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Research Article

# Anatomical Variations of the Nose and Paranasal Sinuses in Sudan

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## Abstract

**Background:** To study the anatomical variations of the nose and paranasal sinuses using Computed Tomography (CT) in Sudan during 2020–2022.

**Methods:** This is a descriptive cross-sectional study conducted in the radiological departments of Sudanese hospitals between 2020 June and 2022 June. The total number of patients was 111 of both sexes.

**Results**: In this study, CT of 111 patients was analyzed. The patients were aged 18–80 years (mean age: 33 years) and comprised of 52.3% females and 47.7% males. The most common anatomical variants in the study group were pneumatization in sphenoid sinus-sellar type (71.2%), attachment of uncinate process into lamina papyrecea (69%), Keros type II (63.1%), deviated nasal septum (42.3%), concha bullosa (37.8%), and Onodi cells (20%). The opacity of the sinus was seen in about half (49.5%) of the CT, with more common sinus involvement being maxillary sinus (35.1%) followed by frontal sinus (8.1%) and ethmoid sinus (6.3%). There was no opacity in the sphenoid sinus in this study.

**Conclusion**: The most common anatomical variants in the study group were pneumatization in the sphenoid sinus-sellar type. The opacity of paranasal sinuses was more common in the maxillary sinuses.

**Keywords:** anatomical variations, CT-scan, nose, paranasal sinus

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# 1. Introduction

Anatomy of the nose and paranasal sinuses have different variations that happen at different phases during the development of the embryo [1]. The sphenoid sinus usually has a central septum dividing the sinus into two parts, on the other hand, the frontal recess usually drains into the middle meatus in 62% of people, or into the ethmoid infundibulum for the rest 38% [2]. The ethmoid sinuses' number, shape, and size of these air cells vary significantly from person to person [3]. The uncinate process of ethmoid bone may insert into the lamina papyracea in 33% of the cases, skull base in 10%, middle turbinate, and a combination of these in 57% [4]. The nasal septum maldevelopment gives rise to the most common anatomical variant; a deviation of the septum (DNS) [5]. Pneumatization of the nasal septum was seen in 27% of the cases reported by Devarajaetal [1, 6]. Haller cells are anatomic variants because they may narrow the ostium of the maxillary sinus or the ethmoid infundibulum. These cells are a predisposing factor for recurrent maxillary sinusitis [7]. Agger nasi cell is the most common anatomic variant of the paranasal sinuses and nasal cavity [8]. Olfactory fossae depth was described by Keros as three variants of fossa [9]. Sinuses hypoplasia, Concha bullosa (CB), pneumatized crista galli, pneumatization of the uncinate process, Onodi cells (OC), and paradoxical middle turbinate are other common anatomical variants [7, 8, 10–14].

Computed Tomography (CT) is a suitable method for providing anatomical information on the nose and paranasal sinuses, and it gives good results describing the anatomical variations [7, 15]. CT is useful for endoscopic surgeons in understanding the anatomical variations of the nose and paranasal sinuses to avoid iatrogenic injuries [7, 15].

This research aimed to study the anatomical variations in the nasal cavity and paranasal sinuses (PNS) in adult Sudanese people using CT. More knowledge of possible variations is essential for the otolaryngologist to operate safely in this complex area that is near the orbit and the brain.

# 2. Methods

## 2.1. Study design and area

The current study is a descriptive, retrospective cross-sectional study conducted in Khartoum State Hospitals in the capital of Sudan.

Study area: Khartoum state hospitals are well-equipped tertiary hospitals that provide health services to patients referred from other states. Data were collected from all radiological departments of all Khartoum State governmental hospitals.

## 2.2. Sample size

All CT scans of the nose and paranasal sinuses in radiological departments of all Khartoum State governmental hospitals were collected and analyzed. The sample includes 111 adult patients with anatomical variations of the nose and paranasal sinuses on a CT scan, fulfilling the inclusion criteria.

Out of the initial 157 scans, 46 patients were excluded for not meeting the inclusion criteria due to prior sinonasal surgery (25 cases), sinonasal tumors (15 cases), and maxillofacial trauma (6 cases).

Inclusion criteria: All participants who underwent a nose and paranasal sinuses CT scan in the

period between 2020 and 2022 in Khartoum State governmental hospitals.

Exclusion criteria: All participants who had previous sinonasal surgery, tumors, or trauma.

### 2.3. Data collection

Data were collected using a well-structured check-list. Selected resident doctors in the radiology departments collected data.

### 2.4. Data analysis

Data were analyzed using the SPSS program version 20.

## 3. Results

This cross-sectional study was conducted to evaluate the anatomical variations of the nose and paranasal sinuses on CT among adult Sudanese patients.

Of the initial 157 patients, 46 were excluded for not meeting the inclusion criteria. Patients with prior sinonasal surgery (25 cases), sinonasal tumors (15 cases), and maxillofacial trauma (6 cases) were excluded, making the final sample size as 111 cases.

Moreover, the age of the patients ranged from 18 to 80 years, and the mean age was 33.4 years.

The largest number of patients were from the age group 18–28 years with 34 patients, representing 30.6% of the total, followed by 31 patients (27.9%) from the 29–38 year-old group, 20 patients (18%) from the 39–48 year-old group, 11 patients (9.9%) each from the 49–58 and 59–58 year-old groups, and only 4 patients (3.6%) from the >68 years group. Overall, 58 patients were females (52.3%) and 53 were males (47.7%). The female-to-male ratio was 1:1.09 (Table 1).

Nasal septum variants were present in 59 patients (53.2%), DNS was found in 47 patients (42.3%), pneumatization of crista galli in 8 patients (7.2%), and pneumatization of the septum in 4 patients (3.6%; Figure **1**; Table 2).

The middle turbinate variant was found in 47 patients (42.3%), CB was seen in 42 patients (37.8%), and paradoxical was seen in 5 patients (4.5%; Figures 2 & 3).

Variations in maxillary sinus were seen in nine patients (8.1%), most of its variation was maxillary sinus hypoplasia which was seen in seven patients (6.35%), and pneumatized maxillary sinus was seen in two patients (1.8%; Figure **1**; Table 3).

Frontal sinus variation was found in 24 patients (21.65%), the most common variant pneumatization of this sinus was seen in 11 patients (9.9%), absent in 5 patients (4.5%), hypoplastic in 4 patients (3.6%), and non-separated sinus in 3 cases (2.7%), and multiple septa were found in 2 cases (1.8%; Figure **4**).

Ethmoid sinus variation patients were 18 (36.9%), the most common pneumatization of bulla ethmoidalis (BE) was seen in 10 patients (9%), followed by Haller cell in 6 patients (5.4%), and excessive pneumatized in 2 patients (1.8%; Figure **5**).

Moreover, OC was found in 23 patients (20.7%). The sphenoid sinus variation was found in 14 patients (12.6%), the most common degree of pneumatization was sellar in 79 patients (71.4%), followed by pre-seller in 19 patients (17.1%), conchal in 9 patients (8.1%) and post sellar in 4 patients (3.6%; Table 4).

The most common type of olfactory fossa depth was Keros classification type II in 70 patients (63.1%), type I in 34 patients (30.6%), and type III in 7 patients (6.3%; Figure **6**).

Considering variations in frontal recess, fronto-ethmoidal cell Kuhn classification type I was found in 18 patients (16.2%), type II in 13 patients (11,7%), type III in 7 patients (6.3%), and type IV in 5 patients (4.5%; Table 5).

International Frontal Sinus Anatomy Classification (IFAC) showed pneumatization of agger nasi in 14 patients (12.6%), supra agger cell in 9 patients (8.1%), supraorbital ethmoid cell in 8 patients (7.2%), and supra agger frontal cell in 7 patients (6.3%); supra bullar cell and supra bullar frontal cell were found in equal number of patients (4 [3.6%]), while frontal septal cell was found in 2 patients (1.8%; Figure **7**; Table 6).

Attachment of the uncinate process to Lamina papyracea was found in 77 patients (69.4%), skull base in 18 patients (16.2%), and middle turbinate in 16 patients (14.4%; Figure **8**).

The only variant in superior turbinate pneumatization was found in six patients (5.4%).

Mucosal abnormalities were detected in about half of the patients (49.5%). The most frequently involved sinus was the maxillary sinus in 39 patients (35.1%), followed by the frontal sinus in 9 patients (8.1%), and ethmoid sinus in 7 patients (6.3%); no opacity was detected in the sphenoid sinus (Figure **9**).

Furthermore, a significant association was seen between the presence of DNS, CB, and the attachment of uncinate process in the middle turbinate, paradoxical of the middle turbinate, and the presence of sinus mucosal opacity (with a significant P-value $< 0.001$) (Table 7).

## 4. Discussion

This study depended on CT for the evaluation of the varied findings in patients with anatomical variations of the nose and PNS, for which 111 cases were enrolled, their ages ranging from 18 to 80 years, and the mean age being 33.4 years.

In this study, patients had a significantly greater incidence of nasal septal deviation and CB which is similar to Calhoum et al.'s results [16]. DNS was shown in 42.3% of CT scans in comparison to an Indian study published by Devaraja et al., where DNS was the most prevalent alteration seen in 83.4% of the cases so the frequency was higher than in the current study [6].

Furthermore, in a previous Sudanese study including 100 CT scans, the most common anatomical variant of the nose and paranasal sinuses was DNS and it was present in 78% of the scans, again this frequency is higher than what was reported in the current study [25]. This might be because in the current study, we eliminated all scans of participants who had a previous history of trauma, tumors, and previous nasal surgery, hence the DNS frequency was low. Regarding the frequency of CB, it was found in 37.8%, compared with the study done in 2017 by Koo et al. in which it was reported in 53.7% [11]. However, Pérez-Pias et al. in 2000 reported the percentage of CB as 24.5% [5]. Again, CB was reported with low frequency in a previous Sudanese study [25].

Maxillary sinus hypoplasia (MSH) was seen in 6.35% of patients in the current study, so it is an uncommon abnormality that comes across in clinical practice. It was in line with a previous study by Sirikci et al. who reported it in 10.4% of their patients [17].

Moreover, in this study, pneumatization of frontal sinuses was about 9.9%, and agenesis was 4.5%. Whereas, a local study done in Sudan showed pneumatized frontal sinus and agenesis in 37% and 11%, respectively, which were higher than this study [19].

Table 1: Age and gender distribution of the study participants.

| **Age group (yr)** | **Frequency** | **Percentage** |
|---|---|---|
| 18–28 | 34 | 30.6 |
| 29–38 | 31 | 27.9 |
| 39–48 | 20 | 18 |
| 49–58 | 11 | 9.9 |
| 59–68 | 11 | 9.9 |
| >68 | 4 | 3.6 |
| Total (Age) | 111 | 100 |
| **Gender** | **Male** | **Female** |
| Male | 53 | 47.7 |
| Female | 58 | 52.3 |
| Total (Gender) | 111 | 100 |

Table 2: Variants of the nasal septum.

| **Variants** | **Frequency** | **Percentage** |
|---|---|---|
| Normal | 52 | 46.8 |
| Deviated | 47 | 42.3 |
| Pneumatization | 4 | 3.6 |
| Pneumatization of crista gali of ethmoid bone | 8 | 7.2 |
| Total | 111 | 100.0 |

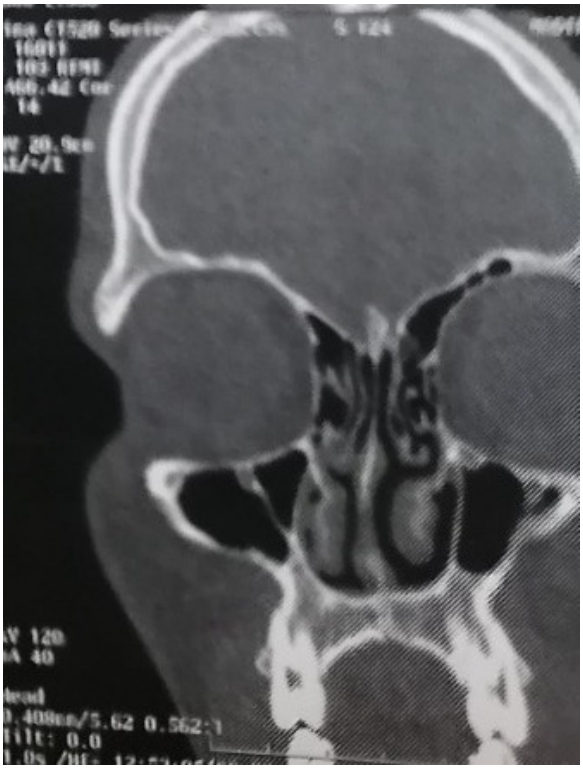

**Figure 1**: CT scan; nasal septum deviation and left small maxillary sinus hypoplasia.

Variations in the ethmoid cell, BE, in the present study were found in 9% of the study population, this is similar to Pérez-Pi na et al. [5].

In this study OC were found in 20.7%, Tawfitk et al. reported the prevalence of OC in 18% of

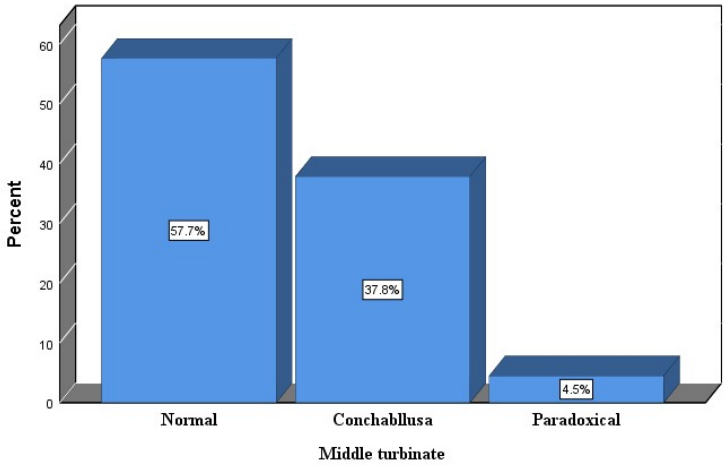


**Figure 2**: Variants in the nasal middle turbinate.

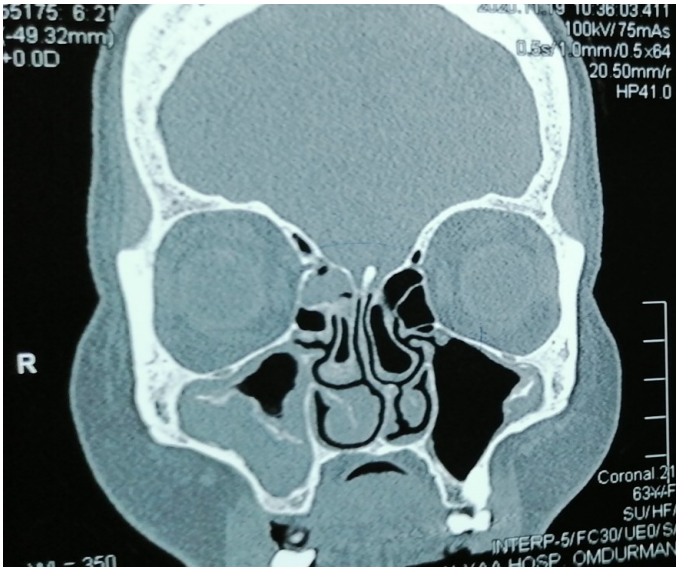


**Figure 3**: CT scan; bilateral concha bullosa.

TABLE 3: Variants in the maxillary sinus.

| Variants | Frequency | Percentage |
|---|---|---|
| Normal | 102 | 91.9 |
| Hypoplastic | 7 | 6.3 |
| Pneumatized | 2 | 1.8 |
| Total | 111 | 100.0 |

Egyptian cases, this agrees with what was found in [20].

Regarding pneumatization of the sphenoid sinus, the most common type was the seller one and is found to be in 71.2%, this agrees with a local study done in Sudan by Kajoak et al., who reported that the sellar type was found in 85% of

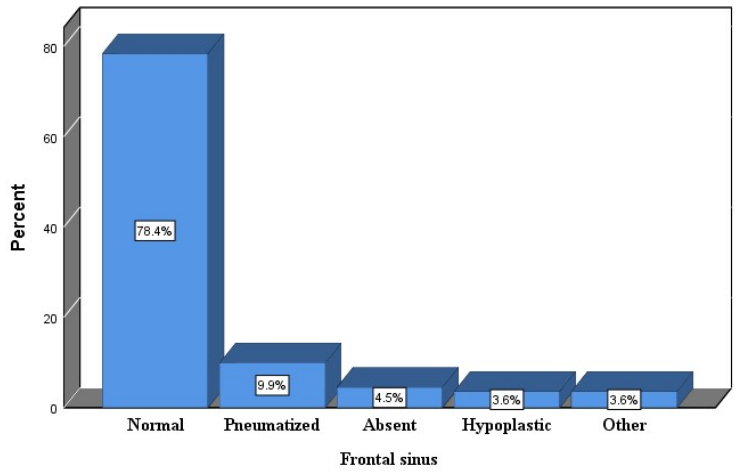


**Figure 4**: Variants in the frontal sinus.

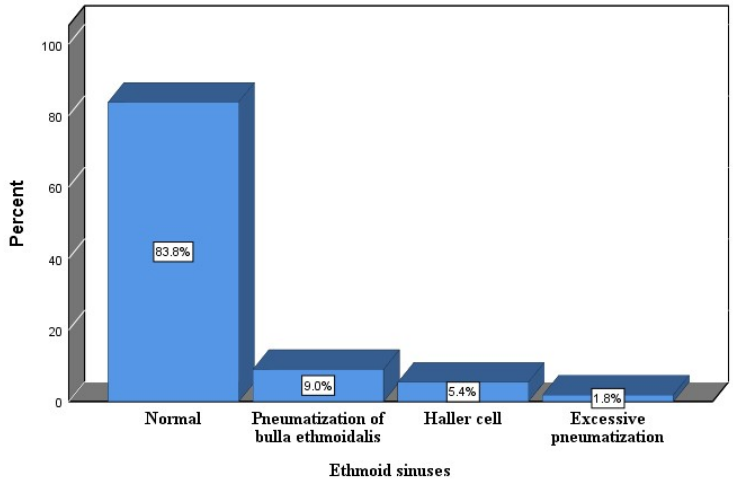


**Figure 5**: Variants in the ethmoid sinus.

TABLE 4: Variants of sphenoid sinus pneumatization.

| Variants | Frequency | Percentage |
|---|---|---|
| **Sellar** | 79 | 71.2 |
| **Presellar** | 19 | 17.1 |
| **Conchal** | 9 | 8.1 |
| **Post sellar** | 4 | 3.6 |
| **Total** | 111 | 100 |

their sample, also similar to a regional study done in Egypt by Tawfitk et al. [2, 20].

In this study, Keros type II was found in 63.1%, followed by type I at 30.6% and type III at 6.3%, compared to a local Sudanese study by Dafalla et al., who found that the most common was the type I in 72% of the patients, while Alazzawi et al. classified 80% of the cases as Keros type I, and 20% of the cases as type II, they considered none to be Keros type III [9, 19].

Regarding variations in frontal recess, Frontoethmoidal air cells with their all types in Kuhn classification are seen ranging from 4.5% to 16.2%

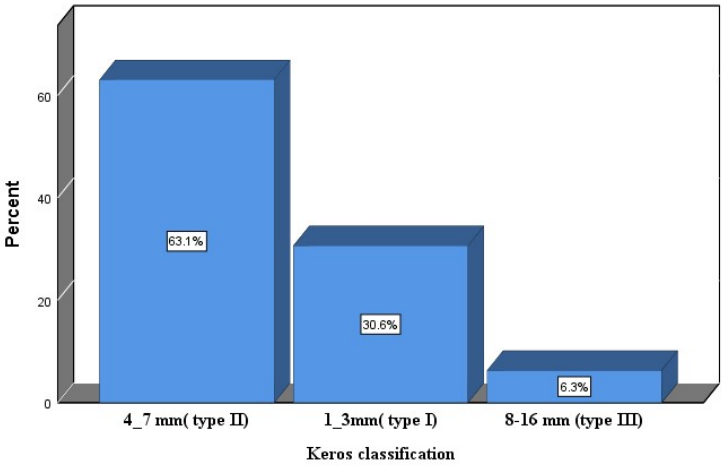


**Figure 6**: Variants of olfactory fossa depth (Keros classification).

TABLE 5: Variants of the frontal recess (Kuhn classification).

| Variants | Frequency | Percentage |
|---|---|---|
| Normal frontoethmoidal cells | 68 | 61.3 |
| Type I | 18 | 16.2 |
| Type II | 13 | 11.7 |
| Type III | 7 | 6.3 |
| Type IV | 5 | 4.5 |
| Total | 111 | 100.0 |

TABLE 6: Variants of the frontal recess.

| Variants | Frequency | Percentage |
|---|---|---|
| No vanant cell | 63 | 56.8 |
| Agger nasai cell | 14 | 12.6 |
| Supra agger cell | 9 | 8.1 |
| Supraorbital ethmoid cell | 8 | 7.2 |
| Supra agger frontal cell | 7 | 6.3 |
| Suprabullar cell | 4 | 3.6 |
| Suprabullarfr | 4 | 3.6 |
| Frontal Septal cell | 2 | 1.8 |
| Total | 111 | 100.0 |

of the current patients, which was consistent with Beale et al.'s study [22].

Wormald et al. in 2003 reported a rate of supraorbital cell and front septal cell at 4% and 2%, respectively [23]. This was similar to the current study which found the percentages to be 7.2% and 2%, respectively.

Agger nasi cells are in the anterior floor of the frontal sinus in 12.6% of the patients in this study, this is like the study done by Kaplanoglo who reported 12.65% [21].

**Figure 7**: CT scan: Variants in pneumatization of agger nasi cells.

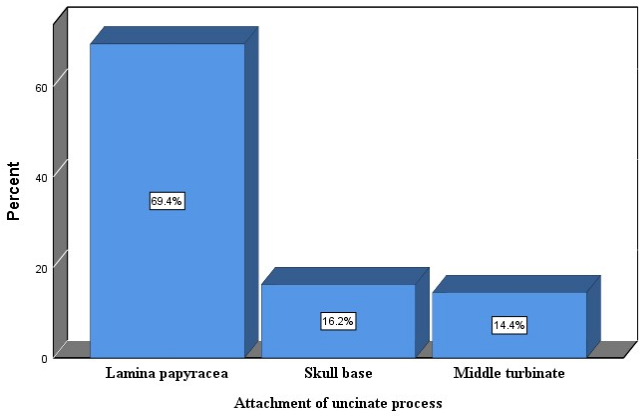


**Figure 8**: Variants in attachment of uncinate process.

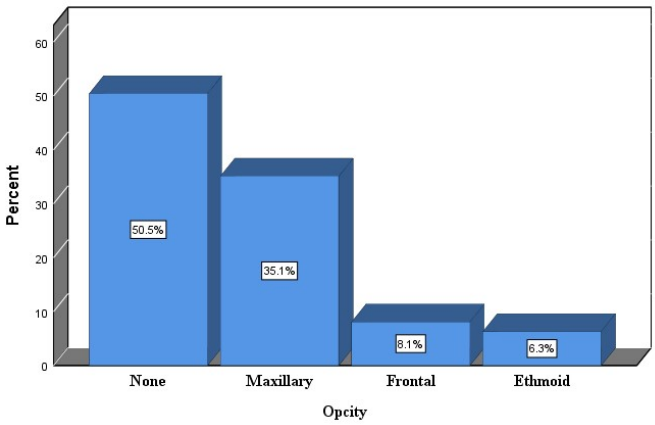


**Figure 9**: Variants in mucosal abnormalities (opacity) of the paranasal sinuses.

The attachment of the uncinate process into the lamina papyracea had the highest prevalence at 69.4%, followed by the skull base (16.2%) and finally the middle turbinate at 14.4%, this was in

Table 7: Correlations between anatomical variations and sinus opacity.

| Anatomical variations | Opacity of paranasal sinuses | | |
|---|---|---|---|
| | Yes% (N) | No% (N) | P-value |
| Deviated nasal septum | (21) %18.9 | (90) %81.1 | 0.0013 * |
| Concha bllusa | (22) %19.8 | (89) %80.2 | >0.001* |
| Paradoxical of the middle turbinate | (11) %9.9 | (100) %90.1 | >0.001* |
| Hallers cell | (5) %4.5 | (105) %95.5 | 1.00 |
| Agger nasai | (7) %6.3 | (104) %93.7 | 1.00 |
| Bulla ethmoidalis | (6) %4.5 | (105) %95.5 | 1.00 |
| Attachment of uncinate process to the middle turbinate | (9) %8.1 | (102) %91.9 | >0.001* |

N: number of patients; *<0.05 significant; >0.05 nonsignificant

agreement with Zhang et al. who reported lamina papyracea as the commonest attachment for the uncinate process in 86% [4].

In this study, the opacity of the sinuses was found in 49.5%, the maxillary sinus was the most commonly involved, followed by the frontal sinus, similar to the study of Devaraja et al. who reported the maxillary sinus opacification in 70.1% [6].

Statistically, there was a significant association (P-value < 0.001) between the presence of DNS, CB, attachment of uncinate process in the middle turbinate, paradoxical of the middle turbinate, and the presence of sinus mucosal opacity which was seen in agreement with Fadda et al., who showed a specific association of anatomic variations in sinus opacity [24].

## 5. Limitations

1. The current study lacks more descriptive reports describing the anatomic variants, critical variants, and sinus opacity. Moreover, it lacks precision in the detection of pathology and anatomical variations, because of the absence of a standard protocol for CT scanning of the nose, paranasal sinuses, and skull base, including window specifications and thickness of cuts.

2. The CT should be reviewed in all three cuts to accurately understand the complex regions.

3. The current study lacks proper history taking and clinical examination including endoscopic findings.

4. The study also lacks collaboration between endoscopic nasal surgeons and radiologists to reach a proper diagnosis and interpretation of scans of the nose and sinuses.

## 6. Conclusion

The most common variation was found to be a sellar type of sphenoid sinus pneumatization. The opacity of paranasal sinuses was found to be more common in the maxillary sinuses. A statistically significant association was found between the presence of DNS, CB, attachment of uncinate process in the middle turbinate, paradoxical of the middle turbinate, and sinus mucosal opacity (P-value < 0.001).

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## Ethical Considerations

The study was approved by the faculty of medicine and health sciences at Omdurman Islamic University Research Committee, Khartoum state. Besides, patient verbal informed consent was provided by all participants or their co-patients in individualized patterns.

## Competing Interests

None.

## Availability of Data and Material

The data and materials used in this study are available upon request from the corresponding author.

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