Influence of septal deviation side on preoperative eustachian tube dysfunction and the effectiveness of septoplasty in alleviating eustachian tube dysfunction

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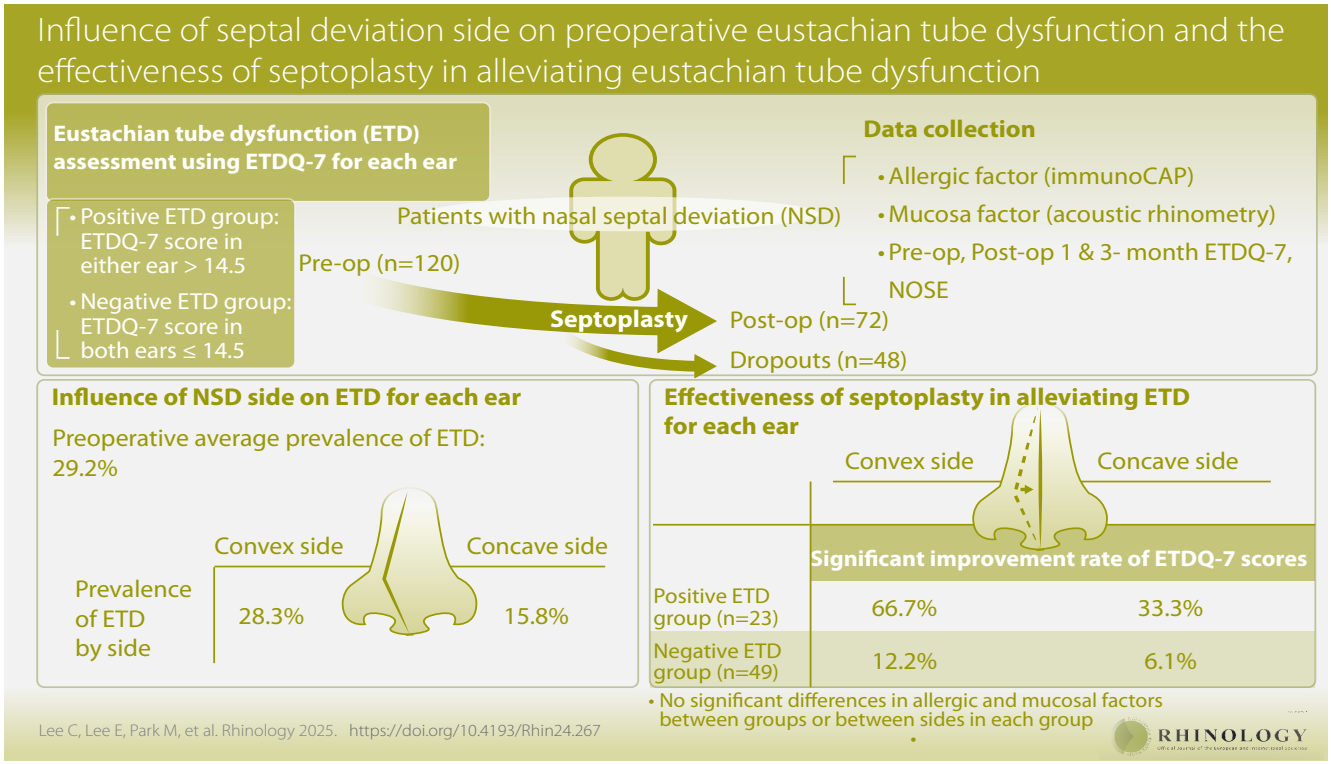

Abstract

Background: The Eustachian Tube Dysfunction Questionnaire 7 (ETDQ-7) serves as a valuable tool for assessing eustachian tube dysfunction (ETD). We investigated the impact of septal deviation side on ETD using preoperative ETDQ-7 scores and evaluated the effectiveness of septoplasty based on postoperative ETDQ-7 scores. **Methodology**: We conducted a retrospective analysis of patients with septal deviation who were scheduled for septoplasty. ETDQ-7 surveys were conducted preoperative and 1 and 3 months postoperative. **Results**: 120 patients were included, with 72 completing the ETDQ-7 at all three time points. The average prevalence of ETD was 29.2%. Preoperative ETDQ-7 scores showed no significant difference between convex and concave nasal sides. However, the prevalence of ETD was significantly higher on the convex side (28.3% vs. 15.8%), especially in unilateral ETD cases. Preoperatively, the positive ETD group had significantly higher ETDQ-7 scores on the convex side while no significant difference was found between concave and convex sides in the negative ETD group. Postoperatively, the positive ETD group showed significant improvement in ETDQ-7 scores with significantly higher on the convex side (66.7% vs. 33.3%). ETDQ-7 scores improved after septoplasty, with more improvement in the positive ETD group. **Conclusions**: Septoplasty significantly improves ETD, particularly in the preoperative positive ETD group, by reducing ETDQ-7 scores. The prevalence of ETD was higher on the convex side preoperatively, and the positive ETD group exhibited significant postoperative improvements, especially on the convex side. This suggests that the direction of septal deviation influences ETD prevalence and surgery outcomes, although septoplasty alleviates ETD on both sides.

Key words: nasal cavity, nasal obstruction, nasal septum, quality of life, demography

Introduction

Eustachian tube dysfunction (ETD) is a multifaceted and prevalent condition that significantly impacts the middle ear's ventilation and pressure regulation, leading to ear fullness and autophony. The ETD Questionnaire (ETDQ-7), a 7-item questionnaire related to symptoms, is widely used for the assessment of ETD [1]. As the Eustachian tube connects the middle ear and nasal cavity, ETD is closely associated with nasal diseases such as chronic rhinosinusitis (CRS) and nasal septal deviation (NSD). Some studies have demonstrated that nasal surgery can improve symptoms of ETD [2-4].

A deviated nasal septum is a structural issue that can lead to nasal obstruction due to narrowing of the nasal passage. Septoplasty is a surgical procedure that has proven an effective treatment for correcting deviated septum. Several studies have explored the relationship between septoplasty and ETD. Recently, Lima et al. conducted a prospective study on septal deviation and ETD, revealing that severe septal deviation can lead to ETD [5]. The negative pressure resulting from narrowing in the nasal cavity can lead to middle ear effusion and worsen Eustachian tube patency. There have also been reports suggesting that the presence of rhinitis, which is associated with mucosal factors such as mucosal swelling, is related to the occurrence of ETD symptoms [6,7]. However, few studies have investigated the frequency of ETD based on the direction of septal deviation, and ETD has primarily been analyzed using only tympanometry, which assesses objective middle ear function.

Thus, in this retrospective study, we aimed to determine the relationship between the direction of septal deviation and the occurrence of ETD symptoms, as well as to examine the impact of septoplasty on ETD, with a particular focus on the direction of septal deviation. Additionally, we conducted blood tests including total IgE, blood eosinophils, and serum specific IgE to screen for allergic rhinitis and used acoustic rhinometry to assess mucosal factors, aiming to verify the pathophysiology by which septal deviation induces ETD symptoms. ETD was evaluated using the ETDQ-7, a validated tool for assessing subjective symptoms related to ETD.

Materials and methods

Patient selection

Adult patients who underwent septoplasty for septal deviation were recruited from February 2021 to October 2021 at Samsung Medical Center in Seoul, Korea. Surgery was performed by four skilled rhinology surgeons (G.H. Rhyu, S.D. Hong, Y.G. Jung, H.Y. Kim). All septoplasties included turbinoplasty. Inclusion criteria were age older than 18 years old and consent to undergo septoplasty. The exclusion criteria included abnormal tympanic membrane findings observed during ear endoscopic examination (such as effusion, myringitis, or perforation) that could contribute to ear symptoms. Additionally, patients who had undergone revision septoplasty or had a history of radiotherapy in the head and neck region were excluded from the study.

Data collection

Questionnaires including Eustachian Tube Dysfunction Questionnaire (ETDQ-7) and Nasal Obstruction Subjective Questionnaire (NOSE) were collected for all recruited patients preoperative and 1 and 3 months postoperative. The ETDQ-7 questionnaire was administered individually for each ear. After administering the ETDQ-7 questionnaire for both ears, patients were categorized into the positive ETD group (ETD (+)) if the score exceeded 14.5 in either ear. If the score was 14.5 or lower in both ears, they were classified into the negative ETD group (ETD (-)).

Septal deviation was used to categorize each nostril into one of two shape types: convex (narrower side) and concave (wider side). The type of septal deviation was defined based on caudal septal deviation, which is the most critical contributor to nasal obstruction symptoms. And the physician determined it via endoscopic exam.

Allergic factors including total IgE, blood eosinophils, serum specific-IgE (ImmunoCAP test, Phadia) were confirmed by blood tests before surgery [8]. We classified patients as allergic rhinitis positive if, through chart review, they exhibited clinical symptoms consistent with ARIA (Allergic Rhinitis and its Impact on Asthma) guidelines (nasal discharge, sneezing, nasal itching, and obstruction) and had clinically relevant allergens identified via ImmunoCAP testing [9,10].

Acoustic rhinometry is performed preoperatively to assess the mucosal factor. The mucosal factor, synonymous with the congestion factor, is defined as the change in cross-sectional area (CSA) on acoustic rhinometry between baseline and after decongestion, divided by baseline CSA [11]. The normal range for the mucosal factor is below 0.5 [12]. A higher mucosal factor indicates a greater than normal amount of reversible congestion volume.

Questionnaires

In this study, we utilized two questionnaires: ETDQ-7 and NOSE. All questionnaires were administered once preoperatively and again at 1 month and 3 months postoperative.

The ETDQ-7, a seven-item questionnaire with a total score ranging from 7 to 49. This validated tool is used to evaluate symptom severity and ETD. A total ETDQ-7 score exceeding 14.5 was indicative of clinically significant ETD [1]. For directional analysis, ETDQ-7 assessments were conducted separately for each ear in each participant. As the minimum clinically important difference (MCID) for ETDQ-7 is 3.5 [13], a decrease in ETDQ-7 score by more than 3.5 points after surgery indicated an improvement in the patient's symptoms related to ETD.

The NOSE scale is composed of five domains: congestion, obstruction, difficulty breathing, sleep, and exercise. These domains were developed to assess the subjective symptoms

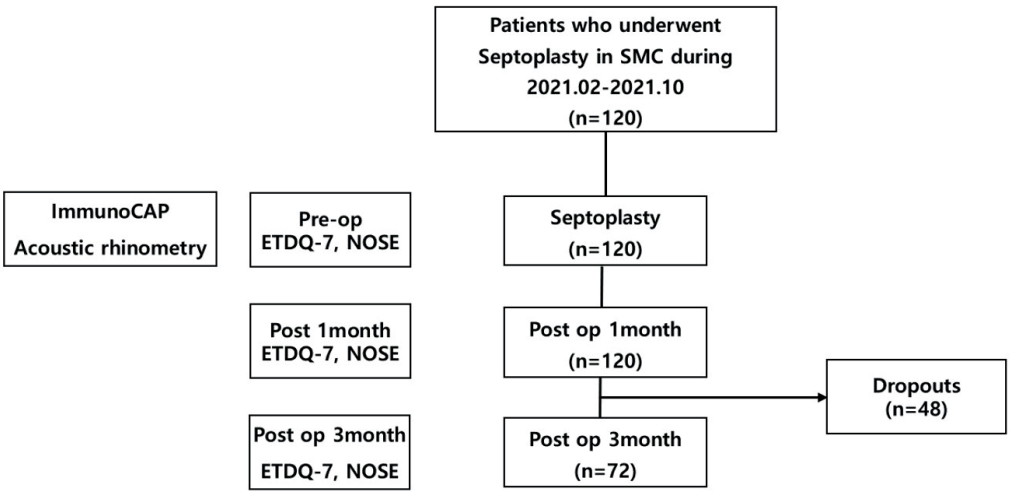

Figure 1. Flow chart of study enrollment.

of patients experiencing nasal obstruction [14]. Scores for each domain range from 0 to 4, and after being summed, they are multiplied by 5 to obtain a total score out of 100 points.

Statistical analysis

All statistical analyses were conducted using SPSS Statistics Software v.21 (SPSS Inc, IBM, NY, USA). Numerical variables such as ETDQ-7, NOSE, mucosal factor, and total IgE were compared with a 2-tailed t-test, while categorical variables were compared using the χ^2 test. The paired t-test was used to compare pre- and postoperative outcomes. In ETDQ-7, a change of over 3.5 after surgery was considered to indicate improvement or aggravation of ETD symptoms, as this value represented the minimum clinically important difference (MCID). A significance level of $p < 0.05$ was employed to indicate statistical significance.

Results

A total of 120 patients who underwent septoplasty for nasal obstruction were enrolled in this study. Before surgery, all patients completed the ETDQ-7 and NOSE, and underwent acoustic rhinometry and ImmunoCAP testing. Among them, there were 48 dropouts by the postoperative 3-month time point (loss to follow-up, no questionnaire) (Figure 1). Therefore, 120 patients were included in the analysis of preoperative data, and 72 patients were included in the analysis of postoperative data.

For preoperative analysis, the average age was 41.2 ± 17.1 years, and 80 (66.7%) were male. In this study, as ETDQ-7 was conducted for both ears, if one ear had a score higher than 14.5 in ETDQ-7, the patient was considered to have ETD (the positive ETD group). Among 120 patients, 35 had ETD (18 bilateral ETD, 17 unilateral ETD), indicating that the prevalence of ETD in septoplasty patients was 29.2%. The preoperative prevalence of ETD in patients with NSD was 29.2%. This figure was significantly higher than the 4.6% prevalence reported for American adults. Previous studies have also suggested that patients with NSD had a higher ETD prevalence compared to the normal population, with figures ranging from 31.6% to 44% on tympanometry [16,17].

On preoperative directional analysis, there was no significant difference in ETDQ-7 scores between the narrower side (convex) and the wider side (concave) (12.2 ± 7.2 vs. 10.7 ± 6.7, $p > 0.05$). When comparing the prevalence of ETD by side, a chi-square test revealed a significantly higher prevalence on the narrower side (28.3% vs. 15.8%, $p < 0.05$). This trend was more pronounced in unilateral ETD (13.3% vs. 0.8%, $p < 0.001$). Preoperative data were summarized in Table 1.

For further analysis, we divided the patients into two groups: those with ETD (positive) and those without ETD (negative) based on the ETDQ-7 score, using a cutoff value of 14.5. If the ETDQ-7 score exceeded 14.5 in either ear, patients were classified into the positive ETD group (ETD (positive)). If the score was 14.5 or lower in both ears, they were classified into the negative ETD group (ETD (negative)).

In preoperative data analysis, the positive ETD group (n = 35) showed a significantly higher ETDQ-7 score on the convex side compared to the concave side (21.6 ± 3.7 vs. 17.0 ± 9.4, $p = 0.02$). However, there was no significant difference in ETDQ-7 scores between sides in the negative ETD group (n = 85). After excluding the 38 cases with missing data due to the absence of acoustic rhinometry, allergic factors did not differ between the two groups, and mucosal factors also showed no significant variation both between the two groups and between the sides within each group (Table 2).

In postoperative analysis, a total of 72 patients were analyzed, excluding the 48 dropouts. There were 49 negative ETD patients and 23 positive ETD patients. The paired t-test revealed no significant change in ETDQ-7 scores after septoplasty in the negative ETD group. However, the positive ETD group exhibited a significant improvement in ETDQ-7 scores following septo-

Table 1. Baseline characteristics of patients undergoing septoplasty (N=120).

Variables	Septoplasty (N=120)		p-value
Age, years	41.2±17.1		
Male, n (%)	80 (66.7%)		
	Convex (narrower side)	Concave (wider side)	
Pre-op ETDQ-7	12.2±7.2	10.7±6.7	>0.05
Pre-op ETD (+), n (%)	34 (28.3%)	19 (15.8%)	<0.05
Unilateral ETD (+), n (%)	16 (13.3%)	1 (0.8%)	<0.001
Bilateral ETD (+), n (%)	18 (15%)		
Total ETD (+), n (%)	35 (29.2%)		

ETD (+): the positive eustachian tube dysfunction group, ETD (-): the negative eustachian tube dysfunction group.

Table 2. Preoperative data according to Eustachian tube dysfunction and direction of septal deviation.

Variables	ETD(-) (n=85)		p-value	ETD(+) (n=35)		p-value
Age, years	43.5±17.4			39.7±15.1		>0.05
Male, n (%)	57 (67.1%)			23 (65.7%)		>0.05
Pre-op NOSE	12.2±5.3			11.1±6.6		>0.05
	Convex	Concave		Convex	Concave	
Pre-op ETDQ-7	8.3±2.0	8.03±1.8	>0.05	21.6±3.7	17.0±9.4	0.02
Allergy (+)	25 (29.4%)			14 (40%)		>0.05
Mucosal factor	0.63±0.60	0.52±0.51	>0.05	0.65±0.54	0.51±0.46	>0.05
Mucosal factor >0.5, n (%)	26/57 (45.6%)	23/57 (40.3%)	>0.05	12/25 (31.6%)	9/25 (28.1%)	>0.05
Mucosal factor average >0.5, n (%)	25/57 (43.9%)			12/25 (48%)		>0.05

The analysis was performed after excluding the 38 cases with missing data due to the lack of acoustic rhinometry.

plasty. In directional analysis, although the positive ETD group had higher ETDQ-7 scores preoperatively, there was no significant difference in ETDQ-7 scores between sides after septoplasty (1 month and 3 months after surgery). There was a higher proportion of clinically significant improvement (exceeding the MCID) in ETDQ-7 scores after septoplasty in the positive ETD group. Moreover, the convex side exhibited a higher clinically significant improvement rate after surgery in the positive ETD group compared to the concave side (66.7% vs. 33.3%, $p < 0.01$) (Table 3).

There was no significant difference in preoperative ETDQ-7 scores between the positive ETD group and the negative ETD group. In postoperative analysis, all questionnaires showed significant improvement after surgery (paired t-test). The ETDQ-7 scores at pre-surgery, and at 1- and 3-months post-surgery were significantly higher in the positive ETD group compared to the negative ETD group. However, the proportion of patients showing an improvement in ETDQ-7 scores exceeding the MCID was also statistically significantly higher in the positive ETD group. In contrast, NOSE scores did not differ significantly between the positive and negative ETD groups (Table 3).

We also conducted further analysis on the group of patients with preoperative ETD who experienced resolution of ETD (ETDQ ≤ 14.5) within 3 months after septoplasty (n = 23). Eight of these 23 patients reported ETD symptoms in both ears, leading to a subgroup analysis of 31 ears based on the direction of septal deviation. This analysis revealed that the resolution of ETD symptoms was significantly more frequent on the convex (narrow) side compared to the concave (wider) side, with rates of 77.3% versus 55.6%, respectively (Table 4). To determine whether the quality of septoplasty influenced ETD improvement, a subgroup analysis was conducted on patients who reported an ETDQ score higher than 14.5 three months post-surgery, indicating persistent ETD. Among the eight patients with bilateral ETD, one showed no improvement above the MCID in either ear, and another showed no improvement above the MCID only on the convex-side ear. For the patient with ETD exclusively on the concave side, significant improvement above the MCID was observed post-surgery. Among the 14 patients with ETD only on the convex side, two did not show significant

Table 3. Postoperative data according to Eustachian tube dysfunction and direction of septal deviation.

Variables	ETD (-) (n=49)		p-value	ETD (+) (n=23)		p-value
Age, years	42.8±15.5			36.9±14.8		>0.05
Male, n (%)	35 (71.4%)			15 (65.2%)		>0.05
Post op 3-month NOSE	3.0 ± 4.2			3.8±4.9		>0.05
	Convex	Concave		Convex	Concave	
Pre-op ETDQ-7	8.2±2.0	8.03±1.8	>0.05	20.8±5.6	15.0±8.5	<0.01
Post-op 1-month	8.5±4.9	8.6±4.7	>0.05	13.0±7.7	12.4±6.2	>0.05
Post-op 3-month	8.1±2.8	8.2±3.0	>0.05	11.0±5.6	10.8±4.3	>0.05
MCID (Change >3.5), n (%)	6 (12.2%)	3 (6.1%)	>0.05	18 (66.7%)	9 (33.3%)	<0.01

ETD (+): the positive eustachian tube dysfunction group, ETD (-): the negative eustachian tube dysfunction group, MCID: minimum clinically important difference.

Table 4. Improvement in ETD according to the direction of septal deviation (cut off value of ETDQ=14.5).

Variables	Pre-op ETD (+) (N=31)		p-value
	Convex (narrower side)	Concave (wider side)	
Bilateral ETD (+)	8		
Unilateral ETD (+)	14	1	
Post-op 3-month ETDQ ≤14.5, n (%)	17/22 (77.3%)	5/9 (55.6%)	<0.05

ETD (+): the positive eustachian tube dysfunction group.

improvement above the MCID. In summary, five ears across four patients did not achieve MCID improvement in ETD. The preoperative mean NOSE score for these four patients was 10.5, and postoperative mean NOSE score was 3.25. Although the sample size was small and the paired t-test did not show a statistically significant difference (p = 0.17), we observed a trend of improvement in nasal symptoms through septoplasty even in patients who did not experience significant improvement in ETD. Furthermore, to investigate whether ETD symptoms improved after septoplasty even in patients with mild nasal obstruction symptoms, we conducted subgroup analysis on 10 patients categorized as mild according to the NOSE scale. Due to the small sample size (n = 10), we performed the Wilcoxon rank test. Although there was a decrease in ETDQ scores preoperatively and postoperatively, the changes were not statistically significant (1 month postoperative: p = 0.14, 3 months postoperative: p = 0.08). However, all three of the patients who showed both a decrease in ETDQ exceeding the MCID and had confirmed ETDQ scores of 14.5 or lower at 3 months postoperatively were in the positive ETD group preoperatively. This finding suggests that even in patients with mild nasal obstruction symptoms, septoplasty may lead to symptom improvement in cases where ETD is present preoperatively. In particular, if ETD symptoms occur on the narrower side of septal deviation, surgical intervention could be considered.

Discussion

Numerous studies have mentioned the relationship between NSD and ETD. Some authors suggested that NSD itself can be a cause of ETD. Multiple theoretical backgrounds have been suggested as the pathophysiology of ETD in the setting of NSD. Septal deviation might induce disruptions in ciliary function, leading to the stagnation of nasal secretions and an elevated risk of infection. Turbulent airflow could contribute to the deposition of microorganisms and pollutants in the eustachian tube opening, leading to inflammation and mechanical obstruction [18,19]. Previous studies reported that approximately 28-44% of patients with septal deviation have preoperative ETD. Many studies have also reported that septoplasty can improve ETD symptoms after surgery [20,21]. However, this was the first study that analyzed the direction of ETD according to septal deviation side and changes after septoplasty.

One key question at the beginning of this study was whether ETD caused by septal deviation occurs bilaterally. One of the suggested pathophysiologies of ETD in NSD is that the narrowing associated with septal deviation increases negative pressure in the nasopharynx, which may reduce the patency of the eustachian tube [22-24]. Low and Willatt investigated the relationship between middle ear pressure and NSD [26]. They first suggested a negative correlation between middle ear pressure on the same side as the narrower nasal passage and the degree

of asymmetry in nasal patency. They observed an improvement in middle ear pressure following septal surgery, suggesting that the turbulence in postnasal airflow caused by a deviated septum might lead to ETD. In this context, we hypothesized that narrowing associated with NSD affects ipsilateral eustachian tube function.

After analysis, we were able to confirm results consistent with our hypothesis. Consistent with previous studies, 29.2% of patients undergoing surgery for NSD reported ETD. Among individuals with septal deviation, the frequency of ETD-associated ear symptoms occurring on the convex (narrow) side was approximately twice as high (28.3% vs. 15.8%). Moreover, when analyzing specifically those patients with ETD symptoms prior to surgery, it was evident that ear symptoms were more severe on the convex (narrow) side. Previous studies reported that mucosal swelling, including turbinate hypertrophy caused by allergic rhinitis, is a significant factor in ETD (25). To investigate this mucosal factor, we performed immunoCAP testing and acoustic rhinometry. There were no significant differences between the positive ETD group and negative ETD groups and also between the convex and concave sides in each group (Table 2). This suggests that, excluding the influence of mucosal factors such as turbinate hypertrophy, septal deviation directly contributes to the development of ETD. These results also support our hypothesis that negative pressure on the narrower side is responsible for ETD symptoms.

The limitations of this study are as follows. Firstly, we did not evaluate the outcomes of septoplasty itself. Although all four rhinology surgeons who performed septoplasty were highly skilled and experienced, we did not assess whether the deviated septum was effectively corrected postoperatively in each case. Secondly, we used the subjective tool ETDQ-7 to diagnose ETD, which, although it is a validated tool, lacks the use of other objective evaluation tools such as tubometry and tympanometry. Since our clinic does not routinely perform these work-ups, such analyses were not feasible. Thirdly, we classified patients into positive ETD group if they had ETD on either side, which may have led to an overestimation of positive ETD cases.

Conclusion

This study shows that septoplasty considerably improves ETD symptoms, particularly on the convex (narrower) side of nasal septal deviation (NSD). Prior to surgery, 29.2% of patients had ETD, with a higher incidence and severity on the convex side. Postoperatively, the positive ETD group improved significantly in ETDQ-7 scores, notably on the convex side, confirming septoplasty's therapeutic influence. These findings emphasize septoplasty as an effective strategy for both nasal obstruction and ETD symptoms, implying that this surgical treatment may have a larger therapeutic purpose.

Authorship contribution

Conceptualization: CHL, EKL, SDH; Data curation: CHL, EKL; Formal analysis: CHL, EKL; Methodology: CHL, SDH; Project administration: CHL, SDH; Visualization: CHL, EKL; Writing original draft: CHL; Writing, review & editing: CHL, MHP, DK, YGJ, HYK, GR, SDH; All authors have thoroughly reviewed and approved the final manuscript.

Conflict of interest

The authors have no conflicts of interest to declare.

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