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Variations of Frontal Sinus and Sphenoid Sinus Pneumatization in Patients with Cleft Lip and Palate: A CBCT Study

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Abstract

Background: This study aimed to evaluate the frontal sinus and sphenoid sinus pneumatization and variations in patients with Cleft Lip and Palate (CLP) on Cone Beam Computed Tomography (CBCT) images and to compare them with a control group.

Methods: In order to evaluate the sphenoid sinus types, CBCT images of 59 patients with CLP and 59 non-cleft individuals and for evaluation of the frontal sinus types, CBCT images of 31 subjects with CLP and 31 non-cleft individuals were obtained. The main types of frontal sinus pneumatization (types 1, 2, and 3) and the main types of sphenoid sinus pneumatization (conchal, presellar, sellar and post-sellar) were analyzed in CLP and control groups. The two groups were compared using chi-square test.

Results: For sphenoid sinus, the sellar and post-sellar types were the most common types in the CLP group and the control group, respectively. The results revealed no significant difference between the CLP group and the control group regarding all types of sphenoid sinus pneumatization. Type 2 was the most common type of frontal sinus pneumatization in both CLP and control groups. The results demonstrated no significant difference between the CLP and control groups regarding all types of frontal sinus pneumatization.

Conclusion: The results showed no significant difference between the CLP and control groups regarding the types of frontal sinus and sphenoid sinus pneumatization, proposing a similar risk of consequences in the CLP group and non-cleft individuals.

Keywords: Cleft lip and palate, Frontal sinus, Pneumatization, Sphenoid sinus

Introduction

Cleft of the Lip and Palate (CLP) is the most common congenital abnormality, which affects the maxillofacial region and has a complex etiology. In addition to failure of fusion of the processes, subjects with CLP show several anatomical variations. Alteration in midface structures can lead to nutritional problems, dental disorders, and malocclusion and implicate the health of ear, nose, throat, and sinuses (1-3).

The sphenoid sinus is located in the center of the cranial base and is bounded by various anatomical structures. The sphenoid sinus is limited by ethmoidal air cells anteriorly, clivus posteriorly, cavernous sinuses laterally, pituitary fossa superiorly, and choana inferiorly (4). Pneumatization of the sphenoid sinus provides a wide cavity, through which the access to large areas of cranial base may be possible. The sphenoid sinus demonstrates various degrees of pneumatization and can progress posteriorly, inferiorly, and laterally (5). The sphenoid sinus has been classified into four types, namely conchal, presellar, sellar, and post-sellar, based on the extent of pneumatization of the posterior wall to the sella turcica. Because of the close adjacency of the carotid artery, the optic canal, and the skull base to the sphenoid sinus, it is vital for surgeons to be aware of its anatomical structures as well as variations (5,6).

The frontal sinus is a unique complex structure that has various sizes, shapes, and pneumatization across individuals. It is located posterior to the superciliary arch between the two bony walls of the frontal bone (7,8). Frontal sinuses are mostly absent at birth and start developing in the second year of life. They reach their full size in the second decade of life. Due to bone resorption and septation, right and left frontal sinuses progress separately and are usually asymmetrical in configuration (9,10). The frontal sinuses are located in the structurers that are affected in formation of CLP. Therefore, the pneumatization of these sinuses may be altered in subjects with CLP (1). The frontal sinus pneumatization extent can be categorized into type 1 (aplasia or hypoplasia), type 2 (medium), and type 3 (hyperplasia) (11).

Although many studies have been conducted on the maxillary sinus in subjects with CLP, to the best of our knowledge, no study has been performed on the evaluation of the frontal sinus pneumatization types in these patients and scarce research has been performed on the sphenoid sinus (4). It seems that air pressure during respiration and expiration is an effective factor in the pneumatization of the paranasal sinuses (1). Therefore, the altered pressure resulting from the cleft palate in patients may affect the pneumatization of sinuses. The present study aims to use detailed classifications from CBCT images to evaluate the variations of frontal sinus and sphenoid sinus pneumatization in subjects with CLP and to compare them with a control group.

Materials and Methods

This study was approved by the institutional Ethics Committee. In order to evaluate the sphenoid sinus types, CBCT images of 59 subjects with CLP (29 females and 30 males) and 59 non-cleft individuals (29 females and 30 males) and in order to evaluate the frontal sinus types, CBCT images of 31 subjects with CLP (14 females and 17 males) and 31 non-cleft controls (16 females and 15 males) were obtained from the archive of the oral and maxillofacial radiology department. The CLP and non-cleft groups were matched regarding age, sex, and ethnicity. The patients had been referred to the oral and maxillofacial radiology department for various regions. The mean age of the participants was 21.3±2.6 years (age range: 20-30 years). CBCT images with sinus pathologies, history of trauma, craniofacial syndrome, and sinus surgical interventions were excluded.

All the CBCT images were obtained using NewTom VGi with a field view 15×15 *cm* (110 *KV*, 3 *mA*) and exposure time of 3.8 *s*. The frontal sinuses and sphenoid sinuses were evaluated separately regardless of other paranasal sinuses. The sphenoid sinuses were classified into four main types based on the position of the posterior sinus wall, with the sella turcica being the reference: conchal (completely missing or minimal sphenoid sinus), presellar (the posterior wall of the sphenoid sinus is in front of the anterior wall of the sella), sellar (the posterior wall of the sphenoid sinus is between the anterior and posterior walls of the sella turcica), and post-sellar (the posterior wall of the sphenoid sinus is behind the posterior wall of the sella turcica) (Figures 1-4). In order to evaluate frontal sinus pneumatization, the supraorbital line,

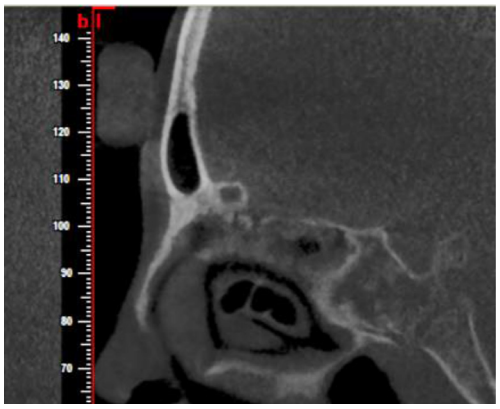

Figure 1. Conchal type.

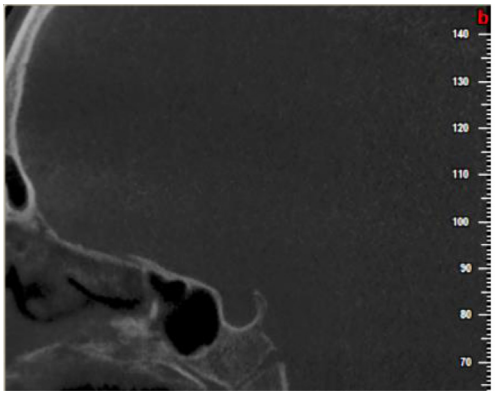

Figure 2. Presellar type.

Figure 3. Sellar type.

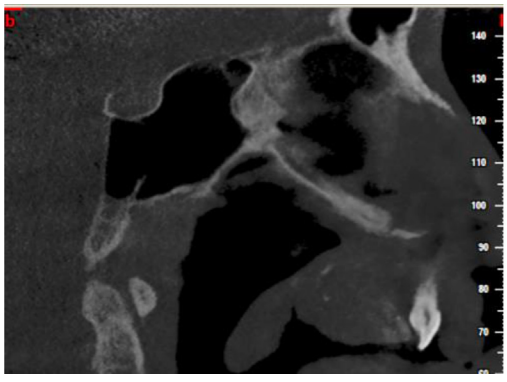

Figure 4. Post-sellar type.

which is the horizontal line tangent to the superior edges of both orbits, and the midorbital line that is the vertical line of midpoint of both orbits parallel to the midsagittal line were designated on the coronal sections of the CBCT images. As proposed by Guerram *et al* (12), the patients' extents of frontal sinus pneumatization were classified as follows:

type 1 pneumatization (aplasia or hypoplasia): no or minimal pneumatization under the supraorbital line (Figure 5),

type 2 pneumatization (medium): frontal sinus limited to the area medial to the midorbital line (Figure 6), and

type 3 pneumatization (hyperplasia): frontal sinus extending in the area lateral to the midorbital line (Figure 7).

All the statistical analyses were performed using the SPSS software for Windows, version 26.0. Chi-square test was used to compare the CLP and non-cleft groups with respect to the categorical variables. The $p<0.05$ was considered statistically significant.

Figure 5. Type 1 frontal sinus pneumatization (hypoplasia).

Figure 6. Type 2 frontal sinus pneumatization (medium).

Figure 7. Type 3 frontal sinus pneumatization (hyperplasia).

Results

The incidence of the four sphenoid sinus types in the CLP and control groups has been depicted in table 1. Accordingly, the sellar type was the most common type in the CLP group (4%), while the post-sellar type was the most frequent type in the control group (47.4%). The least frequent type was the conchal type in control group (6.7%) and presellar type in CLP group (10%). The results of chi-square test revealed no significant difference between the CLP and control groups regarding different types of sphenoid sinus pneumatization (p=0.706).

The prevalence of the anatomical variants of frontal sinus pneumatization of the three groups has been presented in table 2. In this study, the patients were divided into three groups according to the type of frontal sinus pneumatization. It should be noted that only the patients with the same type of frontal sinus on both sides were examined in this study. According to the results, type 2 was the most common type in both CLP (51.6%) and control (54.8%) groups, while type 3 was the least frequent type in both CLP (16.1%) and control (12.9%) groups. The results of chi-square test showed no significant difference between the CLP and control groups in terms of all types of frontal sinus pneumatization (p=1.000). There results also revealed no significant difference between males and females with respect to frontal sinus pneumatization (p>0.05) (Table 3).

Table 1. The frequency of different types of sphenoid sinus pneumatization

Type	CLP group N (%)	Control group N (%)	p-value
Conchal	8(13.5%)	4(6.7%)	0.706
Presellar	6(10%)	5(8.4%)	
Sellar	25(42.3%)	22(37.2%)	
Post-sellar	20(33.8%)	28(47.4%)	

Table 2. Total frequency of different types of the frontal sinus pneumatization

Types	CLP group N (%)	Control group N (%)	p-value
Type 1	10(32.2%)	10(32.2%)	1.000
Type 2	16(51.6%)	17(54.8%)	
Type 3	5(16.1%)	4(12.9%)	

Discussion

Anatomic variations of the structures close to the sphenoid sinus can be implicated during endoscopic sinus surgery. Due to the variations of the paranasal sinuses and its significance in sinus surgery, as the pneumatization of sphenoid sinus is very close proximity to structures including the optic nerve, carotid artery, and skull base, anatomical knowledge of this area is of high importance (15). Thus, the knowledge of the extent of pneumatization of the sphenoid sinus is important for appropriate surgical treatment of its diseases (13). CLP is the most common birth abnormality, which can cause middle

Table 3. Frequency of different types of frontal sinus pneumatization according to gender distribution

	Type 1	Type 2	Type 3	p-value
CLP group N (%)	M=6 (19.3%) F=4 (12.9%)	M=8 (25.8%) F=8 25.8%)	M=3 (9.6%) F=2 (6.4%)	0.855
Control group N (%)	M=7 (22.5%) F=3 (9.6%)	M=7 (22.5%) F=10 (32.2%)	M=1 (3.2%) F=3 (9.6%)	0.212

ear and mastoid problems, dental abnormalities, and paranasal sinus shortage (14). The anatomical structures of subjects with CLP may be different from the normal anatomy, and certain anatomical variations can cause chronic sinusitis (15). Due to the prevalence of rhinosinusitis in patients with CLP, there has been an increase in research on the nasal cavity and paranasal sinuses in these patients (15).

The results of the present study indicated no significant difference between the CLP subjects and the control group with respect to the types of sphenoid sinus pneumatization. According to the review of the literature, the study performed by Yalcin (4) is the only study on the assessment of sphenoid sinus morphology and pneumatization in subjects with CLP. In that study (4), significant differences were found between the CLP and control groups concerning the main types of the sphenoid sinus. However, the present study findings demonstrated no significant difference between the CLP and control groups in this regard. The results of the study conducted by Yalcin (4) suggested that the sphenoid sinus developed less in subjects with CLP than in the non-cleft group (4). In the present study, however, no significant difference was observed between the two groups regarding the pneumatization extension of the sphenoid sinus.

Similar to many other studies (5,16-18), Yalcin (4) disclosed that the sellar type was the most common type amongst the CBCT images of both cleft and non-cleft groups. In the same line, the current study results indicated the sellar type to be the most common type of sphenoid sinus pneumatization in the CLP group. The incidence of the sellar type has been reported to range from 14.6% to 98% (4,17-19). In the present investigation, the incidence of the sellar type was 42% in the CLP group and 36% in the control group. However, Movahedian *et al* (19) and Rahmati *et al* (20) showed that the post-sellar type was the most prevalent sphenoid sinus type. In the present study, the frequency of the post-sellar type pneumatization was 33.8% in the CLP group and 47.4% in the control group. Generally, the post-sellar pneumatization of the sphenoid sinus may pass into the posterior wall and cause cerebrospinal leak (4). In this situation, the risk is lower in subjects with CLP than in non-cleft individuals.

The incidence of the conchal type pneumatization has been reported to be 1-2% in the literature (5,17). However, no case of conchal pneumatization has been detected in some investigations (9,19). In contrast, the present study results indicated that the prevalence of the conchal type pneumatization was 13.5% in the CLP group and 6.7% in the control group. In general, the conchal pneumatization type sinuses are less desired for trans-sphenoidal surgeries, since they require a longer operating time for drilling and the removal of the cancellous bone (21).

The incidence of the presellar type has been reported to range from 1.2% to 6.6% in the literature (16, 18, 21). Nonetheless, the prevalence of the presellar type was reported to be 21% by Hamid *et al* (17) and 24% by Štoković *et al* (5). In the present research, the incidence of the presellar pneumatization type was 10% in the CLP group and 8.4% in the control group. In the study carried out by Yalcin (4), the presellar type was more commonly observed in the CLP group (18.5%). In addition, the sphenoid sinus showed extension into the presellar area in the majority of the subjects with CLP, while it displayed post-sellar and clival extensions in the control group (4).

Knowledge of frontal sinus anatomy is fundamental for the comprehensive evaluation and treatment of frontal sinus diseases. Surgeons dealing with endoscopic sinus surgeries, as well as maxillofacial and skull base surgeries should be aware of the association between certain variations when analyzing CBCT preoperatively for avoiding complications. The treatment of frontal sinus disease has consisted of obliteration or ablation of the sinus, or restoration of drainage into the nose (22). The anatomical variations in frontal sinuses have been well documented in earlier studies. However, there is a need for additional studies regarding subjects with CLP. In the present study, the CBCT images of different types of frontal sinus pneumatization were evaluated in subjects with CLP and were compared to the control group. The results revealed no significant difference between the two groups regarding the types of frontal sinus pneumatization. As frontal sinus pneumatization increases with age and has a great individual variability (23), the subjects with CLP were age-matched with the control group in the present study. Similarly, Francis *et al* (1) indicated no significant difference between subjects with cleft and

the control group concerning the size of the frontal sinuses using modified Waters view. Nevertheless, they demonstrated more bilateral aplasia (type 1) of the frontal sinuses in the CLP group compared to the control subjects aged above four years (1). This finding proved that type 1 pneumatization of the frontal sinuses was more common in subjects with CLP who were younger than 20 years in comparison to the control group. In the present study, however, the percentage of type 1 pneumatization was the same in both groups. Nowak *et al* (24) indicated that the altered function of the nose in physiological respiration influenced the pneumatization of the maxillary and frontal sinuses in subjects with CLP (24). However, the results of the present study showed no statistically significant difference between the two groups with respect to the pneumatization of the sinuses. Therefore, this hypothesis was not supported by the study findings.

In the study carried out by Aslier *et al* (10), 14.2% of the sinuses were hypoplasic and 44.5% of the frontal sinuses were hyperplasic. The overall incidence of the medium type of frontal sinuses was 37.2%. Guerram *et al* (12) demonstrated that the incidence of aplasia and hypoplasia was 11.9%, the incidence of medium type pneumatization was 76.2%, and the prevalence of hyperplasia was 11.9% (12). In the same line, the present study results indicated that type 2 pneumatization was the most common type in both CLP (51.6%) and control (54.8%) groups, while type 3 was the least frequent type in both CLP (16.1%) and control (12.9%) groups. Furthermore, Yazici (11) and Guerram *et al* (12) reported a significant difference between males and females in this regard. Accordingly, frontal sinus hypoplasia (type 1) was more common in females, while hyperplasia (type 3) was more prevalent in males (11,12). However, the present study findings indicated no significant difference between the males and females in this respect ($p>0.05$).

The classification size categories of frontal sinuses began with the research performed by Libaersa *et al* (25) in 1958, which used the supraorbital line as a landmark. In 1978, Rouvière *et al* (26) expanded the classification by using the superomedial angle of the orbital cavity as another landmark. Due to the asymmetrical configuration of frontal sinuses, the size classification of frontal sinuses is difficult in three dimensions (10). In the recent years, with the help of CT and CBCT, metric and non-metric measurements have been utilized to create modeling systems for different configuration of frontal sinus pneumatization in several views (27).

Conventional radiology has several shortcomings such as providing only a two-dimensional assessment of the skeletal structures. In addition, structural superimposition does not allow for detailed exploration of the sinus region. With the help of three-dimensional imaging, clinicians are able to observe anatomical structures precisely. CBCT is a useful method for the evaluation of the paranasal sinuses and compared to CT, it has lower radiation and costs. CBCT provides a three-dimensional evaluation. Therefore, it has a substantial advantage for subjects with CLP compared to other radiological methods (11,28). Hence, CBCT was used for evaluating the frontal sinus and sphenoid sinus pneumatization types in the current study.

Conclusion

The present study results revealed no significant difference between the CLP and control groups in terms of the types of frontal sinus and sphenoid pneumatization. The results also showed no significant difference between females and males in the two groups in frontal sinus pneumatization. This suggested that the risk of complications was the same for the CLP group and non-cleft individuals. Due to the diversity of frontal sinus and sphenoid sinus pneumatization in subjects with CLP, further studies with larger sample sizes are recommended to be conducted on different types of frontal sinus.

Conflict of Interest

Authors declare no conflict of interest.

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