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Impact of Hard Palate Angulation Caused by Septal Deviation on Maxillary Sinus Volume

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Original Investigation

Abstract

Objective: To investigate the effect of hard palate angulation caused by septal deviation on the volume of the maxillary sinus.

Methods: Coronal computed tomographic (CT) scans of 1568 patients aged from 18 to 60 were examined. CT scans of 402 patients were included in the study. On these scans, the maxillary sinus volume, the angle of the nasal septal deviation, and the angulation of the hard palate were calculated using the ImageJ software. Each maxillary sinus volume was statistically compared with each other and with those in the control group. Correlations between palatal angulation and septal deviation were determined.

Results: Deviated nasal septum whether with or without deflection of the hard palate was noted to have caused changes in the volume of the maxillary sinus in both female and male patients. The volume of the maxillary sinus on the deviated side was less than that of the opposite side, and the differences between the volumes of both sinuses were statistically significant ($p<0.05$). No significant differences were noted when compared with the control group. A positive correlation was observed between the nasal septal deviation angle and the angulation of the hard palate.

Conclusion: Regardless of whether or not it affects the hard palate, nasal septal deviation reduces the volume of the maxillary sinus on the deviated side but does not affect the total volume of the maxillary sinuses. Significant differences between the volumes on the two sides can lead to facial asymmetry.

Keywords: Nasal septal deviation, hard palate, maxillary sinus, computed tomography

Introduction

The development of the paranasal sinuses is yet to be elucidated. It is argued that nasal airflow, brain development, muscle strength, and migration play significant roles in their formation (1, 2). Volumes of the maxillary sinus and its anatomical neighborhood depend on aeration (3). Maxillary sinus development is directly associated with the alveolar process and hard palate. Changes in volume after full development are associated with chronological and pathological conditions (4). Decreased airflow through the nasopharynx reduces oxygen pressure and negatively affects paranasal sinus development (5).

Many deformities of the nasal septum are considered as developmental defects. These defects are classified as nasal septal deviations. Babyhood and childhood traumas that are often considered insignificant and go unnoticed are suspected to be the likely causes of several developmental deformities of the nasal septum. Trauma in early life can lead to asymmetry in the entire nasal structure depending on the degree of bending and deviation of the nasal septal cartilage (6).

In previous studies, nasal septal deviation has been shown to affect the volume of the maxillary sinus (7, 8), but to the best of our knowledge, the palatine bone has not yet been evaluated. A good understanding of the developmental variations of the paranasal sinuses will enable us to better comprehend the period of diseases and provide information in the decision-making process for a surgical intervention and the type of surgical procedure (9).

In this study, we calculated the volumes of maxillary sinuses on computed tomographic (CT) scans of paranasal sinuses using the Cavalieri's principle

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to explore whether nasal septal deviations that deflect the hard palate affect the volume of the maxillary sinus.

Methods

From January 2012 to December 2013, 1568 patients aged from 18 to 60 years consulted our otorhinolaryngology clinic with symptoms of headache and inability to breathe through the nose. After obtaining approval from the Research Ethics Committee (2014-06/10) and the department of Radiology, CT scans of the patients' paranasal sinuses taken in the coronal plane were examined. Scans of 1166 patients who presented with damaged anatomical structure caused by previous sinonasal surgery, nasal polyposis, sinonasal tumors or pansinusitis, or whose scans were not properly performed were excluded from the study. We did not obtain informed consent from the patients since this is a retrospective study. Ultimately, CT scans of 202 male and 200 female patients were included in the study.

Patients were assigned to five separate groups as follows:

Group A (n=79): Patients with a right septal deviation accompanied by hard palate angulation.
Group B (n=80): Patients with a left septal deviation accompanied by hard palate angulation.
Group C (n=83): Patients with only right septal deviation.
Group D (n=79): Patients with only left septal deviation.
Group E (n=81): Control patients with no sinonasal pathology.

The evaluation of CT scans were performed in the coronal plane of 5-mm slices (Somatom X; Siemens, Erlangen, Germany) (scan settings: 110 kV, 200 mA, scan field of view [FoV]: 170 mm). Maxillary sinus volumes, nasal septal deviation, and deviation of the hard palate were calculated using ImageJ software (ImageJ, 1.49v: http://rsb.info.nih.gov/ij/) (Figure 1).

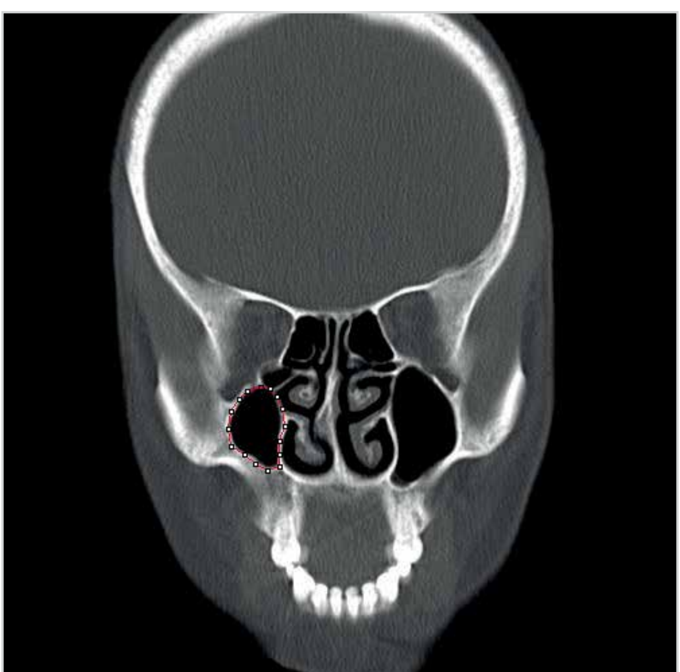

Figure 1. ImageJ program

Measuring the Hard Palate Angle

To eliminate possible imaging errors when measuring hard palate angulation, a line was drawn in the same section between the lesser wings of the sphenoid bone participating in the structure of the orbit on both sides (Figure 2A). This line was projected parallelly so that its segment at the hard palate level (Figure 2B) formed one ray of the angle and the line tangent to the base of the hard palate (Figure 2C) formed another ray of the angle (Figure 2D). Since the lesser wings of the sphenoid bone that participate in the structures of the orbits on both sides were taken as a reference, the patient's head was deemed to be improperly positioned and the scan was excluded if both eyeballs did not simultaneously appear on the same slice. Hard palate angulation was measured at the level where the angle of septum deviation was the largest, using the ImageJ software.

Calculating the Maxillary Sinus Volume

Cavalieri's principle was used for calculating the total volumes. Volumes of both maxillary sinuses were calculated using the planimetry method with ImageJ software. Maxillary sinus areas were measured one by one on each slice from the moment they appeared on the slices. The total number multiplied by the interslice distance equaled the total volume (Figure 3). Data for maxillary sinus volumes were individually compared (with both the deviated side and the other side) and with those of the control group.

Measuring the Nasal Septal Deviation Angle

The curvature of the septum was measured as the angle (Figure 4D) formed by the line drawn between the crista galli (Figure 4A) and the crista nasalis of the maxilla (Figure 4B), and the line drawn through the maximum deviated point (Figure 4C) using ImageJ software.

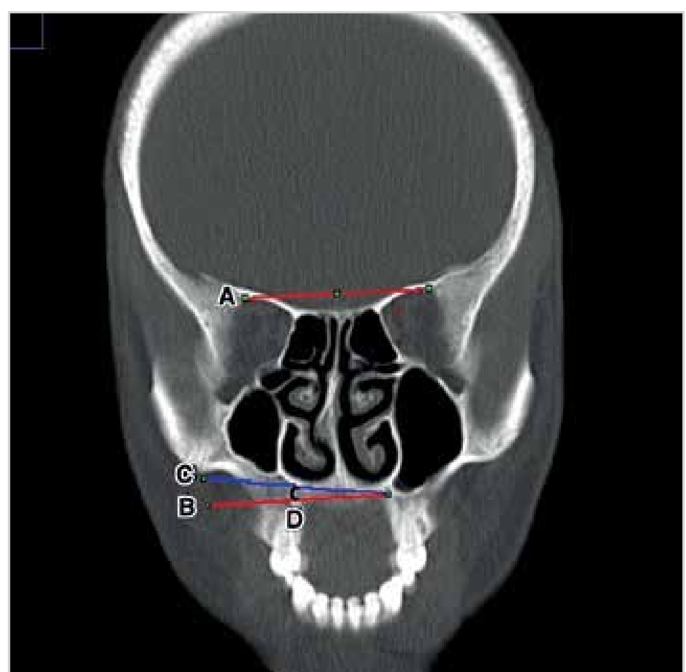

Figure 2. Measuring the angle of the hard palate

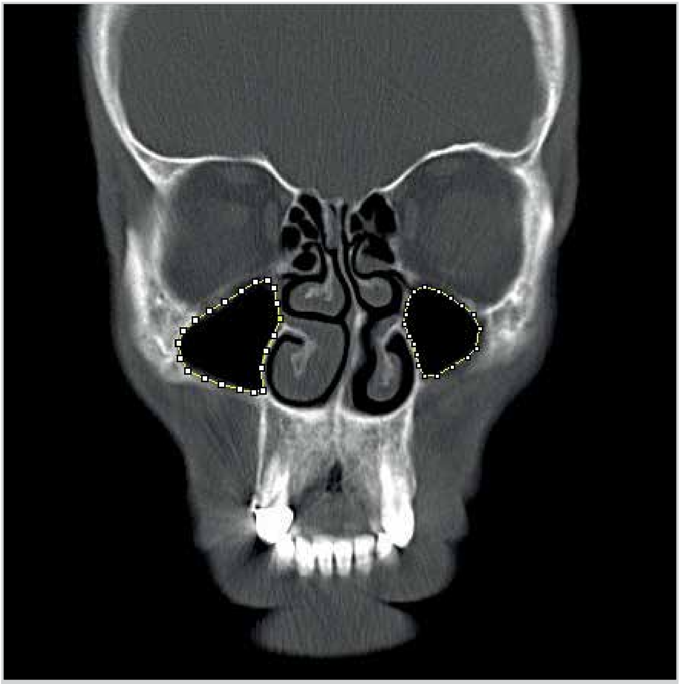

Figure 3. Calculating the volume of the maxillary sinus

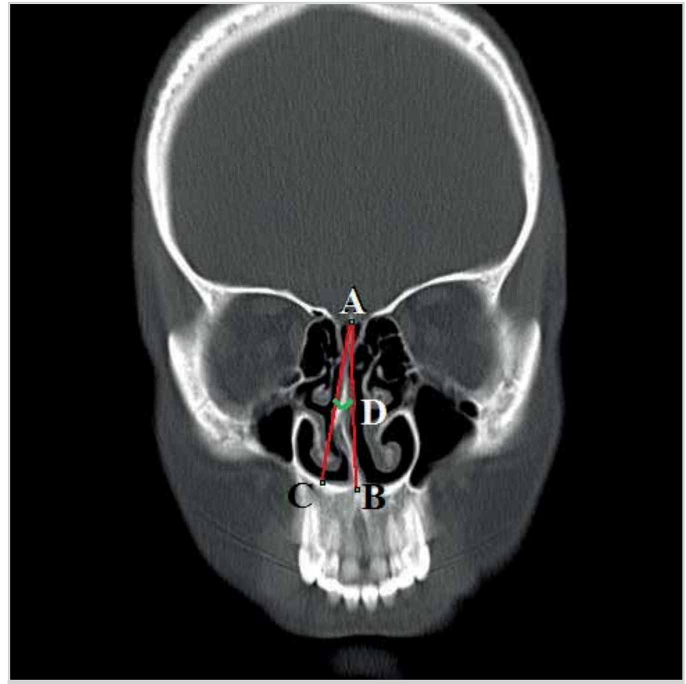

Figure 4. Measuring the angle of nasal septal deviation

Table 1. Statistical data of male patients

Groups		Volume of Right Maxillary Sinus (cm³)(Min-Max)	Volume of Left Maxillary Sinus (cm³) (Min-Max)	Total Volume of Maxillary Sinus (cm³)(Min-Max)	Angle of Nasal Septal Deviation (Mean±SD)	Angle of Hard Palate (Mean±SD)	Correlation between Angle of Nasal Septal Deviation and Hard Palate "r"
Group A	(n=40)	9.32 (4.47-17.61)[a,b]	11.39 (5.75-18.22)[a]	20.71 (10.22-35.83)[a]	14.42±4.73	7.75±2.65	0.504
Group B	(n=39)	11.73 (5.04-20.07)[a]	9.40 (3.48-19.29)[a,b]	21.14 (8.52-39.36)[a]	14.32±3.28	6.96±1.67	0.328
Group C	(n=41)	9.43 (3.07-13.68)[a,b]	10.98 (4.18-14.28)[a]	20.41 (7.25-27.88)[a]	13.96±3.75		
Group D	(n=41)	11.28 (4.88-17.37)[a]	9.58 (4.58-16.99)[a,b]	20.86 (9.58-34.36)[a]	14.12±3.56		
Control (n=41)		10.64 (3.77-17.01)	10.69 (3.23-17.65)	21.34 (7.00- 34.03)			

[a]: Statistically insignificant compared to the maxillary sinus volumes in the control group ($p>0.05$)
[b]: Statistically significant compared to the volume of the maxillary sinus on the opposite side with no septal deviation ($p<0.05$)

Statistical analysis

Data were analyzed using SPSS software. Since the data did not meet the assumptions of parametric tests, groups were compared using the non-parametric Mann–Whitney U test. Correlation between the groups was analyzed with Pearson's correlation. A value of $p<0.05$ was considered statistically significant.

Results

In both the male and female patient groups, nasal septal deviation (right or left) with or without angulation of the os palatinum had caused reduction in the maxillary sinus volume on the deviated side compared with that on the opposite side ($p<0.05$). However, no statistically significant differences were found between the volumes of the deviated and the opposite sides compared with the control group ($p>0.05$). In addition, no statistically significant differences were found between the maxillary sinus volumes of each patient group compared with those of the control group ($p>0.05$). In both the female and the male patient groups, a positive correlation was noted between the angulation of the palatine process and the angle of the nasal septal deviation. Angulation in the palatine process was observed to have increased with nasal septal deviation. Demographic and statistical data of the groups are provided in Tables 1 (male patients) and 2 (female patients).

Table 2. Statistical data of female patients

Groups		Volume of Right Maxillary Sinus (cm3) (Min-Max)	Volume of Left Maxillary Sinus (cm3) (Min-Max)	Total Volume of Maxillary Sinus (cm3) (Min-Max)	Angle of Nasal Septal Deviation (Mean±SD)	Angle of Hard Palate (Mean±SD)	Correlation between Angle of Nasal Septal Deviation and Hard Palate "r"
Group A	(n=39)	7.40 (2.43-12.56)[a,b]	9.00 (3.77-14.87)[a]	16.41 (6.33-26.61)[a]	13.28±2.61	9.60±3.03	0.684
Group B	(n=41)	9.12 (3.55-16.25)[a]	7.57 (2.93-12.96)[a,b]	16.69 (6.48-27.22)[a]	13.35±3.10	10.61±2.24	0.199
Group C	(n=42)	7.86 (3.02-15.56)[a,b]	8.89 (5.46-16.85)[a]	16.84 (8.99-32.41)[a]	12.75±3.76		
Group D	(n=38)	8.80 (4.63-13.22)[a]	7.53 (4.07-12.58)[a,b]	16.33 (8.70-25.05)[a]	12.92±4.12		
Control (n=40)		8.17 (3.68-15.34)	8.51 (3.53-15.61)	16.68 (7.21-30.95)			

[a]: Statistically insignificant compared to the maxillary sinus volumes in the control group was (p>0.05)
[b]: Statistically significant compared to the volume of the maxillary sinus on the opposite side with no septal deviation (p<0.05)

Discussion

Nasal septal deviations are deformities that present with a deflection, angulation, or luxation of the bones and the cartilage, which form the septal roof. While such deformities are often deemed to be an outcome of nasal micro-fractures, they are also believed to occur as a result of minor facial traumas as well as during the neonatal period (10, 11). Changes in the intrauterine position of the fetus and the newborn, increased transnatal pressure, and traumas during labor are believed to lead to changes in septal development and hence to deviation (10, 12). The nasal septum has a direct role in the development of the premaxilla and an indirect role in the development of the maxilla (12). Holton et al. (13) showed that septal deviations are associated with the hard palate and the lateral wall asymmetry of the nasal cavity. A study conducted with twins with different septal structures reports that septal deviations affect the anteroposterior development of the nose and the maxilla (14). Nasal septal deviations that arise in the fetal period are also reported to lead to both facial asymmetry and malocclusion (15). While the prevalence of nasal septal deviations is reported to be 20%-31%, a study on patients consulting an otorhinolaryngology clinic for any reason reports this rate as 89.2% (16).

While nasal airflow plays a crucial role in the development of the paranasal sinuses and the craniofacial skeleton (17), positive airflow in the nasopharynx plays an important role in the development of paranasal sinuses. The obstruction of airflow and reduced oxygen pressure interrupt the development of the paranasal sinus (18). Hypertrophy of the pharyngeal tonsil, which causes obstruction in the posterior paranasal sinus, and nasal septal deviation affecting the development of the maxilla can disrupt the development of paranasal sinuses (4). Oral breathing in the absence of nasal airflow and pressing down the mandible and pulling the tongue down and forward affects the development of the maxillofacial skeleton (19).

The development patterns of paranasal sinuses vary by gender and age. While maxillary sinuses can develop differently on the two sides, no significant differences were reported when maxillary sinus volumes were compared between the genders and the volumes of each side (3, 20). However, Karakas and Kavakli (21) and Uchida et al. (22) reported that paranasal sinus volumes differed between genders. Age and alveolar process height are reported to be the major factors affecting the maxillary sinus volume (23). Barghouth et al. (24) report that the right maxillary sinus is considerably longer than the left maxillary sinus in babies younger than 9 months, and the left maxillary sinus is longer than the right one in children older than eight years. Since the incomplete development of the maxillary sinuses in childhood can be misleading, we included patients older than 18 years in our study.

Factors leading to reduced nasal airflow can also lead to differences in the volumes of paranasal sinuses. Firat et al. (25) report to have found the total volume of ethmoid cells on the deviated side of a nasal septum to be significantly reduced compared with the other side. In our study, we likewise found that maxillary sinus volume on the deviated side of the septum was reduced regardless of an angulation of the hard palate (p<0.05). This suggests that the angulation of the hard palate is caused by the deviated nasal septum rather than the reduced volume of the maxillary sinus, since the presence or absence of an angulation of the hard palate caused no significant differences in the volume of the maxillary sinus. The positive correlation between the angle of the deviation and the angle of the hard palate seems to support our observation. In addition, no difference was reportedly found compared with the control group in the maxillary sinus volume of patients with antrochoanal polyps, a condition that reduces nasal airflow without any causing anatomic changes (26). A recent study comparing oral breathing and nasal breathing showed the volume of the maxillary sinus to be smaller in patients who breathe through their mouth (27). This suggests that the factor impacting a change in the paranasal sinuses must have occurred in the developmental stage of the sinuses. While Koppe et al. (28) report to have found that an untreated cleft palate did not affect the maxillary sinus volume in adult patients, we found that an angulated hard palate did not affect the volume of the maxillary sinuses. This suggests that the key factor affecting the volume of the maxillary sinuses is the deviation of the nasal septum.

Previous studies that have calculated paranasal sinus volumes using several methods report that the calculation method had neither any influence on the results nor showed statistically significant differences between the results (7, 22, 29). We used the ImageJ software with the planimetry method and Cavalieri's principle in our calculations. While previous studies (6, 7, 21, 30) report maxillary sinus volumes to range from 11.1 cm^3 to 23.0 cm^3, our results were found to be consistent with those reported in the literature.

Conclusion

In the present study, we found that the presence of a septal deviation leads to reduced maxillary sinus volume on the deviated side regardless of whether or not it affects the os palatinum but does not affect the total volume. Results of previous studies and the present study suggest that nasal septal deviation has a significant impact on the development of the paranasal sinuses.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Fırat University School of Medicine (2014-06/10).

Informed Consent: Informed consent was not received due to the retrospective nature of the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - E.S.; Design - E.S.; Supervision - E.S., A.K.; Data Collection and/or Processing - E.S.; Analysis and/or Interpretation - E.S.; Literature Search - H.I.S.; Writing - E.S.; Critical Reviews - A.K., M.Ö.

Conflict of Interest: The authors have no conflict of interest to declare.

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