applied on the palatal bone instead of the teeth to induce mid-palatal suture separation. Using TPD expansion yielded more efficient expansion at a ratio of dental to skeletal expansion of 1.37 (1st molar):1, demonstrating a more efficient skeletal nasal cavity expansion.

This study suggests that skeletally anchored TPD achieves a more favorable and predictable widening of the lateral nasal walls throughout the nasal airway. The extent of skeletal expansion compares favorably to other techniques[23,24,29]. It is apparent that forces applied by TPD in the posterior maxilla enable the separation of the entire length of midpalatal suture, even in the posterior region that is most resistant to expansion[8,33], thus enabling greater nasal airway expansion. Compared to RPE, TPD expansion resulted in a greater degree of lateral nasal wall expansion, less tooth movement while yielding a greater reduction in nasal airway pressure (76% vs 46%[17]). Based on the results of this study with the possibility of persistent OSA following maxillary expansion by RPE and the efficiency of airway expansion with TPD, we suggest that skeletally anchored expansion may be considered as a first line expansion method when the goal is nasomaxillary expansion for the treatment of OSA.

Finally, despite further nasal cavity expansion to reduce nasal resistance and improve upper airway collapsibility, OSA was improved in most of the children, but not fully resolved in any of the children. Furthermore, 8% of the children showed no improvement based on PSG. While nightly respiratory disturbances improved, the disorder persisted despite symptomatic improvement. This is the opposite outcome of the CHAT study where there was resolution of OSA but no symptomatic improvement with watchful waiting[26]. The multifactorial nature of the OSA syndrome may account for the residual OSA and the continued search for strategies to not only enlarge the upper airway but to also improve the neurosensory/neuromotor response.

The limitations of this study were the small sample size, and lack of a control group as this is a retrospective study. The retrospective approach limited our ability to obtain posttreatment PSG in four patients, which was due to insurance denial for PSG coverage. This might have been avoided if the study was conducted prospectively. Another limitation is that the study does not characterize changes in nasal cavity volume and nasal transport phenomena that might address nasal airway resistance. Nasal resistance was not measured and was not simulated with CFD. Data showing this relationship would help to validate further the CFD model used to calculate airflow values. However, it should be recognized that although the use of CFD to simulate airway dynamics is commonly used, it is merely a simulation and not a real-time airway study, thus any conclusion solely based on the result of CFD should be cautioned. Future work is needed at defining the optimum parameters of expansion (the amount and the rate) for each patient and analyzing further resistance transport phenomena.

4. Conclusions

This study suggests that skeletally anchored distraction improves OSA in children with persistent or recurrent OSA previously treated by RPE. TPD achieves significant expansion of the nasal airway with a small residual diastema and a limited increase in maxillary dentoalveolar width, which are all important considerations in patients without maxillary constriction. The nasal airway expansion resulted in improved airflow dynamics as modeled by CFD analysis that correlated with improvement of OSA. This underscores the importance of early comprehensive multimodal treatment of pediatric sleep disordered breathing as residual symptoms and abnormal respiratory values persisted after prior therapy, highlighting the crucial role of the orthodontist in treating pediatric OSA.

Links of interest

The authors declare that they have no interest in the data published in this article.

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