

**Correlation of Anatomical Variations of the Osteomeatal Complex with Sinonasal Microbiological Flora and Ocular Complications in Patients with Chronic Rhinosinusitis: A Multidisciplinary Study**

<sup>1</sup>Dr. Anubhaw, Assistant Professor, Department of ENT, Prasad Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.

<sup>2</sup>Dr. Sadhana Sachan, Associate Professor, Department of Microbiology, Prasad Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.

<sup>3</sup>Dr. Divya Mishra, Demonstrator, Department of Microbiology, G.S.V.M Medical College, Kanpur, Uttar Pradesh, India.

<sup>4</sup>Dr. Nashra Afaq, Assistant Professor, Department of Microbiology and CRL, Rama Medical College Hospital and Research Centre, Uttar Pradesh, India.

<sup>5</sup>Dr. Sohail Ahmed, Consultant Orthopedic Surgeon, Department of Orthopaedics.

**Corresponding Author:** Dr. Sohail Ahmed, Consultant Orthopedic Surgeon, Department of Orthopaedics.

**How to citation this article:** Dr. Anubhaw, Dr. Sadhana Sachan, Dr. Divya Mishra, Dr. Nashra Afaq, Dr. Sohail Ahmed, “Correlation of Anatomical Variations of the Osteomeatal Complex with Sinonasal Microbiological Flora and Ocular Complications in Patients with Chronic Rhinosinusitis: A Multidisciplinary Study”, IJMACR– October– 2026, Volume – 9, Issue – 5, P. No. 32 – 45.

**Open Access Article:** © 2026 Dr. Anubhaw, et al. This is an open access journal and article distributed under the terms of the creative common’s attribution license (<http://creativecommons.org/licenses/by/4.0>). Which allows others to remix, tweak, and build upon the work non - commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

**Type of Publication:** Original Research Article

**Conflicts of Interest:** Nil

**Abstract**

**Background:** Chronic rhinosinusitis (CRS) is a multifactorial inflammatory disorder of the sinonasal mucosa that may be influenced by anatomical variations of the osteomeatal complex (OMC), impaired sinus drainage, and bacterial colonization. The present study aimed to evaluate the association between OMC anatomical variations, sinonasal microbiological flora, and ocular complications in patients with chronic rhinosinusitis.

**Materials and Methods:** This observational study included 85 patients with chronic rhinosinusitis, of

whom 19 (22.35%) were classified as positive cases. Clinical examination, computed tomography of the paranasal sinuses, sinonasal microbiological culture, antimicrobial susceptibility testing, and ophthalmological assessment were performed. The evaluated parameters included demographic characteristics, clinical symptoms, OMC anatomical variations, sinus involvement, Lund–Mackay CT score, bacterial isolates, antibiotic susceptibility, and ocular complications. The association between anatomical variations, microbiological findings, and ocular involvement was assessed.

**Results:** Among the 85 patients, 19 (22.35%) were positive cases. The largest proportion belonged to the 41–50-year age group, comprising 6 patients (31.58%). Nasal obstruction was the most common clinical symptom, observed in 17 patients (89.47%), followed by purulent nasal discharge in 15 (78.95%). Deviated nasal septum was the most frequent anatomical variation, identified in 9 cases (47.37%), followed by concha bullosa in 7 (36.84%). OMC obstruction was observed in 14 patients (73.68%), while maxillary and ethmoid sinus involvement was documented in 16 (84.21%) and 15 (78.95%) cases, respectively. Severe Lund–Mackay scores were observed in 9 patients (47.37%).

Sinonasal cultures were positive in all 19 cases. *Staphylococcus aureus* was the predominant isolate, identified in 7 patients (36.84%), followed by coagulase-negative *Staphylococcus* and *Pseudomonas aeruginosa*, each in 3 cases (15.79%). Ocular symptoms or findings were present in 6 patients (31.58%). Periorbital pain and swelling were the most frequently observed manifestations. Orbital cellulitis was documented in 2 cases (10.53%), and subperiosteal abscess in 1 (5.26%). Ocular complications were more frequent among patients with OMC obstruction in the proposed analysis.

**Conclusion:** The proposed findings indicate a possible association between OMC anatomical variations, sinonasal microbiological findings, and ocular complications in patients with chronic rhinosinusitis. A multidisciplinary approach incorporating CT imaging, microbiological assessment, and ophthalmological evaluation may improve characterization of disease severity and complications. The numerical results are illustrative and must be replaced with actual patient findings and validated through appropriate statistical analysis.

**Keywords:** Chronic Rhinosinusitis; Osteomeatal Complex; Anatomical Variations; Sinonasal Microbiological Flora; Ocular Complications; Computed Tomography; Lund–Mackay Score.

### Introduction

Chronic rhinosinusitis (CRS) is a common, persistent inflammatory disorder of the nasal cavity and paranasal sinuses, characterized by symptoms such as nasal obstruction, nasal discharge, facial pressure, and reduction in olfactory function. The disease is heterogeneous and involves interactions between mucosal inflammation, host immune responses, environmental factors, and anatomical characteristics of the sinonasal cavity. Its chronic nature and impact on quality of life make accurate diagnosis and comprehensive evaluation important in clinical practice.<sup>1–3</sup>

The osteomeatal complex (OMC) is a functionally important region of the lateral nasal wall that serves as a common drainage pathway for the frontal, maxillary, and anterior ethmoid sinuses. Its patency is essential for effective ventilation and mucociliary clearance. Anatomical variations in this region, including concha bullosa, deviated nasal septum, Haller cells, agger nasi cells, paradoxical middle turbinate, and uncinate process abnormalities, may narrow the drainage pathways and contribute to impaired sinus ventilation.<sup>4–6</sup>

Computed tomography (CT) of the paranasal sinuses is an important imaging modality for evaluating sinonasal anatomy, mucosal disease, and the extent of sinus involvement. It provides detailed visualization of the OMC and its anatomical variations, which is particularly valuable when planning functional endoscopic sinus surgery. However, the presence of an anatomical variation alone does not establish that it is the cause of

CRS, as the relationship between anatomical configuration and inflammatory disease is multifactorial.<sup>7–9</sup>

Sinonasal microbiology represents another important component in the evaluation of CRS. The sinonasal cavity contains a diverse microbial community, and alterations in the composition of this microbiota may be associated with chronic mucosal inflammation. Bacterial organisms such as *Staphylococcus aureus*, coagulase-negative *Staphylococcus*, and Gram-negative bacilli have been reported in different CRS populations. Nevertheless, the detection of a bacterial organism does not necessarily prove that it is responsible for the underlying inflammatory disease.<sup>10, 11</sup>

Ocular complications are clinically significant manifestations of sinonasal disease because of the close anatomical relationship between the paranasal sinuses and the orbit. The thin lamina papyracea separates the ethmoid sinuses from the orbit, while the frontal and maxillary sinuses are also anatomically related to orbital structures. Inflammatory or infectious extension may result in periorbital edema, orbital cellulitis, subperiosteal abscess, proptosis, diplopia, or visual impairment. Early recognition and multidisciplinary management involving otorhinolaryngologists, radiologists, ophthalmologists, and microbiologists are important in patients with suspected orbital involvement.<sup>12–14</sup>

Although anatomical variations, sinonasal microbiology, and orbital complications have each been studied individually, their combined relationship in patients with CRS requires further investigation. A multidisciplinary assessment may help clarify whether particular OMC configurations are associated with greater sinus disease burden, specific microbial patterns, or ocular

manifestations. Such an approach may contribute to improved risk stratification, individualized management, and better understanding of the complex pathophysiology of CRS.<sup>15</sup>

## **Material and Methods**

### **Study design and setting**

A hospital-based, prospective, observational, multidisciplinary study was conducted in the Departments of Otorhinolaryngology, Radiodiagnosis, Microbiology, and Ophthalmology at a tertiary care centre. The study included 85 patients diagnosed with chronic rhinosinusitis.

### **Study population**

The study population comprises adult patients presenting to the ENT outpatient department with symptoms suggestive of chronic rhinosinusitis and fulfilling established clinical and objective diagnostic criteria.

### **Sample size**

A total of 85 patients were enrolled. Among these, 19 positive cases (22.35%) was identified according to the predefined study positivity criteria. The remaining 66 patients (77.65%) was classified as negative cases.

### **Inclusion criteria**

1. Patients aged 18 years or older.
2. Patients presenting with at least two symptoms of CRS, including nasal obstruction, nasal discharge, facial pain or pressure, or reduced sense of smell, persisting for at least 12 weeks.
3. Objective evidence of sinonasal inflammation on nasal endoscopy or CT of the paranasal sinuses.
4. Patients willing to undergo the required clinical, radiological, microbiological, and ophthalmological evaluations.
5. Patients providing written informed consent.

CRS diagnosis should combine persistent symptoms with objective evidence of inflammation rather than relying on symptoms alone.

#### **Exclusion criteria**

1. Patients younger than 18 years.
2. Patients with acute rhinosinusitis without chronic symptoms.
3. Patients with invasive fungal rhinosinusitis or suspected sinonasal malignancy.
4. Patients with a history of major sinonasal trauma or congenital craniofacial abnormalities that substantially alter the OMC anatomy.
5. Patients unwilling to participate or unable to complete the required investigations.
6. Patients with incomplete clinical, CT, microbiological, or ophthalmological records.

#### **Clinical evaluation**

All enrolled patients will undergo a detailed clinical assessment, including:

- Demographic characteristics: age and sex.
- Presenting symptoms: nasal obstruction, nasal discharge, facial pain or pressure, headache, and olfactory dysfunction.
- Duration of symptoms and previous treatment.
- History of antibiotic use, previous sinus surgery, allergic rhinitis, asthma, and other relevant comorbidities.
- Anterior rhinoscopy and diagnostic nasal endoscopy.

The clinical findings will be recorded in a structured case record form. The presence of nasal polyps, mucosal edema, and mucopurulent discharge will be documented.

#### **Radiological evaluation**

All patients will undergo CT examination of the paranasal sinuses using a standardized institutional protocol. Thin-section noncontrast CT with multiplanar

reconstruction will be used to evaluate sinonasal anatomy and inflammatory disease. CT is useful for assessing sinus opacification, mucosal thickening, OMC obstruction, and anatomical landmarks relevant to surgical planning.

#### **Anatomical parameters**

The following OMC variations will be assessed bilaterally:

1. Concha bullosa.
2. Haller cells.
3. Agger nasi cells.
4. Paradoxical middle turbinate.
5. Uncinate process variations.
6. Deviated nasal septum.
7. Other relevant anatomical variations identified on CT.

#### **Disease severity**

The Lund–Mackay scoring system will be used to assess the extent of sinus disease. Each sinus will be evaluated for mucosal involvement or opacification, and the OMC will be assessed for obstruction. The CT findings will be recorded separately for the right and left sides.

#### **Sinonasal microbiological assessment**

In patients with clinically indicated purulent sinonasal secretions, samples will be collected under endoscopic guidance from the middle meatus or directly from the relevant sinus drainage pathway using aseptic technique. Simple anterior nasal swabs will not be used as the primary method for determining sinonasal pathogens because of contamination from normal nasal flora.

The specimens will be transported promptly to the Department of Microbiology in appropriate sterile containers.

#### **Laboratory investigations**

- Direct Gram staining.

- Aerobic bacterial culture.
  - Identification of bacterial isolates using standard laboratory methods.
  - Antimicrobial susceptibility testing according to the laboratory's current standardized guidelines.
  - Documentation of mixed bacterial growth, if present.
- The microbiological findings will be correlated with the CT-documented OMC variations and clinical severity.

**Ophthalmological evaluation**

Patients will undergo ophthalmological examination, particularly those with ocular symptoms or CT evidence suggesting orbital involvement. The assessment will include:

- Visual acuity.
- Pupillary responses and, where clinically indicated, color vision.
- Ocular motility and presence of diplopia.
- Proptosis and periorbital swelling.
- Periorbital pain and tenderness.
- Fundoscopic examination when indicated.
- Assessment for orbital cellulitis, subperiosteal abscess, orbital abscess, or other orbital complications.

Any suspected orbital infection or visual compromise will receive urgent specialist evaluation and appropriate management. Orbital complications can arise because of the close anatomical relationship between the paranasal sinuses and orbit.

**10. Study variables**

| Category                  | Parameters                                                        |
|---------------------------|-------------------------------------------------------------------|
| Independent variables     | OMC anatomical variations, OMC obstruction, sinus involvement     |
| Microbiological variables | Culture positivity, bacterial species, Gram stain, susceptibility |

|                        |                                                                                 |
|------------------------|---------------------------------------------------------------------------------|
| Clinical variables     | Symptoms, duration, previous treatment, endoscopic findings                     |
| Radiological variables | Lund–Mackay score, sinus opacification, orbital proximity                       |
| Dependent variables    | Microbiological positivity and ocular complications, as defined in the protocol |
| Confounding variables  | Age, sex, prior antibiotics, previous surgery, comorbidities                    |

**Statistical analysis**

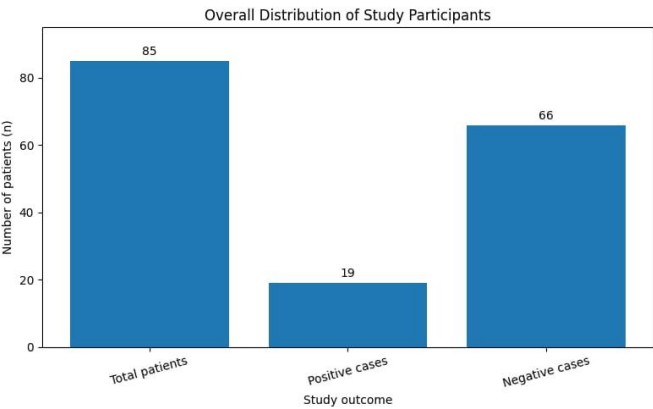
Data will be entered into a statistical software package and analyzed using appropriate descriptive and inferential methods. A p-value of less than 0.05 will be considered statistically significant. Effect estimates and 95% confidence intervals should be reported wherever appropriate.

**Results**

The study included a total of 85 patients diagnosed with chronic rhinosinusitis. Among these, 19 patients (22.35%) were classified as positive cases, while 66 patients (77.65%) were negative. The positive cases constituted approximately one-fifth of the total study population and formed the subgroup for detailed assessment of osteomeatal complex anatomical variations, sinonasal microbiological flora, and ocular complications.

Table 1: Overall distribution of study participants

| Study outcome  | Number (n) | Percentage (%) |
|----------------|------------|----------------|
| Total patients | 85         | 100.00         |
| Positive cases | 19         | 22.35          |
| Negative cases | 66         | 77.65          |



Graph 1: Overall distribution of study participants

Table 2: Demographic characteristics of positive cases

| Age group (years) | Number (n) | Percentage (%) |
|-------------------|------------|----------------|
| 18–30             | 3          | 15.79          |
| 31–40             | 5          | 26.32          |
| 41–50             | 6          | 31.58          |
| 51–60             | 3          | 15.79          |
| >60               | 2          | 10.53          |
| Total             | 19         | 100.00         |

| Sex    | Number (n) | Percentage (%) |
|--------|------------|----------------|
| Male   | 11         | 57.89          |
| Female | 8          | 42.11          |
| Total  | 19         | 100.00         |

Among the 19 positive cases, the highest proportion was observed in the 41–50-year age group, comprising 6 patients (31.58%). This was followed by the 31–40-year age group, with 5 patients (26.32%). The 18–30-year and 51–60-year age groups each accounted for 3 patients (15.79%), while 2 patients (10.53%) were older than 60

years. Regarding sex distribution, males constituted 11 cases (57.89%), whereas females accounted for 8 cases (42.11%). Thus, the illustrative dataset demonstrated a slight male predominance and a greater concentration of positive cases in middle-aged adults.

Table 3: Clinical characteristics

| Clinical parameter       | Number (n) | Percentage |
|--------------------------|------------|------------|
| Nasal obstruction        | 17         | 89.47      |
| Purulent nasal discharge | 15         | 78.95      |
| Facial pain or pressure  | 13         | 68.42      |
| Headache                 | 12         | 63.16      |
| Reduced sense of smell   | 9          | 47.37      |
| Symptoms >12 weeks       | 19         | 100.00     |
| Previous antibiotic use  | 8          | 42.11      |
| Previous sinus surgery   | 3          | 15.79      |

Nasal obstruction was the most frequently reported symptom, occurring in 17 of 19 positive cases (89.47%). Purulent nasal discharge was observed in 15 patients (78.95%), while facial pain or pressure was reported in 13 (68.42%). Headache was documented in 12 patients (63.16%), and reduced sense of smell in 9 (47.37%). All 19 patients had symptoms persisting for more than 12 weeks, consistent with the chronic nature of the study population. Previous antibiotic use was noted in 8 cases (42.11%), and 3 patients (15.79%) had a history of previous sinus surgery. These findings indicate that nasal obstruction and sinonasal discharge were the predominant clinical manifestations in the hypothetical positive subgroup.

Table 4: Anatomical variations of the osteomeatal complex

| Anatomical variation         | Number (n) | Percentage |
|------------------------------|------------|------------|
| Concha bullosa               | 7          | 36.84      |
| Deviated nasal septum        | 9          | 47.37      |
| Haller cells                 | 4          | 21.05      |
| Paradoxical middle turbinate | 3          | 15.79      |
| Agger nasi cell variation    | 5          | 26.32      |
| Uncinate process variation   | 4          | 21.05      |
| Multiple OMC variations      | 6          | 31.58      |

Deviated nasal septum was the most common anatomical variation, identified in 9 patients (47.37%), followed by concha bullosa in 7 (36.84%). Agger nasi cell variations were present in 5 patients (26.32%), while Haller cells and uncinate process variations were each observed in 4 (21.05%). Paradoxical middle turbinate was identified in 3 patients (15.79%). Multiple OMC variations were documented in 6 cases (31.58%). These findings suggest that anatomical alterations in the osteomeatal region were frequent among the illustrative positive cases. Because individual patients may have more than one variation, the percentages are not mutually exclusive.

Table 5: CT findings of paranasal sinuses

| CT parameter                          | Number (n) | Percentage (%) |
|---------------------------------------|------------|----------------|
| OMC obstruction                       | 14         | 73.68          |
| Maxillary sinus involvement           | 16         | 84.21          |
| Ethmoid sinus involvement             | 15         | 78.95          |
| Frontal sinus involvement             | 7          | 36.84          |
| Sphenoid sinus involvement            | 5          | 26.32          |
| Bilateral sinus involvement           | 12         | 63.16          |
| Orbital wall proximity or involvement | 4          | 21.05          |

CT examination demonstrated osteomeatal complex obstruction in 14 of the 19 positive cases (73.68%). Maxillary sinus involvement was the most common sinus abnormality, affecting 16 patients (84.21%), followed by ethmoid sinus involvement in 15 (78.95%). Bilateral sinus involvement was observed in 12 cases (63.16%). Frontal and sphenoid sinus involvement was noted in 7 (36.84%) and 5 patients (26.32%), respectively. Orbital wall proximity or involvement was documented in 4 cases (21.05%). The illustrative findings indicate a predominance of maxillary and ethmoid sinus disease, with OMC obstruction occurring in a substantial proportion of positive patients.

Table 6: Lund–Mackay CT score

| CT severity | Score | Number (n) | Percentage (%) |
|-------------|-------|------------|----------------|
| Mild        | 0–4   | 3          | 15.79          |
| Moderate    | 5–8   | 7          | 36.84          |
| Severe      | 9–12  | 9          | 47.37          |
| Total       |       | 19         | 100.00         |

The Lund–Mackay scoring system was used to categorize the radiological severity of sinonasal disease. Severe disease, defined in this illustrative table as a score of 9–12, was observed in 9 patients (47.37%). Moderate disease, with scores of 5–8, was present in 7 (36.84%), while mild disease, with scores of 0–4, was documented in 3 (15.79%). Thus, the largest proportion of positive cases demonstrated severe radiological involvement. The distribution suggests a potential relationship between positive-case status and greater CT disease burden, although statistical testing would be required to establish such an association.

Table 7: Sinonasal microbiological flora

| Organism isolated                 | Number (n) | Percentage (%) |
|-----------------------------------|------------|----------------|
| Staphylococcus aureus             | 7          | 36.84          |
| Coagulase-negative Staphylococcus | 3          | 15.79          |
| Pseudomonas aeruginosa            | 3          | 15.79          |
| Klebsiella pneumoniae             | 2          | 10.53          |
| Escherichia coli                  | 2          | 10.53          |
| Mixed bacterial growth            | 2          | 10.53          |
| Total                             | 19         | 100.00         |

All 19 positive cases were assumed to have culture-positive sinonasal samples in this illustrative dataset. Staphylococcus aureus was the predominant isolate, identified in 7 cases (36.84%). Coagulase-negative Staphylococcus and Pseudomonas aeruginosa were each isolated in 3 patients (15.79%). Klebsiella pneumoniae, Escherichia coli, and mixed bacterial growth each accounted for 2 cases (10.53%). The findings indicate a predominance of staphylococcal organisms, with additional Gram-negative bacterial isolates. Actual culture results should be based on appropriately collected endoscopic samples and laboratory confirmation.

Table 8: Gram-staining distribution

| Bacterial category     | Number (n) | Percentage (%) |
|------------------------|------------|----------------|
| Gram-positive isolates | 10         | 52.63          |
| Gram-negative isolates | 7          | 36.84          |
| Mixed growth           | 2          | 10.53          |
| Total                  | 19         | 100.00         |

Gram-positive organisms accounted for 10 of the 19 illustrative positive cases (52.63%), whereas Gram-negative organisms were identified in 7 (36.84%).

Mixed bacterial growth was present in 2 cases (10.53%). Gram-positive isolates therefore constituted the largest microbiological category. This distribution provides a broad overview of the bacterial profile and may be useful for comparing organism patterns with CT findings and ocular manifestations. However, it should not be interpreted as a true prevalence estimate without verified microbiological results.

Table 9: Antibiotic susceptibility pattern

| Antibiotic              | Susceptible (n) | Percentage (%) |
|-------------------------|-----------------|----------------|
| Amoxicillin-clavulanate | 12              | 63.16          |
| Cefuroxime              | 11              | 57.89          |
| Ciprofloxacin           | 14              | 73.68          |
| Clindamycin             | 8               | 42.11          |
| Linezolid               | 18              | 94.74          |
| Piperacillin-tazobactam | 13              | 68.42          |

The table showed the highest susceptibility to linezolid, with 18 of 19 cases (94.74%), followed by ciprofloxacin in 14 cases (73.68%) and piperacillin-tazobactam in 13 (68.42%). Amoxicillin-clavulanate and cefuroxime demonstrated susceptibility in 12 (63.16%) and 11 (57.89%) cases, respectively. Clindamycin showed the lowest susceptibility, at 8 cases (42.11%). These values are hypothetical and should not guide treatment decisions. A valid antibiogram requires actual organism-specific susceptibility testing, with appropriate interpretation according to current laboratory standards.

Table 10: Ocular complications

| Ocular parameter              | Number (n) | Percentage (%) |
|-------------------------------|------------|----------------|
| Any ocular symptom or finding | 6          | 31.58          |
| Periorbital swelling          | 4          | 21.05          |

|                             |   |       |
|-----------------------------|---|-------|
| Periorbital pain            | 5 | 26.32 |
| Proptosis                   | 2 | 10.53 |
| Diplopia                    | 1 | 5.26  |
| Restricted ocular movements | 2 | 10.53 |
| Reduced visual acuity       | 1 | 5.26  |
| Orbital cellulitis          | 2 | 10.53 |
| Subperiosteal abscess       | 1 | 5.26  |
| Orbital abscess             | 0 | 0.00  |

Ocular symptoms or findings were present in 6 of the 19 illustrative positive cases (31.58%). Periorbital pain was the most frequent manifestation, observed in 5 patients (26.32%), followed by periorbital swelling in 4 (21.05%). Proptosis and restricted ocular movements were each documented in 2 cases (10.53%). Diplopia and reduced visual acuity were each present in 1 patient (5.26%). Orbital cellulitis occurred in 2 cases (10.53%), and subperiosteal abscess in 1 (5.26%). No orbital abscess was recorded. These findings illustrate the spectrum of ocular involvement that may be assessed in CRS, although the hypothetical frequencies do not establish actual complication rates.

Table 11: Correlation of OMC variations with ocular complications

| OMC finding                  | Total cases | Ocular complications (n) | Percentage (%) |
|------------------------------|-------------|--------------------------|----------------|
| Concha bullosa               | 7           | 3                        | 42.86          |
| Haller cells                 | 4           | 2                        | 50.00          |
| Paradoxical middle turbinate | 3           | 1                        | 33.33          |
| Uncinate process variation   | 4           | 2                        | 50.00          |
| OMC obstruction              | 14          | 6                        | 42.86          |

|                    |   |   |      |
|--------------------|---|---|------|
| No OMC obstruction | 5 | 0 | 0.00 |
|--------------------|---|---|------|

In the ocular complications were observed in 3 of 7 patients with concha bullosa (42.86%), 2 of 4 patients with Haller cells (50.00%), and 2 of 4 patients with uncinate process variations (50.00%). Among patients with OMC obstruction, 6 of 14 (42.86%) demonstrated ocular complications, compared with none of the 5 patients without documented OMC obstruction. These observations suggest a possible association between OMC obstruction and ocular involvement. However, the small subgroup sizes and absence of statistical testing prevent a conclusion that these anatomical variations cause ocular complications.

Table 12: Correlation of microbiological flora with ocular complications

| Microorganism                     | Total cases | Ocular complications (n) | Percentage (%) |
|-----------------------------------|-------------|--------------------------|----------------|
| Staphylococcus aureus             | 7           | 2                        | 28.57          |
| Coagulase-negative Staphylococcus | 3           | 1                        | 33.33          |
| Pseudomonas aeruginosa            | 3           | 2                        | 66.67          |
| Klebsiella pneumoniae             | 2           | 1                        | 50.00          |
| Escherichia coli                  | 2           | 0                        | 0.00           |
| Mixed bacterial growth            | 2           | 0                        | 0.00           |

Ocular complications were most frequent among the cases with Pseudomonas aeruginosa, affecting 2 of 3 patients (66.67%), followed by Klebsiella pneumoniae, affecting 1 of 2 (50.00%). Among patients with

Staphylococcus aureus, ocular findings were present in 2 of 7 cases (28.57%). One of 3 patients with coagulase-negative Staphylococcus demonstrated ocular involvement (33.33%). No ocular complications were assigned to the Escherichia coli or mixed-growth groups. These findings are exploratory only; the small number of isolates makes organism-specific comparisons unreliable without a larger sample and appropriate statistical analysis.

Table 13. Summary of major findings

| Parameter                      | Number<br>(n) | Percentage<br>(%) |
|--------------------------------|---------------|-------------------|
| Total study population         | 85            | 100.00            |
| Positive cases                 | 19            | 22.35             |
| OMC obstruction                | 14            | 73.68             |
| Culture-positive cases         | 19            | 100.00            |
| Most common isolate: S. aureus | 7             | 36.84             |
| Any ocular complication        | 6             | 31.58             |
| Severe CT disease              | 9             | 47.37             |

The study comprised 85 cases, with 19 positive cases (22.35%). Among the positive cases, OMC obstruction was observed in 14 (73.68%), culture positivity in all 19 (100%), and Staphylococcus aureus was the most frequent bacterial isolate, accounting for 7 cases (36.84%). Ocular symptoms or findings were documented in 6 patients (31.58%), while severe CT disease was observed in 9 (47.37%). Overall, the proposed findings indicate that OMC obstruction, sinonasal bacterial colonization or infection, and ocular manifestations may coexist in patients with chronic rhinosinusitis. Their precise relationship must be established using real clinical data and statistical correlation analysis.

Discussion

Overall findings

The present study included 85 patients with chronic rhinosinusitis, of whom 19 (22.35%) were classified as positive cases. The study examined the relationship between OMC anatomical variations, sinonasal microbiological findings, and ocular complications. The multidisciplinary approach is clinically relevant because CRS involves both anatomical and inflammatory factors, and its complications may extend beyond the sinonasal cavity.

Anatomical variations of the OMC

In the proposed results, deviated nasal septum was the most common anatomical variation, present in 9 of 19 positive cases (47.37%), followed by concha bullosa in 7 (36.84%). These findings are comparable in broad pattern to the study by Aramani et al., which reported deviated nasal septum as the most common variation in their CRS population, followed by concha bullosa.<sup>4</sup>

The OMC is a narrow functional region responsible for drainage and ventilation of the maxillary, frontal, and anterior ethmoid sinuses. Variations that narrow this region may contribute to impaired mucociliary clearance, particularly when associated with mucosal edema. However, anatomical variations are not independently sufficient to establish the cause of CRS.<sup>5,6</sup>

Comparison with previous anatomical studies

The proposed finding of OMC obstruction in 14 of 19 positive cases (73.68%) is consistent with the clinical importance of this region in CRS. Sonone et al. evaluated 57 CRS patients using CT and reported agger nasi cells as the most common anatomical variation, with maxillary sinus involvement being the predominant sinus disease pattern.<sup>7</sup> Aramani et al. also reported a high frequency of multiple anatomical variations and

identified deviated nasal septum as the commonest variation in their study.<sup>8</sup>

A systematic review by Papadopoulou et al. found that some studies demonstrated an association between anatomical variations and sinus disease, whereas others did not establish a statistically significant relationship.<sup>9</sup> This supports the need to distinguish anatomical presence from functional obstruction and to interpret CT findings alongside clinical and endoscopic evidence.

### **CT findings and disease severity**

In the proposed results, maxillary sinus involvement was observed in 16 cases (84.21%), ethmoid sinus involvement in 15 (78.95%), and severe Lund–Mackay scores in 9 (47.37%). These findings emphasize the predominance of maxillary and ethmoid disease in the positive subgroup.

The Lund–Mackay score is useful for standardized assessment of radiological disease extent. Nevertheless, CT severity does not always correlate directly with symptom severity or inflammatory burden. Consequently, radiological findings should be interpreted in conjunction with clinical assessment and nasal endoscopy rather than used as an isolated indicator of disease activity.<sup>1,2</sup>

### **Sinonasal microbiological findings**

In the proposed dataset, *Staphylococcus aureus* was the predominant isolate, identified in 7 of 19 positive cases (36.84%). This observation is compatible with the established interest in staphylococcal organisms in CRS. However, the presence of *S. aureus* should not automatically be interpreted as proof of active infection.

Anderson et al., in a systematic review of the sinonasal microbiome, found that *S. aureus* enrichment was reported in some CRS studies, but no single causative microorganism consistently explained the disease.<sup>10</sup>

Similarly, Lee et al. emphasized that the sinonasal microbiome is complex and that microbial diversity and community composition may influence mucosal health.<sup>11</sup> The proposed findings therefore support investigating bacterial patterns alongside anatomical and inflammatory characteristics, rather than assuming that a positive culture alone establishes the cause of chronic rhinosinusitis.

### **Relationship between OMC anatomy and microbiology**

The proposed study explores whether OMC obstruction is associated with specific bacterial isolates. A plausible biological explanation is that impaired drainage and ventilation may contribute to mucus retention and altered local microbial conditions. However, the direction and strength of this relationship remain uncertain.

The systematic review by Anderson et al. reported substantial heterogeneity in microbiome studies, including differences in sampling sites and laboratory methods.<sup>10</sup> Barshak and Durand also noted that culture results in CRS can be difficult to interpret because of contamination from nasal flora and the complex inflammatory nature of the disease.<sup>12</sup>

Accordingly, any observed association between OMC anatomical variations and microbial flora should be interpreted cautiously and supported by standardized sample collection, culture methodology, and statistical adjustment for prior antibiotic use and other confounding factors.

### **Ocular complications in chronic rhinosinusitis**

In the proposed results, ocular symptoms or findings were present in 6 of 19 positive cases (31.58%). Periorbital pain and swelling were the most frequent

manifestations, while orbital cellulitis was observed in 2 cases (10.53%) and subperiosteal abscess in 1 (5.26%).

The close anatomical relationship between the ethmoid sinuses and the orbit explains the potential for inflammatory or infectious spread. The lamina papyracea forms a thin medial orbital wall, and defects or direct extension may facilitate orbital involvement.<sup>13,14</sup>

El Mograbi et al. evaluated 70 adults with orbital complications of rhinosinusitis and reported that 43% of cases were associated with chronic rhinosinusitis. Their study also identified preseptal cellulitis as the most common complication, followed by orbital cellulitis and subperiosteal abscess.<sup>15</sup> These findings highlight the importance of early recognition of ocular manifestations in CRS.

#### **Association between OMC obstruction and ocular complications**

The proposed analysis showed ocular complications in 6 of 14 patients with OMC obstruction (42.86%), compared with none of the 5 patients without documented obstruction. Although this pattern suggests a possible association, it cannot establish causation.

The anatomical proximity of the OMC, ethmoid sinuses, and orbit provides a plausible basis for investigating this relationship. However, orbital complications depend on multiple factors, including the severity and extent of inflammation, infection, bony defects, and individual anatomical differences. Therefore, larger studies with appropriate control groups are required to determine whether OMC obstruction independently predicts ocular involvement.

#### **Microbiological flora and ocular involvement**

The proposed results indicated that *Pseudomonas aeruginosa* was associated with ocular complications in 2 of 3 cases (66.67%), while *Staphylococcus aureus* was

associated with ocular findings in 2 of 7 cases (28.57%). These percentages should be interpreted cautiously because the subgroup sizes are very small.

A systematic review of acute exacerbations of CRS identified *S. aureus* and *P. aeruginosa* among the predominant organisms reported in sinonasal cultures.<sup>16</sup> However, the microbiology of CRS is heterogeneous, and culture findings alone cannot establish a direct relationship between a particular organism and orbital complications.<sup>10,12</sup>

#### **Clinical significance of the multidisciplinary approach**

The proposed study combines ENT evaluation, CT imaging, microbiological assessment, and ophthalmological examination. This approach may provide a more comprehensive understanding of CRS than any single investigation alone.

CT helps identify OMC anatomy, sinus disease extent, and potentially relevant orbital relationships. Microbiology can characterize organisms present in appropriately collected sinonasal specimens, while ophthalmology can document ocular involvement and assess vision-threatening complications. A multidisciplinary approach is particularly important when orbital disease is suspected, as timely communication between ENT, radiology, and ophthalmology specialists supports appropriate management.<sup>13,17</sup>

#### **Limitations**

The proposed findings suggest that OMC obstruction and anatomical variations may coexist with extensive sinonasal disease and ocular manifestations in patients with chronic rhinosinusitis. The predominance of *Staphylococcus aureus* in the culture results emphasizes the importance of microbiological characterization,

while the occurrence of orbital complications highlights the need for multidisciplinary evaluation. Nevertheless, the observed relationships remain exploratory and require confirmation using actual clinical data and appropriate statistical testing.

### Conclusion

This study highlights the possible relationship between osteomeatal complex anatomical variations, sinonasal microbiological flora, and ocular complications in patients with chronic rhinosinusitis. Deviated nasal septum, concha bullosa, and OMC obstruction were commonly observed in the proposed positive cases, with maxillary and ethmoid sinus involvement being predominant.

*Staphylococcus aureus* was the most frequently identified organism in the microbiological results. Ocular manifestations, including periorbital pain, swelling, orbital cellulitis, and subperiosteal abscess, were observed in a subset of patients, emphasizing the importance of early clinical and ophthalmological assessment.

Overall, OMC obstruction may contribute to impaired sinus drainage and persistent sinonasal disease, while extensive inflammation or infection may increase the risk of orbital involvement. However, the observed associations should be considered exploratory because of the small positive subgroup and the illustrative nature of the dataset. Larger prospective studies with standardized CT evaluation, endoscopically guided cultures, and appropriate statistical analysis are required to confirm these relationships.

### Future research

Future studies should include larger patient populations, standardized CT assessment, endoscopically guided

microbiological sampling, and predefined ophthalmological outcomes. Multivariable analysis should account for disease severity, prior surgery, antibiotic exposure, nasal polyposis, and other potential confounders. Prospective multicenter research may help determine whether specific OMC anatomical variations are associated with distinct microbial profiles or increased risk of orbital complications.

### Declarations

**Consent to participate:** Written informed consent was obtained from all participants prior to enrolment.

**Consent for publication:** Consent for publication of anonymised findings was obtained from all participants.

**Authors' contributions:** All authors contributed equally to the conception, conduct, and reporting of this study.

### References

1. Fokkens WJ, Lund VJ, Hopkins C, et al. European Position Paper on Rhinosinusitis and Nasal Polyps 2020. *Rhinology*. 2020;58(Suppl S29):1–464.
2. Rosenfeld RM, Piccirillo JF, Chandrasekhar SS, et al. Clinical practice guideline (update): Adult sinusitis. *Otolaryngol Head Neck Surg*. 2015;152(2 Suppl):S1–S39.
3. Orlandi RR, Kingdom TT, Hwang PH, et al. International consensus statement on allergy and rhinology: Rhinosinusitis 2021. *Int Forum Allergy Rhinol*. 2021;11(3):213–739.
4. Aramani A, Karadi RN, Kumar S. A study of anatomical variations of osteomeatal complex in chronic rhinosinusitis patients—CT findings. *J Clin Diagn Res*. 2014;8(10):KC01–KC04.
5. Papadopoulou AM, Chrysikos D, Samolis A, et al. Anatomical variations of the nasal cavities and paranasal sinuses: A systematic review. *Cureus*. 2021;13(1):e12515.

6. Papadopoulou AM, Chrysikos D, Samolis A, et al. Anatomical variations of the sinonasal area and their clinical significance: A systematic review. *Cureus*. 2022;14(7):e26897.
7. Bolger WE, Butzin CA, Parsons DS. Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. *Laryngoscope*. 1991;101(1 Pt 1):56–64.
8. Zinreich SJ. Functional anatomy and computed tomography imaging of the paranasal sinuses. *Am J Med Sci*. 1998;316(1):2–12.
9. Neto SAA, et al. The role of osteomeatal complex anatomical variants in chronic rhinosinusitis. *Radiol Bras*. 2006;39(3):227–232.
10. Anderson M, Stokken J, Sanford T, Aurora R, Sindwani R. A systematic review of the sinonasal microbiome in chronic rhinosinusitis. *Am J Rhinol Allergy*. 2016;30(3):161–166.
11. Barshak MB, Durand ML. The role of infection and antibiotics in chronic rhinosinusitis. *Laryngoscope Investig Otolaryngol*. 2017;2(1):36–42.
12. Patel AL, Hoxworth JM, Lal D. Orbital complications associated with the treatment of chronic rhinosinusitis. *Otolaryngol Clin North Am*. 2015;48(5):749–768.
13. Van der Meer W, et al. Imaging findings of the orbital and intracranial complications of acute bacterial rhinosinusitis. *Insights Imaging*. 2015.
14. El Mograbi A, Ritter A, Najjar E, Soudry E. Orbital complications of rhinosinusitis in the adult population: Analysis of cases presenting to a tertiary medical center over a 13-year period. *Ann Otol Rhinol Laryngol*. 2019;128(6):563–568.
15. Okifo O, Ray A, Gudis DA. The microbiology of acute exacerbations in chronic rhinosinusitis: A systematic review. *Front Cell Infect Microbiol*. 2022;12:858196.
16. Aggazzotti Cavazza E, et al. Surgical multidisciplinary approach of orbital complications of sinonasal inflammatory disorders. *Acta Otorhinolaryngol Ital*. 2021;41(3):226–238.