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Original Article

Impact of Septoplasty on Cognitive Function

Septoplastinin Bilişsel İşlev Üzerine Etkisi

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ABSTRACT

Objective: This study explored the impact of septoplasty on cognitive functions, including selective attention, information processing speed, and response inhibition and investigated the factors associated with these effects.

Methods: A total of 73 patients who underwent septoplasty for septal deviation were included. Assessments were conducted at baseline and again at six months postoperatively to evaluate the nasal obstruction symptom evaluation (NOSE) score, peak nasal inspiratory flow (PNIF), Sniffin' Sticks (SS), retronasal olfactory threshold test (ROTT), and Stroop test. Wilcoxon signed-rank and McNemar's tests were used to analyse differences between repeated measurements obtained before and after surgery. Additionally, Spearman's correlation, linear regression, and logistic regression analyses were performed. Results with p-value ≤ 0.05 were considered significant.

Results: Postoperative assessments revealed statistically significant improvements in NOSE, PNIF, SS discrimination, SS TDI, ROTT, and Stroop A–D scores (each $p<0.05$). SS TDI and ROTT scores were significantly correlated both preoperatively ($r=0.238$) and postoperatively ($r=0.295$). . Furthermore, significant correlations were observed among NOSE, PNIF, SS, ROTT, and Stroop tests. However, PNIF, SS, and ROTT did not show any statistically significant improvement in the postoperative cognitive test results.

Conclusions: Septoplasty significantly improved nasal airflow, both orthonasal and retronasal olfaction, and cognitive functions, including selective attention, information-processing speed, and response inhibition. However, it is unclear whether cognitive improvements are attributable to enhanced olfactory function or alleviation of nasal obstruction.

Keywords: Nasal septum, Nasal obstruction, Olfaction, Cognition, Neuropsychological tests

ÖZ

Amaç: Bu çalışma, septoplastinin seçici dikkat, bilgi işleme hızı ve tepki inhibisyonu da dahil olmak üzere bilişsel işlevler üzerindeki etkisini ve bu etkilerle ilişkili faktörleri araştırmaktadır.

Yöntemler: Septal deviasyon nedeniyle septoplasti geçiren toplam 73 hasta çalışmaya dahil edilmiştir. Değerlendirmeler, başlangıçta ve ameliyattan 6 ay sonra, Burun Tıkanıklığı Semptom Değerlendirme (NOSE) skoru, Pik Nazal İnspiratuvar Akım (PNIF), Sniffin' Sticks (SS), Retronazal koku eşiği testi (ROTT) ve Stroop testi değerlendirilerek yapılmıştır. Ameliyat öncesi ve sonrası alınan tekrarlanan ölçümler arasındaki farklılıkları analiz etmek için Wilcoxon İşaretli Sıralama testi ve McNemar testi kullanılmıştır. Ek olarak, Spearman korelasyonu, doğrusal regresyon ve lojistik regresyon analizleri yapılmıştır. Anlamlılık eşiği p değeri 0,05 olarak belirlenmiştir.

Bulgular: Ameliyat sonrası değerlendirmeler, NOSE skoru, PNIF, SS ayırt etme, SS TDI skoru, ROTT ve Stroop A-D skorlarında istatistiksel olarak anlamlı iyileşmeler ortaya koymuştur (her biri $p<0,05$). Hem ameliyat öncesi ($r=0,238$) hem de ameliyat sonrası ($r=0,295$) SS TDI skoru ile ROTT arasında korelasyon tespit edilmiştir. Ayrıca, NOSE, PNIF, SS, ROTT ve Stroop testleri arasında anlamlı korelasyonlar gözlemlenmiştir. Bununla birlikte, PNIF, SS ve ROTT, ameliyat sonrası bilişsel test sonuçlarındaki iyileşmeler üzerinde istatistiksel olarak anlamlı bir etki göstermemiştir.

Sonuçlar: Septoplasti, nazal hava akımını, ortonazal ve retronazal koku işlevini, seçici dikkat, bilgi işleme hızı ve yanıt inhibisyonu gibi bilişsel işlevleri önemli ölçüde geliştirmiştir. Bununla birlikte, bilişsel işlevlerdeki iyileşmelerin koku alma fonksiyonunun gelişmesinden mi yoksa burun tıkanıklığının giderilmesinden mi kaynaklandığı, belirsizliğini korumaktadır.

Anahtar kelimeler: Nazal septum, burun tıkanıklığı, koku alma, kognisyon, nörofizyolojik testler

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INTRODUCTION

Olfactory dysfunction secondary to reduced nasal airflow is a common symptom observed in patients with nasal septal deviation and those who have undergone septoplasty[1]. The sense of smell is mediated by receptor cells in the nasal neuroepithelium, thus, anatomical alterations in nasal structures such as the septum or turbinates, can adversely affect olfactory perception by altering nasal airflow[2]. Nasal obstruction is one of the most frequent symptoms of sinonasal diseases[3], and septal deviation is the underlying cause in approximately one-third of the cases[4]. Both nasal obstruction and olfactory dysfunction due to septal deviation can significantly impair the quality of life of patients[1]. Cognitive functions include a wide range of processes, such as learning and memory, organisation, planning, problem-solving, concentration, sustained attention, environmental perception, and calculation. Severe nasal obstruction may impair cognitive function owing to chronic or nocturnal hypoxia. Cognitive dysfunction has recently been reported in patients with chronic rhinosinusitis with nasal polyps[5]. Olfactory dysfunction is associated with impaired cognitive performance[6]. However, the combined influence of nasal obstruction and olfactory dysfunction on cognition is limited, and the existing data are insufficient to elucidate how these symptoms are modified by septoplasty. This study aimed to investigate the potential role of septoplasty in selective attention, information processing speed, resistance to interference from automatic processes, and the underlying mechanisms.

MATERIALS AND METHODS

Study Design and Ethics Approval

This study was a prospective clinical trial conducted in the Department of Otorhinolaryngology at Dokuz Eylül University between January 2024 and January 2025. The Institutional Review Board of Dokuz Eylül University (decision number: 2024/03-21, dated: 17.01.2024). Informed consent was obtained from all participants.

Study Population and Sample Size

The study included patients scheduled for septoplasty due to nasal septum deviation (NSD). The primary outcome measure was postoperative performance on the Stroop test. However, due to a lack of relevant data, the sample size was calculated based on a previously published study by Arslan et al.[5], which used a methodological design similar to this study. Power analysis of the preoperative and postoperative Stroop scores estimated that 59 participants would be required to achieve 80% power at a 5% significance level. Taking into account a reported average dropout rate of 26%[5], the target sample size was adjusted to 75. After 2 participants withdrew, the study included 73 patients.

Inclusion and Exclusion Criteria

The inclusion criteria for the study were individuals aged 18-65 years, with at least primary school education, and who were scheduled to undergo septoplasty due to NSD. The exclusion criteria were the presence in the patient's history of any neurological, visual, audiological, or systemic diseases that could impair cognitive function, including sleep disturbances and obstructive sleep apnoea; comorbid conditions affecting the olfactory system, such as chronic rhinosinusitis, nasal polyps, or nasal masses; suspected or confirmed pregnancy; and withdrawal of informed consent. Paranasal sinus computed tomography was performed to systematically exclude alternative pathologies and to substantiate the clinical indications for septoplasty.

Data Collection Procedures

All participants underwent preoperative and a 6-month postoperative evaluation including ENT examination, nasal obstruction symptom evaluation (NOSE) scale[7], peak nasal inspiratory flow meter (PNIF) (Clement Clarke International, Harlow, Essex, United Kingdom)[8] measurement, video-endoscopic nasal examination using a rigid 30 degree 4 mm 18 cm nasal telescope (Hopkins Telescope, Karl Storz, Germany), Sniffin' sticks (SS) orthonasal olfactory test[9] (Sniffin' Sticks, Burghart, Germany), retronasal olfactory threshold test (ROTT)[10], and the Stroop colour-word test (SCWT)[11]. NOSE, PNIF, and patient examinations were conducted by SH, a resident medical doctor and author of the current manuscript, under the supervision of ACC and MCE, who are also authors of the manuscript and otorhinolaryngologists, with ACC and MCE serving, respectively, as SH's former and latter supervisors. SS and ROT tests were performed by HEE, an audiologist and author of the current manuscript, who is experienced in olfactory test batteries and olfactory rehabilitation therapy under the supervision of both ACC and MCE. The SCWT was implemented by OA, a psychologist and author of the current manuscript, who has experience in olfactory test batteries and olfactory rehabilitation therapy, under the supervision of both ACC and MCE.

All the materials and devices were calibrated and validated.

Dependent and Independent Variables

The data, including the scores on NOSE[7], PNIF[8], SS[9], ROTT[10], and Stroop tests[11] were evaluated as dependent variables. Age, sex, degree of deviation (mild, moderate, or severe)[12], Cottle's classification of the nasal deviation area[13], smoking status, history of rhinological surgery, education level, and comorbidities were evaluated as independent variables.

The NOSE scale served as a subjective assessment tool. It comprises five items, each scored 0-4, and the total score is multiplied by 5 to yield a final score out of 100[7].

The PNIF (Clement Clarke International, Harlow, Essex, United Kingdom) measurement was performed to assess nasal patency, as introduced before[8]. Prior to testing, all patients rested for 20 minutes to acclimate to ambient conditions. An instrument mask was securely positioned over the mouth and nosewithout gaps. Following a forceful exhalation, participants were instructed to inhale strongly through the nose with the mouth sealed. Three measurements were obtained for each nostril and for both nostrils combined (global). The highest value from each set was recorded. The global measurements were used in the statistical analyses to mitigate potential complexities associated with bilateral nasal deviations.

The orthonasal olfactory function was evaluated using the test (Burghart, Germany), which includes three subtests: odor threshold, discrimination, and identification. The combined scores of these subtests were recorded as the TDI (Threshold-Discrimination-Identification) score[9]. A TDI score of ≥30.5 was classified as normosmic, 16.5-30.5 as hyposmic, and <16.5 as anosmic[14].

The retronasal olfactory evaluation was performed utilizing a freshly prepared phenyl ethyl alcohol (PEA) dilution protocol, which has been previously standardized within our department[10]. High-purity PEA (99%) was employed in a 2:1 serial dilution ranging from 1/400 to 1/1,638,400. Solutions were administered in 13 series of four vials each, with each vial containing either PEA or water. Prior to testing, participants were acclimated to the odor presented orthonasally. Subsequently, solutions were applied to the mid-dorsal surface of the tongue with their mouths open, and participants were asked to report their perception of odor. The olfactory threshold was identified as the lowest concentration at which four correct responses were consistently recorded. Scores of 8 or less indicate hyposmia, whereas scores of 9 or higher indicate normosmia. A ROTT score of ≤8 indicated hyposmia, whereas ≥9 represented normosmia[10].

Cognitive function was assessed utilising the SCWT, which evaluates attention, response inhibition, and executive functioning. Individuals were expected to name the colour in subset A, read the written word in subset B, and match the colour to the word, despite the incongruence in subset C. Finally, subset D represented the interference score and was calculated by subtracting the Stroop B score from the Stroop C score. Performance on all subtests was measured in seconds, with shorter durations indicating better performance. The cut-off values for subsets A–D were set at 42, 35, 89, and 44, respectively. As stated in a time-based validation study[15], scores that meet or fall below these thresholds were considered normal, whereas extended scores may indicate mild cognitive impairment (MCI).

Statistical Analysis

Data analysis was conducted using IBM SPSS Statistics version 29.0. The Shapiro-Wilk test was used to assess the distributional characteristics of the variables. Continuous variables that are normally distributed are reported as the mean ± standard deviation. For non-normally distributed continuous variables, the median (minimum–maximum) was reported. The Wilcoxon signed-rank test was used to compare repeated numerical measurements obtained before and after surgery. Categorical variables were summarized as frequencies and percentages, and the McNemar's test was applied to evaluate repeated categorical measurements over the same time frame. To identify the factors influencing statistically significant parameters, linear regression was used for numerical variables and binary logistic regression for categorical variables. Additionally, the impact of potential independent variables previously emphasised in the literature—specifically Cottle zones[8] [1-3 (anterior) vs. 4-5 (posteiror)], degree of deviation[16] (mild and moderate (non-severe) vs. severe), smoking status[17,18], and sex[19-20]—on improvement in PNIF, SS olfactory, and ROTT olfactory groups was examined using binary logistic regression analysis. Spearman's rank correlation tests were conducted to assess associations. The threshold for statistical significance was set at $p<0.05$.

RESULTS

A total of 75 patients who underwent septoplasty for NSD were included in this study. However, 2 patients withdrew for personal reasons, resulting in a final cohort of 73 participants. The demographic characteristics and features of NSD among participants are presented in Table 1.

A comparison of pre- and postoperative values showed significant postoperative improvements in NOSE, PNIF,

Table 1. Demographic characteristics and nasal septum deviation features		
Variable	**Category**	**n (%)***
Gender	Female	26 (35.6%)
	Male	47 (64.4%)
Age (years)		32.5±1.4
Degree of NSD	Mild	5 (6.8%)
	Moderate	37 (50.7%)
	Severe	31 (42.5%)
Cottle zone	Zone 1	6 (8.2%)
	Zone 2	26 (35.6%)
	Zone 3	28 (38.4%)
	Zone 4	10 (13.7%)
	Zone 5	3 (4.1%)
Education level	Primary school	1 (1.4%)
	High school	19 (26.0%)
	Higher education	53 (72.6%)
Smoking status	Smoker	39 (53.4%)
	Non-smoker	34 (46.6%)
Type of surgery	Primary	71 (97.3%)
	Revision	2 (2.7%)
Comorbidity	Present	10 (13.7%)
	Absent	63 (86.3%)
*number (percentage)		

SS discrimination, SS TDI, ROTT, and all Stroop subtests (A-D) ($p<0.05$, Table 2). The postoperative improvement in categorical variables, assessed using McNemar's test, is presented in Table 3.

Correlation Analysis

Spearman's correlation analysis was conducted to assess the associations between NOSE, PNIF, SS-TDI, ROTT, and Stroop A–D before and after surgery. Statistically significant results are presented in Tables 4 and 5.

The impact of potential independent variables previously emphasised in the literature—specifically Cottle zones [1-3 (anterior)vs. 4-5 (posteiror)], degree of deviation (mild and moderate (non-severe) vs. severe), smoking status, and sex—on improvement in PNIF, SS olfactory, and ROTT olfactory groups was examined using binary logistic regression analysis. Among these variables, the degree of deviation had a statistically significant effect on the improvement observed in the SS and ROTT olfactory groups (Table 6). In the SS olfactory group, 80% of the patients with severe deviation experienced improvement, whereas 54% of those with mild or moderate deviation experienced similar improvement ($p<0.019$). In the retronasal olfactory group, 45% of patients with severe deviation showed postoperative improvement, whereas 73.8% of patients with mild or moderate deviation showed postoperative improvement ($p<0.019$).

Improvements in either the values or the groups of PNIF, SS TDI, and ROTT had no statistically significant effects on Stroop A–D test results (Tables 7 and 8). Similarly, factors such as education level, sex, and age were found to have no significant impact on the Stroop A-D tests (Tables 7 and 8).

Table 2. Comparison of preoperative and postoperative values of NOSE, PNIF, SS subtests (threshold, identification, discrimination, and TDI), ROTT, and Stroop tests (A-D)				
Parameter	**Preoperative Median (Min-Max)**	**Postoperative Median (Min-Max)**	**p-value**	**Effect size**
NOSE score	11 (4-18)	2 (0-14)	<0.001*	large
PNIF	70 (20-150)	100 (50-170)	<0.001*	large
SS threshold	7.5 (0-10.75)	7.5 (4.25-10.25)	0.056	small
SS identification	13 (8-16)	13 (7-16)	0.920	small
SS discrimination	13 (4-16)	14 (5-16)	<0.001*	medium
SS total	33.5 (19-41.5)	33.7(18.5-40.25)	0.003*	medium
ROTT	9 (1-13)	11 (5-13)	<0.001*	large
Stroop A	38 (24-80)	34 (23-58)	<0.001*	large
Stroop B	30 (18-70)	29 (18-70)	<0.001*	medium
Stroop C	70 (43-140)	65 (37-120)	<0.001*	large
Stroop D	41 (-8-100)	34 (2-89)	<0.001*	large

NOSE: Nasal obstruction symptom evaluation, PNIF: Peak nasal inspiratory flow, SS: Sniffin' sticks, TDI: Threshold-discrimination-identification, ROTT: Retronasal olfactory threshold test, SCWT: Stroop color-word test

*p-value calculated using the Wilcoxon Signed-Rank Test. Effect size: small: r value 0.1 to 0.3, medium: r value 0.3 to 0.5, large: r value >0.5 (37). *p<0.05

Table 3. Comparison of pre- and postoperative values of normosmic, hyposmic, cognitively healthy, and mild cognitive impairment (MCI)-suspected groups

Parameter	Preoperative Group	Postoperative Group	p-value	Effect size
Sniffin' Sticks	Normosmic: 53 (72.6%) Hyposmic: 20 (27.4%)	Normosmic: 65 (89%) Hyposmic: 8 (11%)	0.004*	small
Retronasal olfactory threshold test	Normosmic: 38 (52.1%) Hyposmic: 35 (47.9%)	Normosmic: 64(87.7%) Hyposmic: 9 (12.3%)	<0.001*	small
Stroop A	Healthy: 54 (74%) MCI-suspected: 19 (26%)	Healthy: 62 (84.9%) MCI-suspected: 11 (15.1%)	0.008*	small
Stroop B	Healthy: 56 (76.7%) MCI-suspected: 17 (23.3%)	Healthy: 62 (84.9%) MCI-suspected: 11 (15.1%)	0.070	small
Stroop C	Healthy: 64 (87.7%) MCI-suspected: 9 (12.3%)	Healthy: 66 (90.4%) MCI-suspected: 7 (9.6%)	0.500	small
Stroop D	Healthy: 45 (61.6%) MCI-suspected: 28 (38.4%)	Healthy: 61 (83.6%) MCI-suspected: 12 (16.4%)	<0.001*	small

*p-value calculated using the McNemar Test.

Effect size (Cohen's g value) : small: 1.22 to 1.86, medium: Cohen's g value 1.86 to 3.00, large: Cohen's g value >3.00 (38).

SS: Sniffin' Sticks, ROTT: Retronasal Olfactory Threshold Test, SCWT: Stroop Color-Word Test, MCI: Mild Cognitive Impairment.

*p<0.05

Table 4. Preoperative Spearman Correlation Coefficients (ρ) and corresponding p-values demonstrating statistical significance of statistically significant results

	SS TDI [ρ(p)]	NOSE [ρ(p)]	PNIF [ρ(p)]
SS TDI		-0.244 (0.038*)	0.267 (0.022*)
ROTT	0.238 (0.043*)		
Stroop A	-0.316 (0.006*)		
Stroop B	-0.282 (0.016*)	0.268 (0.022*)	
Stroop C		0.276 (0.018*)	

ρ<0.30= weak correlation 0.30≤ ρ<0.50 = moderate correlation, ρ≥0.50= strong correlation

*: p<0.05

Table 5. Postoperative spearman correlation coefficients (ρ) and corresponding p-values demonstrating statistical significance of statistically significant results

	PNIF (ρ(p))	ROTT (ρ(p))	Stroop C (ρ(p))
SS TDI		0.295 (0.011*)	-0.294 (0.012*)
NOSE	-0.445 (<0.001*)		
Stroop A		-0.292 (0.012*)	

ρ<0.30 = weak correlation 0.30≤ ρ<0.50 = moderate correlation, ρ≥0.50 = strong correlation, *p<0.05

DISCUSSION

This study showed that septoplasty in patients with NSD enhanced nasal airflow, olfaction, selective attention, information processing speed, and the capacity to reduce the disruptive impact of automatic processes.

Postoperative Recovery of Nasal Obstruction and Olfaction

Six-month postoperative measurements showed that septoplasty was successful in improving nasal obstruction and orthonasal and retronasal olfactory function. Olfactory function often improves after septoplasty because of enhanced nasal airflow[1,3,21]. However, transient olfactory loss can occur in the early postoperative phase, with gradual recovery typically occurring within 3 to 12 months[22,23]. Nonetheless, no significant changes in olfactory ability have been reported[21,23]. Data on retronasal olfaction are also limited. In our study, the incidence of retronasal hyposmia before septoplasty was higher than that of orthonasal hyposmia. Current evidence suggests retronasal olfaction is more dependent on nasal patency and airflow, which may explain why it is more severely impaired preoperatively than orthonasal olfaction[16,24]. Based on these results, the correlation between retronasal and orthonasal olfaction is unclear. For instance, Hernandez et al.[25] showed a significant correlation between PNIF and ROT but not with orthonasal olfaction, which is in contrast to our findings. Although previous research has indicated an association between nasal airflow and olfactory performance[26], PNIF may not accurately represent the airflow that reaches the olfactory cleft. Additionally, olfactory function is influenced not only by nasal airflow but also by a complex interplay of neural mechanisms, receptor activity, and central processing pathways.

One of the key findings of our study was that enhanced postoperative orthonasal and retronasal

Table 6. Effect of independent variables (cottle zone, deviation degree, gender, and smoking on changes in PNIF, SS TDI, and ROTT olfactory groups

		p	OR	95% CI intervals	
				Lower	Upper
Improvement in PNIF	**Cottle zone**	0.999	2.262	0.035	11.425
	Deviation degree	0.795	0.805	0.157	4.133
	Gender	0.359	0.343	0.035	3.371
	Smoking	0.483	0.521	0.085	3.215
Improvement in SS-TDI	**Cottle zone**	0.451	0.591	0.151	2.322
	Deviation degree	0.019*	3.901	1.245	12.223
	Gender	0.708	0.803	0.255	2.527
	Smoking	0.231	0.514	0.173	1.526
Improvement in ROTT	**Cottle degree**	0.796	0.843	0.230	3.090
	Deviation degree	0.019*	0.297	0.107	0.822
	Gender	0.686	1.256	0.416	3.796
	Smoking	0.396	1.593	0.543	4.668

*p-value was calculated using binary logistic regression analysis. *p<0.05

PNIF, Peak Nasal Inspiratory Flow; SS, Sniffin' Sticks; TDI, Threshold–Discrimination–Identification; ROTT, Retronasal Olfactory Threshold Test, OR: Odds Ratio, CI: Confidence Interval.

Table 7. Effect of Changes in PNIF, SS-TDI, and ROTT Valus on Changes in SCWT Results

		p	β	95% CI intervals	
				Lower	Upper
Improvement in Stroop A	**Improvement in PNIF**	0.292	-0.124	-0.076	0.023
	Improvement in SS-TDI	0.179	-0.161	-0.615	0.117
	Improvement in ROTT	0.249	-0137	-0.981	0.258
	Age	0.223	0.144	-0.183	0.043
Improvement in Stroop B	**Improvement in PNIF**	0.174	-0.161	-0.068	0.013
	Improvement in SS-TDI	0.629	-0.058	-0.370	0.225
	Improvement in ROTT	0.138	-0.161	-0.882	0.124
	Age	0.315	0.119	-0.139	0.045
Improvement in Stroop C	**Improvement in PNIF**	0.782	-0.033	-0.090	0.068
	Improvement in SS-TDI	0.107	-0.197	-1.059	0.105
	Improvement in ROTT	0.492	0.083	-0.643	1.325
	Age	0.183	0.158	-0.058	0.296
Improvement in Stroop D	**Improvement in PNIF**	0.654	0.053	-0.057	0.090
	Improvement in SS-TDI	0.148	-0.175	-0.945	0.145
	Improvement in ROTT	0.112	0.192	-0.177	1.668
	Age	0.056	0.234	0.003	0.331

PNIF, Peak Nasal Inspiratory Flow; SS, Sniffin' Sticks; TDI, Threshold–Discrimination–Identification; ROTT, Retronasal Olfactory Threshold Test, β:Regression Coefficient, CI: Confidence Interval

*p-value was calculated using linear logistic regression analysis.

olfactory functions correlated with the degree of NSD at various levels. The SS-TDI scores exhibited a statistically significant relationship with the severity of deviation. Specifically, among patients with severe deviation, 80% experienced an improvement in orthonasal olfactory function, compared with 54% of patients with mild or moderate deviation. Conversely, the rate of retronasal olfaction improvement was higher in patients with

Table 8. Effect of change in PNIF group, SS-TDI group, and ROTT group, education level, and gender on changes in SCWT group results					
		p	OR	95% CI intervals	
				Lower	Upper
Improvement in Stroop A group	PNIF group	00.053	0.124	0.021	0.749
	SS-TDI group	0.242	0.437	0.109	1.748
	ROTT group	0.903	0.916	0.221	3.790
	Education Level	0.379	2.017	00.423	9.624
	Gender	0.171	-0.137	0.054	1.682
Improvement in Stroop B group	PNIF group	0.192	0.335	0.065	1.734
	SS-TDI group	0.737	1.202	0.411	3.514
	ROTT group	0.324	0.590	0.207	1.684
	Education Level	0.834	0.880	0.266	2.912
	Gender	0.393	0.614	0.201	1.879
Improvement in Stroop C group	PNIF group	0.710	0.641	0.061	6.686
	SS-TDI group	0.142	0.368	0.097	1.395
	ROTT group	0.137	0.360	0.094	1.382
	Education Level	0.599	1.496	0.333	6.716
	Gender	0.362	1.931	0.469	7.958
Improvement in Stroop D group	PNIF group	0.089	0.222	0.039	1.260
	SS-TDI group	0.193	0.444	0.131	1.508
	ROTT group	0.693	0.779	0.226	2.687
	Education Level	0.999	1.001	0.250	4.006
	Gender	0.455	1.635	0.450	5.935

PNIF: Peak Nasal Inspiratory Flow, SS: Sniffin' Sticks, TDI: Threshold-discrimination-identification, ROTT: Retronasal olfactory threshold test, OR: Odds ratio, CI: Confidence interval

p-value was calculated using binary logistic regression analysis.

mild or moderate deviations (73.8%) than in those with severe deviations (45%). This suggested that although a correction in severe deviations can result in a substantial increase in orthonasal airflow, milder cases appear to have a better retronasal olfactory function[16].

Another remarkable result of our research was the absence of any association between PNIF recovery and the Cottle zones similar to the research by Şahin[8], who found enhanced PNIF values across various Cottle zone groups but did not observe any significant differences between those.

Our study did not reveal significant effects of gender, age, or smoking on postoperative improvements in PNIF and olfaction. Although some studies have reported that women exhibit higher olfactory sensitivity than men[19,20] and that smoking can negatively affect the olfactory epithelium or olfactory bulb volume[17,18], sex and smoking have not been reported to significantly improve PNIF in other studies, as well[8,27,28.]. However, postoperative satisfaction after septoplasty has been shown to decline with age[29].

Postoperative Recovery of Cognitive Fuctions

The results of our study also indicated enhanced cognitive performance as assessed by the SCWT The postoperative reductions in completion times across all SCWT components (A-D) suggest improvements in information processing speed, selective attention, and cognitive control. Notably, subgroup analyses indicated statistically significant improvements in SCWT A and D scores, particularly among participants with suspected MCI. This finding is especially pertinent to SCWT-D, as this component primarily reflects resistance to interference and the inhibition of automatic responses, which are crucial aspects of executive functioning. Consequently, the observed improvement could indicate a clinically meaningful increase in cognitive control owing to the strong association between interference regulation, cognitive flexibility, and inhibitory mechanisms.

SCWT-C is widely recognised as a fundamental condition used to elicit the Stroop effect. In this subtest, participants were required to identify the ink colour instead of reading the associated word, which required them to suppress their automatic reading tendencies and to engage in higher-order executive processes. From this perspective, the postoperative correlations between olfactory assessments and SCWT performance, especially the relationship between SS scores and SCWT-C, could imply a connection between olfactory dysfunction and cognitive impairment.

M emorisation tasks and practice effects are inherent in cognitive assessments such as the Stroop test and must be taken into account when interpreting results. Although the test demonstrates high levels of consistency and reliability across repeated administrations, with practice effects predominantly observed when assessments occur at very short intervals[30,31], these effects are expected to be mitigated by the six-month interval used in this study. Nonetheless, even with extended intervals, repeated exposure to the same cognitive paradigm may introduce bias. Additionally, the absence of a control group presents a significant limitation. While our hypothesis was that septoplasty would produce postoperative increases in nasal airflow, olfaction, and performance on the Stroop test, including a control group would have facilitated differentiation between improvements attributable to surgical intervention, spontaneous recovery, or residual learning effects over time. Yet, establishing such a control group was challenging, if not impossible, given the difficulty of precisely matching patients on variables such as age, sex, educational background, profession, hobbies, and baseline cognitive function—all of which could influence cognitive task performance.

Link Between Cognition and Olfaction & Nasal Airflow

The interplay between olfactory function and cognitive processes is underpinned by robust anatomical and functional connections between the olfactory system and various cognitive networks. Central to this relationship are brain regions, including the prefrontal cortex, hippocampus, and entorhinal cortex, which together integrate olfactory perception with attention, memory, and decision-making. Notably, olfactory stimulation induces oscillatory brain activity across distinct frequency bands, with beta and gamma oscillations being particularly significant in odour-related cognitive tasks. These oscillatory patterns, observed in the piriform cortex, entorhinal cortex, and hippocampus, correlate with proficient performance in olfactory-centric cognitive activity. This implies that multiple neural networks engage in a coordinated fashion during the processing of olfactory information highlighting the importance of olfactory function in cognitive health[32].

To examine the distinct mechanisms of olfactory processing, it is essential to differentiate orthonasal from retronasal olfaction, although both are mediated by the same olfactory receptors. Orthonasal olfaction predominantly drives external behavioural responses, whereas retronasal olfaction is intricately associated with internal perception, reward processing, and taste integration, engaging the amygdala and insular cortex[33]. Recent research by Chen et al.[34] demonstrated a notable association between psychophysical olfactory assessment scores and white matter abnormalities in individuals with olfactory dysfunction, highlighting the integration of the olfactory network with cognitive regions of the brain. Notably, retronasal olfaction exhibited a stronger correlation with white-matter connectivity, which may reflect simultaneous gustatory processing. However, the underlying neural mechanisms that facilitate the interaction between retronasal olfaction and broader brain functions are poorly understood and warrant further investigation[35].

In terms of the association between nasal patency and cognition, Price and Eccles[36], for instance, observed that reticular activation allows airflow through a single nostril, which enhances cortical arousal and bilateral brain activity, specifically, the activity is most significantly observed in the contralateral hemisphere. This finding demonstrates that nasal airflow can affect cognitive function by interacting with the reticular formation. During breathing, the gamma and beta oscillations, synchronised with olfactory processing, occur in the piriform cortex, hippocampus, and amygdala. These oscillations vanish during mouth breathing, indicating that nasal respiration is essential for cognitive processes[32,37].

Although the literature has indicated potential anatomical and physiological links among olfaction, nasal airflow, and cognition, our regression analysis — unlike our correlation analysis, which yielded partial correlations among the three measures —did not reveal any significant effect of PNIF, SS-TDI, and ROTT on Stroop performance. Therefore, we could not ascertain whether the observed cognitive improvements were primarily attributable to enhanced nasal airflow or to olfactory function, although both factors may have contributed. Similarly and more interestingly, while it is important to acknowledge the potential influence of advanced age and low educational attainment[11,38] on Stroop test outcomes, our regression analysis did not yield statistically significant results in this regard either.

Some critical issues should be considered. Our results may be influenced by heterogeneous participant characteristics and non-linear relationships among the variables. Additionally, confounding factors such as sleep quality and obstructive sleep apnoea were not assessed preoperatively, which may have limited our analysis. N asal obstruction primarily impairs cognitive performance through sleep fragmentation, nocturnal hypoxia, and daytime sleepiness. Although our volunteers were screened for obstructive sleep apnoea and other sleep disorders that could affect cognitive capacity before participating in the study, and those with suspected disorders were excluded, the lack of validated diagnostic tools, such as polysomnography and the Pittsburgh Sleep Quality Index, should be acknowledged as a limitation. We did not perform objective tests of nasal patency, airflow, olfaction, or neurological function, such as rhinomanometry, acoustic rhinometry, electro-olfactography, and functional magnetic resonance imaging, due to technical limitations. Additionally, our cohort was relatively young, which can affect the generalisability of the results. However, this situation was beyond our control. Patients were included during the relevant period based solely on the inclusion and exclusion criteria.

This pilot study evaluated the cognitive effects of septoplasty using the Stroop test and makes a significant contribution to scientific knowledge. However, our results did not demonstrate a direct mechanistic link among enhanced cognition, orthonasal and retronasal olfactory function, and airflow, which may be due to complex interactions among these three factors and to the possible confounding factors noted as limitations. Further research is warranted to elucidate these relationships and clarify the implications of septoplasty for cognitive health.

CONCLUSION

This study demonstrated that septoplasty among individuals with NSD improved nasal airflow, orthonasal and retronasal olfaction, selective attention, information-processing speed, and ability to mitigate the disruptive effects of automatic processes. At Six months postoperatively, septoplasty demonstrated efficacy according to NOSE, PNIF, SS, and ROTT outcomes. Notably, the correlations observed among these parameters in this study indicated concordance among the measures of postoperative success.

However, because PNIF, SS TDI, and ROTT did not show a statistically significant impact on cognitive improvement, our results could not establish a direct causal relationship among enhanced cognitive function, nasal airflow, and relief from olfactory impairment.

Ethics

Ethics Committee Approval: This study was a prospective clinical trial conducted in the Department of Otorhinolaryngology at Dokuz Eylül University between January 2024 and January 2025. The Institutional Review Board of Dokuz Eylül University (decision number: 2024/03-21, dated: 17.01.2024).

Informed Consent: Informed consent was obtained from all participants.

Footnotes

Author Contributions

Surgical and Medical Practices: S.H., A.Ç.Ç., M.C.E., Concept: S.H., A.Ç.Ç., H.E.E., Ö.A., M.C.E., Design: S.H., A.Ç.Ç., H.E.E., Ö.A., M.C.E. , Data Collection and/or Processing: S.H., A.Ç.Ç., H.E.E., Ö.A., M.C.E., Analysis or Interpretation: S.H., A.Ç.Ç., H.E.E., Ö.A., M.C.E., Literature Search: S.H., A.Ç.Ç., H.E.E., Ö.A., M.C.E., Writing: S.H., A.Ç.Ç., H.E.E., Ö.A., M.C.E.

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