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Original Article

Endoscopically-assisted surgical expansion (EASE) for the treatment of obstructive sleep apnea

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A B S T R A C T

Objective: The aim of this retrospective study was to evaluate the results of an outpatient surgical procedure known as endoscopically-assisted surgical expansion (EASE) in expanding the maxilla to treat obstructive sleep apnea (OSA) in adolescent and adults.
Methods: Thirty-three patients (18 males), aged 15–61 years, underwent EASE of the maxilla. All patients completed pre- and post-operative clinical evaluations, polysomnography, questionnaires (Epworth Sleepiness Scale [ESS] and Nasal Obstruction Septoplasty Questionnaire [NOSE]) as well as cone beam computed tomography (CBCT).
Results: With EASE, the overall apnea hypopnea index (AHI) improved from 31.6 ± 11.3 to 10.1 ± 6.3. The oxygen desaturation index (ODI) improved from 11.8 ± 9.6 to 1.8 ± 3.7, with reduction of ESS scores from 13.4 ± 4.0 to 6.7 ± 3.1. Nasal breathing improved as demonstrated by reduction of the NOSE scores from 57.8 ± 12.9 to 15.6 ± 5.7. Expansion of the airway from widening of the nasal floor was consistently evident on all postoperative CBCT; the anterior nasal floor expanded 4.9 ± 1.2 mm, posterior nasal floor expanded 5.6 ± 1.2 mm, and the dental diastema created was 2.3 ± 0.8 mm. Mean operative time was 54.0 ± 6.0 min. All patients with mild to moderate OSA were discharged the same day; patients with severe OSA were observed overnight. All patients returned to school or work and regular activities within three days.
Conclusions: EASE is an outpatient procedure that improves nasal breathing and OSA by widening the nasal floor in adolescents and adults. Compared to current surgical approaches for maxillary expansion, EASE is considerably less invasive and consistently achieves enlargement of the airway with minimal complications.

1. Introduction

Since the first report of maxillary expansion for the treatment of obstructive sleep apnea (OSA) by Cistulli et al., in 1998 [1], its efficacy in expanding the airway and improving OSA has been validated repeatedly [2–5]. However, the majority of studies regarding maxillary expansion to treat OSA have occurred in the pediatric population. This is because maxillary expansion is performed easily in children via use of an orthodontic expander as part of a routine, non-invasive procedure.

As the maxilla matures during puberty, ossification of the midpalatal suture occurs with resultant posterior-to-anterior formation of mineralized bridges [6]. In adults and adolescents, maxillary expansion is more challenging due to skull maturation, which results in increased resistance to suture separation [7]. Therefore, surgically-assisted rapid palatal expansion (SARPE) is typically needed to facilitate widening of the maxilla in non-growing patients [8–10]. However, SARPE is an invasive procedure associated with potential complications, which include significant hemorrhage, excessive lacrimation, loss of bone and teeth, and significant pain and numbness [11,12], as well as aesthetic changes including nasal base widening and lip shortening [13–15]. In addition, SARPE is associated with a prolonged recovery due to residual pain and swelling. Most important, SARPE may not achieve

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the surgical goal of expanding the airway, especially in the posterior nasal aspect (Fig. 1).

In 2004, Guilleminault and Li reported their initial experiences using SARPE to surgically expand the maxilla and using mandibular widening to treat OSA [16]. To reduce the invasiveness, minimize risks and improve outcomes of maxillary expansion, the surgical technique has evolved over the past 15 years. The aim of this retrospective study was to assess the results of using endoscopically-assisted surgical expansion (EASE) as a significantly less invasive approach of maxillary widening surgery for the treatment of OSA.

2. Materials and methods

2.1. Subjects

This study retrospectively reviewed patients (aged 15 or older) who underwent EASE of the maxilla to treat OSA. Data evaluated included clinical and operating room records, polysomnography (PSG) records, Epworth Sleepiness Scale (ESS) questionnaires, Nasal Obstruction Septoplasty Effectiveness (NOSE) questionnaires and cone beam computed tomography (CBCT) results.

2.2. Surgical procedure: endoscopically-assisted surgical expansion (EASE)

The same surgical procedure, specifically EASE, was performed in all patients. Under general anesthesia, a transpalatal distractor (TPD, KLS Martin Group, Jacksonville, FL) was inserted onto the palate at the region of the first molar. The TPD was activated such that the footplates fully engaged the bone, and each footplate was stabilized with a screw. A stab incision in the posterior tuberosity was made, and the pterygomaxillary suture was identified using a periosteal elevator. Gentle pterygomaxillary separation was achieved with a piezoelectric blade (DePuy Synthes, Switzerland). During separation of the pterygomaxillary suture, a finger was placed intraorally to palpate separation of the suture while avoiding injury to the intraoral mucosa. Using a nasal endoscope for visualization, midpalatal osteotomy was performed with a piezoelectric blade. The midpalatal osteotomy was initiated from the posterior nasal spine (PNS) at the junction between the nasal septum and nasal floor with the blade angling towards the midline (Fig. 2). The entire osteotomy was performed with the piezoelectric blade cutting through the nasal mucosa and bone while taking care to avoid injuring palatal mucosa. The osteotomy was carried anteriorly to within 2–3 mm of the anterior nasal spine (ANS). The ANS and bone in between the roots of the central incisors was not disturbed. The midpalatal osteotomy was performed bilaterally to ensure symmetrical separation of the midpalatal suture and expansion of the nasal floor. The TPD was activated for 1.5 mm at the completion of the osteotomy to facilitate separation of the midpalatal suture.

2.3. Expansion process

The TPD was activated between five and seven days after surgery by 0.3 mm per day. The expansion process is deemed complete when either the patient has experienced no further clinical improvement with continual expansion or when there has been 7 mm expansion. Once expansion was completed, the TPD was locked and removed under local anesthesia two months later.

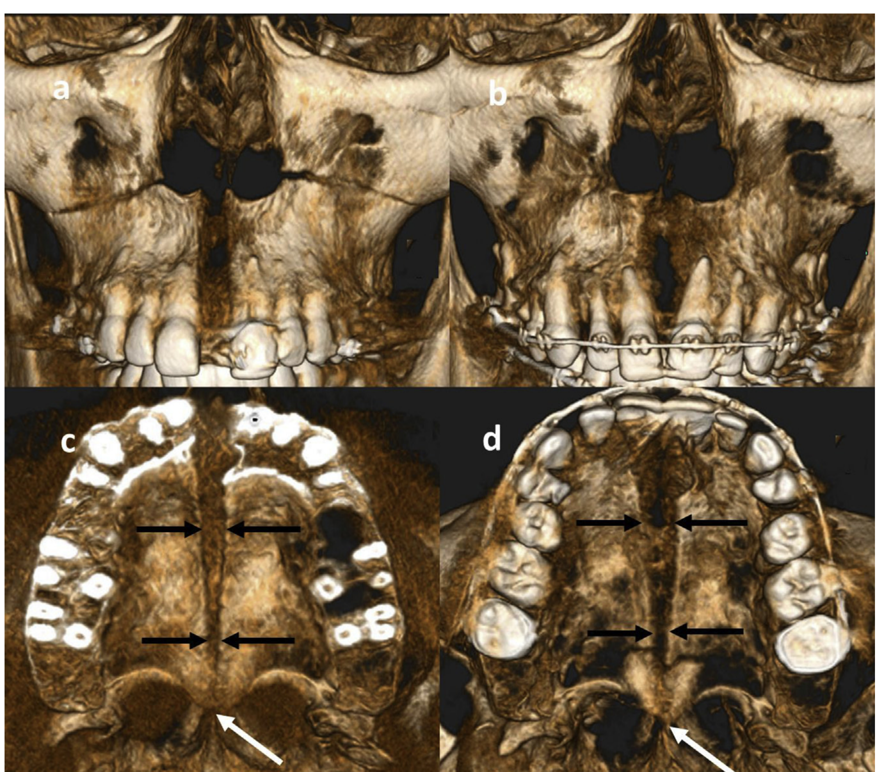

Fig. 1. (a) Frontal view of CBCT demonstrating maxillary widening between the roots of central incisors. (b) Frontal view showing the dental diastema being closed. (c) Palatal view demonstrating that the nasal floor was widened in a tapered fashion (black arrows), but the posterior region remained unchanged (white arrow). (d) Palatal view showing that further expansion led to greater anterior widening (black arrows) but failed to open the posterior nasal airway (white arrow).

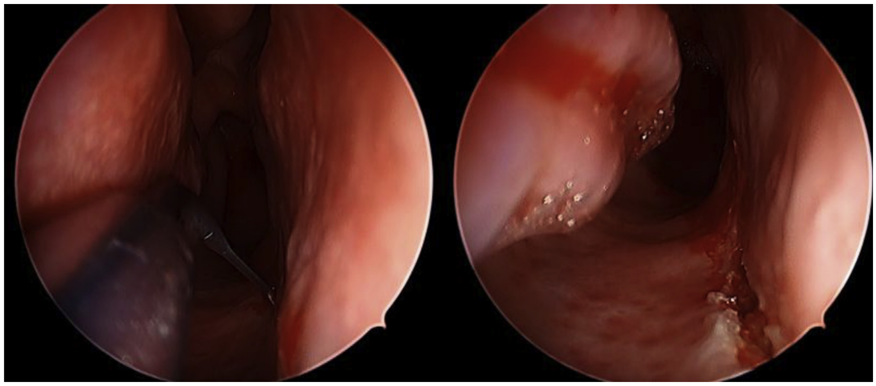

Fig. 2. Right nasal endoscopic view showing the midpalatal osteotomy.

2.4. Polysomnography

PSG was performed within two years before surgery, and post-operative PSG was performed within six weeks after removal of the TPD. In-lab PSG included electroencephalography, electrooculogram and electromyography of chin and leg movements; respirations were monitored with a nasal cannula, mouth thermistor, uncalibrated inductive plethysmography, thoracic and abdominal bands, snore microphone, position sensor and finger pulse oximetry. PSG scoring was based on 2012 American Academy of Sleep Medicine (AASM) recommendations.

2.5. Cone beam computed tomography (CBCT)

All patients underwent CBCT preoperatively and at three months postoperatively. CBCT scans were acquired in the supine position in extended field modus (FOV: 16 × 22 cm, scanning time 2 × 20s, 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. NNT software (QR sri, Verona, Italy) was used to viewing and OnDemand3D Fusion software (OnDemand3D Technology, Tustin, CA) was used for superimposition of pre- and post-treatment images for comparison and measurements. The measurement methods were derived from a previously published study [17].

2.6. Questionnaires

ESS and NOSE questionnaires were administered at preoperative appointments (1–3 weeks prior to surgery) and between three and four months postoperatively just prior to TPD removal.

2.7. Statistical analyses

Descriptive statistics and frequency distributions were performed on demographic and clinical characteristics. Summary measures were computed as means and standard deviations for continuous variables or counts and proportions for categorical variables. The paired samples Wilcoxon signed-rank test was used to compare preoperative and postoperative parameters due to the small sample size and skewed distribution of some measures. Data were evaluated for extreme, implausible, and missing values. All analyses were performed using R Studio version 1.1.383 with a 2-sided p-value less than 0.05 to indicate statistical significance.

3. Results (Table 1)

Thirty-three patients (18 males) were evaluated in this retrospective study. The mean age was 29.4 ± 14.6 years (range 15–61). The AHI improved from 31.6 ± 11.3 to 10.1 ± 6.3, and the overall AHI reduction was 68%. The oxygen desaturation index (ODI) improved from 11.8 ± 9.6 to 1.8 ± 3.7 and the ESS score decreased from 13.4 ± 4.0 to 6.7 ± 3.1. The lowest oxygen saturation increased from 89.4 ± 3.1 to 92.1 ± 2.1. Nasal breathing improved as per the NOSE questionnaire from 57.8 ± 12.9 to 15.6 ± 5.7. The anterior nasal floor expanded 4.9 ± 1.2 mm (measured at ANS), posterior nasal floor expanded 5.6 ± 1.2 mm (measured at PNS), and the dental diastema created was 2.3 ± 0.8 mm (range 1–5) at the completion of expansion (Figs. 3–5).

The mean operative time was 54.0 ± 6.0 min. Body mass index (BMI) increased from 24.7 ± 2.6 to 25.0 ± 2.5. Patients with mild to moderate OSA (19 patients) were discharged the same day, while patients with severe OSA were observed overnight and discharged the following morning. All patients returned to work and regular activities within three days.

Overall, 31 patients (93.9%) experienced improvement and 29 patients (87.9%) noted significant improvement, which was defined

Table 1
Preoperative and postoperative values for demographic and clinical characteristics of all patients (n = 33).

	Preoperative mean ± SD or count (%)	Postoperative mean ± SD or count (%)	p-value[a]
Demographic characteristics			
Age (years)	29.4 ± 14.6	–	–
Male	18 (54.5%)	–	–
Female	15 (45.5%)	–	–
Clinical characteristics			
Body mass index (BMI;kg/m^2)	24.7 ± 2.6	25.0 ± 2.5	0.11
Anterior nasal spine (ANS) Expansion (mm)	–	4.9 ± 1.2	–
Posterior nasal spine (ANS) Expansion (mm)	–	5.6 ± 1.2	–
Dental diastema created (mm)	–	2.3 ± 0.8	–
Procedure time (min)	–	54.0 ± 6.0	–
Oxygen desaturation index (ODI)	11.8 ± 9.6	1.8 ± 3.7	**<0.0001**
Apnea hypopnea.index (AHI)	31.6 ± 11.3	10.1 ± 6.3	**<0.0001**
Minimum oxygen saturation (%)	89.4 ± 3.1	92.1 ± 2.1	**<0.0001**
Epworth sleepiness score (ESS)	13.4 ± 4.0	6.7 ± 3.1	**<0.0001**
Nasal obstruction septoplasty effectiveness (NOSE)	57.8 ± 12.9	15.6 ± 5.7	**<0.0001**

[a] p-values determined using Wilcoxon signed-rank test.

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Fig. 3. (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 showing a 2 mm diastema despite 5 mm of nasal floor expansion (see CBCT showing the 5 mm widening in Figure 3d).

as a >50% reduction in AHI as well as reduction of ESS and NOSE scores. During and post-expansion, two of the patients who were bilevel-dependent noted improved symptoms while on bilevel with decreased AHI values, decreased IPAP and/or EPAP pressures, and reduced air leak (Fig. 6).

However, none of these patients were able to eliminate bilevel use and were thus considered surgical failures. Two other patients experienced improvement in nasal breathing as per improved NOSE scores, but these patients did not experience significant improvement in PSG or ESS scores and were thus also considered surgical failures. Despite insufficient clinical improvement, all four patients achieved successful maxillary expansion on CBCT.

Two patients experienced minor complications. Both patients misunderstood the instructions regarding expansion and had

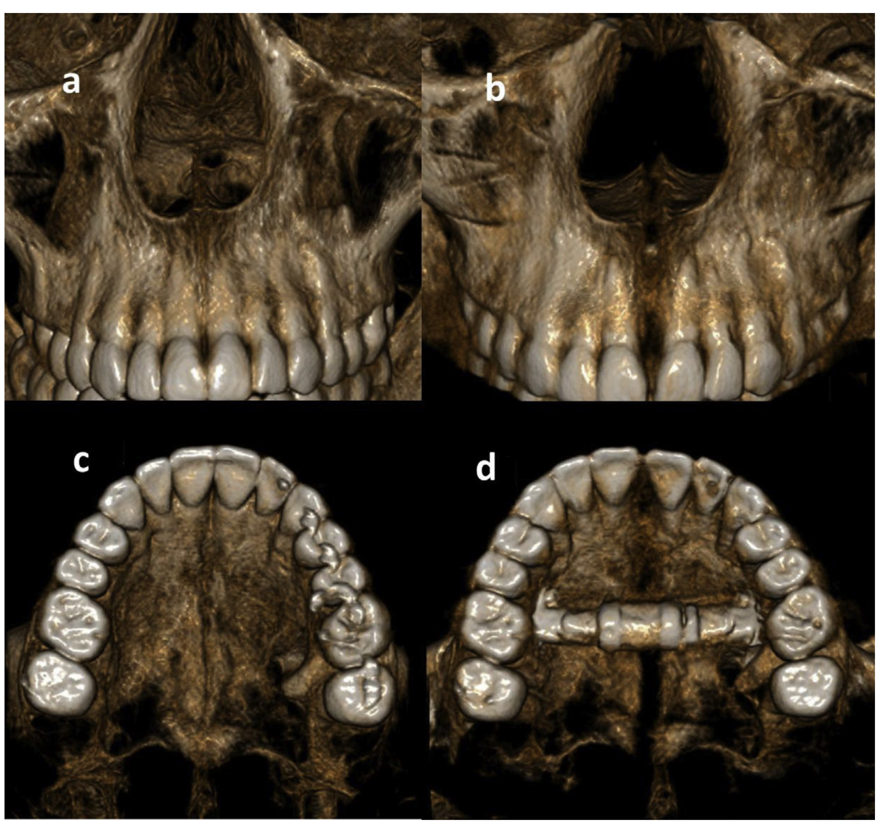

Fig. 4. CBCT of the patient in Fig. 2. (a) Preoperative frontal view. (b) Postoperative frontal view at the completion of expansion showing a 5 mm opening at the ANS. (c) Preoperative palatal view. (d) Postoperative palatal view at the completion of expansion showing a 5 mm opening at the PNS. Note the small dental diastema.

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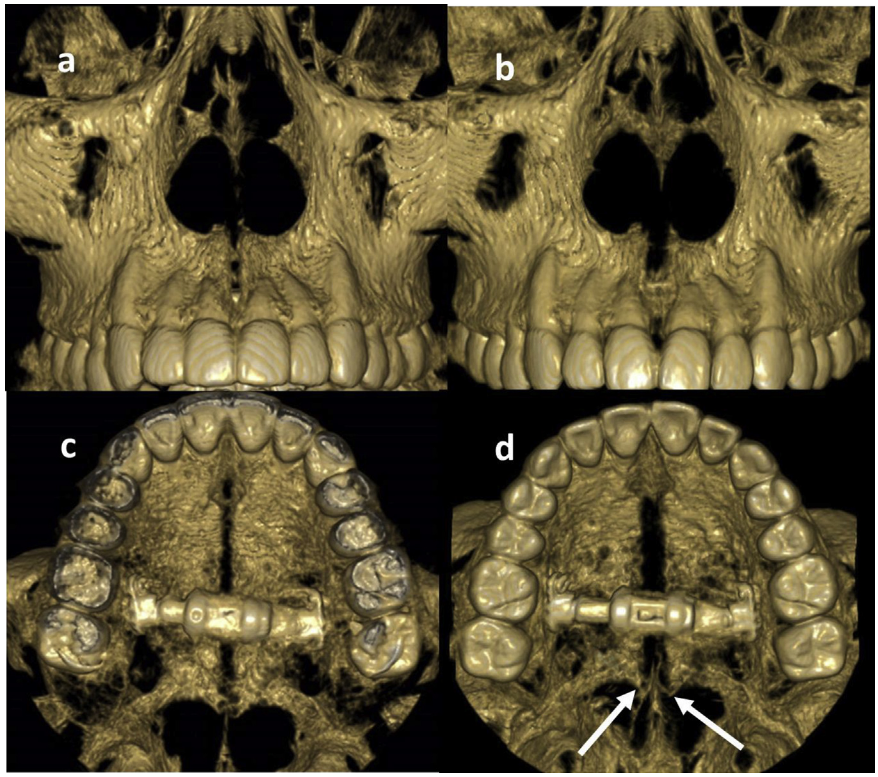
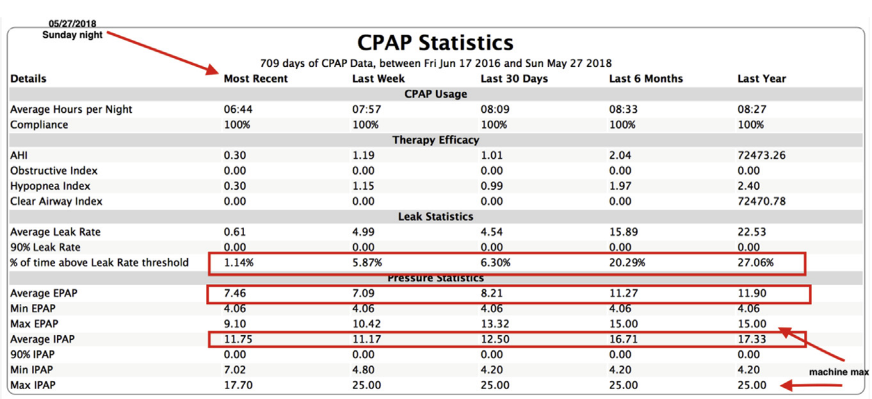


Fig. 5. (a) Frontal view of CBCT of another patient at the initial phase of expansion with opening of the midpalatal suture. (b) Frontal view of CBCT showing continual expansion that resulted in greater opening of the nasal floor (5 mm separation of the ANS). (c) Palatal view of CBCT at the initial phase of expansion. Note the separation of the midpalatal suture. (d) Palatal view of CBCT demonstrating widening of the palate (PNS widened 6 mm). Note the absence of a dental diastema despite significant widening of the nasal floor.

turned the expander in the opposite direction. Both patients required adjustment of the device under local anesthesia in the office setting.

4. Discussion

Maxillary expansion is a dental procedure that was originally designed to widen a narrow maxilla for the treatment of dental deformities. Numerous expanders have been used and include tooth-borne, bone-borne and hybrid (attached to teeth and bone) devices with or without SARPE. Although the objective of maxillary expansion is to expand bone rather than teeth, almost all of these expansion methods cause varying degrees of lateral tilting of the dentoalveolar component due to pressure from the expanders. When applying this maxillary expansion to treat OSA rather than to treat dental deformities, the goal is to expand the nasal floor as much as possible to enlarge the airway since expansion of the dentoalveolar component does not affect the airway at all. With the existing maxillary expansion procedures (excluding EASE), it is necessary to over-expand the dental alveolus to induce secondary widening of the nasal floor. This results in an undesired effect in which the degree of dental widening greatly exceeds the degree of nasal floor widening and results in an unsightly, large diastema and significant malocclusion. Such traditional approaches to maxillary expansion increase the orthodontic treatment time and risks jeopardizing the vitality of teeth [18,19]. It is noteworthy that, the extent of nasal floor widening is inconsistent, inadequate and often nonexistent [20–22], especially in the posterior nasal region. This is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CPAP Statistics

709 days of CPAP Data, between Fri Jun 17 2016 and Sun May 27 2018

Details	Most Recent	Last Week	Last 30 Days	Last 6 Months	Last Year
CPAP Usage					
Average Hours per Night	06:44	07:57	08:09	08:33	08:27
Compliance	100%	100%	100%	100%	100%
Therapy Efficacy					
AHI	0.30	1.19	1.01	2.04	72473.26
Obstructive Index	0.00	0.00	0.00	0.00	0.00
Hypopnea Index	0.30	1.15	0.99	1.97	2.40
Clear Airway Index	0.00	0.00	0.00	0.00	72470.78
Leak Statistics					
Average Leak Rate	0.61	4.99	4.54	15.89	22.53
90% Leak Rate	0.00	0.00	0.00	0.00	0.00
% of time above Leak Rate threshold	1.14%	5.87%	6.30%	20.29%	27.06%
Pressure Statistics					
Average EPAP	7.46	7.09	8.21	11.27	11.90
Min EPAP	4.06	4.06	4.06	4.06	4.06
Max EPAP	9.10	10.42	13.32	15.00	15.00
Average IPAP	11.75	11.17	12.50	16.71	17.33
90% IPAP	0.00	0.00	0.00	0.00	0.00
Min IPAP	7.02	4.80	4.20	4.20	4.20
Max IPAP	17.70	25.00	25.00	25.00	25.00

machine max

Fig. 6. Bilevel readings before and during the expansion process. Note the reduction in IPAP, EPAP, AHI and leak.

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because the posterior region of the maxilla has been shown to be the most resistant to expansion [9,22]. Traditional maxillary expansion procedures thus cause an undesirable fan shape expansion characterized by excessive anterior dental widening and minimal to no posterior nasal airway expansion. Although this expansion pattern may improve nasal breathing, we have found that this expansion pattern does not significantly improve OSA (unpublished data). We postulate that the posterior nasal floor is the most important area to expand when optimizing airway size to treat OSA. Widening of the posterior hard palate not only increases nasal airway volume, but also may expand the retropalatal airway region because several palatopharyngeal muscles originate from the posterior hard palate.

The results of this study demonstrated that EASE is a novel surgical approach that can be used to achieve consistent expansion of the nasal floor throughout the entire nasal region to treat OSA. Notably, in contrast to traditional maxillary expansion procedures [18,23,24], EASE not only achieved the greatest degree of airway expansion in the posterior nasal floor, but also did so with a much smaller resultant anterior diastema. We believe the use of a bone-borne expander applied in posterior maxilla, along with strategic osteotomy at a high-stress region of the skull, enables EASE to apply adequate forces to separate the midpalatal sutures and expand the nasal floor while preventing tilting of the teeth. Strategic separation of the midpalatal suture, including separation of the PNS, and strategic separation of the pterygomaxillary suture are essential in achieving adequate nasal floor separation. Indeed, the importance of pterygomaxillary separation to facilitate posterior maxillary widening was previously reported with the use of TPD and traditional SARPE technique [25]. Clearly, a less invasive surgical approaching in optimizing airway improvement while minimizing dental changes to reduce postoperative risks and orthodontic treatment time are preferred.

The nasal endoscopic surgical approach (EASE) is considerably less invasive compared to other methods because EASE obviates the need for incisions or bone cuts adjacent to the upper lip, gums, sinus walls and teeth. EASE thus prevents any long-term distortion of the nose and/or upper lip that may have otherwise resulted from muscle stripping and trauma that occur in other surgical maxillary expansion procedures. The avoidance of traditional osteotomy near the tooth roots reduces postoperative pain and swelling while preventing injury to the teeth and bone. The use of piezoelectric blade simultaneously cauterizes the nasal mucosal, thus reducing the risk of bleeding. EASE also enables patients to use PAP therapy for airway protection immediately following surgery. With other methods of maxillary expansion that include incisions and osteotomies at the anterior maxilla and sinus walls, PAP therapy cannot be used immediately postoperatively due to the risk of subcutaneous emphysema.

The majority of the patients in this study experienced improvement in nasal breathing and OSA symptoms within the first week of expansion. Of note, two of the patients who were bilevel-compliant prior to surgery continued bilevel therapy immediately after surgery. The bilevel pressure had to be reduced shortly after initiation of the expansion. This is noteworthy and suggests that even a slight widening of the entire nasal airway had a significant impact on airway patency.

Many factors influence a patient's decision to have surgery to treat his or her OSA. The invasiveness of the operation, extent of improvement, recovery time and time off from work are major considerations. The minimally-invasive nature, low complication rate and short operative duration characteristic of EASE allowed patients to be discharged the same day and return to school or work within a few days. Such benefits of EASE do not exist with other known maxillary expansion surgical techniques.

5. Conclusions

The results of this study demonstrate that OSA and nasal breathing can be improved via EASE of the nasal floor in adolescents and adults. As a novel and minimally-invasive maxillary widening surgical procedure, EASE allows patients to return quickly to their daily activities and has numerous additional advantages compared to that of other surgical widening methods.

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This study was not funded.

Conflicts of interest

The authors had no conflicts of interest to declare in relation to this article.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2018.09.008.

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