

Factors for Maxillary Sinus Volume and Craniofacial Anatomical Features in Adults With Chronic Rhinosinusitis

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Objectives: To compare the volume of the maxillary sinus, dental factors, and craniofacial anatomical features between control subjects and patients with chronic rhinosinusitis (CRS) and to investigate critical factors for the volumetric change in the maxillary sinus in adults.

Design: Retrospective case-control study.

Setting: Tertiary referral center.

Participants: Ninety-nine individuals who visited an allergy and sinus center: 52 control subjects (septal deviation; mean age, 32.69 years) and 47 patients with CRS (mean age, 44.43 years).

Intervention: Cephalometry and computed tomography were performed in all the participants. In blinded tests, dentists investigated the dental status of both groups.

Main Outcome Measures: Maxillary sinus: bone thickness and volume on computed tomography; craniofacial anatomical features: linear and angular variables in

lateral cephalometry; and dental evaluation: malocclusion class, teeth status, and alveolar bone height.

Results: Bony wall thickness of the maxillary sinus significantly increased in patients with CRS ($P < .001$) but showed no relationship with maxillary sinus volume. Maxillary sinus volume significantly decreased in patients with CRS ($P = .001$). Age and alveolar bone height had a negative effect on maxillary sinus volume in both groups. Abnormal teeth had no relationship with maxillary sinus volume in both groups but showed a negative effect on alveolar bone height in the CRS group ($P = .02$). Class II malocclusion associated with anterior movement of the maxilla significantly increased in the CRS group ($P = .006$).

Conclusions: Regardless of CRS, maxillary sinus volume decreased with older age and increased with alveolar bone loss. Regarding craniofacial anatomical features, CRS may have an effect on malocclusion in adults.

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IN THE LITERATURE CONCERNING the volumetric change in the paranasal sinuses, most studies¹⁻⁴ have dealt with sinus and facial growth after endoscopic sinus surgery in pediatric patients. They reported the safety of functional endoscopic sinus surgery performed in children with chronic rhinosinusitis (CRS) and demonstrated no effect on facial growth. However, few studies⁵ have compared maxillary sinus volume between adult patients with CRS and control subjects.

The maxillary sinus has 2 rapid growth phases (ages 0-3 and 7-12 years), and thereafter, modest enlargement occurs until adult size is attained in the person's late teens.⁶ Growth of the maxillary sinus has a direct relationship with the palate and alveolar bone. After the final growth spurt of the maxillary sinus, many chronological and

pathologic events could affect its volume. And, because of its large volume, if there has been a significant volumetric change in the maxillary sinus, it may also affect craniofacial anatomical features.

The objectives of this study were to compare the volume of the maxillary sinus, dental factors, and craniofacial anatomical features between controls and patients with CRS and to investigate critical factors for the volumetric change in the maxillary sinus in adults.

METHODS

A retrospective analysis was performed of data from consecutive patients treated in an allergy and sinus center between June 1, 2007, and June 30, 2008. Patients were excluded if they were children or if they had unilateral rhinosinusitis, congenital craniofacial anomaly, comorbidities

with asthma, aspirin sensitivity, or cystic fibrosis or a history of nasal surgery or facial trauma.

Ninety-nine adults were included: 52 controls (septal deviation; 13 women and 39 men; age range, 18-60 years; mean age, 32.69 years) and 47 patients with CRS (15 women and 32 men; age range, 18-66 years; mean age, 44.43 years). The 2 groups showed a similar sex distribution ($P = .51$), but the CRS group was older than the control group ($P < .001$). The diagnosis of CRS (48.9% with nasal polyposis) was made according to the criteria established by the Rhinosinusitis Task Force of the American Academy of Otolaryngology–Head and Neck Surgery.⁷ Allergic rhinitis was diagnosed based on nasal symptoms, such as watery rhinorrhea, sneezing, itching, and nasal obstruction, and positive skin prick test results (Allergopharma, Hamburg, Germany), according to the criteria of Allergic Rhinitis and Its Impact on Asthma.⁸ Comorbidity of allergic rhinitis was not different between controls (50.0%) and patients with CRS (39.1%) ($P = .07$).

Computed tomography (CT) of the paranasal sinuses and lateral cephalography were performed on all the participants. Axial images were obtained using a spiral CT (Siemens Medical Systems, Erlangen, Germany) (scan setting, 140 kV (peak), 129 mAs; scan time, 1000 milliseconds; and matrix size, 512×512 pixels) without contrast enhancement. Lateral cephalography (Orthophos-3; Siemens Medical Systems) used the standard technique.⁹ The institutional review board of Hanyang University Hospital reviewed and approved all procedures used in this study.

BONY WALL THICKNESS AND VOLUME MEASUREMENT OF THE MAXILLARY SINUS

Overall severity of CRS was evaluated using the Lund-Mackay CT score (mean [SD], 12.28 [3.21]).¹⁰ Then we measured the thickness of the anterior and posterolateral walls of the maxillary sinus. These measurements were performed using an axial image 4 mm below the infraorbital foramen. We selected the midpoint on each wall and measured bony wall thickness using the Picture Archiving and Communication System (PiView STAR; INFINITT, Seoul, South Korea).

Image-processing techniques were used for semiautomatic segmentation of the maxillary sinus. First, the original CT image (Figure 1A) was converted into a binary image (Figure 1B) using a threshold technique to remove soft-tissue densities (inflammation) and to segment the bony boundary of the maxillary sinus. The morphologic closing operation was performed on the binary image to ensure the continuous boundary of the maxillary sinus. Finally, the maxillary sinus was segmented using a region-growing algorithm (Figure 1C). The total volume of the maxillary sinus was measured by multiplying the number of voxels in the segmented region by 1 voxel volume and could be reconstructed into a 3-dimensional image (Figure 1D). We calculated the mean volume of both sides of the maxillary sinus in all the participants.

EVALUATION OF DENTAL FACTORS

In blinded tests, dentists evaluated 3 dental factors: occlusal status, teeth status, and alveolar bone height. Occlusion was clinically evaluated according to the classification of malocclusion by Angle.¹¹ Teeth status was classified into normal and abnormal groups. Abnormal teeth were defined when there was at least 1 positive finding as follows: periodontitis or premolar or molar teeth extraction. Alveolar bone height was defined as the shortest distance between the cortex of the alveolar bone and the inferior wall of the maxillary sinus, perpendicular to the occlusal plane, and the mean value of both sides was calculated.

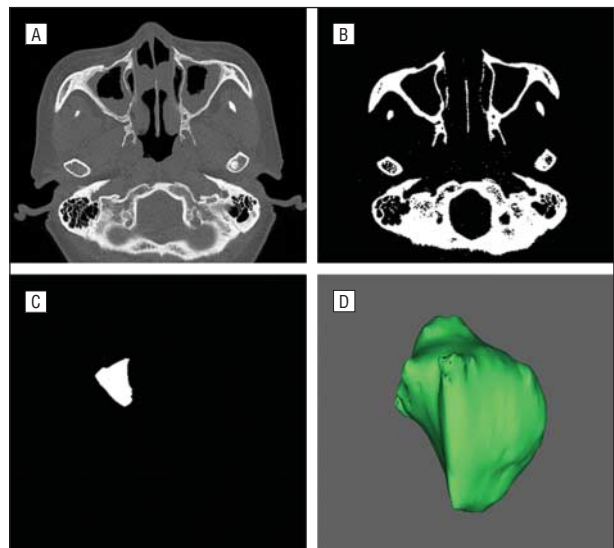


Figure 1. Image-processing techniques for the volume measurement of the maxillary sinus. A, DICOM (digital imaging and communication in medicine) data. B, Binary transformation. C, Segmentation of the maxillary sinus using a region-growing method. D, Three-dimensional volume reconstruction.

CEPHALOMETRIC MEASUREMENT OF CRANIOFACIAL ANATOMICAL FEATURES

First, we defined 5 reference points (nasion [N], sella turcica [S], anterior nasal spine [ANS], posterior nasal spine [PNS], and A-point) and 3 reference planes (sella nasion [SN], palatal plane [PP], and perpendicular to N) (Figure 2A). With these references, we measured 6 variables to represent the craniofacial anatomical features. Four variables were measured to show the anteroposterior anatomical relationship: N to A-point, sella to nasion to A-point (SNA), SN, and ANS-PNS (Figure 2B-D). Two variables were measured to represent the vertical anatomical relationship: N-ANS and SN-PP (Figure 2E and F).

STATISTICAL ANALYSIS

All the values are reported in tables as mean (SD). Parametric values were compared between the 2 groups using a *t* test. Correlation between alveolar bone height and maxillary sinus volume was tested using the Pearson product moment correlation coefficient. Multiple linear regression analysis was used to identify the significant factors for the volumetric changes in the maxillary sinus. Statistical significance was considered to be $P < .05$. Results were analyzed using statistical software (SPSS version 17.0 for Windows; SPSS Inc, Chicago, Illinois).

RESULTS

HYPEROSTOSIS AND MAXILLARY SINUS VOLUME

The anterior and posterolateral walls had significantly increased bone thickness in the CRS group compared with controls ($P < .001$) (Table 1). Allergy and Lund-Mackay CT scores had no relationship with hyperostosis of the maxillary sinus ($P > .05$).

The CRS group had a significantly smaller maxillary sinus volume than did controls ($P = .001$) (Table 1). There was no difference in maxillary sinus volume based on sex and maxillary sinus sides in either group ($P > .05$). Age

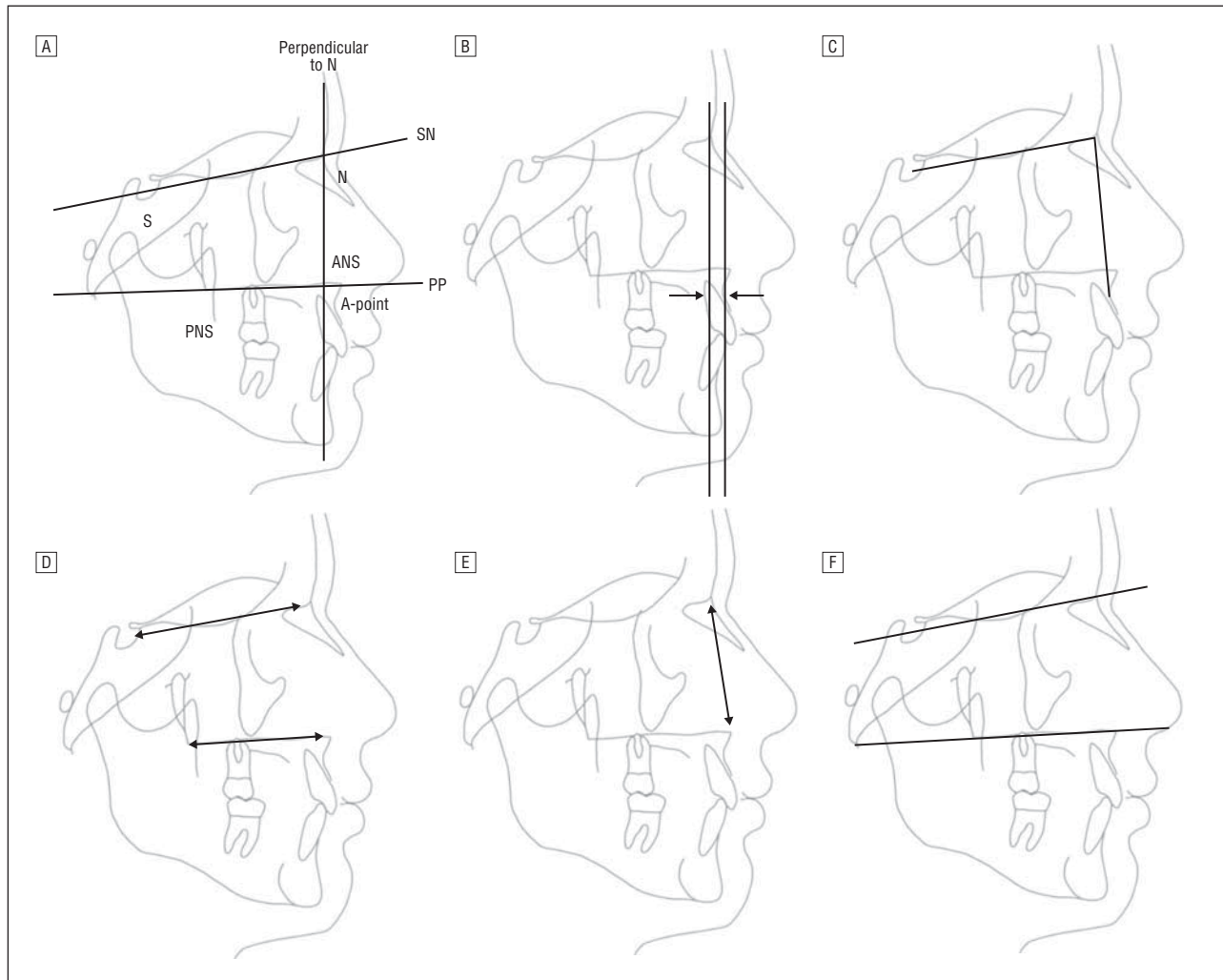


Figure 2. Evaluation of the craniofacial anatomical features in lateral cephalography. A, Reference points (anterior nasal spine [ANS], A-point, nasion [N], sella turcica [S], and posterior nasal spine [PNS]) and planes (sella nasion [SN], palatal plane [PP], and perpendicular to N). B, N to A-point. C, S to N to A-point. D, SN (above) and ANS-PNS (below). E, N-ANS. F, SN-PP.

showed a negative effect on maxillary sinus volume in controls ($r = -0.328$, $P = .02$) and in the CRS group ($r = -0.292$, $P = .046$) (**Figure 3**). The CRS group had a smaller volume than controls in each age group, but it was not statistically significant.

Maxillary sinus volume showed no relationship with anterior ($r = -0.239$, $P = .09$) and posterolateral ($r = -0.183$, $P = .20$) wall thickness in controls. Also, there was no relationship between maxillary sinus volume and anterior ($r = -0.155$, $P = .30$) and posterolateral ($r = -0.226$, $P = .13$) wall thickness in the CRS group.

DENTAL FACTORS AND MAXILLARY SINUS VOLUME

The incidence of class II malocclusion increased significantly in the CRS group compared with the control group ($P = .006$) (Table 1). Abnormal teeth status increased in the CRS group compared with controls but not significantly ($P = .17$). Alveolar bone thickness also was not different between controls and the CRS group ($P = .76$). Abnormal teeth status significantly increased with older age in the control ($P = .003$) and CRS ($P = .001$) groups, but

alveolar bone height showed no difference among the 4 age groups in controls and in the CRS group (**Table 2**).

Maxillary sinus volume was not different between normal and abnormal teeth groups in controls ($P = .14$) and in the CRS group ($P = .49$). However, abnormal teeth status had a negative effect on alveolar bone height in the CRS group ($P = .02$) but not in controls ($P = .07$) (**Table 3**). Alveolar bone height showed a negative correlation with maxillary sinus volume in controls ($r = -0.519$, $P < .001$) and in the CRS group ($r = -0.493$, $P < .001$) (**Figure 4**).

ALTERED CRANIOFACIAL ANATOMICAL FEATURES IN THE CRS GROUP

We measured 4 horizontal and 2 vertical variables using lateral cephalography (Table 1). Both N to A-point ($P = .003$) and SNA ($P = .004$) increased in the CRS group compared with controls. These 2 factors also increased in the group with class II malocclusion ($P < .001$). However, there was no cephalometric variable associated with the volumetric change in the maxillary sinus in controls and the CRS group.

Table 1. Maxillary Sinus, Dental, and Craniofacial Factors in Controls and Patients With Chronic Rhinosinusitis (CRS)

Anatomical Feature and Variable	Control Subjects (n=52)	Patients With CRS (n=47)	P Value
Maxillary sinus, mean (SD)			
Anterior wall, mm	1.10 (0.16)	1.46 (0.39)	<.001 ^a
Posterolateral wall, mm	1.03 (0.16)	1.42 (0.51)	<.001 ^a
Volume, mm ³	20.78 (7.10)	16.09 (7.06)	.001 ^a
Dental			
Class of malocclusion, No.			
I	30	30	.006 ^b
II	7	14	
III	15	3	
Teeth state, No. ^c			
Normal	31	21	.17
Abnormal	20	24	
Alveolar bone, mean (SD), mm	8.04 (3.79)	8.28 (3.99)	.76
Craniofacial, mean (SD)			
Horizontal factors			
N to A-point, mm	-2.92 (4.59)	-0.37 (3.51)	.003 ^a
SNA, °	78.89 (4.59)	81.23 (3.00)	.004 ^a
SN, mm	72.27 (2.52)	72.11 (2.44)	.75
ANS-PNS, mm	51.09 (3.76)	51.56 (3.03)	.51
Vertical factors			
N-ANS, mm	61.73 (3.39)	61.00 (3.57)	.30
SN-PP, °	2.16 (2.64)	1.71 (2.68)	.39

Abbreviations: ANS, anterior nasal spine; N, nasion; PNS, posterior nasal spine; PP, palatal plane; SN, sella nasion; SNA, sella to nasion to A-point.

^a $P < .05$, t test.

^b $P < .05$, χ^2 test.

^c Data were missing for 1 control and 2 patients with CRS.

MODEL OF MAXILLARY SINUS VOLUME IN ADULTS

Several factors were associated with the volumetric change in the maxillary sinus: age, group (control vs CRS), and alveolar bone height. Age ($\beta = -0.26$, $P = .02$) and alveolar bone height ($\beta = -0.51$, $P < .001$) showed a negative association with maxillary sinus volume in the multiple linear regression analysis. However, maxillary sinus volume had no relationship with group ($\beta = -0.15$, $P = .10$). Therefore, we could summarize the relationship between clinical factors and the volumetric change in the maxillary sinus in adults as follows: maxillary sinus volume = $[37.108 - 0.26(\text{age}) - 0.51(\text{alveolar bone height})]$.

COMMENT

Before this study, we had 3 questions about maxillary sinus volume in adults: (1) Is there a volumetric difference in the maxillary sinus between controls and the CRS group? (2) What may be the causative factors for the volumetric change in the maxillary sinus? (3) Can the volumetric change in the maxillary sinus alter the craniofacial anatomical features? Most previous studies¹⁻⁴ were performed in pediatric patients with CRS, and they focused on the effect of endoscopic sinus surgery on facial growth and development. Although a few studies compared the volume of the maxillary sinus between controls and pediatric patients with CRS, they had some limitations: lack of detailed statistics,¹² small study population

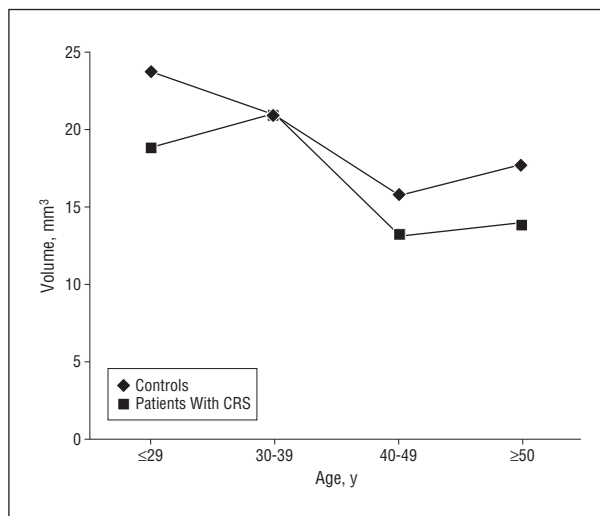


Figure 3. Negative impact of age on maxillary sinus volume in controls ($r = -0.328$, $P = .02$) and patients with chronic rhinosinusitis (CRS) ($r = -0.292$, $P = .046$).

with diverse age groups,¹³ and no concern for the age-related change in the maxillary sinus.¹⁴

A previous study¹⁵ showed that the size of the maxillary sinus measured by horizontal width ($P = .002$) and vertical height ($P < .001$) decreased in the CRS group compared with controls. In the present study, we measured the 3-dimensional volume of the maxillary sinus and revealed that the maxillary sinus of the CRS group had a significantly smaller volume than did that of controls in adults ($P = .001$). Of the clinical factors, age had a strong negative effect on maxillary sinus volume in controls and the CRS group (Figure 3). Maxillary sinus volume was smaller in the CRS group than in controls in each age group, but the differences were not statistically significant. Because the CRS group was much older than controls, age differences between groups may affect the difference in maxillary sinus volume. Patients with CRS are usually presented at older ages than are patients with septal deviation (controls), and, therefore, it is difficult to match the ages precisely between groups in clinical practice. It may be a weak point of this study, but we tried to overcome this problem by showing the results in each age group.

Sinus-related factors (allergy, Lund-Mackay CT scores, and bony wall thickness of the maxillary sinus) had no relationship with the volumetric change in the maxillary sinus. Bony wall thickness of the maxillary sinus increased definitely in the CRS group compared with controls (Table 1). Hyperostosis of the maxillary sinus tended to decrease maxillary sinus volume in both groups, but it was not statistically significant.

The average volume of a developed maxillary sinus at maturity varies between 15 and 20 mL, and these dimensions remain relatively stable once the permanent maxillary teeth have erupted and growth of the maxilla is complete.¹⁶ In edentulous patients, the maxillary sinus may expand farther and continue to extend into the alveolar bone.^{17,18} However, the present study showed that maxillary sinus volume was not different between groups of normal and abnormal teeth in controls and in patients with CRS (Table 3).

Table 2. Relationship Between Age and Dental Factors in Controls and Patients With Chronic Rhinosinusitis (CRS)

Group and Age, y	Teeth Status, No.		P Value ^a	Alveolar Bone Height, mean (SD), mm	P Value ^b
	Normal	Abnormal			
Control subjects			.003 ^c		
≤29	17	5		7.48 (2.59)	.82
30-39	11	4		8.69 (5.44)	
40-49	3	7		8.31 (3.69)	
≥50	0	4		7.82 (2.36)	
CRS			.001 ^c		
≤29	8	0		7.72 (1.44)	.95
30-39	6	4		8.16 (3.73)	
40-49	4	5		8.87 (3.76)	
≥50	3	15		8.30 (5.10)	

^aBy χ^2 test.

^bBy analysis of variance.

^c $P < .05$.

Table 3. Maxillary Sinus Volume and Alveolar Bone Height in Normal and Abnormal Teeth in Controls and Patients With Chronic Rhinosinusitis (CRS)

Variable and Group	Teeth Status		P Value
	Normal	Abnormal	
Maxillary sinus volume, mean (SD), mm ³			
Control subjects	21.87 (6.56)	18.83 (7.76)	.14
CRS	15.45 (6.44)	16.93 (7.70)	.49
Alveolar bone height, mean (SD), mm			
Control subjects	8.83 (3.93)	6.85 (3.31)	.07
CRS	9.75 (3.75)	6.99 (3.81)	.02 ^a

^a $P < .05$, *t* test.

Teeth status and alveolar bone height were not different between the control and CRS groups (Table 1). Abnormal teeth status increased with age in both groups (Table 2) and had a negative effect on alveolar bone height in the CRS group (Table 3). However, it showed no direct relationship with maxillary sinus volume (Table 3). Alveolar bone height showed no relationship with age (Table 2) but had a strong negative effect on maxillary sinus volume in both groups (Figure 4). Therefore, we believe that alveolar bone height may be an independent factor having a negative effect on maxillary sinus volume. It is possible that alveolar bone loss can be accelerated in combined cases of abnormal teeth status and CRS (Table 3).

Most otolaryngologists have an interest in dental sources for maxillary sinusitis.¹⁹ However, there has been little or no attention to the relationship between the volumetric change in the maxillary sinus and dental problems in adults. This study demonstrated that alveolar bone height may be the most important factor for the volumetric change in the maxillary sinus. Therefore, we believe that the osteolytic effect of periodontitis or edentulous state on the alveolar bone could increase maxillary sinus volume. However, CRS-related hyperostosis had no significant effect on maxillary sinus volume.

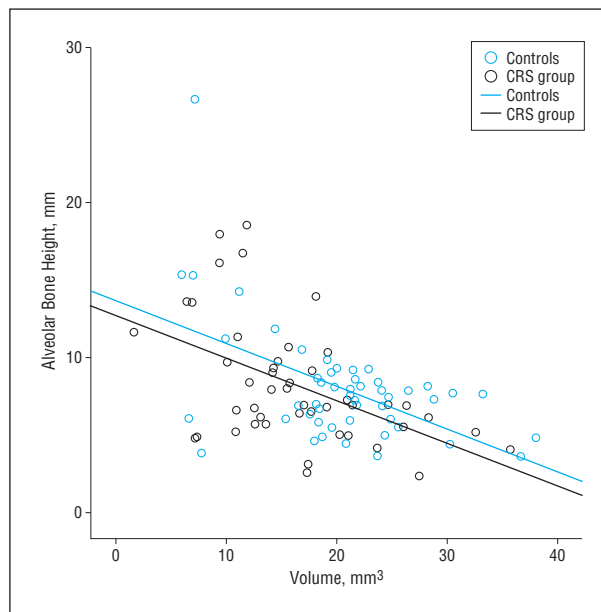


Figure 4. Negative impact of alveolar bone height on maxillary sinus volume in controls ($r = -0.519$, $P < .001$) and patients with chronic rhinosinusitis (CRS) ($r = -0.493$, $P < .001$).

Although the relationship between nasal obstruction or mouth breathing and altered craniofacial growth (long face syndrome and retrognathia) is well known, the relationship between CRS and malocclusion remains unclear.^{20,21} In the CRS group, the present study demonstrated an increased incidence of class II malocclusion and increased horizontal factors (N to A-point and SNA) in cephalometry. Therefore, we believe that the anterior movement of the A-point may be associated with the increased class II malocclusion in the CRS group. The causal relationship between malocclusion and CRS needs further study. Except for the positional change in A-point, volumetric decrease in the maxillary sinus had no effect on craniofacial anatomical features in patients with CRS.

In conclusion, patients with CRS had distinct anatomical changes, such as hyperostosis, decreased volume in the maxillary sinus, increased class II malocclusion, and anterior movement of the A-point. Age and alveolar bone height may be the critical factors for the volumetric change in the maxillary sinus in adults. To identify the clinical significance of the volume decrease in the maxillary sinus in the CRS group, further studies are warranted.

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REFERENCES

1. Bahadir O, Bahadir A, Kosucu P, Livaoglu M. The effect of maxillary sinus surgery on its development. *Acta Otolaryngol.* 2008;128(5):551-555.
2. Van Peteghem A, Clement PA. Influence of extensive functional endoscopic sinus surgery (FESS) on facial growth in children with cystic fibrosis: comparison of 10 cephalometric parameters of the midface for three study groups. *Int J Pediatr Otorhinolaryngol.* 2006;70(8):1407-1413.
3. Bothwell MR, Piccirillo JF, Lusk RP, Ridenour BD. Long-term outcome of facial growth after functional endoscopic sinus surgery. *Otolaryngol Head Neck Surg.* 2002;126(6):628-634.
4. Senior B, Wirtschaffer A, Mai C, Becker C, Belenky W. Quantitative impact of pediatric sinus surgery on facial growth. *Laryngoscope.* 2000;110(11):1866-1870.
5. Sánchez Fernández JM, Anta Escuredo JA, Sánchez Del Rey A, Santaolalla Montoya F. Morphometric study of the paranasal sinuses in normal and pathologic conditions. *Acta Otolaryngol.* 2000;120(2):273-278.
6. Graney DO, Rice DH. Anatomy. In: Cummings CW, Fredrickson JM, Harker LA, et al. eds. *Otolaryngology—Head and Neck Surgery.* 3rd ed. St Louis, MO: Mosby; 1998:1059-1064.
7. Benninger MS, Ferguson B, Hadley J, et al. Adult chronic rhinosinusitis: definitions, diagnosis, epidemiology, and pathophysiology. *Otolaryngol Head Neck Surg.* 2003;129(3)(suppl):S1-S32.
8. Bousquet J, Khaltaev N, Cruz AA, et al; World Health Organization; GA(2)LEN; AllerGen. Allergic Rhinitis and Its Impact on Asthma (ARIA) 2008 update (in collaboration with the World Health Organization, GA(2)LEN and AllerGen). *Allergy.* 2008;63(suppl 86):8-160.
9. Taub PJ. Cephalometry. *J Craniofac Surg.* 2007;18(4):811-817.
10. Lund VJ, Mackay IS. Staging in rhinosinusitis. *Rhinology.* 1993;31(4):183-184.
11. Angle EH. Classification of malocclusion. *Dental Cosmos.* 1899;41:248-264.
12. Ikeda A, Ikeda M, Komatsuzaki AA. CT study of the course of growth of the maxillary sinus: normal subjects and subjects with chronic sinusitis. *ORL J Otorhinolaryngol Relat Spec.* 1998;60(3):147-152.
13. Kim HJ, Friedman EM, Sulek M, Duncan NO, McCluggage C. Paranasal sinus development in chronic sinusitis, cystic fibrosis, and normal comparison population: a computerized tomography correlation study. *Am J Rhinol.* 1997;11(4):275-281.
14. Kim HY, Kim MB, Dhong HJ, et al. Changes of maxillary sinus volume and bony thickness of the paranasal sinuses in longstanding pediatric chronic rhinosinusitis. *Int J Pediatr Otorhinolaryngol.* 2008;72(1):103-108.
15. Cho SH, Shin KS, Lee YS, et al. Impact of chronic rhinosinusitis and endoscopic sinus surgery on bone remodeling of the paranasal sinuses. *Am J Rhinol.* 2008;22(5):537-541.
16. Sicher H. The viscera of head and neck. In: *Oral Anatomy.* St Louis, MO: Mosby; 1975:418-424.
17. Mehra P, Murad H. Maxillary sinus disease of odontogenic origin. *Otolaryngol Clin North Am.* 2004;37(2):347-364.
18. Sharan A, Madjar D. Maxillary sinus pneumatization following extractions: a radiographic study. *Int J Oral Maxillofac Implants.* 2008;23(1):48-56.
19. Kretschmar DP, Kretschmar JL. Rhinosinusitis: review from a dental perspective. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2003;96(2):128-135.
20. Principato JJ. Upper airway obstruction and craniofacial morphology. *Otolaryngol Head Neck Surg.* 1991;104(6):881-890.
21. Smith RM, Gonzalez C. The relationship between nasal obstruction and craniofacial growth. *Pediatr Clin North Am.* 1989;36(6):1423-1434.