ACTA ODONTOLOGICA SCANDINAVICA, 2017
VOL. 75, NO. 5, 345–349
http://dx.doi.org/10.1080/00016357.2017.1310294

ORIGINAL ARTICLE

Evaluation of maxillary sinus volume and dimensions in different vertical face growth patterns: a study of cone-beam computed tomography

Rıdvan Okşayan[a], Oral Sökücü[b] and Seher Yeşildal[b]

[a]Department of Orthodontics, Faculty of Dentistry, Eskişehir Osmangazi University, Eskişehir, Turkey; [b]Department of Orthodontics, Faculty of Dentistry, Gaziantep University, Gaziantep, Turkey

ABSTRACT

Objective: This study aimed to compare sinus volume and dimensions in patients with high-, low-, and normal-angle vertical growth patterns using cone-beam computed tomography (CBCT).

Materials and methods: According to skeletal vertical face growth patterns, 60 adults (31 female, 29 male, average age: 29.90 ± 10.91 years) were divided into three groups equally: high-angle, low-angle, and normal-angle groups. Cephalometric tracings were obtained from CBCT images and SN-GoGn (angle between Sella–Nasion line and Gonion–Gnathion line) cephalometric angular measurements used for the classification of skeletal vertical pattern evaluations. Morphological and dimensional changes in the maxillary sinuses were evaluated on CBCT images. Data were analyzed using the one-way ANOVA, Kruskall–Wallis, and Mann–Whitney *U* statistical tests.

Results: There were no statistically significant differences among the groups in terms of age ($p > .05$). The low-angle vertical growth pattern group showed significantly better results than the high-angle group in the right maxillary sinus length parameter ($p < .05$).

Conclusion: According to the results, the high-angle subjects showed statistically lower values in terms of maxillary sinus length and width than the low-angle subjects. There were no effects of vertical face development on right and left maxillary sinus volumes. The results of this study may be useful in maxillary sinus evaluation when planning for orthognathic surgery and orthodontic mini screw application in various vertical face patterns.

ARTICLE HISTORY
Received 7 December 2016
Revised 13 March 2017
Accepted 17 March 2017

KEYWORDS
Maxillary sinus volume; maxillary sinus dimension; vertical face growth; CBCT

Introduction

The largest paranasal sinus in the facial skeleton is the maxillary sinus, which is located in the main part of the maxilla. Its base is located in the lateral nasal wall, and the upper end of the sinus is found in the zygomatic process of the maxilla. In the postnatal growth period, maxillary sinus growth increases in the first three years and at 7–12 years of age [1,2]. In addition, the maxillary sinus reaches adult size between 12 and 15 years with the same period of maxillary growth [3].

Procedures for evaluating maxillary sinus morphology and dimensions have improved with new advances in dentofacial imaging technologies. Conventional radiographs show limited information and errors in three-dimensional (3D) structure analyses [3]. According to conventional two-dimensional (2D) radiographs, cone-beam computed tomography (CBCT) provides 3D multi-planar images and information on dental and maxillofacial regions [4]. CBCT has some advantages, such as a lower radiation dose than conventional computed tomography (CT), a shorter acquisition time, and lower costs [5,6].

Several studies have pointed to the relationship among the development process of the mid-face and jaws, congenital diseases (including cleft lip and palate), and maxillary sinus size and volume [7,8]. Some studies have addressed the relationship between cleft lip and palate and sinus dimensions. They found that the volume of the maxillary sinus was affected negatively in cleft lip and palate patients [7,8]. Another research study focused on areas of the maxillary sinus in terms of size and volume changes among patients with different breathing types. Tikku et al. [3] revealed that mouth breathers showed a lesser maxillary sinus volume than normal breathers. Contrary to this opinion, Oktay [9] reported that sex and malocclusion had no impact on maxillary sinus size, and sex is only a statistically significant factor in relation to Class II malocclusion. Endo et al. declared no significant differences between the maxillary sinus dimension and the skeletal sagittal jaw relationship (ANB angle) [1].

Although we know that the growth and development of the maxillary sinus occurs in the mid-face, we have not yet seen a study examining the effect of vertical growth patterns on the size and volume of the maxillary sinus with CBCT. In orthodontics, skeletal vertical growth patterns are categorized into three types: high angle (increased vertical face growth pattern), low angle (decreased vertical face growth pattern), and normal angle (placed between high- and low-angle vertical face growth) [10]. Orthodontic treatment time and process was affected by maxillary sinus volume and size also in extraction cases because moving teeth to sinus area is

CONTACT Rıdvan Okşayan ridvan.oksayan@hotmail.com Ortodonti Ana Bilim Dalı, Diş Hekimliği Fakültesi, Eskişehir Osmangazi Üniversitesi, 26000 Eskişehir, Turkey

important factor for new bone apposition and resorption period [11]. And maxillary sinus volume was affected by impacted teeth and another pathologic structure [12].

The purpose of this study was to evaluate sinus dimensions and morphological changes in patients with high-, low-, and normal-angle vertical growth patterns using CBCT.

Material and methods

This retrospective study was approved by the local human ethical committee of Gaziantep University. CBCT images in this study were obtained from Gaziantep University Dentistry Faculty archives, and the as low as reasonably achievable (ALARA) principle was applied when taking all CBCT images of patients. The selection criteria according to which patients were selected were as follows: no skeletal deformity in middle-face region, no pathological findings in maxillary sinus, and completed maxillary growth and development.

About 116 tomographic images were detected for this study and according to skeletal vertical face growth patterns randomly selected 60 adults (31 female, 29 male, average age: 29.90 ± 10.91) were divided into three groups: high-angle group (20 patients: 12 female, eight male; average age: 32.55 ± 13.08 years old), low-angle group (20 patients: eight female, 12 male; average age: 29.35 ± 9.11 years old), and normal-angle group (20 patients: 11 female, nine male; average age: 27.80 ± 10.16 years old).

All tomographic images were obtained in a standing position using a CBCT machine (Planmeca Promax 3D mid, Helsinki, Finland). Exposure parameters were 94 kVp, 14 mA, and 27 seconds. Cephalometric tracings were obtained from CBCT images and SN-GoGn (angle formed between Sella–Nasion line and Gonion–Gnathion line) cephalometric angular measurements used for the classification of skeletal vertical pattern evaluations, and tracings were performed using the Dolphin 9.0 (Dolphin Imaing and Management Solutions, Chatsworth, CA) program. According to the SN–GoGn angle, vertical growth patterns were divided into three groups, where the low-angle group was less than 26°, the normal-angle group was between 26° and 38°, and the high-angle group was more than 38° [13].

Dimensional and volumetric measurements: both the right and left maxillary sinuses were evaluated on CBCT images with the Romexis software system (Planmeca, Helsinki, Finland) in terms of length (distance between the most anterior point to the most posterior point of the maxillary sinus), height (distance between the most superior point to the most inferior point of the maxillary sinus), width (the largest part of the sinus in the transversal plane), and volume [1].

All of the recorded data were compared and analyzed. All statistical analyses were performed with SPSS (Version 17.0, SPSS Inc, Chicago, IL). The one-way ANOVA, Kruskall–Wallis, and Mann–Whitney *U* tests were used for statistical analyses. A significance level of $p < .05$ was used for all statistical analyses.

Table 1. Descriptive statistics (subject number, sex, mean age) of study groups.

Groups	Subject number	Sex (female /male)	Mean age ± std dev. (years)
High angle	20	12/8	32.55 ± 13.08
Normal angle	20	11/9	27.80 ± 10.16
Low angle	20	8/12	29.35 ± 9.11

Results

Descriptive statistics of the study groups are presented in Table 1. Mean left and right maxillary sinus volume for females (right maxillary sinus volume 11.47 ± 4.09, left maxillary sinus volume 11.79 ± 4.50) and males (right maxillary sinus volume 16.60 ± 3.58, left maxillary sinus volume 16.58 ± 4.62) were measured. The results of the age comparison between the groups are shown in Table 2. No statistically significant age differences were found among the vertical facial growth groups ($p > .05$). The results of the right maxillary sinus measurements and their statistical analyses are shown in Table 3. There were no statistically significant differences among groups in terms of right maxillary sinus volume, height, and width ($p > .05$). Of the right maxillary sinus measurements, the only statistically significant result was found to be the length ($p < .05$). The low-angle vertical growth group showed a significantly greater result than the high-angle group in terms of the right maxillary sinus length parameter.

The results of the left maxillary sinus measurements and their statistical analyses are shown in Table 4. Statistical tests showed no significant differences between the left maxillary sinus volume and height measurements among the groups ($p > .05$). In the high-angle group, the mean left maxillary sinus length measurement was statistically smaller than that in the low-angle group ($p < .05$). According to the maxillary sinus width data, the low-angle vertical growth group showed statistically greater results than the high-angle group in the left region ($p < .05$).

Discussion

The goal of this study was to evaluate the volumetric and dimensional sinus changes in patients with high-, low-, and normal-angle vertical growth patterns using CBCT (Figure 1). Volumetric maxillary sinus evaluation studies of patients with cleft lip and palate are more common in the scientific literature, while research studies are limited on the topic of the

Table 2. Statistical results of mean age variables according to one-way Anova test between groups.

Variables	High-angle group, mean ± SD	Normal-angle group, mean ± SD	Low-angle group, mean ± SD	High-normal (*p* value)	Low-normal (*p* value)	High-low (*p* value)
Mean age ± SD (years)	32.55 ± 13.08	27.80 ± 10.16	29.35 ± 9.11	.318	.881	.375

SD: standard deviation.

Table 3. Statistical results of right maxillary sinus variables according to one-way Anova, Kruskall–Wallis and Mann–Whitney *U* tests between groups.

Variables	High-angle group, mean ± SD	Normal-angle group, mean ± SD	Low-angle group, mean ± SD	High normal (*p* value)	Low normal (*p* value)	High low (*p* value)
Right maxillary sinus volume	12.41 ± 4.58	13.85 ± 4.92	15.07 ± 4.17	.543	.639	.062
Right maxillary sinus height	34.56 ± 6.63	37.12 ± 6.27	37.34 ± 5.38	.345	.991	.153
Right maxillary sinus length	35.44 ± 4.14	33.97 ± 5.29	37.59 ± 5.26	.123	.999	.015*
Right maxillary sinus width	27.04 ± 5.50	28.76 ± 4.69	28.48 ± 4.49	.735	.999	.365

SD: standard deviation.
*Statistically significant difference level is $p < .05$.

Table 4. Statistical results of left maxillary sinus variables according to one-way Anova, Kruskall–Wallis and Mann–Whitney *U* tests between groups.

Variables	High-angle group, mean ± SD	Normal angle group Mean ± SD	Low angle group Mean ± SD	High-normal (*p* value)	Low-normal (*p* value)	High-low (*p* value)
Left maxillary sinus volume	12.86 ± 4.38	13.65 ± 5.95	15.33 ± 4.82	.861	.510	.098
Left maxillary sinus height	34.73 ± 7.02	37.90 ± 7.41	37.41 ± 6.27	.206	.999	.125
Left maxillary sinus length	35.27 ± 4.72	37.18 ± 6.13	37.78 ± 4.22	.272	.608	.005*
Left maxillary sinus width	26.06 ± 4.47	26.24 ± 6.17	28.15 ± 4.70	.999	.195	.034*

SD: standard deviation.
*Statistically significant difference level is $p < .05$.

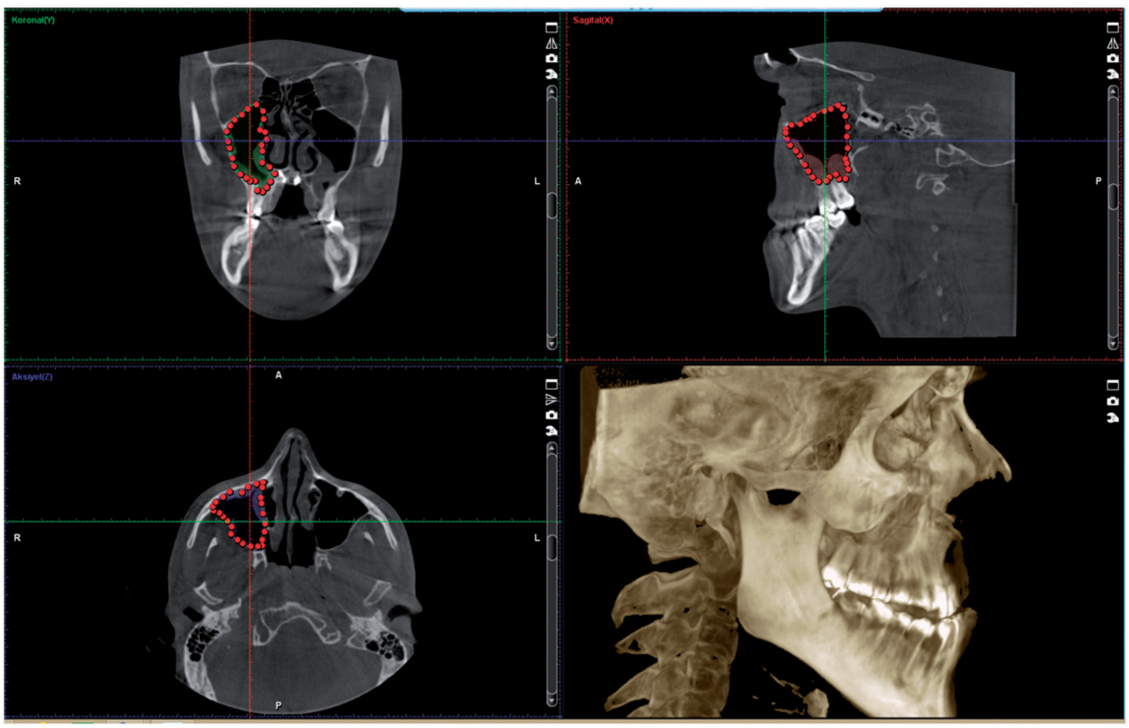

Figure 1. CBCT images and isolated 3D volume of the maxillary sinuses.

impact of vertical face growth patterns on the volume and dimensions of the maxillary sinus [8]. In addition, we have not yet encountered any CBCT studies on the determination of the volume and dimensions of the maxillary sinus in different vertical face patterns in the literature, so our study is the first in this respect. A vertical facial growth evaluation is an important factor in the choice between extraction and non-extraction treatment protocols in orthodontics [14].

Some researchers studied evaluations of maxillary sinus sizes in different malocclusion classes with cephalometric radiographs and orthopantomographs [1,9]. Endo et al. [1] found no significant relationship between maxillary sinus dimensions and different sagittal skeletal jaw types in patients from 12 to 16 years of age. Oktay revealed that female subjects with Angle Class II malocclusions have larger maxillary sinuses than male subjects with an orthopantomographic evaluation. In this study, 3D images were used to evaluate the volume and dimensions of the maxillary sinus, as it is difficult to perform a clear and accurate 2D determination in the complex maxillary sinus region.

Erdur et al. [8] revealed that the volume of the maxillary sinus of unilateral cleft lip and palate subjects was smaller than that of the control group. In our study, we evaluated both right and left maxillary sinus parameters in subjects without deformity and according to our results, there were no statistically significant differences among vertical growth groups in terms of the volume of the right and left maxillary sinuses. However, the volume of the right and left maxillary sinuses in the high- and normal-angle groups was smaller than that in the low-angle group. These findings suggest no correlation between vertical growth types and the volume of the left and right maxillary sinuses. This situation may be explained by the differences among the study groups; our study was performed on subjects without facial deformity and a maxillary sinus size related to age [3,15]. Tikku et al. [3] found that mouth breathers showed a smaller maxillary sinus volume than normal breathers. This may be due to reduced growth of the nasal cavity and deficient development of the maxillary sinus in mouth breathers.

In this study, our results showed no significant differences between vertical growth groups in both right and left maxillary sinus heights. However, the high-angle subjects have smaller maxillary sinus heights on both the right and the left side. Endo et al. [1] revealed that the maxillary sinus length showed a significant positive correlation among upper anterior face heights in individuals aged 12–16 years with the aid of cephalometric radiographs. Considering this finding, the difference between two studies may be due to age because it is known that maxillary sinus dimensions enhance to 20–30 years [16].

In our study, the high-angle group showed a significantly smaller result than the low-angle vertical growth group in both the right and left maxillary sinus length parameters. Endo et al. found no significant association between maxillary sinus length and the sagittal skeletal jaw relationship in a cephalometric evaluation study. In addition, they showed the maxillary sinus length has a significant positive correlation with the upper anterior face height, anterior nasal spina-posterior nasal spina length, and Sella–Nasion length [1]. Contrary to our findings, this may be due to the evaluation of upper and lower facial heights separately in this study. In our research, we studied the total vertical face growth, including both lower and upper vertical face growth. Ryu et al. studied the maxillary sinus dimensions and pneumatization in adult patients with an anterior open bite. They reported that maxillary sinus floor dimension in posterior dental region is greater in adult open bite patients and the basal bone height in the maxillary posterior region is lower than open-bite patients [17].

According to the maxillary sinus width results, the low-angle vertical growth group showed statistically greater results than the high-angle group in the left region. Previously, no studies have been conducted on the relation between vertical face growth and sinus width in the literature. This may be due to the 2D sinus morphology evaluation of previous studies.

Maxillary sinus sizes and volume are important in fixed orthodontic treatments with extractions because teeth are moving mesially and distally. Oh et al. [11] demonstrated a case report and they showed successful orthodontic tooth movement through the maxillary sinus in an adult patient. Another factor is impacted maxillary teeth angulation and impaction depth is affected from maxillary sinus dimensions.

In addition, further CBCT studies are needed regarding the association between the maxillary sinus dimensions and upper and lower facial height with larger and more uniform adult subjects. These maxillary sinus dimensions and volumes should be brought to mind in maxillary molar and premolar intrusion treatment planning in fixed orthodontic treatment.

Conclusion

- There is no significant change among the low, high, and normal face growth groups in terms of the right and left maxillary sinus volume parameters.
- A significant decrease was observed in the maxillary sinus length and width variables in high-angle subjects according to low-angle subjects.
- The results of this study may be useful in maxillary sinus evaluations when planning for orthognathic surgery and orthodontic mini screw application in various vertical face patterns.

Disclosure statement

The authors declare that they have no conflict of interest related to this study.

References

[1] Endo T, Abe R, Kuroki H, et al. Cephalometric evaluation of maxillary sinus sizes in different malocclusion classes. Odontology. 2010;98:65–72.

[2] Livas C, Halazonetis DJ, Booij JW, et al. Maxillary sinus floor extension and posterior tooth inclination in adolescent patients with Class II Division 1 malocclusion treated with maxillary first molar extractions. Am J Orthod Dentofacial Orthop. 2013;143:479–485.

[3] Tikku T, Khanna R, Sachan K, et al. Dimensional changes in maxillary sinus of mouth breathers. J Oral Biol Craniofac Res. 2013;3:9–14.

[4] Agacayak KS, Gulsun B, Koparal M, et al. Alterations in maxillary sinus volume among oral and nasal breathers. Med Sci Monit. 2015;21:18–26.

[5] Guijarro-martinez R, Swennen GR. Cone-beam computerized tomography imaging and analysis of the upper airway: a systematic review of the literature. Int J Oral Maxillofac Surg. 2011;40:1227–1237.

[6] Ariji Y, Kuroki T, Moriguchi S, et al. Age changes in the volume of the human maxillary sinus: a study using computed tomography. Dentomaxillofac Radiol. 1994;23:163–168.

[7] Lopes de Rezende Barbosa G, Pımenta LA, Prettı H, et al. Difference in maxillary sinus volumes of patients with cleft lip and palate. Int J Pediatr Otorhinolaryngol. 2014;78:2234–2236.

[8] Erdur O, Ucar FI, Sekercı AE, et al. Maxillary sinus volumes of patients with unilateral cleft lip and palate. Int J Pediatr Otorhinolaryngol. 2015;79:1741–1744.

[9] Oktay H. The study of the maxillary sinus areas in different orthodontic malocclusions. Am J Orthod Dentofacial Orthop. 1992;102:143–145.

[10] Celik S, Celikoglu M, Buyuk SK, et al. Mandibular vertical asymmetry in adult orthodontic patients with different vertical growth patterns: a cone beam computed tomography study. Angle Orthod. 2016;86:271–277.

[11] Oh H, Herchold K, Hannon S, et al. Orthodontic tooth movement through the maxillary sinus in an adult with multiple missing teeth. Am J Orthod Dentofacial Orthop. 2014;146:493–505.

[12] Oz AZ, Oz AA, El H, et al. Maxillary sinus volume in patients with impacted canines. Angle Orthod. 2017; 87:25–32.

[13] Baysal A, Uysal T. Dentoskeletal effects of Twin Block and Herbst appliances in patients with class II division 1 mandibular retrognathy. Eur J Orthod. 2014;36:164–172.

[14] Staggers JA. Vertical changes following first premolar extractions. Am J Orthod Dentofacial Orthop. 1994;105:19–24.

[15] Barghouth G, Prior JO, Lepori D, et al. Paranasal sinuses in children: size evaluation of maxillary, sphenoid, and frontal sinuses by magnetic resonance imaging and proposal of volume index percentile curves. Eur Radiol. 2002;12:1451–1458.

[16] Park IH, Song JS, Choı H, et al. Volumetric study in the development of paranasal sinuses by ct imaging in Asian: a pilot study. Int J Pediatr Otorhinolaryngol. 2010;74: 1347–1350.

[17] Ryu J, Choi SH, Cha JY, et al. Retrospective study of maxillary sinus dimensions and pneumatization in adult patients with an anterior open bite. Am J Orthod Dentofacial Orthop. 2016;150:796–801.