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Impact of Distraction Osteogenesis Maxillary Expansion on the Internal Nasal Valve in Obstructive Sleep Apnea

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Abstract

Objective. To assess the effect of distraction osteogenesis maxillary expansion (DOME) on objective parameters of the internal nasal valve and correlate findings with subjective outcomes.

Study Design. Retrospective cohort study.

Setting. Tertiary referral center.

Subjects and Methods. After Institutional Review Board approval, included subjects were those with obstructive sleep apnea, had undergone DOME from September 2014 to April 2018, and had cone beam computed tomography scans available before and after expansion. Measurement of the internal nasal valve parameters was performed with Invivo6 Software (version 6.0.3). Interrater reliability of all pre- and postexpansion parameters was measured. Patient-reported outcome measures included the Nasal Obstruction and Septoplasty Effectiveness Scale (NOSE) and Epworth Sleepiness Scale scores, and correlation between objective and subjective outcomes were evaluated by Spearman correlation analysis.

Results. Thirty-two subjects met inclusion criteria. All showed significant improvement in their subjective outcomes as well as an increase in their internal valve parameters. Significant correlation was observed between increased angles and improvement in postexpansion NOSE score (right angle, $P = .024$; left angle, $P = .029$).

Conclusion. DOME widens the internal nasal valve objectively (dimensions), which correlates significantly with subjective improvement (NOSE scores).

Keywords

obstructive sleep apnea, nasal obstruction, high arched palate, maxillary expansion, distraction osteogenesis, internal nasal valve, rapid palatal expander, snoring

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Nasal obstruction is highly prevalent with functional, structural, and pathologic etiology.[1] The narrowest portion of the nasal airway is the internal nasal valve (INV), which is also associated with the maximum resistance.[2,3] The INV was first described by Mink in 1920 referring to it as ''valva,'' meaning ''half of a double folding door.'' The anatomic landmarks include (1) the caudal edge of the upper lateral cartilage laterally, (2) the nasal septum medially, (3) the nasal bony floor inferiorly, and (4) the anterior head of the inferior turbinate posteriorly. The INV angle is measured between the septum and upper lateral cartilage and is approximately 10° to 15°.[4]

The degree of collapsibility of the lateral wall depends on the intrinsic stability of the valve and on the transmural pressure changes during normal and forceful inspiration. As flow increases through a fixed space or volume, pressure in that fixed space decreases. Partial collapse of the upper lateral cartilage normally occurs at a respiratory flow rate of 30 L/min, preventing further increases in intranasal pressure from increasing flow.[5] Small changes in nasal valve size result in large changes in airflow resistance, which in turn affects nasal function[6]; however, some studies showed poor correlation between acoustic rhinometry (AcR)[6] and endoscopic angle measures, as well as between AcR and subjective symptoms.[7]

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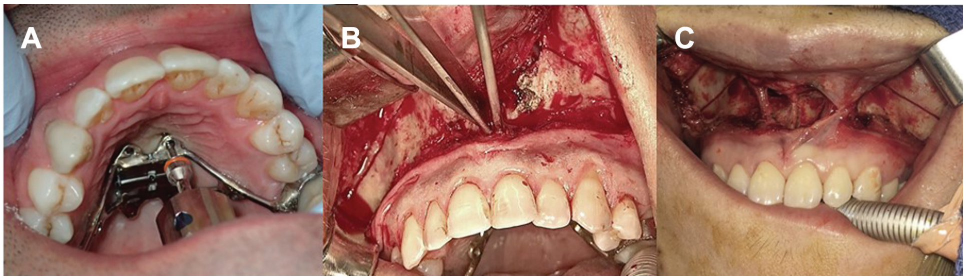

Figure 1. (A) Installation of maxillary expander. (B) LeFort 1 maxillary osteotomy and midpalatal split without pterygomaxillary dysjunction. (C) After DOME osteotomies. DOME, distraction osteogenesis maxillary expansion.

Figure 2. (A) Pre-DOME occlusal view of maxilla. (B) Post-DOME occlusal view of maxilla, with a 10-mm diastema presented between upper central incisors after DOME expansion. (C) Postorthodontic treatment occlusal view of maxilla. Diastema is all closed, but palatal width is maintained after orthodontic treatment. DOME, distraction osteogenesis maxillary expansion.

Computed tomography (CT) was introduced to measure the INV and to correlate with airflow resistance on cadaver specimens, with results showing good correlation with radiologic measurements obtained perpendicular to the acoustic valve rather than traditional coronal cuts.[8] Clinical studies have shown more modifications and details of the most appropriate method for radiologic assessment of the INV and angle.[9,10] These refinements have led to improved accuracy, consistency, and clinical relevance in INV assessment.[9,10]

Distraction osteogenesis maxillary expansion (DOME) was developed at Stanford University to expand the nasal floor and alter the morphology of the hard palate of patients with obstructive sleep apnea (OSA).[11] DOME has been shown to significantly reduce subjective nasal obstructive symptoms. Since DOME effectively increases the width of the nasal floor, it may increase the INV. The aim of this study is to measure the change in INV angle and surface area (SA) before and after DOME and to correlate the change with subjective Nasal Obstruction and Septoplasty Effectiveness Scale (NOSE) and Epworth Sleepiness Scale (ESS) scores.

Methods

The study was approved by the Stanford University Institutional Review Board (no. 36385), with a waiver of a written informed consent since the study is retrospective in nature. Subjects with OSA undergoing DOME from September 2014 to April 2018 with cone beam CT available before and after expansion were included in the study. Inclusion criteria included (1) intolerance of the CPAP (continuous positive airway pressure), (2) no hypertrophy of the either lingual or palatine tonsils, (3) Mallampati class 4 or 3, and (4) narrow palatal arch (0.8-3 cm). Exclusion criteria included (1) subjects <18 years old, (2) diagnosis of dentofacial deformity, (3) diagnosis of malocclusion, and (4) missing ESS or NOSE scores. All subjects underwent DOME by a single surgeon (senior author) in a university hospital setting.

DOME involves the interaction of the orthodontist and the patient with the sleep surgeon.[11,12] The procedure includes the following steps: (1) With the patient under local anesthesia, the orthodontist applies the maxillary expander with fixation by 4 to 6 screws to the midpalate and maxillary bone (**Figure 1A**); (2) then, with the patient under general anesthesia, the surgeon performs a LeFort 1 maxillary osteotomy via 2 lateral mucosal incisions, after which a vertical mucosal incision is made between central incisors to wedge open the midpalate suture by a straight osteotome (**Figure 1B and C**). A gap between the incisors (diastema) is immediately observed upon a successfully opened suture. The expander is then turned on to evaluate its effectiveness. (3) This step is performed by the patient, wherein he or she is asked to turn on the expander daily (0.25-mm expansion per turn) to reach a total of nearly 8 to 10 mm by the end of a 5-week expansion period. (4) Realignment of the teeth by orthodontic treatment starts 1 month after the DOME procedure. All patients were advised a soft diet in the first 2 days postoperative (**Figure 2**).

Measurement of the internal valve angle was performed based on the DICOM files obtained from the orthodontist (A.Y.) using the software Invivo 6 v6.0.3 (Anatomage, San Jose, California). Measurement of the INV is based on

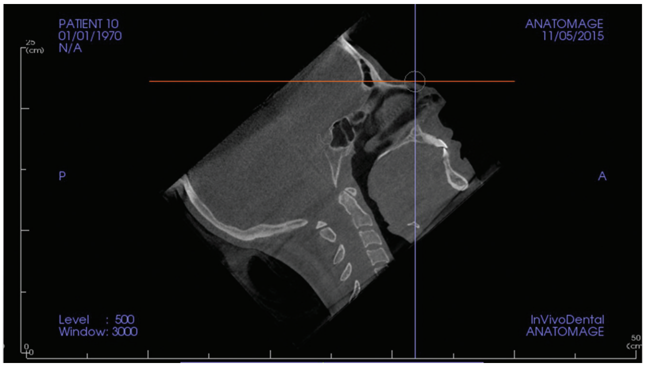

Figure 3. A sagittal view shows a reformatted axial plane that was made parallel to the outer bony nasal dorsum. Then a modified coronal plane perpendicular to the new axial plane was chosen to be 1 slice anterior to the head of the inferior turbinate.

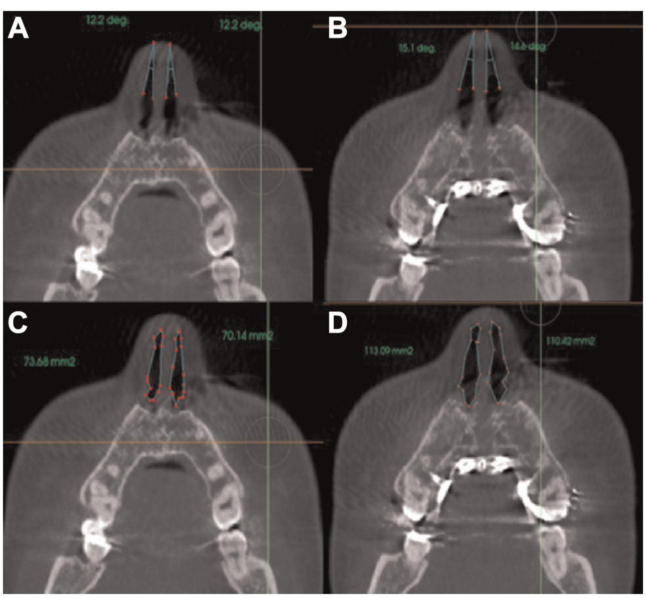

Figure 4. An example of the modified coronal plane shows angle and surface area of the internal nasal valve. The difference in (A, B) angle and (C, D) surface area before and after DOME. DOME, distraction osteogenesis maxillary expansion.

previously published setting and parameters, where a modified coronal plane perpendicular to the expected acoustic axis was used.[10,12] On the sagittal view, a reformatted axial plane was oriented parallel to the outer bony nasal dorsum. Then a modified coronal plane perpendicular to the new axial plane was chosen to be 1 slice anterior to the head of the inferior turbinate (**Figure 3**). For patients with asymmetric appearance of the turbinate's head, coronal cuts were assessed separately for each side.

After the CT slice used to measure the INV was obtained, the angle was measured along the medial and lateral nasal airway lumen margins. Contour irregularities were averaged starting at the lateral margin just above the head of the inferior turbinate. The apex of both margins was extended to the anterior/superior soft tissue outline. The SA was obtained by measuring the margins of the airway lumen (**Figure 4**). Interrater reliability was performed with a second surgeon blinded to the subjects.

Table 1. Demographic Data.

	n (%) or Mean ± SD
Sex	
Female	25 (78.13)
Male	7 (21.87)
Age, y	
Female	42.92 ± 33.01
Male	33.77 ± 15.91
Preoperative INV Angle	
Right	12.09 ± 3.86
Left	11.77 ± 3.99
Preoperative ESS scores	10.30 ± 5.44
Preoperative NOSE scores	10.87 ± 4.70
Preoperative AHI	23.26 ± 20.86

Abbreviations: AHI, apnea-hypopnea index; ESS, Epworth Sleepiness Scale; INV, internal nasal valve; NOSE, Nasal Obstruction and Septoplasty Effectiveness Scale.

Statistical Analysis

Data analysis was performed with SPSS for Windows (version 21; IBM, Chicago, Illinois). Continuous variables were expressed as mean ± SD. Categorical variables were expressed numbers and percentages. Normal distribution of variables was confirmed with the Shapiro-Wilks test.

ESS and NOSE scores and INV angles and SA were normally distributed. The paired sample *t* test was used to assess parameters before and after expansion. Interrater reliability of the right and left INV angles and SA was measured by intraclass correlation coefficient, Cronbach's alpha, and Spearman correlation analysis. Correlations between (1) subjective measures (postexpansion ESS and NOSE scores) and (2) objective measures (INV angles and SAs) were assessed utilizing Spearman correlation analysis. Data for age were not normally distributed and so were expressed as median (range). For all statistical analysis, results were considered significant at $P < .05$.

Results

Out of 75 patients undergoing DOME, 32 met inclusion criteria. Twenty-five men and 7 women were included, with a mean age of 32 years (range, 19-46 years; **Table 1**). The mean preoperative apnea-hypopnea index was 23.26 ± 20.86, while postoperative apnea-hypopnea index was 7.54 ± 5.30 as performed for 15 of 32 subjects (47%). No complaint of pain or malocclusions were noted. Minor asymmetric maxillary expansion occurred in 5 subjects and was correctable by orthodontic treatment. Four patients experienced paresthesia in the anterior maxilla (V2 distribution), which did not exceed 6 months. One patient had lost incisor viability, which was treated by endodontic therapy.

Table 2. Comparison of ESS and NOSE Scores before and after Expansion.

	Before	After	*t* Value	*P* Value
ESS (n = 32)	10.30 ± 5.44	6.53 ± 5.17[a]	5.630	<.001
Nose (n = 32)	10.87 ± 4.70	3.27 ± 2.03[a]	10.156	<.001

Abbreviations: ESS, Epworth Sleepiness Scale; NOSE, Nasal Obstruction and Septoplasty Effectiveness Scale.
[a]Indicates statistical significance.

Table 3. Comparison of Right and Left INV Angles and SAs before and after Expansion.

INV	Before	After	*t* Value	*P* Value
Angle				
Right (n = 32)	12.09 ± 3.86	13.60 ± 2.66[a]	–3.017	.005
Left (n = 32)	11.77 ± 3.99	15.36 ± 3.18[a]	–4.647	<.001
SA				
Right (n = 32)	101.22 ± 25.74	125.13 ± 29.22[a]	–4.886	<.001
Left (n = 32)	96.66 ± 29.67	128.60 ± 37.39[a]	–6.064	<.001

Abbreviations: INV, internal nasal valve; SA, surface area.
[a]Indicates statistical significance.

Table 4. Correlation between Postexpansion NOSE Score and Changes in INV Angle and SA.

	NOSE Score (n = 32)	
INV Change	Spearman Correlation Coefficient	*P* Value
Angle		
Right (n = 32)	–0.412[a]	.024
Left (n = 32)	–0.389[a]	.029
SA		
Right (n = 32)	0.012	.950
Left (n = 32)	–0.166	.380

Abbreviations: INV, internal nasal valve; NOSE, Nasal Obstruction and Septoplasty Effectiveness Scale; SA, surface area.
[a]Indicates statistical significance.

Interrater reliability was either good or excellent for all pre- and postoperative parameters. Spearman correlation coefficients for preoperative measures of the nasal valve angles were 0.886 (P = .019) and 0.923 (P = .009) for the right and left angles, respectively; for the SAs, they were 0.886 (P = .019) for both sides. For postoperative/expansion measures, the Spearman correlation coefficients were 0.995 (P = .001) and 0.966 (P = .002) for right and left angles, respectively; for the SAs and diastema, they were 0.982, 0.957, and 0.993 (P = .001, .003, and .007, respectively).

Significant reduction in patient-reported outcome measures (ESS and NOSE) was observed ($P < .001$; **Table 2**). All measurement parameters showed a significant increase postexpansion (**Table 3**). Correlation between postexpansion NOSE and ESS scores was also statistically significant (P = .0019).

Table 5. Correlation between Postexpansion ESS Score and Changes in INV Angle and SA.

	ESS Score (n = 32)	
INV Change	Spearman Correlation Coefficient	*P* Value
Angle		
Right (n = 32)	–0.132	.485
Left (n = 32)	–0.202	.285
SA		
Right (n = 32)	0.179	.344
Left (n = 32)	–0.150	.429

Abbreviations: ESS, Epworth Sleepiness Scale; INV, internal nasal valve; SA, surface area.

Significant correlation was observed between the postexpansion NOSE score and the increase in postexpansion right and left INV angles (P = .024 and .029, respectively). No significant correlation was observed between NOSE score and SA (**Table 4**). ESS did not reach statistical significance with INV angle or SA (**Table 5**).

Discussion

The high arched palate/narrow maxilla phenotype present with nasal obstruction along with OSA. Physiologically, these patients are at high risk of developing OSA due to high nasal resistance and posterior tongue displacement. Historically, managing a narrow maxilla was described primarily for patients with dentofacial deformities and often involved invasive osteotomies, including pterygoid fracture or multipiece LeFort.[13] The DOME procedure was developed to expand the maxilla at the nasal floor to improve nasal breathing and allow forward position of the tongue. It is characterized by a single LeFort osteotomy and an anterior midpalatal suture separation assisted by a bone-anchored distraction device.[10]

Misevaluating the INV impairment can result in missed causes of nasal obstruction for rhinologists, sleep surgeons, and facial plastic surgeons. Thus, it is mandatory to carefully evaluate this critical area on the basis of objective findings and patients' symptoms. This is crucial for patients with a high arched palate.

This study evaluates the efficacy of DOME in improving subjective and objective outcomes of a specific phenotype with OSA. We hypothesized that since DOME effectively increases the nasal floor, subjective symptomatic response may be correlated to the increase in INV angle. We found that the increase in INV significantly correlates and improves NOSE and ESS scores.

We report mean NOSE scores for all subjects. All subjects in this cohort complained of some degree of nasal obstruction. Some had already been treated with septoplasty (5 of 32, 15.63%). All others were offered septoplasty and inferior turbinate outfracture with or without valve repair.

However, in the setting of narrow maxilla and nasal obstruction, DOME was offered as first-line treatment, but the eventual procedure was based on patient choice.

Accuracy of CT for objective assessment of the internal nasal angle was first introduced in 1983 in relation to AcR. Studies have shown correlation between an increase in the internal valve area and patients' satisfaction after surgery.[14-17] Traditional CT cuts were obtained perpendicular to the hard palate (nasal floor) and were supported by studies performing AcR and radiologic imaging (CT or magnetic resonance imaging).[18-22] However, correlation with a plane perpendicular to the expected acoustic wave showed better correlation with outcomes of AcR.[9-12] At the level of the INV, the acoustic wave arc is parallel to the bony nasal dorsum in the reformatted sagittal plane that leads to the modified coronal plane.[9,10,12]

Strengths of the study includes the use of patient-reported outcome measures to correlate with objective measurements of the nasal airway. Limitations include the retrospective nature of the study, a single-institute experience, and the small number of cases. Another consideration was the objective measurements of the nasal valve, which had a lot of debate; however, we followed the latest consistent methodology of measuring the valve used in the literature[9,10,12] and performed interrater reliability with different interrater methods (intraclass correlation coefficient, Cronbach's alpha, and Spearman correlation analysis) to ensure consistency of measures. Further studies should include a larger series as well as evaluation of aesthetic outcomes, however, patients in this study had no postexpansion cosmetic complaints. We also plan to follow our patients for a longer time to ensure persistence of the outcomes after expansion. The objective assessment of the INV is another potential issue that can be subjected to inconsistency among investigators; however, we followed the most acceptable methods published in literature[9,10,12] that showed good to excellent interrater reliability. Controlling the vector of expansion can also be a challenge for some patients, which may require further attention.

To conclude, we report a cohort of patients with OSA, persistent nasal obstruction, and high-arched palate. In this cohort, DOME was effective in improving ESS and NOSE scores. The improvement is correlated with widening of the INV angle and valve SA. Future studies should focus on further phenotyping of patients with OSA and the importance of both high-arched palate and narrow INV.

Author Contributions

Mohamed Abdelwahab, study design, drafting manuscript, data collection and analysis, final approval, agreement to be accountable for all aspects of the work; **Audrey Yoon**, study design, drafting manuscript, revision, supervision and data analysis and statistical analysis, orthodontic work, follow-up, final approval, agreement to be accountable for all aspects of the work; **Tyler Okland**, drafting, study design, data collection, manuscript revision, final approval, agreement to be accountable for all aspects of the work; **Sasikarn Poomkonsarn**, study design, drafting manuscript and data collection, final approval, agreement to be accountable for all aspects of the work; **Chris Gouveia**, data collection, study design, and manuscript revision, final approval, agreement to be accountable for all aspects of the work; **Stanley Yung-Chuan Liu**, concept initiator, study design, drafting manuscript, revision and supervision, surgeon, follow-up, final approval, agreement to be accountable for all aspects of the work.

Disclosures

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