

Research Article

IMPACT OF CHRONIC AIRWAY INFLAMMATION ON MAXILLARY SINUS VOLUME: A RETROSPECTIVE CBCT STUDY IN ASTHMA AND CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENTS

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ABSTRACT

Objective: This study aimed to investigate volumetric alterations of the maxillary sinus in patients with asthma and chronic obstructive pulmonary disease (COPD).

Materials and Methods: A total of 120 cone-beam computed tomography (CBCT) images from 40 COPD patients, 40 asthma patients, and 40 healthy individuals were retrospectively evaluated. Morphometric analyses were performed using CBCT images, and maxillary sinus volume and surface area were measured using 3D Slicer software. Group comparisons were conducted, and the independent effects of disease status were further evaluated using a General Linear Model (GLM-ANCOVA) adjusted for age and sex.

Results: Group comparisons revealed significantly lower maxillary sinus volume and surface area in the asthma group compared to both the COPD and control groups ($p < 0.05$). The COPD group also showed lower right-sided and total measurements than controls ($p < 0.05$), whereas left-sided differences were not significant. However, in GLM-ANCOVA analysis, asthma did not demonstrate a significant independent effect, and no significant relationship was observed between COPD and sinus volume.

Conclusion: These findings suggest a possible association between asthma and reduced maxillary sinus dimensions; however, this relationship was not independent of other variables and should be interpreted with caution. COPD showed no significant independent association with sinus volume. Further prospective studies are needed to clarify the underlying mechanisms and direction of this relationship.

Keywords: Asthma, chronic obstructive pulmonary disease, cone-beam computed tomography, maxillary sinus

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INTRODUCTION

Asthma is a chronic condition marked by symptoms like wheezing, dyspnea, cough, and chest tightness, with variability in frequency and intensity over time(1). It is characterized by hypersensitivity and chronic inflammation in the airways, which arises from direct or indirect stimuli. Symptoms and airflow obstruction vary with time. These symptoms are generally triggered by several factors, including allergens or irritants, physical activity, air circulation, or respiratory illnesses(2).

According to GOLD 2023, chronic obstructive pulmonary disease (COPD) is a heterogeneous lung disease characterized by persistent and usually progressive airflow limitation, arising from abnormalities in the airways (such as bronchitis and bronchiolitis) and/or the alveoli (emphysema), and presenting with chronic respiratory symptoms including dyspnea, cough, sputum production, and/or exacerbations(3). COPD results from the interplay of genetic predisposition and environmental exposures(4).

Radiologic imaging in dentistry is essential for aiding clinicians in diagnostic and therapeutic decision-making regarding biological and environmental influences in the dentomaxillofacial region. In response to the limitations of dental applications and the clinical demand for cross-sectional imaging, cone-beam computed tomography (CBCT) has been developed for dentomaxillofacial imaging, offering three-dimensional data acquisition at a reduced radiation dose and cost compared to conventional medical computed tomography (CT)(5). Pathologic mechanisms in asthma and COPD patients are believed to influence the architecture and volume of the maxillary sinus. This study aimed to analyze maxillary sinus morphometric changes associated with asthma and chronic obstructive pulmonary disease.

MATERIALS AND METHODS

This study was approved by the Clinical Research Ethics Committee of the Akdeniz University Faculty of Medicine (25.01.2024, Decision No: 61). The research was performed in compliance with the Declaration of Helsinki. The study involved 120 patients admitted to the Dentomaxillofacial Radiology clinic. Prior to initiating the investigation, power analysis calculations were conducted using the G*Power 3.1 application to ascertain the sample size. The power and sample size of the study, as determined by Ararat et al.(6), indicated that participants would achieve

adequate power and effect size, specifically 90% power and an effect size of 0.68.

CBCT images of 120 adult individuals aged 18 years and older were retrospectively reviewed from the radiology archive of Akdeniz University Faculty of Dentistry. The data of the participants were categorized into three groups. The patient group consisted of individuals with asthma (n=40) and COPD (n=40), whose diagnoses were based on previously established clinical diagnoses recorded in the hospital database and patient medical records. The control group (n=40) included individuals with no recorded history of systemic disease or medication use. This study excluded cases with dental implants in the maxillary premolar-molar region, maxillofacial cystic or tumorous conditions, caries, previous surgical interventions, craniofacial abnormalities, obvious sinus opacification, or chronic rhinosinusitis. CBCT images were obtained utilizing the Veraview X800 (J. Morita Mfg. Corp., Kyoto, Japan) following the manufacturer's parameters (FOV: 15 × 14 cm; 4.8 mA; 99 kVp and 35.8 s). All CBCT scans were evaluated in 1 mm thick coronal, axial, and sagittal slices. The scans were examined with i-Dixel (Version 2.3.6.1 J Morita Mfg. Corp.) software. Image acquisition was conducted with a single 360° rotation of the instrument around the patient. All images were preserved in DICOM (Digital Imaging and Communications in Medicine) format.

Volumetric Evaluation of Maxillary Sinuses

The volumetric assessment of maxillary sinuses was conducted using 3D Slicer (5.6.1, www.slicer.org), an open-source tool for medical image analysis in biomedical research. The CBCT image data, formatted in DICOM, were imported into the designated program using the "Import DICOM Files" function. The "Add DICOM Data" function presents the imported image in three panels within the program's workspace, facilitating the analysis of coronal, axial, and sagittal sections (Fig. 1). Subsequent to image transfer, a window was created in all three planes (coronal, axial, sagittal) using the "Crop Volume" feature to improve the clarity and ease of volumetric assessments, distinctly illustrating the right and left maxillary sinuses, with the relevant maxillary sinus prominently displayed (Fig. 2).

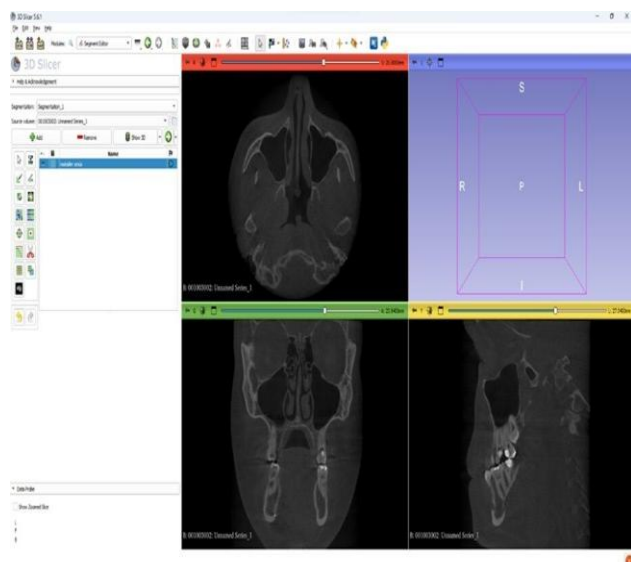


Figure 1. Axial, coronal, and sagittal views of a CBCT dataset imported into 3D Slicer (version 5.6.1).

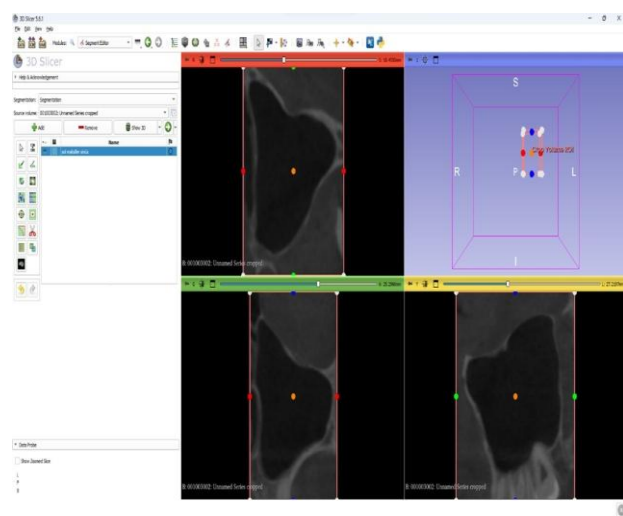


Figure 2. Definition of the region of interest around the left maxillary sinus with the "Crop Volume" module in the axial, coronal, and sagittal planes.

Subsequently, segmentation was performed using the "Segment Editor" module. Although CBCT grayscale values do not correspond to standardized Hounsfield Units (HU), threshold-based segmentation was used as an initial step to delineate the air-filled maxillary sinus cavity. To minimize potential inaccuracies related to grayscale variability, the segmentation was refined using manual correction tools. This semi-automated approach combining thresholding and manual refinement is consistent with previously published CBCT-based volumetric studies (6–8). In the broadest constrained axial section, the boundaries of the maxillary sinus were

carefully delineated using the "Scissors" tool, and the region of interest was separated from adjacent anatomical structures. The segmentation was then further refined using the "Smoothing" function to improve surface continuity and anatomical accuracy. Finally, volume (mm^3) and surface area (mm^2) measurements were obtained using the automated "Segment Statistics" module (Fig. 3).

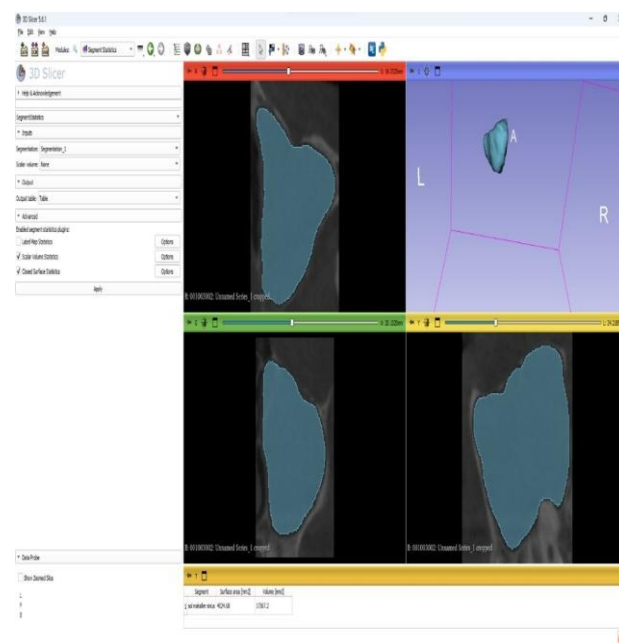


Figure 3. Segmentation of the left maxillary sinus in the axial, coronal, and sagittal planes, its three-dimensional reconstruction, and the surface area (mm^2) and volume (mm^3) values obtained with the "Segment Statistics" module.

Statistical Method

Data were analyzed utilizing IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). The adherence of continuous variables to a normal distribution was assessed using the Shapiro-Wilk test. The study presented categorical variables as frequency (n) and percentage (%), whereas continuous variables were reported as mean $\pm$ standard deviation (SD), median (interquartile range 25–75), and minimum-maximum values. Spearman Rho Correlation Analysis was employed in the correlation analysis of continuous variables due to the non-normal distribution of the data. For normally distributed data in independent two-group studies, the independent-samples t-test was used. For non-normally distributed data, the Mann-Whitney U test was used. The ANOVA test was used when the data had a normal distribution for comparisons between more than two groups that were not related. The Kruskal-Wallis H test was the best non-parametric test to use when the

sample size in at least one group was less than 30. Based on the results of the ANOVA test, the Post-Hoc Bonferroni test was done. Pearson Chi-Square, Fisher–Freeman–Halton exact test, and Post Hoc Bonferroni correction were used to investigate independent categorical variables. A p-value of less than 0.05 was considered statistically significant.

To evaluate the independent effects of asthma and COPD on total sinus volume, a General Linear Model (GLM-ANCOVA) analysis was performed. Total sinus volume was defined as the dependent variable. Two separate models were constructed, one with asthma status and one with COPD status as the disease factor; in both models, sex was included as a fixed factor and age as a covariate. To assess whether the effect of disease status on total sinus volume varied with age, a disease $\times$ age interaction term was included in the model. Additionally, sex $\times$ disease interaction terms were incorporated to examine potential sex-related differences.

Type III sums of squares were used for model estimation. Adjusted means were calculated using the estimated marginal means (EMM) method based on the mean age, and Bonferroni correction was applied for pairwise comparisons. The assumption of homogeneity of variances was assessed using Levene's test. Model fit was reported using R^2 and adjusted R^2 values. Effect sizes were expressed as partial eta squared (partial η^2). A two-sided p-value of <0.05 was considered statistically significant.

Intra-observer reliability was assessed using the Intraclass Correlation Coefficient (ICC) in a randomly selected subset of 30 patients (25% of the total sample). According to the criteria proposed by Koo and Li (9), all measurements demonstrated excellent agreement. The ICC values ranged from 0.918 to >0.999 for area measurements and from 0.922 to 0.999 for volume measurements. These findings indicate a high level of measurement consistency and confirm the reliability of the volumetric assessment method used in this study.

RESULTS

Demographic Data

The mean age of 120 participants (18–85 years) was 55.02 ± 14.85 years. Overall, 63.3% were older than 50 years. The study included 69 women (57.5%) and 51 men (42.5%). Each of the three study groups had 40 participants. The comparison of maxillary sinus measurements by sex is presented in Table 1. In the volumetric assessment of the maxillary sinuses in the COPD, asthma, and control

groups, no statistically significant difference was observed between males and females ($p > 0.05$).

Table 2 presents the results of correlation analyses between age and area and volume measurements in the asthma-COPD and control groups. The "r" value indicated in the analysis results is the correlation coefficient. The correlation coefficient ranges from -1 to +1. Here, +1 indicates a perfect positive correlation, while -1 indicates a perfect negative correlation. It is known that the strength of the relationship is weak when the correlation coefficient approaches zero, and it strengthens when it approaches -1 or +1. Accordingly, $r=0.00$ is interpreted as "no relationship," $r=0.01-0.29$ as "low-level relationship," $r=0.30-0.70$ as "moderate-level relationship," $r=0.71-0.99$ as "high-level relationship," and $r=1.00$ as "perfect relationship." According to the analysis results, no significant relationship was observed between age and area and volume measurements ($p > 0.05$).

Table 1. Analysis of Maxillary Sinus Area and Volume Across Groups by Sex

Variable	Male (Mean ± SD)	Female (Mean ± SD)	p
Asthma/COPD			
Right maxillary sinus area (mm ²)	583.59±148.89	560.27±156.68	0.508 [†]
Right maxillary sinus volume (cm ³)	11.64(9.21-14.17)	10.73(7.34-13.15)	0.209 ^μ
Left maxillary sinus area (mm ²)	595.59±150.4	559.54±146.18	0.289 [†]
Left maxillary sinus volume (cm ³)	11.71(9.75-14.34)	10.16(7.02-12.57)	0.105 ^μ
Total maxillary sinus area (mm ²)	1179.19±287.08	1119.81±286.31	0.367 [†]
Total maxillary sinus volume (cm ³)	22.9(19.42-28.28)	21.06(15.23-25.65)	0.146 ^μ
Control Group			
Right maxillary sinus area (mm ²)	740(670-831)	682(563-773)	0.161 ^μ
Right maxillary sinus volume (cm ³)	15.96(14.62-19.94)	13.98(11.01-16.5)	0.050 ^μ
Left maxillary sinus area (mm ²)	735(620-862)	709(545-760)	0.226 ^μ
Left maxillary sinus volume (cm ³)	15.92(13.74-19.87)	11.64(10.6-17.5)	0.178 ^μ
Total maxillary sinus area (mm ²)	1478(1272-1661)	1321(1160-1527)	0.226 ^μ
Total maxillary sinus volume (cm ³)	31.88(25.62-38.76)	25.62(21.71-33.9)	0.078 ^μ

†Independent Samples T test, Mean ± SD, ^μMann Whitney U test, Median (IQR), Abbreviation: COPD, chronic obstructive pulmonary disease; IQR, interquartile range; SD, standard deviation.

Table 2. Age-Related Variations in Maxillary Sinus Measurements Among Study Groups

	Asthma/COPD		Control	
	r	p	r	p
Right maxillary sinus area	-0.008	0.946	-0.19	0.24
Left maxillary sinus area	0.001	0.996	-0.293	0.066
Total maxillary sinus area	0.016	0.888	-0.259	0.106
Right maxillary sinus volume	0.092	0.415	-0.184	0.255
Left maxillary sinus volume	0.076	0.505	-0.31	0.051
Total maxillary sinus volume	0.092	0.416	-0.274	0.087

Correlation analysis was performed using Spearman's rho.

*p < 0.05 indicates statistical significance. Abbreviation: COPD, chronic obstructive pulmonary disease.

Volume and Area Comparisons

The asthma and COPD groups (case groups) were compared to the control group. Table 3 presents the findings of the investigation regarding the substantial differences in area and volume measurements between case groups. The study results indicate that all measurements exhibit significant variations among disease groups (p<0.001). Post-hoc analyses were employed to identify the specific disease categories exhibiting these significant differences. The outcomes of the Post-Hoc Bonferroni test are presented in the table. The analysis revealed that the maxillary sinus volume and area measurements in asthma patients were statistically lower than those in the other groups (p<0.05). Compared with

the COPD group, the control group had significantly higher right and total sinus area and volume values (p<0.05), whereas the differences in left sinus area (p=0.054) and left sinus volume (p=0.057) were not significant (Table 3).

According to the GLM-ANCOVA analysis presented in Table 4, in which age and sex were included as a covariate and factor, respectively, the overall adjusted model was statistically significant (F = 9.299; p < 0.001) and explained approximately 29% of the variance in total sinus volume (R² = 0.290; adjusted R² = 0.259). Age was found to have a significant independent effect on total sinus volume (F = 10.539; p = 0.002; partial η² = 0.085), whereas the independent effect of sex did not reach statistical significance, although it was close to the significance threshold (F = 3.716; p = 0.056). In the Type III main effects analysis, the independent effect of asthma was not statistically significant (F = 2.232; p = 0.138; partial η² = 0.019). However, in the estimated marginal means (EMM) comparisons adjusted for age, the total sinus volume of the non-asthma group, which comprised the COPD and control participants, was significantly higher than that of the asthma group (28.639 ± 0.943 vs. 18.527 ± 1.431), and the difference between groups was statistically significant (mean difference = 10.111; 95% CI: 6.716–13.507; Bonferroni-adjusted p < 0.001). The non-significant asthma

Table 3. Area and volume values of the study groups

	Control (n=40)	Asthma (n=40)	COPD (n=40)	p ^A	p ¹⁻²	p ¹⁻³	p ²⁻³
Right Area (mm ²)	710.08±139.03	524.55±144.85	614.65±149.42	<0.001	<0.001	0.011	0.019
Left Area (mm ²)	695.85±154.95	530.68±131.61	617.25±152.34	<0.001	<0.001	0.054	0.028
Total Area (mm ²)	1405.93±279.22	1055.23±256.12	1231.9±290.56	<0.001	<0.001	0.017	0.015
Right Volume (cm ³)	15.4±4.38	9.52±3.75	12.91±4.74	<0.001	<0.001	0.033	0.002
Left Volume (cm ³)	15.03±4.64	9.57±3.43	12.75±4.67	<0.001	<0.001	0.057	0.004
Total Volume (cm ³)	30.43±8.74	19.09±6.9	25.66±9.24	<0.001	<0.001	0.036	0.002

Comparison of groups using one-way analysis of variance (ANOVA) followed by Bonferroni post hoc test. Values are expressed as mean ± standard deviation (SD). * p < 0.05 indicates statistical significance. Abbreviation: COPD, chronic obstructive pulmonary disease; n, number of participants.

Table 4. GLM-ANCOVA Analysis of the Main and Interaction Effects of Asthma, Age, and Sex on Total Sinus Volume

Source	Type III Sum of Squares	SD	Mean Square	F	p	Partial η^2	Other (EMM±SE)	Asthma (EMM±SE)
Sex	249.060	1	249.060	3.716	0.056	0.032		
Asthma	149.604	1	149.604	2.232	0.138	0.019	28.639±0.943	18.527±1.431
Age	706.436	1	706.436	10.539	0.002	0.085		
Asthma × Age	2.964	1	2.964	0.044	0.834	<0.001		
Sex × Asthma	13.603	1	13.603	0.203	0.653	0.002		
Error	7641.233	114	67.028					
Corrected Model	3116.437	5	623.287	9.299	<0.001	0.290		
Pairwise Comparison	Mean Difference	SE	95% CI	p				
Other – Asthma	10.111	1.714	6.716–13.507	<0.001				

A General Linear Model (GLM-ANCOVA) analysis was performed. Age was included in the model as a covariate. Type III sums of squares were used. Partial η^2 values were reported to indicate effect sizes. EMM: Estimated Marginal Means, SE: Standard Error, CI: Confidence Interval. Adjusted means were calculated based on the mean age (55.025 years). Bonferroni correction was applied for pairwise comparisons. Levene's test was conducted to assess the assumption of homogeneity of variances, and variance homogeneity was confirmed ($F = 1.997$; $p = 0.118$). The explanatory power of the model was $R^2 = 0.290$ and adjusted $R^2 = 0.259$. EMM comparisons were calculated based on age-adjusted means, and these analyses may yield results that differ from the Type III main effect tests in the model.

× age interaction term ($F = 0.044$; $p = 0.834$) indicates that the effect of asthma on total sinus volume does not vary with age. Similarly, the sex × asthma interaction was not statistically significant ($F = 0.203$; $p = 0.653$). Levene's test confirmed that the assumption of homogeneity of variances was satisfied ($p = 0.118$).

In Table 5, the effects of COPD, age, and sex on total sinus volume were evaluated using a GLM-ANCOVA model. Although the model was statistically significant overall, its explanatory power was limited ($F = 2.395$; $p = 0.042$; $R^2 = 0.095$; adjusted $R^2 = 0.055$). The presence of COPD did not have a significant independent effect on total sinus volume ($F = 1.470$; $p = 0.228$; partial $\eta^2 = 0.013$). Age was also not found to be a significant covariate in this model ($F = 0.045$; $p = 0.833$). When age-adjusted estimated marginal means were examined, total sinus volumes of individuals without COPD (asthma and control participants) and those with COPD were found to be very similar ($24.755 \pm$

1.079 vs. 24.950 ± 1.859). Bonferroni-adjusted pairwise comparisons also revealed no significant difference between the groups (mean difference = -0.195 ; 95% CI: -4.453 to 4.063 ; $p = 0.928$). Additionally, the non-significant COPD × age interaction term ($F = 1.912$; $p = 0.169$) indicates that the effect of COPD on total sinus volume does not vary with age. Similarly, the sex × COPD interaction was not statistically significant ($F = 1.969$; $p = 0.163$). Levene's test results supported the assumption of homogeneity of variances ($p = 0.981$).

Table 5. GLM-ANCOVA Analysis of the Main and Interaction Effects of COPD, Age, and Sex on Total Sinus Volume

Source	Type III Sum of Squares	SD	Mean Square	F	p	Partial η^2
Sex	256.817	1	256.817	3.007	0.086	0.026
COPD	125.573	1	125.573	1.470	0.228	0.013
Age	3.803	1	3.803	0.045	0.833	<0.001
COPD × Age	163.244	1	163.244	1.912	0.169	0.016
Sex × COPD	168.166	1	168.166	1.969	0.163	0.017
Error	9735.171	114	85.396			
Corrected Model	1022.499	5	204.500	2.395	0.042	0.095
Pairwise Comparison	Mean Difference	SE	95% CI	p		
Other – COPD	-0.195	2.149	-4.453 to 4.063	0.928		

A General Linear Model (GLM-ANCOVA) analysis was performed. Age was included in the model as a covariate. Type III sums of squares were used. Partial η^2 values were reported to indicate effect sizes. EMM: Estimated Marginal Means, SE: Standard Error, CI: Confidence Interval. Adjusted means were calculated based on the mean age (55.025 years). Bonferroni correction was applied for pairwise comparisons. Levene's test was conducted to assess the assumption of homogeneity of variances, and variance homogeneity was confirmed ($F = 0.059$; $p = 0.981$). The explanatory power of the model was $R^2 = 0.095$ and adjusted $R^2 = 0.055$.

DISCUSSION

There is increasing evidence that chronic respiratory diseases, such as asthma and COPD, may affect not only the lower respiratory tract but also the anatomical structures of the upper airway (10–13). In the present study, group comparisons revealed lower maxillary sinus volume and surface area in patients with asthma compared to healthy individuals; COPD was associated with smaller right-sided and total measurements in group comparisons but showed no significant independent association in the adjusted model. These findings suggest a possible association between asthma and sinonasal morphological alterations. However, although significant differences were observed in group comparisons, the lack of an independent effect in the GLM-ANCOVA model indicates that these differences should be interpreted with caution. In addition, the underlying mechanisms cannot be directly determined based on the current data. Our findings are partially consistent with previous studies reporting decreased maxillary sinus dimensions in chronic respiratory diseases(6, 14); however, the observed associations may be influenced by other variables rather than a direct effect of the disease itself.

Ararat et al.(6) conducted a retrospective analysis of 80 individuals (40 COPD patients and 40 healthy controls) and found that maxillary sinus volume was statistically significantly lower in COPD patients than in healthy controls ($p < 0.05$). The observed reduction in volume in this study may be associated with chronic inflammatory processes. However, since inflammatory activity was not directly measured and disease staging was not performed, the results should be interpreted with caution, and no direct causal relationship should be inferred.

The relationship between asthma and maxillary sinus volume appears to be more complex and variable than that observed in COPD. Edik et al.(14) reported that both right and left maxillary sinus volumes in asthmatic patients were significantly smaller compared to the control group. However, this relationship may be influenced by multiple factors, including disease severity, duration, inflammatory phenotype, and treatment history. Since these clinical parameters were not available in the present retrospective dataset, further interpretation remains limited. Marino et al.(15) investigated the effect of asthma on paranasal sinus pneumatization and found no association between asthma and altered pneumatization, whereas cystic fibrosis was associated with significantly reduced pneumatization. The

variability observed in asthma-related findings may therefore reflect the heterogeneous nature of the disease.

The “united airway” concept provides a theoretical framework suggesting that the upper and lower respiratory tracts may function as a single inflammatory system(16–20). Chronic inflammation seen in asthma and COPD may be associated with inflammatory changes in the sinus mucosa through increased systemic levels of inflammatory mediators (e.g., IL-6, IL-8, MMP-9)(16, 17). This inflammation may contribute to changes in sinus volume through processes such as mucosal edema, hyperplasia, and tissue remodeling. In chronic respiratory diseases such as asthma and COPD, the observed differences in maxillary sinus volume may be related to alterations in sinus morphology associated with chronic inflammation in the lower airways. However, these mechanisms were not directly evaluated in the present study.

Several mechanisms have been proposed to explain how chronic inflammation may influence maxillary sinus volume. First, chronic inflammation seen in asthma and COPD leads to thickening and edema of the sinus mucosa(21). In asthma, eosinophilic inflammation is known to cause mucosal edema and hyperplasia(16). Second, inflammation negatively affects sinus drainage by impairing ciliary function and increasing mucus production(17). This situation can lead to negative pressure within the sinus and, over time, contribute to the inward collapse of the sinus walls, which in turn may reduce sinus volume. Although these mechanisms have been proposed in the literature, they were not evaluated in the present study and cannot be confirmed solely based on CBCT-derived volumetric analysis.

Aydin et al.(18) demonstrated significant sinonasal involvement in patients with asthma and COPD, with inflammatory changes affecting multiple components of the upper airway. This finding is further supported by Celakovsky et al.(19), who reported nasal symptoms, obstruction, and paranasal sinus opacification in COPD patients, highlighting the importance of upper airway involvement. The presence of mucosal thickening, opacification, and related inflammatory alterations suggests that changes in sinus morphology in COPD and asthma may be associated with inflammatory processes; however, the underlying mechanisms were not directly evaluated in the present study. Consistent with this, Crater et al.(20) reported that sinus abnormalities were common during acute asthma exacerbations. Stelmach et al.(22) identified a high prevalence of sinus abnormalities in

allergic asthmatic patients, emphasizing the clinical relevance of upper airway involvement, particularly in allergic phenotypes. In addition, Hamada et al.(23) demonstrated pronounced sinonasal inflammation in patients with asthma–COPD overlap syndrome, suggesting a potential relationship between lower airway pathologies and upper airway structures. From a clinical perspective, the reduction in maxillary sinus volume observed in patients with asthma and COPD may be associated with certain functional outcomes. For instance, possible effects such as impaired mucociliary clearance, increased susceptibility to infections, or disease control have been discussed in the literature. However, these functional outcomes were not evaluated in the present study, and therefore such interpretations remain speculative.

The shape and size of the maxillary sinus are influenced by genetic and environmental factors, as well as age, sex, and other variables(24). The volume of the maxillary sinus increases from the postnatal period to adulthood and has been reported to continue enlarging until approximately 20–30 years of age(25). However, the pattern of volumetric change over time remains unclear, particularly whether this increase occurs at a constant rate, through growth spurts, or is followed by a reduction in volume with advancing age(26). Aktuna Belgin et al.(27) evaluated CBCT images of 200 patients aged 18 years and older, dividing them into five age groups, and reported a decrease in maxillary sinus volume with increasing age. In contrast, Schriber et al. (28) analyzed CBCT images of 100 patients categorized into two groups (<62 and ≥62 years) and found no significant difference in maxillary sinus volume between the groups. Similarly, Möhlhenrich et al.(29) assessed maxillary sinus volumes in 276 patients over the age of 20 and did not observe a significant association between age and sinus volume. Jun et al.(25) examined CT images of 173 individuals aged 0–80 years, grouping them into eight age categories. They reported that maxillary sinus development continues until the third decade in males and the second decade in females; after this maximum growth period, however, no significant volume change was observed between adjacent age groups. In our study, age showed a significant effect in the asthma model but not in the COPD model, suggesting a context-dependent influence on maxillary sinus volume. These findings indicate that changes in sinus volume cannot be explained solely by age; rather, multiple factors such as inflammation, mucosal thickening, disease duration, and environmental influences are likely to play a role.

This study has several strengths, including the inclusion of multiple patient groups, the use of three-dimensional morphometric analysis, and the application of multivariate statistical modeling to evaluate independent effects. However, several limitations should be considered when interpreting the findings. First, the retrospective design limited access to detailed clinical data, including disease severity, duration, smoking status, and medication history. These factors may act as potential confounders influencing maxillary sinus morphology and volume. In addition, threshold-based segmentation of CBCT grayscale values, which do not correspond to standardized HU, may introduce measurement inaccuracies. Therefore, the findings should be interpreted with caution. Future prospective and longitudinal studies incorporating comprehensive clinical, functional, and inflammatory parameters, along with standardized imaging protocols, are required to better elucidate the underlying mechanisms and clarify the direction of the observed association between chronic respiratory diseases and maxillary sinus morphology.

CONCLUSION

This study demonstrated that maxillary sinus volume and surface area were lower in patients with asthma compared to healthy individuals. However, no independent effect of asthma was observed after adjusting for covariates, and COPD did not show a significant independent association with sinus volume. These findings suggest a possible association between asthma and sinus morphology, which should be interpreted with caution. Further prospective studies are needed to clarify the underlying mechanisms and direction of this relationship.

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Authorship contributions

Conceptualization and methodology, A.R. and S.T.; validation, A.R.; formal analysis, S.T.; investigation, data curation, writing—original draft preparation, writing—review and editing, and visualization, A.R. and S.T.; supervision and project administration, S.T. All authors have read and agreed to the published version of the manuscript.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors declare no competing interests.

Ethics

This study was approved by the Ethics Committee for Clinical Research at the Faculty of Medicine, Akdeniz University (25.01.2024, Decision No: 61).

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