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Original Research

Effect of Vertical Growth Pattern on Maxillary and Frontal Sinus Sizes

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ABSTRACT
Objective: The purpose of the present study was to investigate the frontal and maxillary sinus sizes of individuals with different vertical growth pattern by using lateral and posteroanterior (PA) cephalometric radiographs.
Methods: In the study conducted on 60 individuals selected from male and female patients between the ages of 15 and 17 years, lateral and PA cephalometric radiographs were divided into three groups by vertical skeletal classification. The radiographs of 20 patients with increased vertical growth [Sella–Nasion Plane and Gonion–Gnathion Plane (Sn–GoGn) >38°] were classified as Group 1, the radiographs of 20 patients with decreased vertical growth (Sn–GoGn <26°) were classified as Group 2, and the radiographs of 20 patients with normal growth (Sn–GoGn: 32±6°) were classified as Group 3. The measurements of maxillary and frontal sinus sizes were obtained via ImageJ software.
Results: The differences between the groups for all measurements in both lateral and PA radiographs (p>0.005) were not statistically significant.
Conclusion: The different vertical growth pattern was not effective on maxillary and frontal sinus sizes. Future controlled trials conducted with larger samples are needed to support and extend the findings.
Keywords: Frontal sinus, lateral cephalometric radiography, maxillary sinus, posteroanterior radiography, sinus size

INTRODUCTION

The largest of the paranasal sinuses defined as bone cavities filled with air opening to the nasal cavity is the maxillary sinus. The base of the maxillary sinus is formed by the alveolar process and the hard palate, and its adjacency to the upper posterior teeth continues for life (1). The maxillary sinus reaches its mature size at the age of 12–15 years, in conjunction with the maxillary growth period (2). The frontal sinus, one of the paranasal sinuses, does not exist at birth, and it starts to develop after the age of 2 years. Its development continues until late puberty and is completed at the age of approximately 20 years (3).

The human skeleton is a balanced and dynamic system influenced by various mechanical stresses. Studies to determine the factors affecting the functions, morphologies, and sizes of the paranasal sinuses occupying space in the skull have been drawing attention for a long time (4). It is thought that the development of the maxillary sinus, which has a close relationship with the maxillary structure and the upper posterior teeth, can be affected by skeletal malocclusions (1). The frontal sinus size may be affected by different factors, such as bone density, forces of the masticatory muscles, occlusal relationships, and jaw relationships (4).

In the literature, there are various studies investigating the relationship between maxillary sinus size and malocclusion. Oktay (1) reported that female individuals with Angle Class II malocclusion have broader maxillary sinuses than other malocclusions. Tikku et al. (2) reported that the sinus size of individuals who are breathing through their mouth is smaller than that of individuals with normal respiration. On the other hand, Oksayan et al. (5) suggested that high-angle individuals have smaller maxillary sinuses than low-angle individuals. It was reported that maxillary sinus size is important with respect to providing an opinion on clinical subjects, such as the impacted upper tooth's angle and depth, determination of location in mini-implant applications, and planning orthognathic surgery (5).

The number of studies investigating the relationship between frontal sinus size and malocclusion is few. There are studies reporting that the frontal sinus may be used as an indicator for growth (6, 7) and compatible anterior occlusion (4). However, there is no study in the literature investigating the effects of vertical growth direction on both frontal and maxillary sinus sizes and assessing the correlation between them. The purpose of the present study designed on the basis of such deficiency was to investigate the frontal and maxillary sinus sizes of individuals with different vertical growth patterns using lateral and posteroanterior (PA) cephalometric radiographs.

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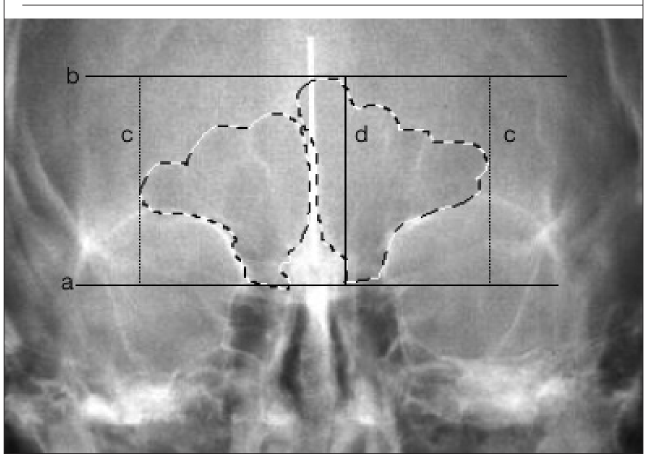
METHODS

This was a retrospective study. Lateral and PA cephalometric films with skeletal Class 1 relationship and different vertical growth patterns (A point: nasion, B point: 0–4°) obtained from systemically healthy patients without craniofacial deformities, such as cleft lip or palate, kept in the archive of the Department of Orthodontics at Gaziantep University's Faculty of Dentistry were included in the present study. The study was approved by the clinical trials ethics committee of Gaziantep University (29.03.2018/14). Written informed consent was obtained from the patients who participated in the study. The power analysis sample size determination revealed that for the analysis of variance (ANOVA) on three groups with an effect size of 0.90 for the frontal sinus area, an alpha level of 0.05, a power of 0.85, and a minimum of 19 subjects in each group were required.

The radiographs used in the study were obtained via X-ray (Planmeca EC Proline PM, Planmeca, Helsinki, Finland) at the Department of Oral Diagnosis and Radiology within Gaziantep University's Faculty of Dentistry, under standard conditions. Exposure parameters were 68–74 kVp, 12 mA, and 0.4–0.5 s. In addition, magnification ratio was 1:1. A total of 102 individuals with skeletal Class I relationship were selected randomly from male and female patients between the ages of 15 and 17 years in the department archive. The frontal and maxillary sinuses of individuals were assessed with respect to their anatomic and physiological integrity from the cephalometric radiographs. Patients with a history of orthodontics treatment or orthognathic surgery, who had experienced trauma or undergone skull surgery, and who had endocrine disorders or hereditary facial asymmetry were excluded from the study. In addition, it was taken care in the selection of radiographs that the films were acquired without rotation. After this procedure was completed, 60 individuals' radiographs were divided into three groups by vertical skeletal classification.

Figure 1. (a) A line has been drawn through the lateral limit of orbital cavities at the nasofrontal suture. (b) The line that parallels to the nasofrontal line has been drawn at the highest point of the frontal sinus. (c) Lines that delineate the maximum lateral limits of the right and left sinuses. (d) Distance between a and b lines.



The lateral and PA cephalometric radiographs of 20 patients with increased vertical growth (Sella–Nasion Plane and Gonion–Gnathion Plane (Sn–GoGn)>38°) were classified as Group 1 (high angle), the radiographs of 20 patients with decreased vertical growth (Sn–GoGn<26°) were classified as Group 2 (low angle), and the radiographs of 20 patients with normal growth (Sn–GoGn: 32±6°) were classified as Group 3 (medium angle).

Maxillary and frontal sinus size measurements were obtained using ImageJ software 1.48v (National Institutes of Health, Bethesda, MD, USA) after the images were calibrated (operated by GBB). For calibration, the ruler was used in the lateral cephalometric radiographs, and the ear rods were used in the PA radiographs. After the images to be assessed were transferred to the software using the size calculation feature, the borders of the maxillary and frontal sinuses were determined; their areas were calculated in cm^2, and their height and width were calculated in cm. Said et al.'s (4) studies for drawings of the frontal sinus area and Sidhu et al. (8) studies for drawings of the maxillary sinus area were considered as a reference. The frontal sinus was measured by calculating the average of the right and left sinus measurements obtained separately. Rectangular coordinates as described by Endo et al. (9) were selected for the assessment of the height and width sinuses. The x-axis is parallel to the Frankfort horizontal plane (Pr–Or), and the y-axis is perpendicular to the Frankfort horizontal plane through the sella. The maximum height, width, and area of the sinuses were measured in the PA and lateral cephalometric radiographs as shown in Figures 1 and 2, respectively.

Figure 2. (a) Maxillary sinus height projected on the y-axis. (b) Maxillary sinus width projected on the x-axis. (c) Frontal sinus height projected on the y-axis. (d) Frontal sinus width projected on the x-axis.

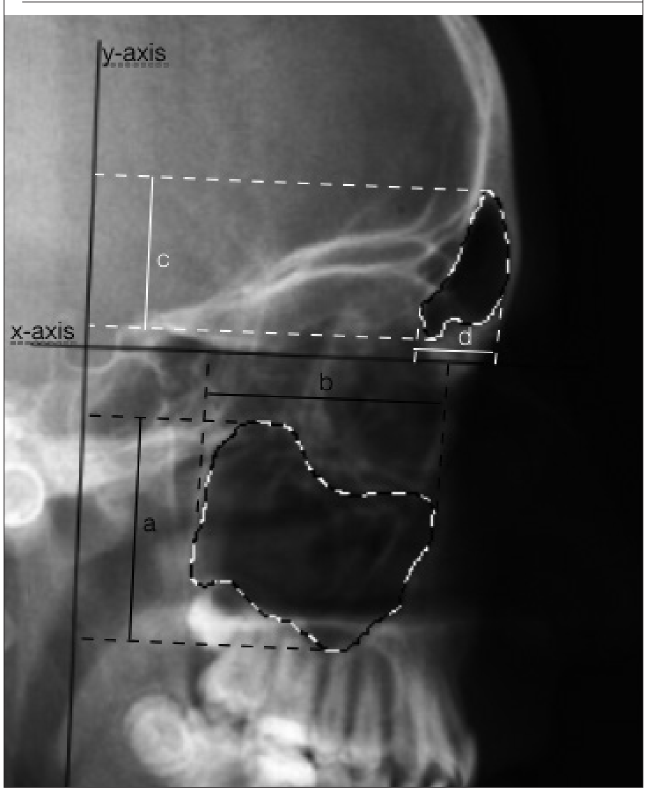


Table 1. Means, standard deviations, and p values for the lateral cephalometric radiograph measurements between the groups

	Groups			
	Group 1 (Mean±SD)	Group 2 (Mean±SD)	Group 3 (Mean±SD)	p
Max area (cm^2)	8.19±0.23	7.63±0.34	7.83±0.20	0.330
Frontal area (cm^2)	1.56±0.95	2.02±0.17	1.59±0.11	0.093
Max width (cm)	3.51±0.07	3.28±0.07	3.39±0.06	0.095
Max height (cm)	3.77±0.08	3.75±0.10	3.84±0.06	0.754
Frontal width (cm)	0.87±0.03	0.95±0.08	0.85±0.05	0.501
Frontal height (cm)	2.58±0.07	2.74±0.08	2.55±0.09	0.228

SD: standard deviation

Table 2. Means, standard deviations, and p values for the posteroanterior cephalometric radiograph measurements between the groups

	Groups			
	Group 1 (Mean±SD)	Group 2 (Mean±SD)	Group 3 (Mean±SD)	p
Frontal area (cm^2)	8.56±0.50	9.71±0.68	9.05±0.56	0.631
Frontal height (cm)	2.57±0.09	2.78±0.11	2.67±0.09	0.614
Frontal width (cm)	4.88±0.19	5.23±0.27	4.89±0.21	0.483

SD: standard deviation

Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 21 (SPSS IBM Corp.; Armonk, NY, USA). The Shapiro–Wilk test was used to test the normality of the distribution of continuous variables. The one-way ANOVA and Least Significant Differences (LSD) test were used to compare variables between the groups when data were normally distributed, and the Kruskal–Wallis analysis was used when data were non-normally distributed. Data are expressed as mean±standard deviation. To determine the method error of five lateral and five PA cephalometric radiographs, the final records were randomly selected, retraced, and digitized at a 15-day interval by the same operator (GBB). The intraclass correlation coefficient (ICC) and 95% confidence interval were used to the test harmony of values and intra-rater reliability. ICC ranged from 0 to 1, where 0 represented no agreement and 1 indicated perfect agreement. A p value of <0.05 was considered statistically significant.

RESULTS

The average ages of individuals included in the study were 16.06±0.18 years for the high-angle group, 16.21±0.17 years for the low-angle group, and 16.09±0.16 years for the medium-angle group. The differences in average age between the groups were not statistically significant (p=0.805). The study included 13 female and 7 male patients in Group 1, 11 female and 9 male patients in Group 2, and 10 female and 10 male patients in Group 3. The difference between the groups with respect to gender was not statistically significant (p=0.627). The correlation coefficient results were >0.89 for intra-examiner reliability, showing high positive correlations and indicating the reliability of the measurements. The area, width, and height measurements of the maxillary sinus and the frontal sinus, which are the measurements from the lateral cephalometric radiographs, are provided in Table 1. The p values of comparisons among groups of these values are provided in the same table. The area, width, and height measurements of PA radiographs and statistical comparison results between the groups are provided in Table 2. According to the results, the difference between the groups in all of the measurements in both lateral and PA radiographs was not statistically significant (p>0.005). The ICC value of 0.831 suggested a high level of harmony between the frontal sinus area lateral and the PA radiograph values (r=0.831, p<0.001).

DISCUSSION

In our study aiming to assess the frontal and maxillary sinus sizes in adolescent individuals with different vertical growth patterns, both frontal and lateral cephalometric radiographs were used. In the study, the error ratio was planned to be decreased by reducing the superimposition rate, which is one of the known disadvantages of two-dimensional radiographs created through the joint use of radiographs obtained based on two different directions. This study is important as it attempts to develop a diagnosis with cheaper two-dimensional radiographs that are routinely used without the need of three-dimensional radiographs exposing the patient to more radiation.

According to our study results, the difference in the age and the gender of the individuals included was not statistically significant between the groups. When considering the effect of age and gender differences on sinus sizes (1, 10), the presence of homogenization is one of the superior aspects of the study. Therefore, by minimizing the individual differences, vertical growth patterns were provided as the only variable.

When examining studies assessing the maxillary sinus in the literature, it was seen that most used lateral cephalometric radiography as two-dimensional radiography. The difficulty of drawing the maxillary sinus with PA radiography due to superposition was given as a reason. Although this condition prevented drawing on two films, as is the case with frontal sinus values, to the best of our knowledge, this is the first study where the correlation between two sinuses is assessed by drawing two sinuses together.

According to the results of our study, a high correlation was found between the measurement values of the frontal sinus area in lateral and PA cephalometric radiographs. Preliminary information was obtained regarding the usability of one radiograph type in place of another in cases where obtaining two radiographs is not possible due to economic, physical, and other reasons.

Said et al. (4) reported that frontal sinus size is affected by vertical skeletal measurements. However, they did not observe a significant difference in the sinus sizes of individuals with different skeletal sagittal oriented malocclusions. They thought that the larger frontal sinus in individuals with open bite malocclusion resulted from the occlusal forces that were transmitted poorly along the nasal pillars associated with the reduced muscular activity in hyperdivergent individuals. Endo et al. (9) reported that there is no significant relationship between maxillary sinus size and sagittal skeletal bone, while reporting that there is a positive correlation between them and upper face height. From these findings, the effects of different vertical patterns on sinus sizes were investigated.

In our study, the statistical difference between the groups was not significant in the measurements in both lateral and PA radiographs. This result is not consistent with the study by Endo et al. (9). In parallel with the study by Oksayan et al. (5), it was suggested that the difference is the result of using the total height instead of using the upper and lower heights separately as in Endo et al.'s method (9) in determining the vertical face sizes.

Oksayan el al. (5) identified significant differences in maxillary sinus lengths and widths, contrary to our study. This is considered to be the result of the difference between the average ages of the individuals included in the groups in the two studies.

Said et al. (4), reporting that the effect of facial height on frontal sinus size is statistically significant, also considered the U1–L1 angle in the grouping of individuals. They suggested that anterior occlusion is important in the transmission of the masticatory forces to the frontal sinuses. It is thought that the difference in the results is due to the fact that this value was not standardized because of the scarcity of samples available when determining the groups in our study. It is considered that this is due to the limitations of the study. We hope that the subject can be enlightened in further detail in more comprehensive future studies in light of this article's findings.

CONCLUSION

Lateral and PA cephalometric radiographs can be used in the calculation of sinus sizes as an effective material, and no significant difference with respect to the effect of different vertical growth tendencies on maxillary and frontal sinus sizes was found.

Ethics committee approval: The study was approved by the Ethics Committee of Gaziantep University (date: 29.03.2018, no: 14).

Informed consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.G., A.G.; Design - M.G., G.B.B., A.G.; Supervision - M.G., A.G.; Resources - M.G., G.B.B.; Materials - G.B.B.; Data Collection and/or Processing - M.G., G.B.B.; Analysis and/or Interpretation - M.G. A.G.; Literature Search - M.G., G.B.B., A.G.; Writing Manuscript - M.G.; Critical Review - M.G., A.G.

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