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Original Article

Investigating paranasal sinuses developmental disorders and septum deviation angle effects on olfactory fossa depth using cone-beam computed tomography

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ABSTRACT

Background: The ethmoid roof separates the ethmoid cells from the anterior cranial fossa. From the medial side, the roof of the ethmoid is connected to the lateral lamella of the ethmoid plate, which is the thinnest bone at the base of the skull and is most vulnerable to damage during endoscopic surgeries. The purpose of this study is to investigate the height of the lateral lamella in patients with hypoplasia/aplasia of the paranasal sinuses and deviation of the nasal septum using reconstructed multiplanar images by cone-beam computed tomography (CBCT).

Materials and Methods: In this descriptive-analytical (cross-sectional) study, 192 CBCT images (89 males and 103 females) with an age range of 18 years and older were examined. These 192 participants included 58 cases of frontal sinus (FS) hypoplasia/aplasia, 42 cases of maxillary sinus (MS) hypoplasia/aplasia, 12 cases of sphenoid sinus (SS) hypoplasia/aplasia, 40 cases of nasal septum deviation, and 40 cases as a control group. As Keros classification indicates, the depth of the olfactory fossa was estimated in three categories: type 1 (1–3 mm), type 2 (4–7 mm), and type 3 (8–16 mm). The height of the lateral lamella was measured in the coronal section in all images. The septum deviation angle was also measured in the coronal section. For statistical analysis, Shapiro–Wilk, independent *t*, nonparametric Mann–Whitney, Pearson correlation, and Kruskal–Wallis tests were done using the SPSS 22 software.

Results: The most common type of olfactory fossa in all disorders and the control group was type II of the Keros classification. The highest average lateral lamella height was in the SS hypoplasia group (6.226 mm) and the lowest in the FS aplasia group (4.411 mm). The lateral lamella height in FS aplasia/hypoplasia groups was significantly lower than the control group ($P = 0.002$ and $P = 0.044$). The average deviation angle of the nasal septum was 19.73° ±5.35° and no significant relationship was found between this angle and the height of lateral lamella ($P = 0.938$). The height of the lateral lamella in the FS hypoplasia group was significantly higher in men than in women ($P = 0.019$), but in other groups, there was no relationship between lateral lamella height and gender. Seventy-five percent of the participants of the nasal septum deviation group were type II of Keros classification and the remaining 25% were type I.

Conclusion: The lateral lamella height in hypoplastic/aplastic FSs is lower than normal, and this information is useful in preventing complications during endoscopic sinus surgery.

Key Words: Nasal septum, olfactory fossa, paranasal sinuses

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INTRODUCTION

The anterior base of the skull is a region between the anterior cranial fossa and the sinus cavities and orbits, which includes the frontal (orbital plate), ethmoid (cribriform plate, lateral lamella, and fovea ethmoidalis), and sphenoid (sphenoidal planum and lesser wing) bones.[1] The lateral lamella is a very thin bony structure with a low resistance to perforation during surgery.[2-4] The lateral lamella is an extension from the middle turbinate to the cribriform plate.[5] The cribriform plate and lateral lamella form the olfactory fossa in which the olfactory bulbs are located. Increased depth of the olfactory fossa is associated with an increased risk of injury during surgery.[1] The Keros classification in 1962 is used to classify the depth of the olfactory fossa and the height of the lateral lamella for preoperative evaluations as follows: type I: 1–3 mm, type II: 4–7 mm, and type III: 8–16 mm. Type III of the Keros classification carries the highest risk of bone erosion or cerebrospinal fluid leakage.[1] The development of paranasal sinuses begins before birth and continues throughout life. Between the ages of 1 and 7 years, the paranasal sinuses continue to expand in all directions along with the development of the nasal cavity and other facial structures. Pneumatization of the paranasal sinuses is completed approximately between 12 and 14 years of age and reaches adult dimensions.[6] Nasal airflow as a result of septum deviation may cause chronic sinusitis, nasal dryness, and subsequent failure of sinus drainage, so septum deviation should be examined before the surgery in the nasal region.[7] There have been studies focusing on the depth of the olfactory fossa concerning the frontal sinus (FS), but about the pneumatization defects of the maxillary sinus (MS) and sphenoid sinus (SS), the studies have been very limited.

Our goal in this cross-sectional radio-anatomical study is to evaluate the depth of the olfactory fossa and the height of the lateral lamella in patients with various types of developmental disorders of the paranasal sinuses, as well as patients with deviated nasal septum compared to the control group with normal paranasal sinuses.

MATERIALS AND METHODS

Study design

This descriptive-analytical and radio-anatomical study has been approved by the Ethics Committee of Islamic Azad University with the code of ethics IR.IAU.KHUISF.REC.1400.310. We assessed the cone-beam computed tomography images of the Oral and Maxillofacial Radiology Department of Azad University of Isfahan, Faculty of Dentistry, to identify cases of developmental disorders of the paranasal sinuses and deviated nasal septum, and among them, 152 cases who met the inclusion criteria including having at least one hypoplastic/aplastic sinus were identified. However, patients with a history of facial trauma, paranasal sinus tumors, generalized nasal polyposis, and patients with a history of sinus surgery were excluded from the study. Thus patients with FS hypoplasia/aplasia, patients with MS hypoplasia/aplasia, patients with SS hypoplasia/aplasia, patients with nasal septal deviation, and a control group of patients with completely normal sinuses were selected. The data were collected by Galileos device (Sirona, Bensheim, Germany) with exposure conditions of 85 kV, 21–35 mAs, and field of view of 15 cm × 15 cm. To measure the depth of the olfactory fossa, we measured the height of the lateral lamella in the coronal section, where the crista galli was best visible, which according to Keros Classification is equal to the lateral border of the cribriform plate between the horizontal part of the cribriform plate and the fovea ethmoidalis[1] [Figure 1].

Group of hypoplastic/aplastic maxillary sinuses

We used the classification system of Bolger *et al*. for MS hypoplasia.[8]

- Type I: Slight decrease in pneumatization with normal uncinate process and open infundibulum
- Type II: Moderate reduction in pneumatization with a hypoplastic or aplastic uncinate process, obstructed infundibulum, and usually a sinus filled with soft tissue
- Type III: Severe defect in pneumatization and with no uncinate process [Figures 2 and 3].

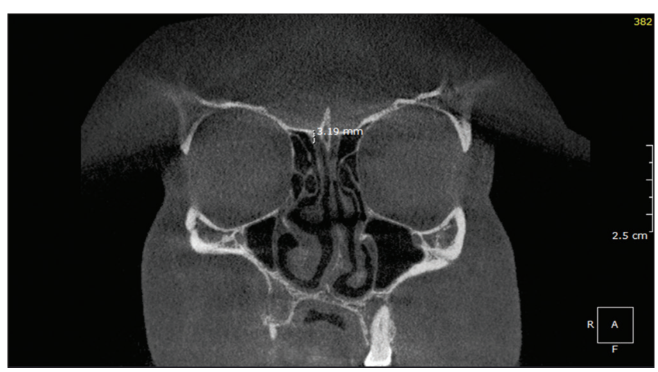

Figure 1: Measuring the height of lateral lamella.

Frontal sinus hypoplasia/aplasia group

According to the method of Guerram *et al*.,[9] FS hypoplasia/aplasia is classified based on the location of the supraorbital and midorbital lines of the FSs:

- Aplasia: Absence of pneumatization
- Hypoplasia: Slight pneumatization under the supraorbital line
- Normal: Pneumatization above the supraorbital line.

Using this method, we evaluated the FSs [Figures 4 and 5].

Group of hypoplastic/aplastic sphenoid sinuses

SS pneumatization has been described by Eggesbø *et al*.:[10]

Hypoplasia in the form of an oval sinus with pneumatization limited to the presphenoid (anterior to the vertical plane of the tuberculum of the sella) and the absence of septa [Figure 6] and aplasia in the form of a complete absence of pneumatization [Figure 7].

We classified the sinuses (hypoplastic/aplastic and normal) based on these definitions and then measured the height of the lateral lamella in all sinuses. Then we compared the lateral lamella height in hypoplastic/aplastic sinuses to the height of lateral lamella in control group which was categorized as normal sinuses.

Statistical analysis

The results are presented as the mean ± standard deviation and the percentage distribution of the data is also reported. The Shapiro–Wilk normality test was used to check the normal distribution of the data in the groups. However, due to the small sample size in the groups of MS aplasia, SS hypoplasia, and SS aplasia, the ability of the Shapiro–Wilk test in detecting normality was very low, so we used nonparametric Mann–Whitney tests in the three mentioned groups. Independent *t*-test was used in the FS hypoplasia/aplasia, MS hypoplasia, and nasal septum deviation groups, and for the MS aplasia and SS hypoplasia/aplasia groups, we used nonparametric Mann–Whitney test. We used Pearson's correlation coefficient test to investigate the relationship between lateral lamella height and nasal septum deviation angle. Finally, we used SPSS 22 software (SPSS Inc., IL, USA) to analyze the data and considered $P < 0.05$ to be statistically significant.

RESULTS

A total of 192 participants consisting of 103 women and 89 men with the age range of 18 years and above were

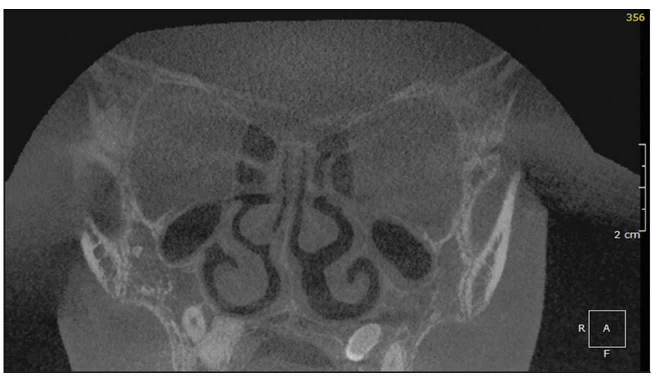

Figure 2: Hypoplastic maxillary sinus type II on the left and right sides.

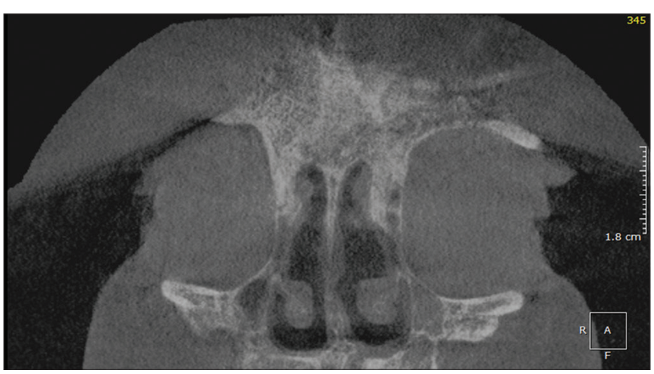

Figure 3: Left maxillary sinus hypoplasia and right sinus type III hypoplasia.

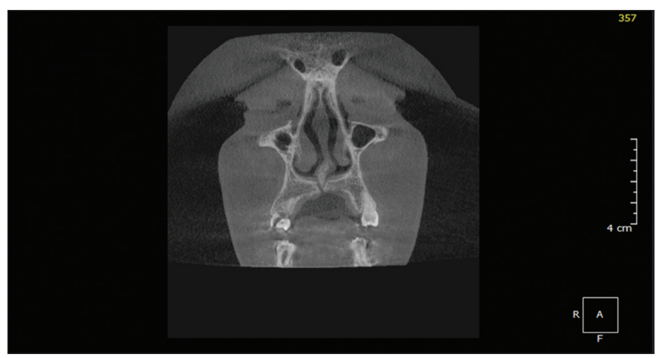

Figure 4: Frontal sinus hypoplasia.

Figure 5: Frontal sinus aplasia.

examined. Fifty-eight cases in the FS hypoplasia/aplasia group, 42 cases in the MS hypoplasia/aplasia group, 12 cases in the SS hypoplasia/aplasia group, 40 nasal septum deviation cases, and 40 cases with completely normal sinuses were included in the control group.

The samples in the Keros classification are shown in Table 1. In all groups, respectively, the highest prevalence was related to type II, followed by type I, and finally, the lowest prevalence was for type III.

The results of Table 2 were obtained concerning the average depth of the olfactory fossa with the height of the lateral lamella in different groups.

In Table 2, in the FS hypoplasia and aplasia group, the average height of the lateral lamella was significantly lower than the control group ($P = 0.044$ in the hypoplasia group and $P = 0.002$ in the aplasia group), and in other disorders, a significant difference was not observed.

Out of 40 MS hypoplasia samples, 26 cases (65%) were type I, 27.5% (11 cases) were type II, and 7.5% (3 cases) were type III.

Then, the height of the lateral lamella was measured and statistically analyzed based on group and sex, which can be seen in Table 3.

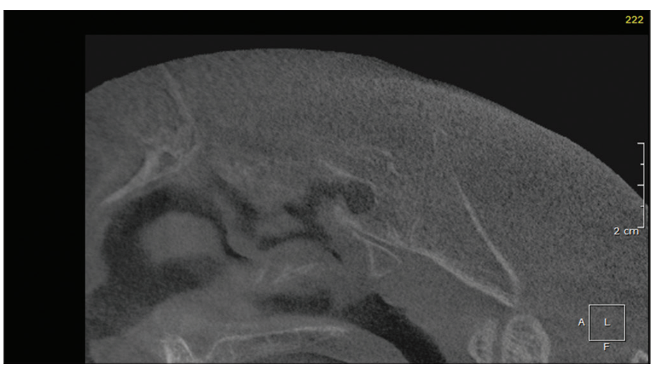

Figure 6: Sphenoid and frontal sinus aplasia in sagittal view.

Figure 7: Sphenoid sinus aplasia.

In Table 3, in the FS hypoplasia group, the height of the lateral lamella is significantly higher in men than in women ($P = 0.019$) and no significant difference was observed in other groups.

Table 1: Keros classification

Disorder	Class Keros	Frequency	Percentage
FS hypoplasia	I	11	34.4
	II	20	62.5
	III	1	3.1
	Total	32	100
FS aplasia	I	11	42.3
	II	15	57.7
	III	0	0
	Total	26	100
MS hypoplasia	I	6	15
	II	31	77.5
	III	3	7.5
	Total	40	100
MS aplasia	I	1	50
	II	1	50
	III	0	0
	Total	1	100
SS hypoplasia	I	0	0
	II	5	100
	III	0	0
	Total	5	100
SS aplasia	I	0	0
	II	7	100
	III	0	0
	Total	7	100
NSD	I	10	25
	II	30	75
	III	0	0
	Total	40	100
Control	I	6	15
	II	29	72/5
	III	5	12/5
	Total	40	100

MS: Maxillary sinus; SS: Sphenoid sinus; FS: Frontal sinus; NSD: Nasal septum deviation

Table 2: Lateral lamella height in different disorders

Lateral lamella length in disorders	*n*	Minimum	Maximum	Mean±SD (mm)	*P*
FS hypoplasia	32	2.20	8.11	4.909±1.51	0.044
FS aplasia	26	2.58	7.18	4.411±1.23	0.002
MS hypoplasia	40	1.66	9.07	5.580±1.58	0.738
MS aplasia	2	3.27	5.52	4.395±1.59	0.237
SS hypoplasia	5	5.05	7.33	6.226±1.08	0.427
SS aplasia	7	4.41	6.67	5.577±0.87	0.881
NSD	40	1.90	7.89	5.355±1.48	0.336
Control	40	1.78	9.13	5.705±1.73	

SD: Standard deviation; FS: Frontal sinus; MS: Maxillary sinus; SS: Sphenoid sinus; NSD: Nasal septum deviation

Table 3: Relationship between sex and lateral lamella height

Lateral lamella length in disorder	Sex	n	Mean±SD (mm)	P
FS hypoplasia	Female	24	4.55±1.34	0.019
	Male	8	5.97±1.55	
FS aplasia	Female	11	4.11±1.29	0.311
	Male	15	4.62±1.19	
MS hypoplasia	Female	25	5.56±1.7	0.917
	Male	15	5.61±1.43	
MS aplasia	Female	2	4.39±1.59	-
	Male	0	0±0	
SS hypoplasia	Female	1	7.03±0	-
	Male	4	6.02±1.13	
SS aplasia	Female	2	5.05±0.65	0.245
	Male	5	5.78±0.92	
NSD	Female	19	5.83±1.34	0.054
	Male	21	4.92±1.5	
Control	Female	19	5.51±2.04	0.416
	Male	21	5.87±1.42	

SD: Standard deviation; FS: Frontal sinus; MS: Maxillary sinus; SS: Sphenoid sinus; NSD: Nasal septum deviation

The average angle of nasal septum deviation was 19.73° ±5.35°, and the average lateral lamella height in the septum deviation group was 5.35 ± 1.48 mm. Pearson's correlation coefficient test was not significant in this relationship ($P = 0.938$); as a result, there was no significant relationship between the degree of the septum deviation angle and the height of the lateral lamella.

DISCUSSION

The clear identification of critical anatomic landmarks in the paranasal sinus region, anterior skull base, and olfactory fossa before and during surgery is mandatory to avoid complications.[11] Three of the most common complications reported during functional endoscopic sinus surgery are intracranial complications (including cerebrospinal fluid leakage), eye injuries (including blindness), and anosmia.[12]

The simultaneous presence of different anatomic variations with pneumatization defects of the paranasal sinuses is common. In past studies, it has been reported that patients with hypoplastic MSs have a higher rate of FS hypoplasia.[13] The relationship between FS pneumatization and the olfactory cavity has been the focus of several previous studies.[14,15] In this study, we examined the effect of pneumatization defects of MS and SS in addition to FS on the depth of the olfactory cavity and also evaluated the effect of nasal septum deviation in this regard.

The effect of the FS pneumatization pattern on the depth of the olfactory cavity has not yet been properly determined. Çomoğlu *et al.*[14] reported a deeper olfactory fossa in hyperpneumatized sinuses, and Gumus and Yildirim[15] also reported a deeper fovea ethmoidalis in hyperpneumatized FSs, as in our study, this fossa is less deep in hypoplastic sinuses. In Kayabasi *et al.*'s study, the height of the lateral lamella in all three hypoplasia/aplasia groups of the FS, MS, and SS was significantly higher than in the control group[13] which is in contrast to our study.

The balance between the pneumatization pattern of the FS and the ethmoid labyrinth can determine the location of the olfactory cavity.[16] In the present study, in all groups of disorders and the control group, type II of the Keros classification was the most common, followed by type I and type III. In Kayabasi *et al.*'s study[13] regarding the group of FS, MS, and control sinuses, the order of prevalence was type III < type I < type II, which was the same in our study. Regarding the SS hypoplasia/aplasia group, after type II, which was the most common, type III and then type I were reported.

In our study, the average deviation angle of the nasal septum was 19.73° ±5.35°. In the study of Bayrak *et al.*,[7] this angle was equal to 10.33° ±13.23° and 12.2° ±12.98° on the right and left sides, respectively. Furthermore, in the study of Damar *et al.*,[17] the average angle was 12.1° and there was no significant difference between men and women, which is similar to the present study.

There was no significant difference in the average height of the lateral lamella on the side of deviation and the opposite side in our study ($P = 0.376$). The results of the studies of Bayrak *et al.*[7] and Asal *et al.*[18] are also consistent with the results of our study, but Saylisoy *et al.*[19] reported a longer lateral lamella on the side of the deviation than on the opposite side, which is contrary to the present study.

In the current study, the average height of the lateral lamella on the deviation side is 5.355 ± 1.48 mm, which has no statistically significant difference compared to the control group ($P = 0.336$). According to the Pearson correlation test, there is no significant relationship between the lateral lamella height and the septum deviation angle in the present study ($P = 0.998$). Bayrak *et al.*[7] also did not find a significant relationship between the depth of the olfactory fossa and the angle of septum deviation ($P < 0.05$), which is consistent with the present study. However, Asal *et al.*[18] concluded that in patients with a higher lateral lamella on the side of deviation, the angle of deviation of the septum is reduced, and vice versa, and in patients with larger angles of deviation, the depth of the olfactory fossa is less on the deviation side ($P < 0.05$), which is in contrast to the results of the present study.

The number of participants in the SS hypoplasia/aplasia group in our study was limited, and this can be a limitation of the present study, as well as the failure to consider the angle of the lateral lamella and the cribriform plate.

CONCLUSION

Patients with FS hypoplasia/aplasia have shorter lateral lamella and subsequently a shallower olfactory fossa. This radio-anatomical information can be useful in preventing surgical complications.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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