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Olfaction and quality of life in patients with nasal septal deviation treated with septoplasty

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ABSTRACT

Objective: Patients with septal deviation-induced nasal obstruction may experience olfactory impairment. This study aimed to evaluate septoplasty-related changes in olfactory function and their effect on patients' quality of life (QoL).

Methods: Prospective study of sixty patients with nasal obstruction and septal deviation and 25 healthy controls. Objective measurements were performed for the evaluation of nasal patency and "Sniffin' sticks" tests were used for quantitative assessment of lateralized and bilateral olfactory performance. All participants self-assessed their smell using a visual analog scale and completed validated questionnaires for nasal obstruction (Nasal Obstruction Symptom Evaluation: NOSE), for nasal symptoms QoL (SinoNasal Outcome Test-22: SNOT-22), for olfaction-associated QoL (Questionnaire of Olfactory Deficits: QOD) preoperatively and six months after septoplasty and reported personal benefit after surgery (Glasgow Benefit Inventory: GBI), six months postoperatively.

Results: Smell was significantly compromised due to septal deviation especially in the more obstructed nasal cavity side. Smell improved significantly after septoplasty (subjective report and olfactory measurements), along with increased nasal patency. Increased nasal cavity volume was significantly correlated with olfactory thresholds but not with suprathreshold measurements. Subjective hyposmia and lateralized olfaction were significantly reduced postoperatively. Postoperatively, normosmic patients reported higher personal benefit from surgery than patients with olfactory disorders. The patients' QoL improved significantly, but it remained lower than the controls' group. Olfaction-associated QoL was not significantly different between patients and controls before and after septoplasty.

Conclusion: Septoplasty leads to improvement in smell perception, and patients with improved smell report greater personal benefit from septoplasty than patients with remaining olfactory deficits.

1. Introduction

Nasal obstruction due to nasal septal deviation may occasionally be accompanied by olfactory impairment due to decreased nasal airflow [1]. These olfactory disorders are closely related to quality of life (QOL) [2,3], although underestimated by patients and overlooked by doctors [4]. Nasal septoplasty is considered to be the "gold" standard for the treatment of nasal septal deviation, because it usually produces an improvement in nasal respiratory airflow. This change of nasal airflow and intranasal volumes improves the transport of air molecules to the olfactory region and seems to be beneficial to the patients' olfactory abilities, as relevance has been found between human olfaction, nasal anatomy and intranasal airflow [5–7]. These changes in smell perception can also affect the patient's satisfaction with the procedure. Although there are studies evaluating the effects of septoplasty on olfactory function [1,8–19], there are only scarce reports on the results of both unilateral and bilateral olfactory measurements pre- and postoperatively [18,20]. In addition, the correlation between nasal airflow measurements and olfactory function assessments before and after septal surgery [14,21] and the effects of changes in olfaction on the quality of life of patients who undergo nasal septoplasty have not been adequately addressed in the literature. Thus, the main objective of the

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present prospective study was to assess the effect of septoplasty on both lateralized and bilateral olfactory function, to evaluate the correlation between the olfactory ability and the nasal patency measurements and to investigate the impact of patients' olfactory status on their nasal symptom-related QOL and satisfaction from septoplasty.

2. Materials and methods

This prospective observational study was conducted from March 2016 to September 2017. Sixty adult patients with nasal obstruction due to nasal septal deviation were included in the study. The diagnosis of septal deviation was based on clinical examination and endoscopic findings. Twenty-five healthy subjects who had similar age and sex distribution and neither nasal obstruction nor septal deviation, were recruited as a control group. Informed consent was obtained from all the enrolled participants. The study protocol was performed in accordance with the Declaration of Helsinki and was approved by the local institutional review board (decision No 3525/10.02.2016).

According to the inclusion criteria, patients aged from 18 to 65 years with nasal obstruction lasting for at least six months and nasal septal deviation upon clinical examination, were enrolled. Exclusion criteria included a clinical evidence or history of allergic rhinitis, sinonasal malignancy, chronic rhinosinusitis with or without nasal polyposis, previous nasal surgery, radiation therapy to the head and neck, nasal fracture or trauma in the past three months, craniofacial syndrome, septal perforation, nasal valve collapse, Wegener granulomatosis, sarcoidosis, pregnancy or cognitive disorders. Patients were also excluded if they suffered from a recent upper airway infection, exposure to chemicals, known post-viral or post-traumatic hyposmia or any neurological or systematic diseases associated with decreased smell perception or if they had any simultaneous nasal procedure other than septoplasty, in particular rhinoplasty and sinus surgery.

A detailed history with special focus on factors that affect olfaction, including smoking habits, medication, job, and recreational activities, was taken from all the enrolled participants. The patients were preoperatively subjected to a comprehensive clinical otorhinolaryngological examination, including anterior rhinoscopy and nasal endoscopy. Skin prick allergy testing and sinus imaging when medically justified, completed the clinical investigation in order to identify participants that met the exclusion criteria. According to the side of septal deviation, the nasal cavities were divided into narrow (more obstructed) and wide side.

A visual analog score (from 0 to 10) was used for subjective grading of patients′ olfactory disturbance, with grade “10” signifying very poor smell and grade “0” indicating almost normal smell. Olfactory function of all participants was quantitatively assessed using “Sniffin' sticks” test (Burghart, Wedel, Germany), that includes specific tests for odor threshold (OT), odor discrimination (OD), and odor identification (OI) [22–24]. Results were aggregated to a “Threshold Discrimination Identification (TDI) score” [24,25]. TDI score ranges from 0 to 48. Values of 16 or less represent anosmia, values between 16 and 30.5 represent hyposmia, and values over 30.75 represent normosmia [24]. Olfactory tests were performed for each nostril separately and for both nostrils (birhinal olfaction). A difference in score of at least three points of OT scores between the two nostrils signified a clinically meaningful difference in olfactory performance (lateralized olfaction) [26]. A clinically significant change of olfactory function after surgery was assumed when the TDI score differed by six points [27].

All participants underwent active anterior rhinomanometry (Homoth – 400, Medizinelektronik GmbH, Belgium) for the measurement of nasal resistance (NR). Nasal resistance was assessed in each nostril separately. Total NR was calculated by the standard formula total NR = (right NR × left NR) / (right NR + left NR) [28]. The value of nasal airflow at 150 Pa was taken for all assessments of nasal airflow. Acoustic rhinometry (Acoustic Rhinometer A1, GM instruments, UK) was utilized to measure minimal cross-sectional area (MCSA) and volume (VOL) over a length of 5 cm into the nasal cavity on both the right and left sides of the nose. In this study, total minimal cross-sectional area (TMCSA) and total nasal cavity volumes (TVOL) were calculated by averaging the right and left nasal measurements to minimize the effect of the nasal cycle [29]. Ten minutes before rhinomanometry and acoustic rhinometry, decongestion of each nostril was performed with two puffs of 0.1% xylometazoline spray to diminish the potential effect of the nasal cycle [29].

The olfactory tests and objective nasal measurements were performed preoperatively and six months postoperatively. At these time points all subjects also filled in four widely used questionnaires, translated, and validated into the Greek language: the Nasal Obstruction Symptom Evaluation (NOSE) questionnaire, assessing severity of nasal obstruction symptoms, the SinoNasal Outcome Test-22 (SNOT-22), assessing nasal symptom-related QOL, the Questionnaire of Olfactory Deficits (QOD) assessing olfaction-associated QOL and a postoperative general-health survey for the evaluation of patients' satisfaction with the surgical procedure, the Glasgow Benefit Inventory (GBI). NOSE is a five-item, disease- specific questionnaire for the measurement of nasal obstruction. Each item is scored from zero to four. The sum of scores is multiplied by five, resulting in a final score which ranges from zero (no symptoms) to 100 (severe nasal obstruction) [30,31]. In the SNOT-22 questionnaire, patients rate 22 different symptoms related to nasal function, physical status and emotional aspects on a scale from 0 (no symptom) to 5 (severe symptom) [32,33]. QOD is an olfaction-specific QOL questionnaire, for the assessment of daily life problems due to olfactory dysfunction. It consists of 25 statements (17 “negative”, 2 “positive”, 6 “socially desired”), answered in a four - point scale, with a maximum score of 57 points. High scores indicate a strong impairment in QOL [34,35]. GBI is a validated measure of patient's benefit, developed especially for surgical interventions. It is an 18-item post-intervention questionnaire and gives a total score which ranges from +100 (maximum positive change) to −100 (maximum negative change) [36,37].

All patients underwent surgery under general anesthesia. The surgical procedure was standardized and included a hemitransfixion incision followed by an elevation of the septal mucoperichondrium in both sides, accessing all areas of deviation. Then partial resections and reshaping of the deviated areas were performed. In all patients, inferior turbinate enlargement was treated with radiofrequency. Silicone splints, fixed on the nasal septum to prevent septal hematoma formation, were removed on the fourth postoperative day. The anterior nasal packings were removed after 48 h. No major complication was encountered postoperatively. All operations were performed by the same consultant surgeon, who did not participate in the questionnaires' collection and analysis of data, and was blinded to the patients' scores before and after treatment.

2.1. Statistical analysis

Data were analyzed with IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY, USA) version 25.0. Descriptive statistics were obtained; quantitative variables studied are presented as means with standard deviation while qualitative variables are expressed as frequencies (percentages). Normality of the data was ascertained with the Kolmogorov-Smirnov test. For the not normally distributed data, the Mann-Whitney *U* test and the Wilcoxon *t*-test were used. For differences of qualitative parameters between groups, the Chi-square test was applied. The change of frequency of lateralized olfaction after septoplasty was defined as dichotomous data [difference > 3 points in odor threshold (OT) test between the two nostrils: lateralized olfaction, difference < 3 points: non-lateralized olfaction]. Thus, the Mc Nemar's test for related binary data was used. Spearman's (ρ) correlation coefficients were calculated to check the correlations between olfactory scores and objective nasal patency measurements. A p value of < 0.05 was accepted as the statistical significance level.

Table 1
Olfactory assessment scores of the patients (preoperatively and 6 months after surgery) and the control participants.

		Control group	Patient group		p[a]
			Preoperatively Mean (SD)[b]	Postoperatively Mean (SD)[b]	
OT	Narrow side		3.15 (1.91)	5.91 (2.75)	< 0.001
	Wide side		4.56 (2.92)	6.74 (2.92)	< 0.001
	Bilateral	9.2 (2.19)	**4.78 (2.88)**	**6.98 (3.03)**	< 0.001
OD	Narrow side		7.76 (2.43)	9.48 (1.72)	< 0.001
	Wide side		8.93 (2.55)	10.06 (2.09)	0.01
	Bilateral	13.12 (1.67)	**9 (2.76)**	**11.35 (2.45)**	0.008
OI	Narrow side		8 (1.74)	11.18 (1.88)	< 0.001
	Wide side		9.75 (1.46)	11.76 (1.95)	< 0.001
	Bilateral	13.32 (2.18)	**10.08 (1.69)**	12.08 (1.97)	< 0.001
TDI	Narrow side		19.04 (3.52)	26.58 (4.28)	< 0.001
	Wide side		23.25 (4.46)	28.57 (4.36)	< 0.001
	Bilateral	35.64 (2.62)	**23.87 (4.28)**	**29.42 (4.72)**	< 0.001

OT: Olfactory Threshold, OD: Olfactory Discrimination, OI: Olfactory Identification, TDI: Threshold Discrimination Identification.
Bold: Statistically significant difference compared to control group. All $p < 0.001$.
[a] Wilcoxon Signed Rank test for paired samples comparison between pre- and post-treatment scores.
[b] SD: standard deviation.

3. Results

Sixty patients and 25 healthy subjects were enrolled in the study. The patients' group consisted of 34 males (56%) and 26 females (44%) with a mean age of 32.98 ± 11.98 years. The control group comprised of 13 males (52%) and 12 females (48%) with a mean age of 29 ± 8.87 years.

Regarding the preoperative olfactory function, patients presented lower olfactory scores (OT, OD, OI, and TDI) compared to controls. Patients were found to have higher nasal resistance (TNR), and lower nasal patency (TMCSA, TVOL) compared to controls. All these differences reached statistical significance ($p < 0.001$ for all the parameters, as demonstrated in Tables 1 and 2). Postoperative quantitative assessment of patients' unilateral and bilateral olfactory function revealed a statistically significant improvement in all olfactory scores ($p < 0.001$; Table 1). Also, there was a statistically significant improvement in patients' NR, MCSA, and VOL values, indicating that there was a postoperative significant nasal resistance decrease and nasal patency increase ($p < 0.001$ for all parameters; Table 2). Six months after surgery, there were no statistically significant differences in all nasal objective measurements and olfactory identification scores between the patients' and control groups ($p > 0.05$ for all parameters as shown in Tables 1 and 2). However, OT, OD, and TDI scores maintained their statistically significant difference between the two groups ($p < 0.05$ for all the variables - Table 1). Correlation analysis between olfactory scores and nasal objective measurements revealed a statistically significant correlation between the baseline and the postoperative olfactory threshold (OT) score and total nasal cavity volume (TVOL) (Graph 1).

Table 2
Objective nasal measurements of the patients (preoperatively and 6 months after surgery) and the control participants.

		Control group	Patient group		p[a]
			Preoperatively Mean (SD)[b]	Postoperatively Mean (SD)[b]	
NR	Narrow side		0.98 (0.34)	0.41 (0.21)	< 0.001
	Wide side		0.7 (0.35)	0.36 (0.22)	< 0.001
	TNR	0.14 (0.07)	**0.41 (0.26)**	0.17 (0.1)	< 0.001
MCSA	Narrow side		0.2 (0.13)	0.67 (0.24)	< 0.001
	Wide side		0.58 (0.27)	0.8 (0.2)	< 0.001
	TMCSA	0.85 (0.21)	**0.37 (0.19)**	0.73 (0.21)	< 0.001
VOL	Narrow side		8.56 (6)	16.25 (12.33)	< 0.001
	Wide side		13.53 (7.28)	17.25 (11.15)	0.002
	TVOL	18.68 (6.70)	**11.05 (6.46)**	16.93 (11.44)	< 0.001

NR: Nasal Resistance, MCSA: Minimal Cross-Sectional Area, VOL: Volume, TMCSA: Total Minimal Cross-Sectional Area.
Bold: Statistically significant difference compared to control group. All $p < 0.001$.
[a] Wilcoxon Signed Rank test for paired samples comparison between pre- and post-treatment scores.
[b] SD: standard deviation.

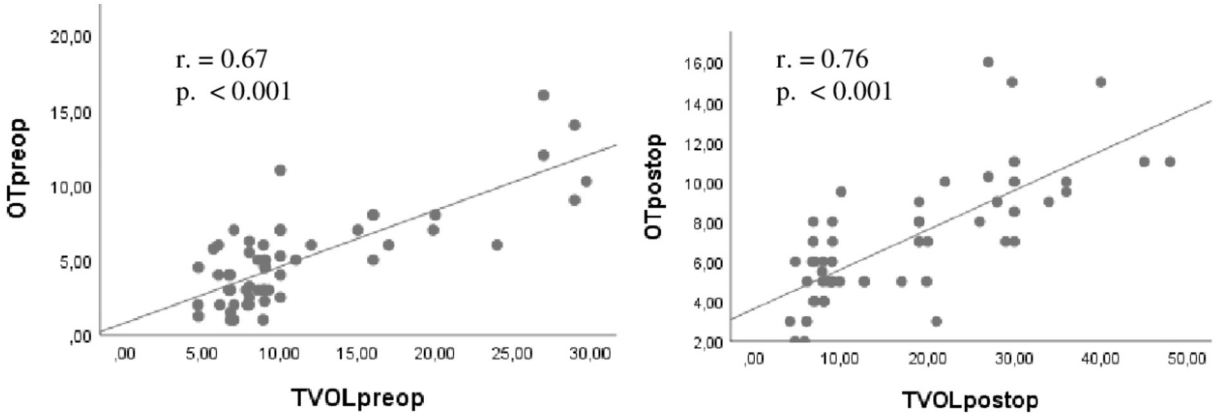
Patients showed preoperatively apart from lower olfaction scores, statistically significant worse subjective smell perception (indicated with the VAS score), a higher rate of lateralized olfaction, more severe nasal obstruction symptoms (NOSE) and worse nasal symptom-related QoL (SNOT-22) than controls (Table 3). Postoperatively, there was an increase of the percentage of patients with normal olfactory function, lower frequency of lateralized olfaction, decrease in nasal obstruction symptoms severity (NOSE) and improvement of nasal symptom-related QoL (SNOT-22). All these changes were statistically significant ($p < 0.001$ for all parameters - Table 3). Pre- and post-treatment olfaction-associated QoL was worse, though not with statistical significance compared to controls ($p > 0.05$; Table 3).

Patients with lateralized and non-lateralized olfaction were compared regarding symptoms, olfaction-associated and nasal symptom-related QoL and satisfaction with the surgical procedure. Both preoperatively and six months after surgery patients without lateralized olfaction tended to have better subjective evaluation of their olfactory status (indicated with the VAS scores), less impaired QoL due to olfactory disorders (QOD), milder nasal obstruction symptoms (NOSE) and better nasal symptom-related quality of life (SNOT-22) (Table 4). Postoperatively patients without lateralized olfaction showed more benefit and higher satisfaction with the surgical procedure (GBI) than patients with lateralized olfaction (Table 4). However, except for nasal obstruction symptom severity, these differences were not statistically significant ($p > 0.05$; Table 4).

Six months after surgery normosmic patients had a better subjective rating of smell perception, better olfaction-associated QoL, less nasal obstruction symptoms, a better nasal symptom-related QoL and more personal benefit than patients who still reported olfactory deficits. Except for olfaction-associated QoL, the differences in all these parameters reached statistical significance (Table 5). However, both patients' subgroups had statistically significant higher nasal symptom severity (NOSE) and reduced nasal symptom-related QoL (SNOT-22) compared to the controls (Table 5).

4. Discussion

An important finding of the current study was that, although nasal obstruction is the leading symptom in patients with nasal septal deviation, olfactory impairment is also common. Bilateral olfactory function (tested with Sniffin' sticks) and nasal patency were decreased in the patients' group compared to the controls. In the present study, higher olfactory thresholds, as well as reduced olfactory discrimination and identification were found at the narrower side of the nasal cavity prior to surgery. Studies investigating the association between the intranasal airflow and olfactory function have shown that the structure of the nasal cavity which has a significant effect on intranasal airflow, is affecting the magnitude of odorant molecules transported to the olfactory epithelium [5–7,38]. Leopold et al. [5] studied the relationship between nasal anatomy and human olfaction and identified an area localized in the upper meatus below the cribriform plate influencing olfaction. It has also been demonstrated that structural changes in the



Graph 1. Correlation between olfactory threshold and total nasal cavity volume pre - and postoperatively.

Table 3
Olfaction and QoL measurements of the patients (preoperatively and 6 months after surgery) and the control participants.

	Control group	Patient group		p[d]
		Preoperatively	Postoperatively	
TDI [mean, (SD)]	35.64 (2.62)	**23.87 (4.28)**	**29.42 (4.72)**	< 0.001[a]
VAS [mean, (SD)]	1.7 (0.3)	**5.2 (0.7)**	2.51 (1.03)	< 0.001[a]
QOD [mean, (SD)]	6.92 (2.08)	8.85 (5.11)	7.91 (3.42)	0.25[a]
NOSE [mean, (SD)]	7.4 (6.78)	**76.1 (20)**	**27.73 (27.05)**	< 0.001[a]
SNOT-22 [mean, (SD)]	12.9 (8.86)	**42.93 (19.57)**	**26.7 (18.9)**	< 0.001[a]
Olfactory function, by TDI				< 0.001[b]
Normosmics [n, (%)]	25 (100%)	**10 (16.67%)**	**19 (32%)**	
Hyposmics [n, (%)]		44 (73.30%)	39 (65%)	
Anosmics [n, (%)]		6 (10%)	2 (3%)	
Lateralized olfaction [n, (%)]	4 (16%)	**16 (27%)**	11 (18%)	< 0.001[c]

SD: standard deviation.
TDI: Threshold Discrimination Identification, VAS: Visual Analog Scale, QOD: Questionnaire of Olfactory Disorders, NOSE: Nasal Obstruction Symptom Evaluation, SNOT-22: Sino Nasal Outcome Test-22.
Bold: Statistically significant difference compared to control group. All $p < 0.001$.
[a] Wilcoxon Signed Rank test for paired samples
[b] Chi-square test
[c] Mc Nemar's test.
[d] p: comparison between pre- and post-treatment scores

Table 5
Comparison of smell perception, symptoms, QoL and satisfaction with the surgical procedure, 6 months after surgery, between patients with olfactory deficits and normosmics.

	Control group (n = 25) Mean (SD[a])	Patients group (n = 60) Mean (SD[a])		p[b]
		Olfactory deficits (n = 41)	Normosmics (n = 19)	
VAS	1.7 (0.3)	**3.67 (0.65)**	1.79 (0.71)	< 0.001
QOD	6.92 (2.08)	8.27 (4.33)	7.02 (3.4)	0.14
NOSE	7.4 (6.78)	**33.9 (4.29)**	**13.61 (4.51)**	< 0.001
SNOT-22	12.9 (8.86)	**30.97 (12.11)**	**22 (13.96)**	0.014
GBI		5.35 (2.18)	18.05 (3.51)	0.002

Bold: Statistically significant difference compared to control group. All $p < 0.001$.
VAS: Visual Analog Scale, QOD: Questionnaire of Olfactory Disorders, NOSE: Nasal Obstruction Symptom Evaluation, SNOT-22: SinoNasal Outcome Test-22, GBI: Glasgow Benefit Inventory.
[a] SD: standard deviation.
[b] Mann–Whitney U test for independent samples: comparison between patients with olfactory deficits and normosmics.

nasal valve area and the upper nasal cavity strongly affect airflow patterns and odorant transport to the olfactory region, with subsequent effects on olfactory function [4,38]. Previous investigations have also found that septal deviation results in decreased olfactory function at the obstructed nasal side. Pfaar et al. [18] found that septal deviation results in decreased odor thresholds at the obstructed nasal side, while Altundag et al. [39] reported that odor thresholds, odor discrimination,

Table 4
Comparison of symptoms, QoL and satisfaction with the surgical procedure between patients with and without lateralized olfaction, preoperatively and 6 months after surgery.

	Preoperatively		p[a]	Postoperatively		p[a]
	Group A (n = 16) Mean (SD)[b]	Group B (n = 44) Mean (SD)[b]		Group A (n = 11) Mean (SD)[b]	Group B (n = 49) Mean, SD[b]	
VAS	5.67 (0.55)	4.95 (0.63)	0.12	3.57 (0.94)	2.98 (0.73)	0.08
QOD	10.18 (1.83)	8.36 (0.6)	0.73	8.97 (0.46)	7.72 (1.32)	0.08
SNOT-22	48.8 (22.25)	42.11 (19.95)	0.362	28.25 (15.64)	27.81 (15.38)	0.575
NOSE	91.8 (2.69)	70.45 (2.95)	< 0.001	62.27 (4.33)	20 (3.26)	< 0.001
GBI				6.79 (7.04)	9.8 (1.88)	0.09

Group A: patients with lateralized olfaction. Group B: patients without lateralized olfaction.
n: number of patients.
VAS: Visual Analog Scale, QOD: Questionnaire of Olfactory Disorders, SNOT-22: Sino Nasal Outcome Test-22, NOSE: Nasal Obstruction Symptom Evaluation, GBI: Glasgow Benefit Inventory.
[a] Mann–Whitney U test for independent samples.
[b] SD: standard deviation.

and odor identification were decreased at the narrower side. Gupta et al. [14] demonstrated that the combined olfactory score (odor threshold and odor identification) was decreased at the deviated nasal side. In accordance with previous studies [20], the mean value of bilateral olfactory measurements converged to the score of the wide side of the nasal cavity, indicating that an individual's olfactory status mainly depends on the olfactory function of the ″better olfaction″ nostril.

Nasal septoplasty is associated with a decrease in nasal resistance and increased nasal patency [40]. Septal surgery, through nasal airflow improvement, may positively affect olfactory function possibly by enhancing transport of odor molecules to the olfactory cleft [5]. In this study, an improvement in most of the patients' olfactory abilities, including odor thresholds, odor identification, and odor discrimination, was observed six months after surgery. Previous studies evaluating olfaction before and after septoplasty presented controversial results, with the majority of them showing an improved smell perception [1,9,11–14,16,19,20,41,42] and others showing either no significant change [17,18] or different degrees of hyposmia after surgery [13]. It is worth mentioning that hyposmia was temporary in most patients in these studies. Kilicaslan et al. [13] found that one week after septoplasty total olfactory function was decreased, while six weeks after surgery, the olfactory performance was not significantly changed. However, total olfactory status was significantly improved six and twelve months after septoplasty. Similarly, in the study of Dalgic et al. [12] odor thresholds, odor discrimination and odor identification were not significantly changed during the first postoperative week but were improved three months after septoplasty. Savvateeva et al. [16] detected a significant improvement in olfactory function one month after surgery, and there was further improvement during the following four months. Wound healing and edema may decrease nasal cavity volume and airflow during the early postoperative period. Usually, one month after surgery and during the late postoperative period (four to twelve months after surgery), as wound healing progresses, nasal cavity volume increases and nasal airflow improves, as does the olfactory function [12,13,16]. Therefore, it seems essential to inform patients about the possibility of a temporary decrease of olfactory function following septoplasty.

Furthermore, the controversial results reported in different studies (Table 6) may be related to the wide variety of olfactory tests used, varying follow-up times or further surgical procedures that risk causing direct trauma or vascular damage to the olfactory epithelium and worsen edema of the nasal cavity [43]. In our patients' cohort, six months following septal surgery, improvement of olfactory function was noted in 40 (67%); no change was seen in 18 (26%), and reduced olfactory function was observed in four (7%) patients. Similar to our study, Damm et al. [1] reported improved olfaction in 77% of the patients two months after surgery, and Gupta et al. [14] found smell improvement in 70.6%, no change in 20.1% and reduced olfaction in 7.3% of the patients, one month after septoplasty. In contrast, Pade et al. [17] reported smell improvement in 13%, no change in 81%, and decreased function in 7% of patients four months after septoplasty.

In the present study, preoperatively as well as six months after surgery, a significant correlation was found between olfactory thresholds and nasal cavity volume measured by acoustic rhinometry. Correlations were not found for odor discrimination or odor identification, both of which are suprathreshold tests of olfactory function. Similarly, in a recent study by Masala et al. [7] with healthy volunteers, positive correlations were found between olfactory sensitivity at threshold level and nasal cavity volume, while the correlations between olfactory thresholds and minimal cross-sectional area in both nostrils were negative. In addition, no significant correlations were found between odor identification and nasal anatomy. These findings, in accordance with previous works [6,44], suggest that larger nasal cavity volume may also be related to a larger surface with more olfactory receptive structures. The current results are supported by the observations of Damm et al. [6] who assessed the nasal cavity volume and its relation to olfactory function in normosmic subjects with the use of MRI-scans. They demonstrated significant correlations between odor threshold measurements and volumes of the segment in the upper meatus directly below the cribriform plate and the anterior segment of the inferior meatus, while no such correlations were observed for odor identification and odor discrimination. In contrast, Güzelkücük et al. [21] and Frasnelli et al. [45] focusing on the relationship between the intranasal airflow and olfactory function of patients awaiting septal surgery found no correlation between olfactory function and parameters of acoustic rhinometry (nasal cavity volume) [21,44] or rhinomanometry (nasal resistance) [44]. One possible interpretation of this discrepancy may be that odor thresholds seem to be more dependent on the intranasal ventilation and the peripheral olfactory input [46]. In turn, nasal airflow has a weaker impact on suprathreshold olfactory functions such as odor discrimination and identification [47], which appear to be determined by individual experience and conscious cognitive processes to a higher degree than odor thresholds [48]. In combination with the presently reported data, these findings seem to indicate that odor thresholds exhibit a strong correlation with the intranasal anatomy while such correlations are weak for suprathreshold olfactory function.

In the present study, lateralized olfaction was observed in 27% of patients with septal deviation preoperatively. In accordance with prior studies [15,18,20] septoplasty resulted in fewer patients (18%) with a significant lateralized difference in olfactory function, and this rate was almost the same for the control group (16%). None of the previous studies that investigated the presence of lateralized olfaction in patients who underwent septoplasty included a control group. Gudziol et al. [49] found a lateralized olfaction in 15% of 479 healthy people. Furthermore, subjective evaluation of olfactory performance (VAS), olfaction-associated QoL (QOD), nasal symptom-related QoL (SNOT-22) and personal benefit from the surgical procedure (GBI) did not differ significantly between patients with and without lateralized olfaction. This may be partly explained by the fact that the wider and “better olfaction” side of the nose mainly affects the bilateral olfaction [20,45]. As a result, the presence of lateralized olfaction in patients with septal deviation has no significant effect on their subjective smell perception, olfaction-associated and nasal symptom-related QOL.

Another important finding was that patients who became normosmic after surgery were more satisfied with the operation and had a more improved subjective evaluation of their olfactory status than the patients who still presented olfactory deficits. However, olfaction-associated and nasal symptom-related QoL did not differ significantly between these two patients' subgroups. In accordance with a previous study by Bugten et al. [50], despite the fact that six months after septoplasty patients' nasal symptom-related QoL was significantly improved, it remained significantly lower in the patient group compared to the control group. Nevertheless, in the current study, patients' olfaction-associated QoL (QOD) was not significantly impaired both before and after surgical correction of the deviated septum compared to the control group. Olfactory disorders usually lead to disturbances in critical areas of daily life such as food appreciation, harm avoidance, personal hygiene, and social communication [51,52]. In patients with nasal septum deviation, olfactory impairment often co-exists with other nasal obstruction symptoms related to decreased nasal patency. In previous research, it was found that nasal obstruction symptoms' severity rather than olfactory function was a prognostic factor of patients′ general quality of life improvement after septoplasty [53]. So, even though in patients with chronic rhinosinusitis or nasal polyposis olfactory impairment significantly affects patients' nasal symptom-related and general QoL [54], in patients with septal deviation QoL reduction is mainly attributed to nasal obstruction rather than olfactory disorders.

To the best of our knowledge, this is the first study to address the association between changes in olfactory status, personal benefit after surgical treatment, olfaction-associated and nasal symptom-related QoL

Table 6
Olfaction in patients with nasal septal deviation treated with septoplasty.

Studies	n	O	Olfactory assessment	Test	Pre-operative olfaction	FU	Post-operative olfaction
Durr et al. [19], 2002	41	SP, SRP	Olfactory tests (OT, OI) Subjective	SST	NR	5.4 m	Improvement of OT scores.
Damm et al. [1], 2003	30	SP, IT	Olfactory tests (OT, OI, OD) (OT lateralized) Subjective:VAS	SST	33% normosmics 60% hyposmics	6-13w	SR: 77% improved. Normosmics: 80%. of Improved: OD (70%), OI (80%), OT (5%)
Pfaar et al. [18], 2004	25	SP	Olfactory tests (OT, OI, OD) Lateralized	SST	80% normosmics 20% hyposmics Narrow side: OT worse	4 m, 9 m	No OT side-difference postop No change of overall olfactory function
Pade et al. [17], 2008	150	SP	Olfactory tests (OI) Subjective	SST	NR	4 m 2–11 m	improvement: 13%, no change: 81%, decrease: 7%
Philpott et al. [41], 2008	30	SP	Olfactory tests (OT, OI) Subjective: question	COT	OT reduced, OI good SR: 46.7% reduced olfaction	12 m	Improvement in olfaction (COT), mainly in OT
Savvateeva et al. [16], 2011	40	SP	Olfactory tests (OT, OI) Subjective: VAS	SST	75%, hyposmia SR of hyposmia: 60%	1 m, 4 m	Improvement in all olfaction parameters in 1 and 4 months
Fyrmpas et al. [15], 2012	30	SP	Olfactory tests (OI) lateralized Subjective: VAS	12 SST	20% lateralized olfaction	2 m	13% lateralized olfaction, decrease of subjective hyposmia
Gupta et al. [14], 2015	37	SP	Olfactory tests (OT, OI) lateralized Subjective: SFNQ, VAS	CCCRC (COS)	VAS – COS and SFNQ – COS (obstructed side) correlated	4w	Improvement of SR and COS for the obstructed side. Improvement of smell in70.6%
Bugten et al. [50], 2016	86/93 controls	SP	Subjective: VAS SNOT 20		Patients had worse smell than controls	6 m	Smell improvement. Patients had worse smell than controls
Dalgic et al. [12], 2016	39	SP	Olfactory tests (OT, OI, OD)	SST	NR	1w, 3 m	At 3 months, increase for OT, OD, OI.
Berkiten et al. [42], 2016	50	SP	Olfactory tests (OT, OI) Subjective: SNOT22	CCCRC	NR	6w	Improvement in olfaction
Kilicaslan et al. [13], 2016	37	SP, RF	Olfactory tests (OT, OI)	CCCRC	NR	1w, 6w, 6 m, 12 m	Total olfaction and OT improved at 6 and 12 months. No changes in OI.
Choi et al. [20], 2016	5	SP	Olfactory tests (OT) lateralized	BTT	NR	6 m	Improved birhinal BTT
Haytoglu et al. [10] 2017	116	SP	Olfactory tests (OI)	B-SIT	Lower scores in type 3 NSD	1 m, 3 m	Smell improved in type 3 NSD patients
Turk et al. [11], 2017	30	SP	Olfactory tests (OT, OI, OD)	SST	NR	6 ± 3w	Improvement in TDI, OD, OI, OT scores

n: number of patients, O: type of operation, FU: follow-up, m: months, w: weeks.
OT: Olfactory threshold, OI: Olfactory identification, Olfactory discrimination, SST: Sniffin' Sticks Test, COT: Combined Olfactory Test, Lateralized: each side of the nose tested separately, CCCRC: Connecticut Chemosensory Clinical Research Center test, COS: combined olfactory score, BTT: Butanol Threshold Test, BSIT: Brief Smell Identification test.
NSD: nasal septal deviation, SP: septoplasty, SRP: septorhinoplasty, IT: inferior turbinectomy, RF: radiofrequency.
SR: Subjective report, VAS: Visual Analog Scale, SFNQ: Short form nasal questionnaire, SNOT: Sino Nasal Outcome Test, NR: Not Reported.

in patients treated for septal deviation. For this purpose, validated, olfaction-associated, and disease-specific QoL questionnaires were used, and comparisons with healthy controls were performed. Previous studies focused mainly on the effects of septoplasty on olfactory function without providing clinically meaningful information for the relationship of olfaction with patients' quality of life. Additionally, quantitative smell tests for the lateralized and the bilateral assessment of olfactory performance were utilized, providing objective data for smell perception besides self-reporting of olfaction. It is worth mentioning that all the presented data were obtained during a longer follow up period (six months) in comparison to the vast majority of the previous studies. Furthermore, in two previous works where the long-term effects of septoplasty on olfactory function were evaluated, no significant changes in olfactory performance were further demonstrated during the later postoperative period from 6 to 9 and 12 months after surgery [13,18]. Finally, nasal measurements were performed pre- and postoperatively for the objective evaluation of the nasal patency and the investigation of the correlation between nasal airflow, intranasal volume, and olfactory function. However, for a more comprehensive assessment of olfactory function in patients with septal deviation, further studies with larger cohorts and with varying degrees of septal deviation and comparisons of olfactory function results of typical endonasal septoplasty with different surgical procedures (such as external approach septoplasty, endoscopic septoplasty or septorhinoplasty) are required.

5. Conclusion

Septal deviation results in olfactory impairment especially in the more obstructed side of the nasal cavity. It has been demonstrated in this study that nasal septoplasty provides a favorable outcome for most of the patients, in terms of olfactory function, through nasal airflow improvement. Changes in intranasal volume seem to correlate with olfactory thresholds but not with the suprathreshold olfactory function

that probably depends on cognitive processes to a higher degree than odor thresholds, which in turn are more affected by intranasal airflow. Septal surgery also results in fewer patients with lateralized olfaction, but this parameter does not seem to significantly affect patients' QOL and subjective evaluation of sense of smell. Further, postoperative patients' QOL scores, though significantly improved, remain lower compared to the scores of the healthy controls. Olfactory disorders do not seem to play a significant role in the nasal symptom-related QOL of patients with nasal septal deviation who undergo septoplasty. However, six months after surgery, patients with a better olfactory status report more personal benefit from surgery than patients with remaining olfactory deficits.

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Ethical approval

This study was performed in accordance with the ethical standards of the institutional research committee and the 1964 Helsinki declaration and its later amendments.

Declaration of Competing Interest

The authors Konstantinos Valsamidis, MD, MsC, PhD, Athanasia Printza, MD, MSc, PhD, Konstantinos Titelis, MD, Jannis Constantinidis, MD, PhD Stefanos Triaridis, MD, MSc, PhD, declare that there is no conflict of interest related to this paper.

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