

ISSN:

2542-2758 (Print) 2542-2804 (Online)

ARTICLE INFO:

Received Date: 13 April, 2025

Accepted Date: 21 July, 2025

Published Date: 31 August, 2025

KEYWORDS:

Anatomy, Anatomic variations, Computed tomography, Maxillary Sinus, Nasal Septum Deviation, Nasal Septum

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Access the article online



DOI: 10.62065/bjhs689

CITATION:

Khatun S, Timsinha S, Gautam M, Khanal T. Anatomical Variants of Deviated Nasal Septum and Its Association with Maxillary Sinus Volume. 2025; 10 (2): 23-28.

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Anatomical Variants of Deviated Nasal Septum and Its Association with Maxillary Sinus Volume

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Introduction: Deviated Nasal Septum (DNS) is among the most frequently encountered anatomical variations of the nasal cavity, yet its clinical significance particularly in relation to maxillary sinus morphology and impact on adjacent sinus structures remains debatable.

Objectives: This study aimed to determine the prevalence and subtype distribution of DNS using Mladina's classification, examine its association with age and gender, and evaluate whether DNS laterality influences maxillary sinus volume.

Methodology: A descriptive cross-sectional study was conducted on 222 patients who underwent high resolution computed tomography (HRCT) scan of the nose and paranasal sinuses. DNS types and laterality were classified according to Mladina's criteria. Maxillary sinus volumes were measured bilaterally, and their relationship with DNS type and side was statistically analyzed.

Results: DNS was identified in 49.5% of the subjects, with a higher prevalence in males (60.9%) and in the 18–25 age group (40.9%). Type 2 (33.6%) and type 5 (28.2%) were the most common types observed. Right-sided deviations were more frequent overall. No statistically significant association was observed between laterality of DNS and maxillary sinus volume. Although gender-based differences in sinus dimensions were observed, they did not correlate significantly with DNS.

Conclusion: While DNS is a common anatomical variation with distinct patterns in age, gender, and type, it does not appear to have a significant impact on influence maxillary sinus volume. These findings highlight the importance of considering DNS as part of a broader anatomical assessment, particularly when evaluating patients with sinonasal complaints.

Introduction

The nasal septum is a central cartilaginous and bony structure that divides the nasal cavity into two compartments and plays a vital role in airway regulation, nasal physiology, and mucociliary function. Deviated Nasal Septum (DNS) refers to an alteration in the normal alignment of this septum and represents one of the most common anatomical variations of the nasal cavity, with prevalence rates reported to range between 20% and 79% across different populations.¹⁻³

DNS can be congenital or acquired and is commonly associated with nasal obstruction, alteration in airflow dynamics, and chronic rhinosinusitis.^{4,5} While DNS

is widely acknowledged in radiological and surgical evaluations, its actual clinical significance remains controversial. Some studies have suggested that DNS alone may not be a sufficient etiological factor for sinonasal disease, while others propose that specific types or severities of deviation can contribute to pathophysiological outcomes.^{6,7}

Mladina's classification system, which categorizes septal deviations into seven distinct types based on their morphology and location, has provided a systematic framework for evaluating DNS.⁸ The Mladina classification system was employed in this research because of its comprehensive and organized method for classifying septal deviations according to clinical presentation and anatomical structure. This classification has been extensively referenced and utilized in radiological and surgical research for its capability to standardize results and inform treatment strategies. Few studies have explored the clinical and anatomical implications of these DNS subtypes in detail, particularly in relation to maxillary sinus volume - a parameter of interest in assessing sinus ventilation and drainage.

Moreover, variations in the prevalence and characteristics of DNS with respect to demographic factors such as age and gender remain inconclusive. Several studies have reported a higher prevalence of DNS among males and in younger age groups,⁹⁻¹¹ while others have found no significant demographic correlations.

The association of DNS laterality with the adjacent maxillary sinus volume also varies in various studies. Some studies have reported decreased sinus volume on the side of deviation, suggesting compromised drainage or developmental asymmetry,^{12,13} whereas others have failed to identify a significant relationship.⁶ In light of these gaps, the present study was undertaken to determine the prevalence and morphological patterns of DNS using Mladina's classification, evaluate the association of DNS with demographic factors such as age and gender and assess whether the laterality of DNS is associated with volumetric changes in the maxillary sinus using computed tomography (CT) imaging.

Methodology

A descriptive, cross-sectional study was conducted in Department of Radiology at Nobel Medical College Teaching Hospital between July, 2023 and July, 2024. Ethical clearance letter was obtained from Institutional Research Committee of Nobel Medical College Teaching Hospital prior to data collection. Written informed consent was acquired from all patients before data collection. The study included adult patients (age ≥ 18 years and above) who underwent high-resolution computed tomography (HRCT) scans of the nose and paranasal sinuses for various clinical indications. HRCT is regarded as the gold standard for assessing sinonasal anatomy in both diagnostic and preoperative planning scenarios, provides comprehensive bony detail, allowing for precise evaluation of septal deviation types according to Mladina's classification and accurate sinus volume measurement. Participants with a history of nasal injury, prior nasal surgery, or sinonasal tumors were not included in the

study.

The minimum sample size was obtained using the formula for prevalence studies [$n = Z^2 p(1-p)/d^2$] where; n = required sample size; Z = Z-score (1.96 for 95%), p = prevalence of DNS (64.5%), d = error margin (5%). The minimal required sample obtained was 352. Adjusting for finite population per year (600), the calculated sample size was 222.

Participants were selected through convenience sampling from patients attending the radiology department of this tertiary care center. Demographic data, including age, gender, and medical history, were collected. HRCT scans of the nose and paranasal sinuses acquired from Siemens somatom 128-slices CT scanner were evaluated to assess the presence and types of DNS using Mladina's classification, and to calculate maxillary sinus volumes using specialized volumetric software (Siemens syngo workstation). Sinus volume was assessed using HRCT images obtained in axial, coronal, and sagittal views. The volume was determined utilizing a semi-automated region-of-interest (ROI) tracing tool found in the radiology software. The boundaries of each sinus were drawn by hand on sequential slices, and the software calculated the overall volume based on slice thickness and outlined area. This technique offers dependable volumetric assessment and has been corroborated in earlier anatomical research. Every HRCT scan was examined and interpreted by one senior radiologist expertise in head and neck imaging. This was executed to ensure uniformity and minimize differences in interpretation among observers. To reduce bias, the radiologist was unaware of the clinical history and symptoms of the patients during the interpretation process. Established protocols were adhered to throughout the image acquisition and reporting process. Utilizing a single assessor also minimized inter-observer bias. Furthermore, instances with low-quality images or previous sinonasal surgeries were omitted to prevent confounding variables.

Maxillary sinus volumes were measured and analyzed in relation to the side of DNS deviation. DNS was categorized according to Mladina's classification in the following way:⁸

Type 1 unilateral vertical ridge at the nasal valve area but no interference with the function of the nasal valve.

Type 2 resembles type 1 but involves more significant blockage and disruption of the nasal valve.

Type 3 unilateral vertical ridge at the head level of the middle turbinate.

Type 4 specifies two crests, one at the level of the middle turbinate's head and another on the opposite side in the valve area, disrupting the functions.

Type 5 Unilateral ridge at the base of the septum; the opposite side of the septum remains straight.

Type 6 Unilateral sulcus at caudal ventral part of the septum and ridge at other side accompanying asymmetry of the nasal cavity.

Type 7 Mix of types from 1 to 6.

Statistical analysis was performed using SPSS version 25. Descriptive statistics were used to summarize the data. Independent t-tests were used to assess the association of maxillary sinus volume with DNS laterality and gender. Pearson correlation was used to examine the relationship between maxillary sinus volume and age. A p-value <0.05 was considered statistically significant.

Results

A total of 222 patients underwent CT scan analysis, comprising 117 (52.7%) males and 105 (47.3%) females. The age range was 18 to 84 years, with a mean of 34 ± 14.9 years.

Deviated nasal septum (DNS) was identified in 110 patients, yielding a prevalence of 49.5%. DNS was more frequent in males (n=67, 60.9%) than females (n=43, 39.1%). Among those with DNS, the most common variant was Type 2 (n=37, 33.6%), followed by Type 5 (n=31, 28.2%) and Type 1 (n=13, 11.8%), as shown in Figure 1. Type 3 (n=6, 5.45%) and Type 7 (n=4, 3.6%) were the least prevalent.

Regarding septal deviation laterality, 55 (50%) cases had right-sided deviation, 46 (41.8%) had left-sided, and 9 (8.2%) had bilateral deviation (Type 4 – S-shaped). The distribution of laterality by DNS type is illustrated in Figure 2.

Age-wise analysis of DNS cases revealed that the majority (n=45, 40.9%) belonged to the 18–25-year age-group, with Type 5 and Type 2 being the most common in this cohort (see Table 1).

Comparison of maxillary sinus volume across DNS lateralities showed no statistically significant difference (p > 0.05), as presented in Table 2. Gender-wise analysis indicated that males had significantly larger mean maxillary sinus volumes than females on the right side (p = 0.000), while differences on the

left side were not statistically significant (p = 0.262) (Table 3). Descriptive statistics for sinus volumes across age groups are summarized in Table 4. No significant correlation was observed between age and sinus volume (p = 0.195 for right sinus; p = 0.657 for left sinus).

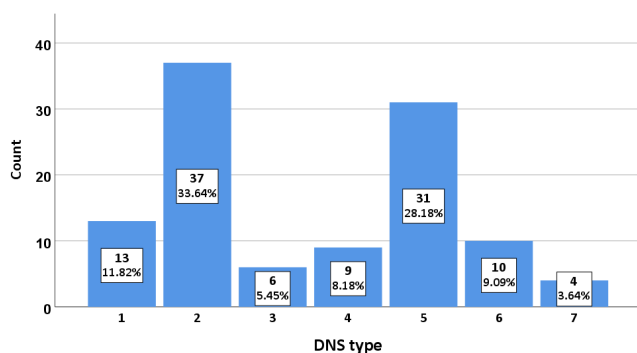


Figure 1: Bar chart demonstrating Prevalence of DNS types

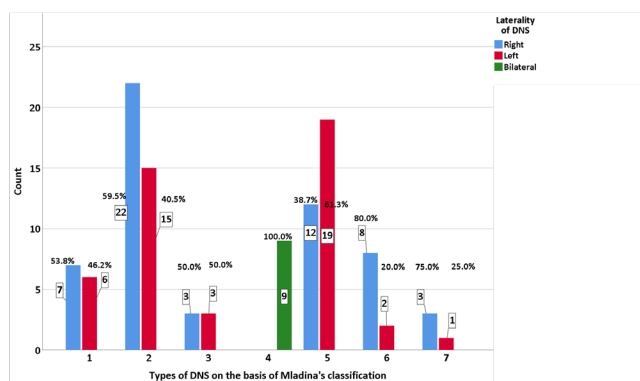


Figure 2: Types of DNS on the basis of Mladina's classification

Table 1: Distribution of DNS types in various age ranges

Age range (years)	DNS Types N (%)							
	1	2	3	4	5	6	7	Total
18-25	3 (23.1%)	14 (37.8%)	2 (33.3%)	3 (33.3%)	15 (48.4%)	7 (70.0%)	1 (25.0%)	45 (40.9%)
26-35	3 (23.1%)	11 (29.7%)	4 (66.7%)	3 (33.3%)	8 (25.8%)	0 (0.0%)	1 (25.0%)	30 (27.3%)
36-45	3 (23.1%)	5 (13.5%)	0 (0.0%)	2 (22.2%)	7 (22.6%)	0 (0.0%)	2 (50.0%)	19 (17.3%)
46-55	0 (0.0%)	3 (8.1%)	0 (0.0%)	1 (11.1%)	1 (3.2%)	0 (0.0%)	0 (0.0%)	5 (4.5%)
56-65	2 (15.4%)	4 (10.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (30.0%)	0 (0.0%)	9 (8.2%)
66-75	2 (15.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.8%)
Total	13 (100.0%)	37 (100.0%)	6 (100.0%)	9 (100.0%)	31 (100.0%)	10 (100.0%)	4 (100.0%)	110 (100.0%)

Table 2: Statistics showing Maxillary sinus volume in various DNS lateralities

Maxillary Sinus Volume	DNS Laterality	N	Mean (mm3)	Std. Deviation (mm3)	Independent Sample T-Test (p value)
Right Sinus	Right	55	15157.9758	6389.97868	0.688
	Left	46	15643.9638	5596.00521	
	Bilateral	9	17311.78	6538.21	
	Absent DNS	112	15638.48	5168.69	
Left Sinus	Right	55	14699.6545	5320.85194	0.764
	Left	46	14985.8043	3957.95254	
	Bilateral	9	15656.67	4662.43	
	Absent DNS	112	16710.32	10620.75	

Table 3: Descriptive Statistics of Gender-wise Maxillary Sinus Dimension in total subjects

Maxillary Sinus Mean S.D.			Male		Females		Total		*p value
			Mean	S.D.	Mean	S.D.			
Right Sinus	Breadth	mm	32.63	4.71	30.61	4.41	31.67	4.67	0.000
	Depth		40.32	4.63	38.17	4.39	39.30	4.63	
	Height		37.22	5.63	34.66	6.51	36.01	6.18	
	Volume	mm ³	16938.21	5533.29	14084.35	5331.82	15588.41	5611.42	
Left Sinus	Breadth	mm	32.03	3.88	29.93	4.50	33.74	28.82	0.262
	Depth		39.89	4.02	37.82	4.24	38.91	4.24	
	Height		37.65	4.87	34.98	6.26	36.39	5.72	
	Volume	mm ³	16403.13	4511.01	15153.59	11038.24	15812.13	8271.02	

*p-value obtained from independent sample t-test

Table 4: Age-wise Descriptive Statistics of Maxillary sinus volume in total subjects

Age range (years) Mean (mm3)	Right sinus Volume		Left sinus Volume	
	Standard Deviation	Mean (mm3)	Standard Deviation	
18-25	15641.08	5669.82	16000.99	11495.32
26-35	14401.88	5393.23	14665.20	5229.33
36-45	15214.04	5041.68	15292.41	4733.18
46-55	16654.53	5854.87	16362.37	4000.09
56-65	18728.89	5468.34	18755.19	5964.34
66-75	13640.00	.00	13020.00	.00
76+	15734.67	9522.43	17533.00	8056.35
Pearson correlation (p value)	0.195		0.657	

Discussion

This study aimed to study the prevalence and types of Deviated Nasal Septum (DNS) using Mladina’s classification its association with age and gender and the impact of DNS laterality on maxillary sinus volume. Deviated Nasal Septum (DNS) was present in nearly half of the study population (49.5%) with Type 2 and Type 5 being the most commonly observed variants. This distribution emphasizes the morphological variability of DNS and as a

prevalent anatomical alteration within the sinonasal framework. The observed prevalence aligns with similar studies conducted in South Asian populations, by Kumbhare et al. and Ashwinirani et al.^{3,15} Gender-based analysis revealed, a higher prevalence of DNS in males (60.9%) compared to females (39.1%), mirroring the trends reported by Baig et al., Alsaggaf et al., and Rao et al.^{5,10,11} This sex-based disparity may reflect underlying anatomical or hormonal influences on nasal and sinus development, although further research is needed to clarify these mechanisms.

The type of DNS in our sample predominantly included type 2 (33.6%) and type 5 (28.2%), aligning with reports by Ashwinirani et al. and Rao et al.^{11,15} However, there remains some variation across studies, with Baig et al. identifying type 5 as the most prevalent.¹⁰ These discrepancies may be attributed to ethnic, environmental, or methodological differences, particularly in how DNS types are interpreted or classified via imaging.

Laterality patterns in our study revealed a slight right-side dominance (50.0%), particularly in type 2 deviations, whereas type 5 showed more frequent left-sided deviations. Although this observation supports the findings of Taneja et al.,¹³ who reported a higher incidence of right-sided deviations in the general population, it contrasts with studies that associate left-sided DNS with chronic sinus disease. This highlights the complexity of correlating septal deviation direction with clinical outcomes.

Our findings showed the highest occurrence of DNS in 18–25 age group (40.9%), suggesting a potential developmental origin or early onset of septal deviation. This is consistent with previous work by Babakhanov et al., who linked DNS to craniofacial development and dento-maxillary discrepancies.⁹

Importantly, our results demonstrated no statistically significant relationship between DNS laterality and maxillary sinus volume. This suggests that the presence and orientation of septal deviation alone may not be sufficient to impact sinus volume, supporting findings by Alsaggaf et al. who emphasized the multifactorial nature of sinus pathology.⁵ However, our findings diverge from those of Jadia et al. and Taneja et al., who reported decreased maxillary sinus volume on the deviated side, potentially due to impaired ventilation and drainage. The divergence may stem from differences in sample composition, inclusion criteria (e.g., symptomatic vs. asymptomatic patients), or CT imaging methodologies.^{12,13}

Although our volumetric analysis did not reveal significant changes in sinus size related to DNS, it's important to note that sinus function and disease risk are not solely determined by gross anatomical volume. Factors such as mucosal thickening, obstruction of osteomeatal complex, and mucociliary clearance likely play more critical roles in pathogenesis. This is supported by a study by Shoib who emphasized the relevance of symptom severity over structural deviation in determining clinical significance.⁴ Our study further supports the view of Devaraja et al. and Adeel et al., who found that the coexistence of DNS with other anatomical variants, such as concha bullosa or uncinate process variations, may be more predictive of chronic rhinosinusitis than DNS alone.^{6,7} This highlights the need for a comprehensive radiological and endoscopic evaluation in symptomatic patients. While CT imaging remains the gold standard for assessing sinonasal anatomy, its diagnostic utility is enhanced when interpreted in the context of patient-reported symptoms and endoscopic findings. As emphasized by Shrestha et al. and Verma et al.,^{14,16} early imaging can help identify atypical manifestations, such as sinus hypoplasia or epiphora, that may be clinically silent yet structurally significant.

Conclusion

This study highlights the high prevalence of Deviated Nasal Septum, particularly among younger individuals and males, with type 2 and type 5 variants being the most commonly observed subtypes as per Mladina's classification. Although variations in type and laterality were documented, no significant association was found between DNS laterality and maxillary sinus volume. These findings suggest that although DNS is a frequent anatomical variation, its isolated presence may not significantly influence maxillary sinus size. Nevertheless, DNS remains an important anatomical consideration in the evaluation of sinonasal disorders, especially in the context of other coexisting anatomical abnormalities and clinical presentations.

Limitations

The cross-sectional design of the study precludes evaluation of temporal or progressive changes in DNS or sinus volume over time. The research was conducted at a single tertiary care institution, which may limit the external validity and applicability of the findings to broader, more diverse populations. The analysis was based solely on radiological findings without integration of clinical symptomatology such as nasal obstruction or recurrent sinus infections. This restricts the interpretation of the anatomical variations in terms of their functional or pathological significance. The study evaluated gross maxillary sinus volume without accounting for important contributing factors such as mucosal thickening, ventilation status, or inflammatory changes that could influence sinus health.

Recommendations

Conducting multicenter studies with larger and more diverse sample populations would enhance the generalizability of findings across various demographic and geographic groups. Incorporating clinical data, including symptom scores, endoscopic findings, and medical history, would provide a more comprehensive understanding of the functional implications of DNS. Long-term prospective studies including common anatomical variations (e.g., concha bullosa, Haller cells, paradoxical middle turbinate) are needed to assess whether certain types or orientations of DNS predispose individuals to the development or progression of sinonasal pathology.

Acknowledgement

The authors would like to express sincere gratitude to the faculties and staffs of Department of Radiology, Nobel Medical College Teaching Hospital for their invaluable support in accessing the images and records. We are also thankful to all the participants involved without whom this study would not have been possible.

Conflict of Interest: None

Financial Disclosure: None

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