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Morphometric Analysis of Sphenoid Sinus: Impact on Influencing Factors through Cone Beam Computed Tomography

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KEYWORDS

Sphenoid Sinus, Cone Beam Computed Tomography, Morphometry, Influencing Factors, Three-Dimensional Imaging

ABSTRACT:

Introduction: The sphenoid sinus exhibits considerable morphological variability, influenced by factors such as age, gender, and sinus condition. These variations are crucial for surgical planning, particularly in procedures involving the skull base and neurovascular structures.

Materials and Methods: A total of 109 CBCT scans of sphenoid sinuses devoid of pathologies were evaluated. DICOM files from CBCT scans were imported into semi-automatic software, and each patient's sphenoid sinus was evaluated for morphological parameters such as configuration, symmetry, extension, shape, and septation. In addition, potential influencing factors such as age, gender, and sinus condition were correlated with morphometric parameters of the sphenoid sinus.

Results: This study showed that configuration ($p<0.001$) and septation ($p<0.001$) of sinuses shows statistically significant difference in symmetrical and asymmetrical sinuses.

Conclusion: This study suggests that there is significant impact of influencing factors on the morphological characteristics of sphenoid sinus.

Introduction

The Sphenoid sinus is one of the four paired paranasal sinuses present in the sphenoid bone, situated near essential structures such as the optic nerve, pitutary gland, and cavernous sinus[1]. Other adjacent structures with critical importance include the hypophysis and the internal carotid artery[5].Enclosed within the body of the sphenoid bone, it is connected to the neurocranium and viscerocranium through several skull bones[1]. The bony septum separates two sinuses from each other and is located in the midline. Sizes and shapes of the sphenoid sinuses vary between individuals[3]. First seen radiographically at the age of 2 to 3 years, the sphenoid sinus reaches mature size in adolescence by the age of 12–14 years[1]. Hamberger classified the sphenoidal sinus into conchal, presellar and sellarwhich served as a

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foundation for transsphenoidal surgeries for 30 years[2]. Cone beam computed tomography is a better technique for assessing the paranasal sinuses and has superiorities when compared to CT, such as a shorter imaging time, lower cost, and lower radiation exposure[3]. The morphology of sphenoid sinus is influenced by several factors including age, gender and sinus condition. These factors collectively contribute to the variability in the shape, size and internal structure of the sphenoid sinus, making it a unique anatomical feature in each individual. Sphenoid sinusitis can cause headaches, often retro-orbital or frontal which mimic dental pain due to shared nerve pathways with other paranasal sinuses. Despite not being close to teeth, its inflammation can impact dental structures. Understanding sphenoid sinus anatomy and its connections is crucial for dental professionals to accurately diagnose and to treat related dental pain, and for safely assessing the pituitary gland or addressing sinus related issues surgically, avoiding complications. The goal of this study is to evaluate morphological characteristics of sphenoid sinus and correlate it with influencing factors.

Materials and Methods

The study received approval from the Institutional Ethical Committee of St. Joseph Dental College and Hospital. [IEC PROTOCOL NUMBER: SJDC/CEC/OMR/2025/002]

With reference to studyby Singh P et al [1] and using G*Power with an alpha level of 0.05, a power of 80%, and an effect size of 0.1327646, a minimum sample of 218 SSs (109 subjects) was deemed adequate. The study group consisted of the records of patients who had CBCT scans with various indications in the CBCT archive of Department of Oral Medicine and Radiology, St. Joseph Dental College and Hospital.This retrospective study was performed utilizing CBCT scans of 109 patients (62 males and 47 females) studies under coronal, axial and sagittal views.

Inclusion Criteria

1. Male and female patients ≥15 years.
2. Superior quality CBCT images depicting the complete face to the orbit and the skull base.
3. Scans were acquired for all oral and maxillofacial diagnostic and treatment purposes, excluding any past history of maxillofacial trauma or anomalies.

Exclusion Criteria

1. Subjects with sphenoid sinus pathologies, cleft lip or palate, craniofacial osseous abnormalities, or a history of trauma or evidence of orthognathic surgery.
2. Scans of subjects below 15 years of age, as there was no complete pneumatization of the sphenoid sinus.
3. Scans that are not of superior diagnostic quality (acquisition and patient related artifacts).

CBCT scans were exposed using a Rainbow CBCT machine (Dentium co. Ltd. South Korea) with exposure parameters of 94 kVp, 8 mA tube current, 20 sec scan time.CBCT scans were imported to Digital Imaging and Communications in Medicine format (DICOM) and analysed in Rainbow Viewer (software version 1.1.0).

Morphological Characteristics of Sphenoid Sinus

With reference to study done by Singh P et al[1], the following morphological characteristics were studied and evaluated.

1. The Symmetry in axial view was characterized as symmetrical or asymmetrical based on the location and deviation (whether deviated or non-deviated) of the inter-sinus septa.
2. The Configuration in axial view was categorized as solitary, paired, or complex based on whether inter-sinus septa were present or absent. For compound SS, the primary/main inter-sinus septum was determined to be the most significant.
3.In order to determine the kind of Extension in sagittal view, Tepedino et al[16] manually digitized two anatomical landmarks: (1) the most anterior point of the anterior wall of sella (AAS) and (2) the most posterior point of the posterior wall of sella (PPS). According to Yamashita et al[17] classification, there are two tangents that pass through the landmarks mentioned above(Figure 1). The anterior and posterior boundaries of the pituitary fossa are both shown by the first and second lines, respectively. As a result, the extension type was categorized based on Pirinc et al[18] as sellar, post-sellar, presellar, and conchal.

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Figure 1: Line passing through AAS and line passing through

4. Interms of Shape, the sinus was divided into well-defined and amorphous categories in the coronal view according to the shape of the 3D reconstructed model of the air cavity. Among the well-defined shapes were the pentagon, quadrilateral, triangular, and spherical (figure2,3,4,5).

5. In case of Septation, based on the number of intra-sinus septa present, the sinus was classified aswithout septum, single septum, double septa, and multiple septa in axial view.

The above morphological characteristics were evaluated and correlated with potential influencing factors:

1. Age: Patients were divided into four age groups, namely 15–29 years, 30–44 years, 45–59 years and > 60 years.

2. Gender: Male and Female.

3. Sinus condition: Healthy and Pathological.

For the assessment of shape of sphenoid sinus, the segmentation and measurements were performed semiautomatically by manually defining the borders of the sphenoid sinus and croppingthe selected region in sagittal, coronal, and axial views. Automatic segmentation of the sinus cavity is done based on the markings.

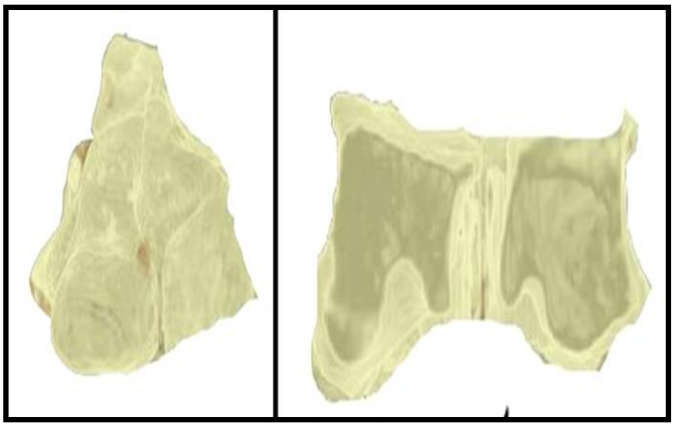

Figure 2: Triangular shape **Figure 3:** Quadrilateral shape

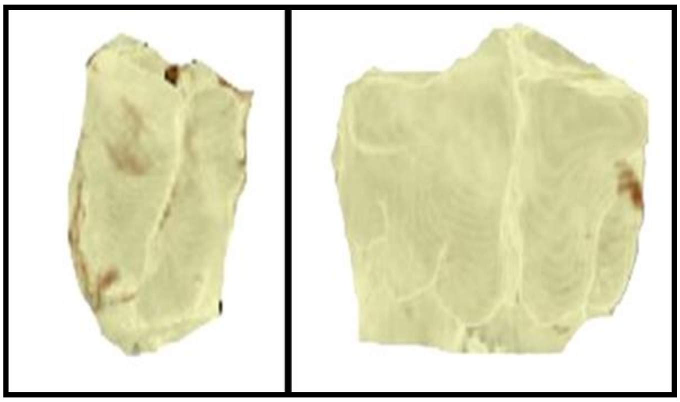

Figure 4: Spherical shape **Figure 5:** Pentagon shape

Statistical Analysis

Data were analysed using SPSS 20.0.The Chi-square test was used to evaluate categorical data among the genders.

Results

Overall 109 participants, 62 males and 47 females, were involved in this retrospective study.

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Table 1: Distribution of sphenoid sinus morphometric characteristics across different age groups

		Age group				p value
		15-29yrs	30-44yrs	45-59yrs	greater than 60yrs	
Configuration	Solitary	0.0%	66.7%	33.3%	0.0%	0.210
	Paired	30.1%	31.1%	30.1%	8.7%	
Extension	Conchal	2(100%)	0(0.0%)	0(0.0%)	0(0.0%)	0.217
	Presellar	1(33.3%)	2(66.7%)	0(0.0%)	0(0.0%)	
	Sellar	14(23.7%)	16(27.1%)	23(39.0%)	6(10.2%)	
	Post sellar	14(31.1%)	18(40.0%)	10(22.2%)	3(6.7%)	
Shape	Spherical	10(38.5%)	6(23.1%)	8(30.8%)	2(7.7%)	0.247
	Triangular	5(19.2%)	11(42.3%)	9(34.6%)	1(3.8%)	
	Quadrilateral	12(33.3%)	9(25.0%)	11(30.6%)	4(11.1%)	
	Pentagon	2(10.5%)	10(52.6%)	5(26.3%)	2(10.5%)	
	Amorphous	2(100%)	0(0.0%)	0(0.0%)	0(0.0%)	
Septation	No septum	16(26.7%)	18(30.0%)	17(28.3%)	9(15.0%)	0.177
	Single septum	7(23.3%)	11(36.7%)	12(40.0%)	0(0.0%)	
	Double septum	7(38.9%)	7(38.9%)	4(22.2%)	0(0.0%)	
	Multiple septa	1(100%)	0(0.0%)	0(0.0%)	0(0.0%)	
Chi-square test						

The table 1 shows the distribution of sphenoid sinus (SS) characteristics across different age groups, with no significant differences in configuration, extension, shape, or septation. For the solitary configuration, it was predominantly found in the 30-44 years age group (66.7%) and the 45-59 years age group (33.3%), with a p-value of 0.210, indicating no significant difference. The paired configuration was evenly distributed across the 15-29 years (30.1%), 30-44 years (31.1%), and 45-59 years (30.1%) age groups, with a lower occurrence in those over 60 years (8.7%). In terms of extension, the conchal type was found exclusively in the 15-29 years age group (100%), with a p-value of 0.217, indicating no significant difference. The presellar extension was most common in the 30-44 years group (66.7%), and the post sellar extension was most frequent in the 30-44 years group (40.0%). For shape, the spherical shape was most common in the 15-29 years group (38.5%), followed by the 45-59 years group (30.8%). Triangular and quadrilateral shapes had varying distributions, with triangular shapes peaking in the 30-44 years group (42.3%) and quadrilateral shapes in the 15-29 years group (33.3%). The p-value for shape distribution was 0.247. The septation characteristic showed no septum most frequently in the 30-44 years group (30.0%), single septum in the 45-59 years group (40.0%), and double septum evenly distributed in the younger age groups, with a p-value of 0.177.

Table 2: Distribution of sphenoid sinus morphometric characteristics across Gender

		Gender		p value
		Males	Females	
Configuration	Solitary	4(66.7%)	2(33.3%)	0.478
	Paired	58(56.3%)	45(43.7%)	
Extension	Conchal	2(100%)	0(0.0%)	0.526
	Presellar	1(33.3%)	2(66.7%)	
	Sellar	33(55.9%)	26(44.1%)	
	Post sellar	26(57.8%)	19(42.2%)	
Shape	Spherical	14(53.8%)	12(46.2%)	0.631

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	Triangular	16(61.5%)	10(38.5%)	
	Quadrilateral	21(58.3%)	15(41.7%)	
	Pentagon	9(47.4%)	10(52.6%)	
	Amorphous	2(100%)	0(0.0%)	
Septation	No septum	37(61.7%)	23(38.3%)	0.497
	Single septum	16(53.3%)	14(46.7%)	
	Double septum	9(50.0%)	9(50.0%)	
	Multiple septa	0(0.0%)	1(100%)	
Chi-square test				

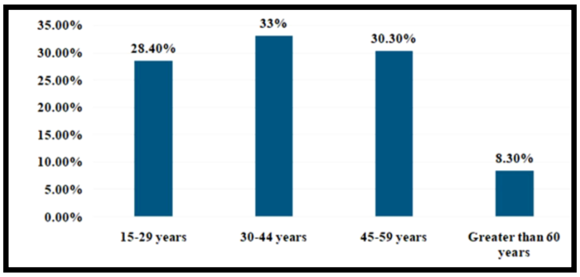
The table 2 states that for configuration, the paired SS was more common in both males (56.3%) and females (43.7%), while solitary SS was more prevalent in males (66.7%) compared to females (33.3%). In terms of extension, the sellar type was most frequent in both genders, with 55.9% of males and 44.1% of females having this extension, followed by post-sellar, which was more common in males (57.8%) compared to females (42.2%). Regarding shape, the spherical shape was slightly more common in males (53.8%) than females (46.2%), while the pentagon shape was more prevalent in females (52.6%). For septation, single septum was observed in both genders with a similar distribution and the differences observed were not statistically significant (p-values for configuration = 0.478, extension = 0.526, shape = 0.631, septation = 0.497).

Table 3: Distribution of sphenoid sinus morphometric characteristics across symmetry

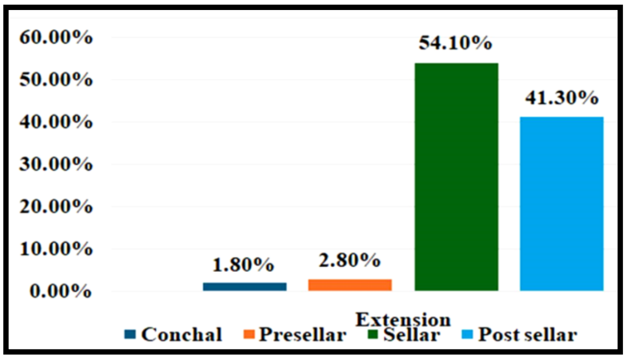
		Symmetry		P value
		Symmetrical	Asymmetrical	
Configuration	Solitary	0(0.0%)	6(100%)	0.025*
	Paired	49(47.6%)	54(52.4%)	
Extension	Conchal	1(50.0%)	1(50.0%)	0.290
	Presellar	0(0.0%)	3(100%)	
	Sellar	30(50.8%)	29(49.2%)	
	Post sellar	18(40%)	27(60%)	
Shape	Spherical	11(42.3%)	15(57.7%)	0.482
	Triangular	11(42.3%)	15(57.7%)	
	Quadrilateral	18(50.0%)	18(50.0%)	
	Pentagon	7(36.8%)	12(63.2%)	
	Amorphous	2(100%)	0(0.0%)	
Septation	No septum	31(51.7%)	29(48.3%)	0.000*
	Single septum	4(13.3%)	26(86.7%)	
	Double septum	13(72.2%)	5(27.8%)	
	Multiple septa	1(100%)	0(0.0%)	
Chi-square test;*statistically significant				

The table 3 states that for configuration, the solitary SS was exclusively found to be asymmetrical (100%), while paired SS was evenly distributed between symmetrical (47.6%) and asymmetrical (52.4%) cases. The difference observed was statistically significant with a p-value of 0.025. In terms of extension, the Conchal type was evenly distributed between symmetrical and asymmetrical, while the Presellar extension was entirely asymmetrical (100%). For the shape, there were no significant differences between symmetrical and asymmetrical SS, with similar distributions of spherical, triangular, quadrilateral, and pentagon shapes in both groups (p-value = 0.482). Regarding septation, a significant difference was observed (p-value = 0.000), with no septum being more common in symmetrical SS (51.7%), while asymmetrical SS showed a higher prevalence of single septum (86.7%). Additionally, double septum was more frequently observed in symmetrical SS (72.2%), while multiple septa appeared exclusively in symmetrical SS (100%).

Graph 1: Distribution of Age



Graph 2: Distribution of types of extension



Graph 2 shows that sellar extension was most common among the study population followed by post sellar and presellar whereas conchal was found to be least common.

Discussion

For precise diagnosis, pathology knowledge, and pre-operative surgical evaluation of the sphenoid sinus, a comprehensive understanding of the normal morphology and role of potential influencing factors is essential.The present studyconfirmed that SS morphology varies across sinus shapes, extension, configuration and septation. Gibelliet al[12] highlighted a high frequency of the sellar type (74%) in their study which is in accordance with the present study(54.10%) followed by post sellar type(41.30%) of extension.However in contrast to the present study, the postsellar type (74%) was found to be most frequent in the study by P Singh et al[1] , Oksuzler et at[24] and Kim et al [40]. Further, the frequency of conchal and presellar SS was very low in the present study. This study showed that postsellar (57.8%) type of extension was common among males when compared to females which is in accordance with study by P Singh et al[1]. The shape of the SS may be indicative of the progressionof extension into the adjacent bone.For instance, the pentagonshape suggests the extent of pneumatization into the greater wing and pterygoid plate of the sphenoid bone.A previous study by Rennie et al[6] analysed the 3-dimensional forms (3D) of SS in detail where Rennieet al. observed six 3D forms of SS in theirstudy, the present study identified fivedifferent forms which are spherical, triangular, quadrilateral, pentagon and amorphous forms[1].In the present study, quadrilateral type(50%) was found to be the most common shape, whilepentagon (36.8%) was the least frequent in accordance to study by Rennie et al [6]. This study showed that pentagon shape was common among females (52.6%) when compared to males which is in accordance with study by P Singh et al[1]. The SS is usually divided into paired or compoundsinuses by one or more inter-sinus/main septa. In the caseof a paired sinus, the septum is often paramedian and deviated laterally, thus dividing the sinusinto two asymmetric sinuses[13]. The inter-sinus septum is considered tobe a crucial structure for trans-sphenoidal surgery as it liesin close proximity to the optic nerve and internal carotidartery and sometimes may be attached to the bone covering these vital structures [20]. Therefore, careful consideration isrequired if inter-sinus septum is planned to be perforatedduring trans-sphenoidal surgery to avoid inadvertent injuryto the optic nerve or to the internal carotid artery.Some studieshave identified a solitary or a compound sinus[1]. Hamidet al [21] noticed a solitary sinus in 10.8%,while Sareenet al[26] observed a compound sinus in 80%which was in contrast to study by P Singh et al[1], where a frequency of 7.4% for solitary and 1.4%for compound sinuses was observed, which is in accordance to present study where solitary configuration is 66.7%.

Limitations

Other parameters such as volume, diameter of sinus are needed to be studied. Larger populations and different ethnicities are needed to be studied to generalise the morphological characteristics of sphenoid sinus. The impact of influencing factors on the morphological characteristics is needed to be studied for different populations across the world.

Conclusion

The sphenoid sinus, which is ensconced within the complicated architecture of the sphenoid bone, has exceptional anatomical diversity, exhibited by variations in its form. An array of parameters, including chronological age, biological sex, and underlying pathological disorders, exerts a significant impact on its morphometric attributes. Its diversity requires stringent preoperative imaging and planning, particularly in endoscopic trans-sphenoidal approaches to the skull base. Such complex anatomical and physiological insights highlight the importance of personalizing therapeutic approach to ensure precision and safety in sphenoid sinus operations.

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