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The effect of nasal septal deviation on the volumes of the paranasal sinuses

Nazal septum deviyasyonunun paranazal sinüslerin hacimleri üzerine etkisi

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ABSTRACT

Objectives: This study aims to determine the effect of nasal septal deviation (NSD) on the volumes of the paranasal sinuses, also considering the sex of the patients.

Patients and Methods: One hundred and eighty-four patients (95 females, 89 males; mean age: 32.4±12 years; range, 17 to 69 years) with NSD were included in the retrospective study between January 2018 and March 2020. Patients were grouped according to the radiologically measured NSD angle: Group 1, <90° (mild deviation); Group 2, 90-150° (moderate deviation); Group 3, >150° (severe deviation). The volumes of the frontal, maxillary, and sphenoid sinuses on the deviated and opposite sides were calculated and compared.

Results: There was no statistically significant difference between the deviated- and opposite-side volumes of the frontal, maxillary, and sphenoid sinuses of the female patients in all three groups and male patients in Groups 1 and 3 (p>0.05). Maxillary sinus volume on the deviated side was smaller than the opposite side in male patients in Group 2 (p=0.028). The frontal sinus volume on the deviated side and maxillary sinus volume on the opposite side of the male patients in Group 2 were higher than Groups 1 and 3 (p=0.046, p=0.017).

Conclusion: Nasal septal deviation does not affect the volumes of the paranasal sinuses in females. Moderate NSD in males may affect the volumes of frontal and maxillary sinuses.

Keywords: Computed tomography, nasal septal deviation, paranasal sinus volume, paranasal sinus, three-dimensional imaging.

ÖZ

Amaç: Bu çalışmada nazal septum deviasyonun (NSD) paranazal sinüslerin hacimleri üzerine olan etkisinin, hastaların cinsiyeti de dikkate alınarak belirlenmesi amaçlandı.

Hastalar ve Yöntemler: Nazal septum deviasyonu olan 184 hasta (95 kadın, 89 erkek; ort. yaş: 32.4±12 yıl; dağılım, 17-69 yıl) Ocak 2018 ve Mart 2020 tarihleri arasında retrospektif çalışmaya dahil edildi. Hastalar radyolojik olarak ölçülen NSD açısına göre gruplandırıldı: Grup 1, <90° (hafif deviasyon); Grup 2, 90-150° (orta deviasyon); Grup 3, >150° (ileri deviasyon). Deviasyon olan taraf ile karşı taraftaki frontal, maksiller ve sfenoid sinüslerin hacimleri karşılaştırıldı.

Bulgular: Her üç gruptaki kadın hastalar ile Grup 1 ve 3'teki erkek hastaların frontal, maksiller ve sfenoid sinüs hacimlerinin, deviasyon tarafı ile ve karşı taraf arasında istatistiksel olarak anlamlı fark yoktu (p>0.05). Grup 2'deki erkek hastalarda deviasyon tarafındaki maksiller sinüs hacmi karşı tarafa göre daha küçüktü (p=0.028). Grup 2'deki erkek hastaların deviasyon tarafındaki frontal sinüs hacmi ve karşı taraftaki maksiller sinüs hacmi Grup 1 ve 3'e göre daha yüksekti (p=0.046, p=0.017).

Sonuç: Nazal septal deviasyon, kadınlarda paranazal sinüslerin hacimlerini etkilememektedir. Erkeklerde orta derecede NSD, frontal ve maksiller sinüslerin hacimlerini etkileyebilir.

Anahtar sözcükler: Bilgisayarlı tomografi, nazal septal deviasyon, paranazal sinüs, paranazal sinüs hacmi, üç boyutlu görüntüleme.

The four paired paranasal sinuses, namely frontal, maxillary, ethmoid, and sphenoid sinuses, are complicated anatomical structures that have profoundly diverse dimensions and morphologies. These morphological variations present themselves in different age and sex populations, and they can be

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observed on both sides of the same individual.[1] The assessment of the radiological anatomy of the paranasal sinuses is a crucial step in patients who will undergo functional endoscopic sinus surgery or transsphenoidal pituitary surgery for these anatomical variations. Paranasal computed tomography (CT) is a valuable imaging modality for the elaborate assessment of the anatomical structures of the paranasal sinuses and the detection of these variations.

Although the precise mechanisms in the development of the paranasal sinuses are not completely elucidated, it has been stated that nasal airflow and nasopharyngeal positive air pressure are two important factors in the development of these structures.[2] Nasal septal deviation (NSD), which is highly prevalent, is a major cause of nasal obstruction and increases upper airway resistance, decreases nasal airflow, and leads to disruption of the gaseous exchange.[3,4] Although there are many studies in the literature investigating the effects of NSD on the volumes of the paranasal sinuses, it has not yet been fully elucidated whether sex affects this condition. Hence, this study was conducted to investigate the effect of the NSD on the pneumatization of the frontal, maxillary, and sphenoid sinuses, considering the sex of the patients.

PATIENTS AND METHODS

The paranasal CT scans and clinical records of the patients who were admitted to the Otolaryngology Department of the Kırklareli Training and Research Hospital between January 2018 and March 2020 were retrospectively analyzed. Patients who had nasal polyposis, S-shaped septal deviation, concha bullosa, signs of sinusitis, craniofacial deformities, history of maxillofacial trauma, and history of previous sinonasal surgery/systemic diseases that could affect the anatomical structures of the paranasal sinuses were excluded from the study. After exclusion, 184 patients (95 females, 89 males; mean age: 32.4±12 years; range, 17 to 69 years) were enrolled in the study.

All paranasal CT examinations were performed by the same CT scanner (Siemens Somatom go.Now; Siemens Healthcare GmbH, Forcheim, Germany) with the following parameters of acquisition: 130 kV, 80 mAs, 0.75-mm slice thickness, and reconstruction filters of H40 smooth for soft tissues and H70 sharp for bone. The segmentation and three-dimensional volumetric assessment of the bilateral frontal, maxillary, and sphenoid sinuses were performed with the ITK-SNAP 3.8.0 open-source software (Figures 1-3). The ITK-

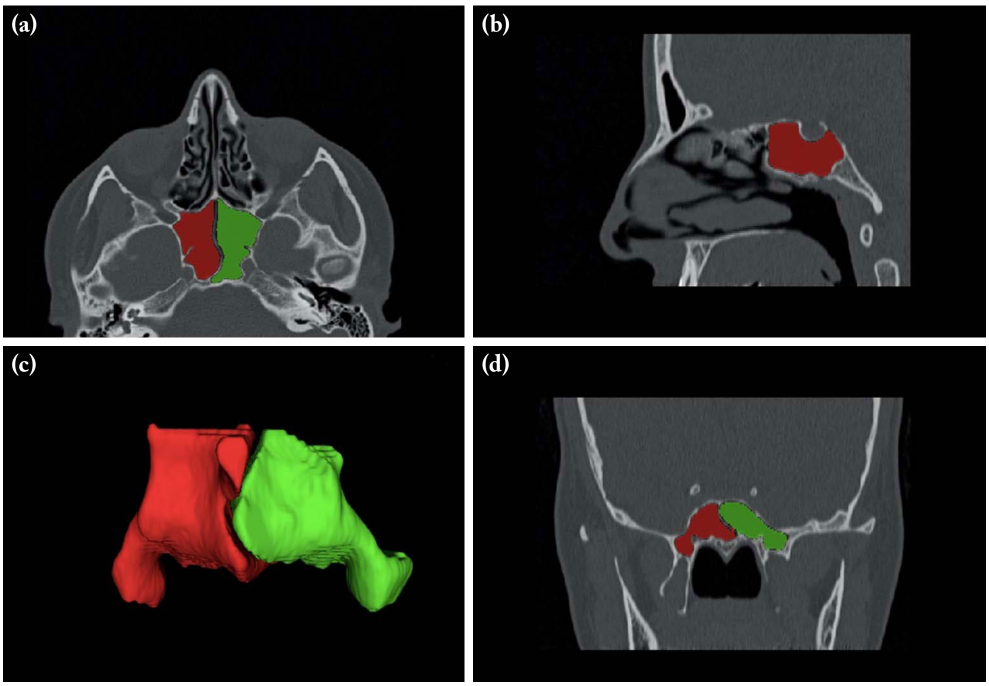

Figure 1. An example of the segmentation of sphenoid sinuses through the ITK-SNAP software. **(a, b, d)** Visualization of the computed tomography scan according to transvers, sagittal, and coronal axes. **(c)** Visualization of the three-dimensional model obtained by segmentation [right (red) and left (green) sphenoid sinuses].

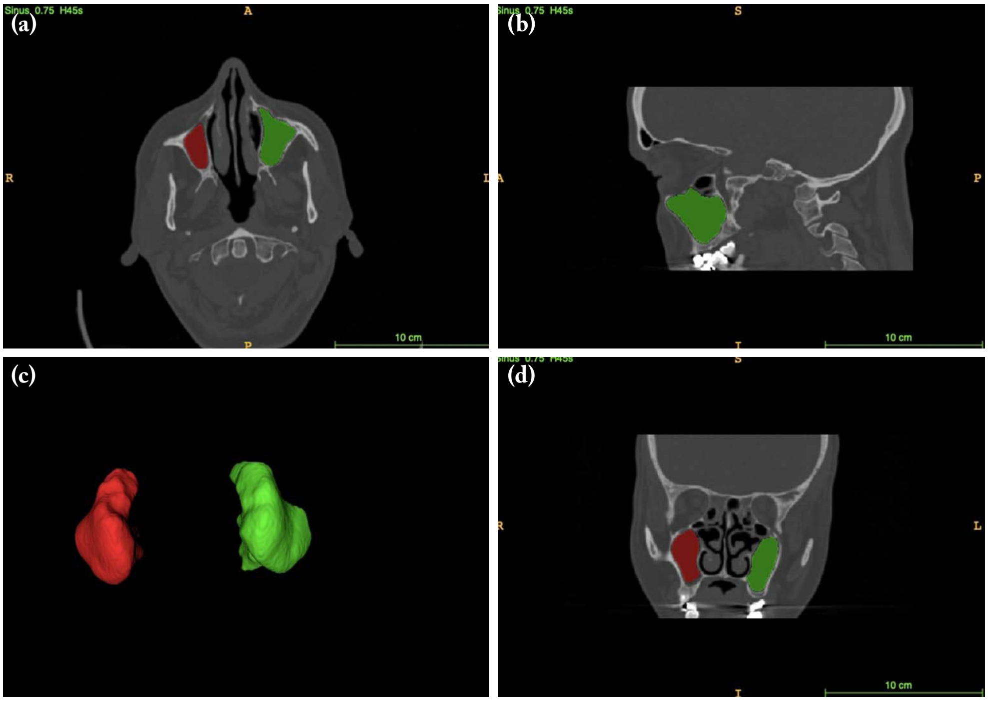

Figure 2. An example of the segmentation of maxillary sinuses through the ITK-SNAP software. **(a, b, d)** Visualization of the computed tomography scan according to transvers, sagittal, and coronal axes. **(c)** Visualization of the three-dimensional model obtained by segmentation [right (red) and left (green) maxillary sinuses].

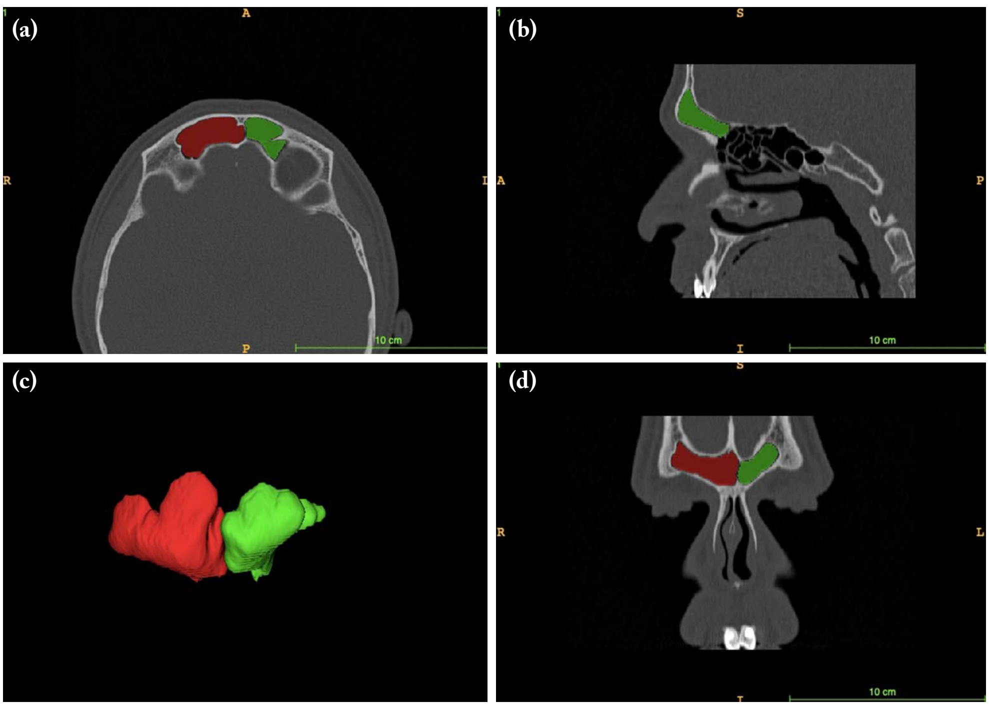

Figure 3. An example of the segmentation of frontal sinuses through the ITK-SNAP software. **(a, b, d)** Visualization of the computed tomography scan according to transvers, sagittal, and coronal axes. **(c)** Visualization of the three-dimensional model obtained by segmentation [right (red) and left (green) frontal sinuses].

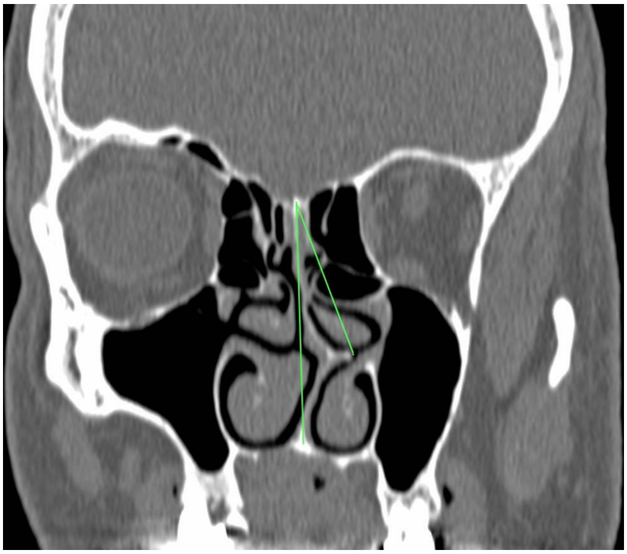

Figure 4. The measurement of the nasal septal deviation angle.

SNAP software allows semiautomatic segmentation of the paranasal sinuses according to the grey levels, creates three-dimensional models, and calculates volumes of these models.[5] This software was validated and is used widely for the volumetric assessment of the paranasal sinuses.[6,7] For the creation of the three-dimensional model and volumetric assessment, an automatically increasing "seed" was placed in each sinus to be measured, penetrating the entire air space within the boundaries of the bone walls. All volumetric measurements were repeated twice with 14-day intervals, and the mean of the measured values was used.

The degree of the NSD was measured by the evaluation of coronal CT images. The angle between the two drawn linear lines, one from the crista galli to the most deviated part of the nasal septum and the other one from the maxillary spine to the crista galli, was determined as the deviation angle (Figure 4). According to the NSD grading system defined by Elahi et al.,[8] patients were divided into three groups:[9,10] Group 1 included patients with an NSD angle <9° (mild deviation), Group 2 included patients with an NSD angle between 9-15° (moderate deviation), and Group 3 included patients with an NSD angle >15° (severe deviation).

Statistical analysis

Data were analyzed using SPSS version 15.0 software (SPSS Inc., Chicago, IL, USA). Data were expressed as mean ± standard deviation (SD) or median (interquartile range) as appropriate. One-way analysis of variance and the Kruskal-Wallis test were used for the analyses of more than two independent groups. A paired t-test and the Wilcoxon test were used for dependent group analyses. Student's t-test was used to compare dependent groups, and the Mann-Whitney U test was used for independent groups. A *p*-value <0.05 was considered statistically significant.

RESULTS

The direction of the NSD was left-sided in 92 (50%) patients and right-sided in 92 (50%) patients (Table 1). The deviation angles of the nasal septum were found to range between 4.1 and 30°, with a mean value of 12±5.2. Group 1 included 61 patients [31 (50.8%) females, 30 (49.2%) males] with a mean NSD angle of 6.6±1.3 (range, 4.1 to 8.8). Group 2 included 63 patients [33 (52.4%) females, 30 (47.6%) males] with a mean NSD angle of 11.4±1.4 (range, 9.1 to 14.8). Group 3 included 60 patients [31 (51.7%) females, 29 (48.3%) males] with a mean NSD angle of 18.2±2.9 (range, 15.1 to 30). No significant difference was

Table 1
Demographic data of the study population

	Group 1 (n=61)			Group 2 (n=63)			Group 3 (n=60)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			32.4±12.1			31.8±12.0			33.3±12.2	0.756
Sex										0.985
Male	30	49.2		30	47.6		29	48.3		
Female	31	50.8		33	52.4		31	51.7		
Direction of the NSD										0.737
Right	29	47.5		34	54.0		29	48.3		
Left	32	52.5		29	46.0		31	51.7		
Degree of the NSD			6.6±1.3			11.4±1.4			18.2±2.9	<0.001

SD: Standard deviation; NSD: Nasal septal deviation.

Table 2
The mean frontal, maxillary, and sphenoid sinus volumes of the female and male patients

	Females (n=95)	Males (n=89)	
	Mean±SD	Mean±SD	*p*
Mean frontal sinus volume (cm³)	3.1±2.1	5.1±3	<0.05
Mean maxillary sinus volume (cm³)	13.7±3.9	17.3±5.1	<0.05
Mean sphenoid sinus volume (cm³)	4.4±2.6	5.8±3	<0.05

SD: Standard deviation.

Table 3
Comparison of the frontal, maxillary, and sphenoid sinus volumes of the male and female patients according to the NSD group

	Group 1 (n=30)	Group 2 (n=30)	Group 3 (n=29)	
	Mean±SD	Mean±SD	Mean±SD	*p**
Male patients				
Frontal sinus volume (cm³)				
Deviated side	4.67±3.42	6.28±3.66	4.42±2.55	0.046
Contralateral side	4.5±2.32	5.98±4.13	4.53±3.08	0.201
p#	0.723	0.600	0.836	
Maxillary sinus volume (cm³)				
Deviated side	15.81±4.59	18.56±4.95	17.03±4.39	0.078†
Contralateral side	16.33±5.21	19.88±5.65	16.58±4.80	0.017†
p#	0.133	0.028	0.355	
Sphenoid sinus volume (cm³)				
Deviated side	5.42±2.75	6.52±3.70	5.49±3.44	0.473
Contralateral side	5.68±3.12	5.35±3.24	6.41±3.18	0.346
p#	0.758	0.192	0.312	
Female patients				
Frontal sinus volume (cm³)				
Deviated side	3.41±2.08	2.66±1.78	3.66±1.92	0.107
Contralateral side	2.98±1.99	3.12±2.57	2.92±1.91	0.976
p#	0.266	0.406‡	0.109	
Maxillary sinus volume (cm³)				
Deviated side	13.22±4.11	13.80±3.84	14.12±3.59	0.530
Contralateral side	13.29±3.97	13.63±4.40	14.29±3.38	0.289
p#	0.797	0.556	0.624	
Sphenoid sinus volume (cm³)				
Deviated side	5.06±2.58	4.29±2.53	3.84±2.63	0.135
Contralateral side	4.77±3.37	4±2.22	4.82±2.35	0.519
p#	0.709	0.612	0.149	

NSD: Nasal septal deviation; SD: Standard deviation; # Paired t-test; * Kruskal-Wallis H test; † One-way ANOVA test; ‡ Wilcoxon Signed-Rank test.

observed in terms of age, sex, and direction of the NSD between the three groups.

The mean frontal sinus volume (FSV), maxillary sinus volume (MSV), and sphenoid sinus volume (SSV) of the female and male patients are demonstrated in Table 2, and mean volumes of all three sinuses were higher in male patients than in female patients ($p<0.05$).

The mean FSV, MSV, and SSV of the male and female patients according to the NSD group is demonstrated in Table 3. In male patients of Group 2, the deviated side MSV was statistically smaller than the opposite side (p=0.028), and the deviated side FSV and the opposite side MSV were statistically higher than in Groups 1 and 3 (p<0.05, Table 3).

DISCUSSION

Nasal septal deviation, which can be encountered in up to 65% of the general population, may significantly affect the dimensions, shapes, and morphologies of the sinonasal anatomical structures.[11] It has been reported that the incidence of the Onodi cells, concha bullosa, and anterior clinoid pneumatization was higher in patients with NSD.[12] It may cause inflammation of the paranasal sinuses by affecting the structure of the ostiomeatal complex, disturbing normal mucociliary clearance, and changing nasal airflow.[13]

Frontal sinuses are air-filled structures originating embryologically from the ethmoid sinuses. Frontal sinuses become radiologically visible at the age of six and reach their final dimensions at the age of 15.[7,14] The size and the shape of these structures vary widely among individuals, even in homozygotic twins, and it has been stated that the mean value of the FSV varies between 0 and 37 cm^3.[9,15] In the studies carried out to research the impact of NSD on the FSV, it has been reported that mild, moderate, and severe NSDs, as they were graded in our study, do not affect the FSV.[9,16] According to our outcomes, no significant difference was observed between deviated and opposite-side FSV in both sexes of all three groups. The deviated side FSV of the male patients in Group 2 was statistically higher than the deviated side FSV of male patients of Groups 1 and 3.

The maxillary sinuses are the largest paranasal sinuses and have important functions, such as decreasing the weight of the skull, humidification/warming of the inspired air, and improvement of speech resonance.[8] The maxillary sinus development has two acceleration phases; the first one starts at birth and continues to the age of three, the second one starts at the age of seven and continues to the age of 12, and the adult size is reached at the age of 15.[17,18] The dimension of the maxillary sinus varies considerably, and previous studies have reported that the mean MSV could change between 11.1±4.5 and 23.0±6.7 cm^3.[19] Karataş et al.[9] used the same grading system used in the current study to the determine the septal deviation degree and reported that the MSV tends to be higher on the deviated side in moderate septal deviations, and no significant difference was observed in the mild and severe septal deviation groups. Kalabalik and Tarım Ertaş[1] concluded that the MSV tends to be smaller on the side of the NSD in patients with NSD >9°, but there was no significant difference in patients with mild NSD. Kapusuz Gencer et al.[10] and Orhan et al.[18] reported that MSV tends to be smaller on the side of the NSD, but they did not investigate the effect of the NSD degree. According to our findings, MSV on the opposite side of male patients of the moderate septal deviation group (Group 2) was statistically higher than the deviated side. This observation could be attributed to the location of the NSD. In a recently conducted study, Kalsotra et al.[20] reported that patients with NSD causing blockage in the ostiomeatal complex had smaller maxillary sinuses compared to the side opposite to the deviation. Therefore, further studies investigating both the location and degree of NSD are necessary to draw more precise conclusions.

The sphenoid sinuses have a close relationship with vital anatomical structures, such as the optic nerve, internal carotid artery, Vidian nerve, and the pituitary gland, and care should be exercised when performing a functional endoscopic sinus surgery or transsphenoidal pituitary surgery.[21] The morphology and the dimensions of sphenoid sinuses vary considerably between individuals, and sphenoid sinus pneumatization is classified as asconchal, presellar, sellar, and postsellar types.[22] In a recently conducted study, Gibelli et al.[6] demonstrated that the mean SSV varies between 4.2 and 4.6 cm^3 for females, and it varies between 4.7 and 5.2 cm^3 for males. In a study conducted to investigate the relationship between NSD and SSV, it was reported that the SSV on the deviated side was significantly smaller than the opposite side.[23] However, Sahin et al.[16] could not find a difference between the SSV of the deviated and opposite sides. The results obtained in the current study revealed that no significant difference was observed between the deviated- and opposite-side SSV for all three groups of female and male patients.

The development of paranasal sinuses and nasal structures may differ depending on sex in the childhood period, and these differences could affect the adult shape and configuration of the sinuses. Two studies in the literature reported that the volumes of the frontal, maxillary, and sphenoid sinuses tend to be higher in males than in females.[1,6] Our results were in concordance with the literature, and the mean FSV, MSV, and SSV of the males were higher than females. A study conducted to investigate the postnatal growth pattern of the maxillary sinus reported that sex-related differences occur over the age of eight years.[24] On the other hand, a study investigating the age-related differences of NSDs revealed that NSD is more common in older children, particularly those over five years of age.[25] Nasal septal deviation, which occurs during the rapid growth phase of the paranasal sinuses, may have a significant effect on the adult size of the sinuses. Further studies are needed to understand the impact of NSD on the development of the paranasal sinuses, specifically in the pediatric population.

The primary limitation of the current study is its relatively small population size. Another limitation concerns the determination of whether the location of nasal septal deviation affects paranasal sinus volume. Further research, involving larger sample sizes and focused investigation into the location of the septal deviation, is necessary to obtain more reliable results.

In conclusion, the presence of NSD does not affect the volumes of the frontal, maxillary, or sphenoid sinuses in female patients. In male patients with moderate septal deviation, the deviated-side MSV is smaller than the contralateral side. Frontal sinus volume on the deviated side and MSV on the contralateral side tend to be higher in male patients with moderate septal deviation than in male patients with mild and severe deviations.

Ethics Committee Approval: The study protocol was approved by the Kirklareli University Local Ethics Committee (date: 20.07.2020, no: 247/4. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Because of this is a retrospective study informed consent is not required.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: All authors contributed equally to the article.

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