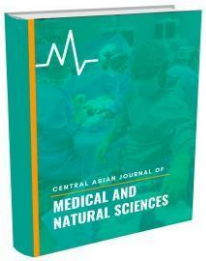

CENTRAL ASIAN JOURNAL OF MEDICAL AND NATURAL SCIENCES
https://cajmns.centralasianstudies.org/index.php/CAJMNS
Volume: 07 Issue: 01 | January 2026 ISSN: 2660-4159

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Article

Morphological Structural Changes of the Mucous Layer of the Syndrome Space in Chronic Syndrome

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Abstract: Chronic sinusitis is a persistent inflammatory disease of the maxillary sinus that leads to pronounced morphological remodeling of the mucous membrane and impairment of its physiological functions. This study aimed to evaluate histomorphological changes in the maxillary sinus mucosa in patients with chronic sinusitis. The study included 36 patients aged 18–60 years with clinically and radiologically confirmed chronic sinusitis and 12 control subjects without inflammatory sinus pathology. Biopsy samples of the maxillary sinus mucosa were obtained during functional endoscopic sinus surgery and processed using standard histological techniques. Sections were stained with hematoxylin–eosin and Masson's trichrome to assess epithelial thickness, preservation of ciliated epithelium, glandular hyperplasia, and submucosal fibrosis. The results demonstrated a significant increase in epithelial thickness, marked loss of ciliated epithelium, frequent glandular hyperplasia, and moderate to severe submucosal fibrosis in patients with chronic sinusitis compared to controls ($p < 0.05$). These structural alterations impair mucociliary clearance, promote secretion stagnation, and contribute to disease chronicity and resistance to conservative therapy. Histomorphological assessment of the sinus mucosa is therefore essential for understanding disease progression and optimizing treatment strategies.

Keywords: Chronic Sinusitis, Sinus Cavity, Mucosa, Histomorphological, Fibrosis, Hyperplasia, Autoimmune, Allergic.

Citation: Tolmasovich T. R., Abror qizi A. P. Morphological Structural Changes of the Mucous Layer of the Syndrome Space in Chronic Syndrome. Central Asian Journal of Medical and Natural Science 2026, 7(1), 592-599.

Received: 14th Sep 2025
Revised: 31st Oct 2025
Accepted: 16th Nov 2025
Published: 24th Jan 2026

1. Introduction

Due to the increasing incidence of chronic sinusitis among the world's population, it is important to study the structural changes that develop in the mucous membrane of the sinus cavity in the pathogenesis of the disease . The main cause of sinusitis is upper respiratory tract infection, which is why this disease is more common in the autumn-winter season. Long-term course of the disease leads to the formation of irreversible structural changes in the mucous membrane of the maxillary sinus [1], [2], [3].

Chronic sinusitis is one of the most common chronic inflammatory diseases in otorhinolaryngology. The disease lasts more than 12 weeks and is characterized by constant or recurrent clinical symptoms. As a result of the chronic process, the mucous membrane of the maxillary sinus loses its normal anatomical and physiological properties. Structural changes in the mucous membrane contribute to the severity of the disease, drug resistance and the development of complications [4], [5].

Our study design was based on a prospective observational study, with participants initially selected and continuously monitored in real time, and aimed to study histomorphological changes in the mucosa of the maxillary sinus in patients with chronic sinusitis [6].

Research objective

To identify and evaluate histomorphological changes occurring in the mucosa of the maxillary sinuses in patients with chronic sinusitis.

2. Materials and Methods

The study included 36 patients aged 18-60 years: 18, 30, 45, 60 years with a diagnosis of chronic sinusitis. The diagnosis was confirmed by clinical symptoms such as nasal congestion, purulent discharge, and facial pain lasting more than 12 weeks, endoscopic examination, and computed tomography (CT) results. Patients with acute sinusitis, individuals who had previously undergone surgery in the paranasal sinuses, and patients with autoimmune, allergic, or systemic inflammatory diseases were not included in this experiment, since it was not possible to determine whether the mucosal changes in them were due to sinusitis or another cause. All included patients underwent functional endoscopic sinus surgery (FESS).

As a control group, the maxillary sinus mucosa was taken from 12 individuals who had undergone surgery for odontogenic cysts or traumatic conditions without signs of inflammation. During the surgical procedure, a 3-5 mm biopsy sample was taken from the maxillary sinus mucosa. The obtained tissues were fixed in 10% neutral formalin solution and embedded in paraffin blocks in a standard manner. The next stage was the histological examination of the biopsy samples taken for the experiment. For this, 4–5 μm thick sections were prepared from paraffin blocks and stained with the following dyes: Hematoxylin-eosin to assess the general histological structure of the mucosa; Masson trichrome to identify submucosal fibrosis and collagen fibers. Histological preparations were evaluated under a light microscope, and their epithelial thickness (μm), degree of preservation of ciliated epithelium (%), presence or absence of mucous gland hyperplasia, and degree of submucosal fibrosis (on a 0-3 point scale) were analyzed.

The computer program designed to analyze the obtained data and statistical data — Statistical Package for the Social Sciences (SPSS) based on, Data were processed using the statistical software 26.0 and expressed as mean ± standard deviation. Differences between groups were assessed using the Student t-test and Mann–Whitney U test. $P < 0.05$ was considered statistically significant.

The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants, and the study was approved by the local ethics committee.

3. Results and Discussions

The results of the histomorphological study showed that there were significant and stable structural changes in the mucosa of the maxillary sinuses of patients with chronic sinusitis compared to the control group. In order to further clarify the results of the study, several typical clinical cases were selected from patients with chronic sinusitis:

In our study, an 18-year-old woman was ill for 14 weeks with chronic nasal congestion and purulent discharge. CT showed a mucosal thickness of 6 mm in the right maxillary sinus. A biopsy was obtained during FESS. Histological analysis showed an epithelial thickness of 110 μm, partial loss of ciliated epithelium, glandular hyperplasia, and moderate submucosal fibrosis [7], [8].

In our study, a 30-year-old man presented with facial pain and nasal congestion for 16 weeks. CT scan revealed mucosal thickening in both maxillary sinuses. Biopsy revealed an epithelial thickness of 118 μm, with almost no ciliated epithelium, glandular hyperplasia, and severe submucosal fibrosis.

In our study, a 45-year-old woman was ill for 12 weeks with chronic nasal congestion and nasal pain. Biopsy revealed an epithelial thickness of 115 μm, partially preserved ciliated epithelium, glandular hyperplasia, and moderate fibrosis.

In our study, a 60-year-old woman presented with facial pain and nasal congestion for 13 weeks. CT scan revealed mucosal thickening in the left maxillary sinus. Biopsy revealed an epithelial thickness of 116 micrometers, with almost no ciliated epithelium, glandular hyperplasia, and moderate submucosal fibrosis.

Table 1. Age of patients and morphological parameters of the maxillary sinus mucosa [9].

Patient No.	Age (young)	Epithelial thickness (μm)	Ciliated epithelium preservation (%)	Submucosal fibrosis (0–3 points)
1	18	110± 1.5	25	2
2	30	118± 1.7	20	3
3	45	115± 1.5	18	2
4	60	116± 1.7	18	3

The clinical examples presented are fully consistent with the results of the general histomorphological analysis (Table 2). In particular, in all cases, epithelial thickening, destruction of the ciliated epithelium, hyperplasia of the glandular apparatus, and submucosal fibrosis were observed, which confirms the structural rearrangements characteristic of chronic sinusitis. These individual cases were evaluated as clinical manifestations of the statistically determined general patterns.

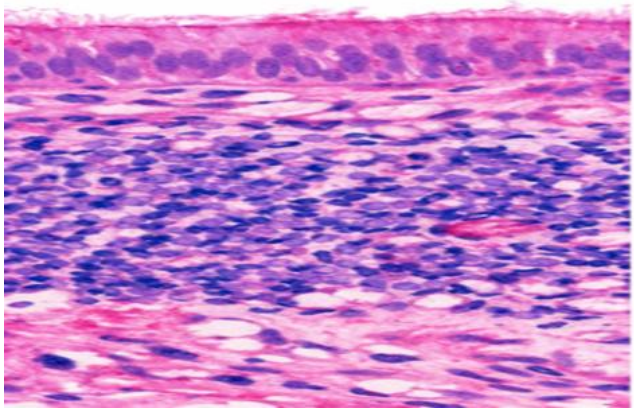

Figure 1. Epithelial thickening and loss of ciliated epithelium due to chronic sinusitis indicate impaired mucociliary clearance [10].

Figure 1 illustrates histological changes in the maxillary sinus mucosa in chronic sinusitis. The epithelial layer shows marked thickening with disruption and partial loss of the ciliated epithelium. These alterations indicate impaired mucociliary clearance, which contributes to mucus retention, reduced self-cleaning capacity of the sinus cavity, and persistence of chronic inflammation.

Table 2. Morphological indicators of the mucous membrane of the sinus cavity in chronic sinusitis [11].

Structural changes	Morphological description	Chronic sinusitis (n = 36)	Control group (n = 12)
Epithelial thickening	Hyperplasia of the epithelial layer, formation of multi-row epithelium	112.4 ± 18.6 micrometers	41.7 ± 9.3 micrometers
Ciliated epithelium destruction	Partial or complete loss of eyelashes, uneven location	22 ± 6 % saved	91 ± 4 % saved
Glandular hyperplasia	Increased number and size of mucous glands	69 %	0 %
Submucosal fibrosis	Increased collagen fibers, thickening of connective tissue	72% (2–3 points)	16% (1 point)

Note: Data are presented as mean ± standard deviation. $P < 0.05$– statistically significant difference.

Table 2 summarizes the main histomorphological differences in the sinus mucosa between patients with chronic sinusitis and the control group. In chronic sinusitis, a marked increase in epithelial thickness is observed compared to controls, indicating epithelial hyperplasia. There is a significant loss of ciliated epithelium, reflecting impaired mucociliary function. Glandular hyperplasia is frequently present in affected patients, while it is absent in the control group. In addition, submucosal fibrosis is more pronounced in chronic sinusitis, demonstrating increased collagen deposition and connective tissue thickening associated with long-standing inflammation

Selected clinical cases demonstrate that the histomorphological changes identified in chronic sinusitis are also clearly manifested in individual patients and increase the reliability of the obtained statistical results.

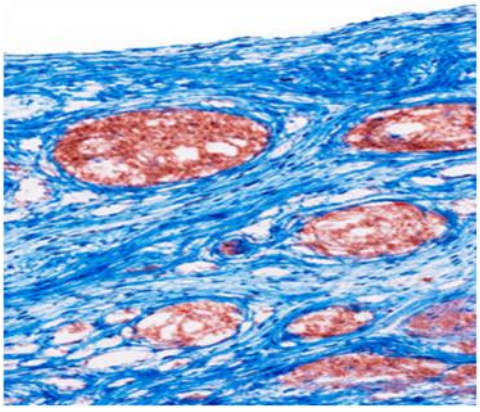

Figure 2. Submucosal fibrosis and glandular hyperplasia reflect secretion stagnation and changes in mucosal structure [12].

Figure 2 demonstrates pronounced submucosal fibrosis with dense collagen fiber deposition and evident hyperplasia of mucous glands. These structural alterations indicate chronic inflammatory remodeling of the sinus mucosa, leading to increased mucus production, impaired drainage, and stagnation of secretions, which contribute to the persistence of chronic sinusitis [13], [14], [15].

In the chronic sinusitis group, a significant increase in epithelial thickness and partial or complete loss of cilia were observed. This is associated with impaired mucociliary clearance, i.e., the self-cleaning system of the sinus cavity, and stagnation of purulent secretion, which is consistent with chronic inflammatory processes reported in the literature [16], [17].

Glandular hyperplasia leads to increased mucus secretion, which explains the stagnation of secretion in the maxillary sinus and the duration of infection. This result is consistent with other studies: glandular hyperplasia is more common in chronic rhinosinusitis.

Fibrosis, as determined by Masson's trichrome staining, reduces mucosal elasticity and reduces the effectiveness of conservative treatment. These changes have been shown to be associated with the duration and chronicity of the inflammatory process. However, the degree of fibrosis in patient samples is consistent with the overall statistical results.

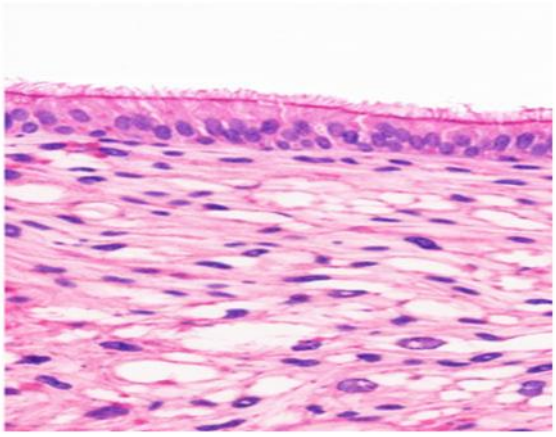

Figure 3. Normal mucosa shows a healthy condition of epithelium and submucosal layer in the control group [18].

Figure 3 shows normal maxillary sinus mucosa from the control group, characterized by a well-preserved ciliated epithelial layer and an intact submucosal structure. The epithelium displays normal thickness, and the underlying connective tissue appears loose without signs of fibrosis or glandular hyperplasia, indicating a healthy mucosal architecture and effective mucociliary function.

The histomorphological study showed that in patients with chronic sinusitis, significant and stable changes occur in all layers of the mucous membrane of the sinus cavity. The epithelial layer thickened by an average of 112.4±18.6 μm , compared with 41.7±9.3 μm in the control group , the difference being statistically significant ($P<0.001$). Along with epithelial thickening, cilia were preserved in only 22±6% of patients, compared with 91±4% in the control group, which indicates a significant violation of mucociliary clearance. The loss of the ciliated epithelial layer leads to the accumulation of mucus and microbes in the sinuses, which explains the stagnation of purulent secretions and the persistence of the chronic inflammatory process [19], [20].

When the submucosal layer was assessed with Masson's trichrome stain, moderate to severe fibrosis was observed in 72% of patients, compared with only 16% of controls. These fibrotic changes reduce the elasticity of the mucosa, which further impairs the self-cleaning function of the maxillary sinus. High levels of fibrosis also reduce the effectiveness of conservative treatment, justifying the need for surgical intervention.

Mucous gland hyperplasia is noted in 69% of patients, which explains the increased secretion of mucus and mucus stagnation. Epithelial thickening and loss of cilia, along with increased glandular activity, play an important role in the pathogenesis of the disease,

since impaired mucociliary clearance ensures the continuation of the chronic inflammatory process.

The results of the analysis of individual patients confirm the general statistical indicators. For example, in an 18-year-old female patient, the epithelium thickness was 110 micrometers, cilia were partially lost, moderate submucosal fibrosis, and glandular hyperplasia were observed. In a 30-year-old male patient, the epithelium was 118 micrometers; glandular hyperplasia and severe fibrosis were noted. In a 45-year-old female patient, the epithelium was 115 micrometers, the ciliated epithelium was partially preserved, and moderate fibrosis was noted. In a 60-year-old woman, the epithelium was 116 micrometers, and glandular hyperplasia and moderate submucosal fibrosis were observed. These individual examples show that structural changes in the floors of the maxillary sinus in chronic sinusitis are stable and clinically significant.

The results obtained are consistent with the literature. Smith and Kennedy reported epithelial thickening and loss of the ciliated epithelial layer in chronic sinusitis, while Fokkens et al. reported that glandular hyperplasia is common in chronic rhinosinusitis [21]. The presence of submucosal fibrosis reduces mucosal elasticity and reduces the effectiveness of conservative therapy [22]. However, fibrosis and hyperplasia serve as important indicators in planning surgical intervention.

The results show that histomorphological changes in all layers of the sinus mucosa are of fundamental scientific and clinical importance in determining the diagnosis and treatment strategy for chronic sinusitis, as well as in developing a surgical approach tailored to individual patient characteristics. Timely use of therapy and surgical interventions aimed at restoring mucociliary clearance can improve the clinical outcome of the patient.

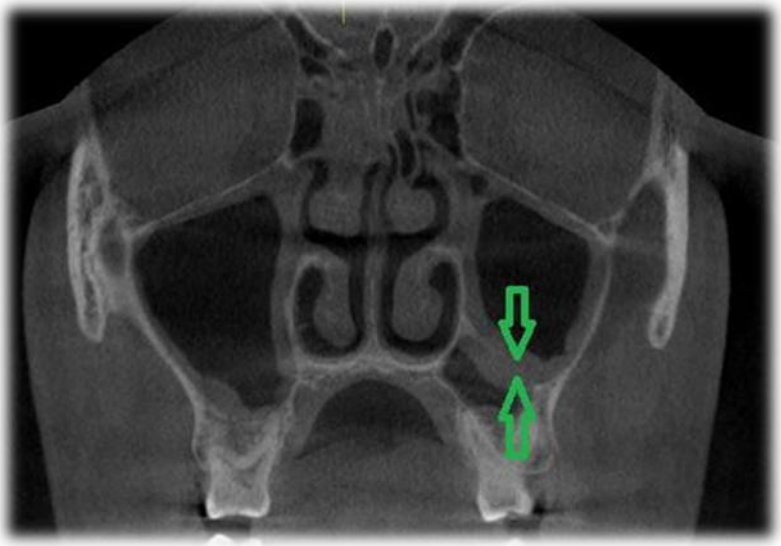

Figure 4. CT scan of chronic hyperplastic sinusitis [23].

Figure 4 presents a computed tomography (CT) image of chronic hyperplastic sinusitis, demonstrating marked thickening of the maxillary sinus mucosa and partial reduction of the sinus cavity lumen. These radiological findings reflect chronic inflammatory changes and correlate with histomorphological evidence of mucosal hyperplasia and impaired sinus ventilation and drainage.

In our study, the approximately threefold increase in epithelial thickness compared to the control group indicates the development of epithelial hyperplasia and metaplastic processes in the mucosa under the influence of prolonged inflammation. The thickening

of the epithelial layer limits the diffusion of oxygen and nutrients and disrupts the normal physiological functions of the mucosa. This is consistent with the processes of epithelial remodeling in chronic rhinosinusitis described by other authors.

The self-cleaning system of the maxillary sinus is the main protective mechanism of the respiratory tract. Ciliated epithelial layer and loss of function create conditions for stagnation of mucous secretion, proliferation of microorganisms, and continuation of the inflammatory process. These results indicate that damage to the ciliated epithelium is one of the leading links in the pathogenesis of chronic sinusitis.

Hyperplasia of the glandular apparatus was detected in a large proportion of patients and was accompanied by increased mucous secretion. Although the increase in the number and size of the glands is considered, on the one hand, as a protective mechanism, on the other hand, excessive secretion leads to impaired drainage in the maxillary sinus. As a result, stagnation of secretion increases, creating a favorable environment for infection. This condition is clinically associated with purulent discharge and a relapsing course of the disease [24], [25].

The high level of submucosal fibrosis indicates a long-term chronic inflammatory process. The increase in collagen fibers reduces the elasticity of the mucosa and limits its regenerative capabilities. This leads to a decrease in the effectiveness of conservative treatment and an increase in the need for surgical intervention. In our study, the high level of fibrosis was directly related to changes in the epithelium and glandular apparatus, reflecting the complex remodeling of the mucosa.

The presented individual clinical cases fully confirm the general histomorphological results, demonstrating that the identified structural changes are not just statistical indicators, but rather situations that occur in real clinical practice. This increases the practical significance of the research results.

4. Conclusions

The results of our study show that chronic sinusitis leads to structural reorganization of the mucous membrane, weakens the activity of the self-cleaning system of the sinus cavity, and causes the continuation of the inflammatory process with stagnation of secretion. As a result, the effectiveness of conservative therapy decreases, and the need for surgical intervention increases. In general, the processes of epithelial and submucosal reorganization that develop in the mucous membrane of the sinus cavity in chronic sinusitis constitute the morphological basis of the progression of the disease and resistance to treatment. These facts indicate the need for early detection of chronic sinusitis, treatment measures before the formation of irreversible changes in the mucous membrane, and justify the importance of morphological assessment in choosing treatment tactics.

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