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Volumetric Evaluation of Maxillary and Frontal Sinuses in Children aged 9–14 years using Cone-Beam Computed Tomography — A Pilot Study

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Abstract

Background: Literature sums up numerous advantages of volumetric evaluation of maxillary and frontal sinuses in the field of pathology and forensic sciences. However, studies involving pediatric age groups are scarce.

Aims and Objectives: To evaluate the volumes of maxillary and frontal sinuses in children aged 9–14 years of age and establish a correlation, if any, between the volumes and the age and sex of the children.

Settings and Design: A retrospective pilot study

Methods and Material: Volumetric measurements of the maxillary and frontal sinuses were conducted on CBCT scans of 30 children aged 9–14 years, divided into three groups as, those aged 9–10 years in group A, 11–12 years in group B, and 13–14 years in group C.

Statistical analysis used: One way ANOVA test to compare the sinus volumes within the groups and unpaired t-test to compare the difference in the volumes in males and females as well as between right and left maxillary sinuses were used.

Results: The mean values of the volumes of the right and left maxillary, total maxillary, and frontal sinuses in Group A were 8.4940 ± 1.1966 cm3, 8.3774 ± 1.2047 cm3, 16.8714 ± 2.1212 cm3, and 2.1903 ± 0.8870 cm3; in Group B were 8.7553 ± 0.9067 cm3, 8.3937 ± 1.1461 cm3, 17.1490 ± 1.5732 cm3, and 3.0469 ± 1.5907 cm3; and in Group C were 11.9895 ± 2.230 cm3, 12.6164 ± 1.6797 cm3, 24.6059 ± 4.38536 cm3, and 7.6546 ± 1.7763 cm3, respectively. The difference in the values among all the three age groups was statistically significant (p <

0.001). However, there was no significant difference in the values between males and females or between the right and left maxillary sinuses.

Conclusion: The study provides volumetric data of maxillary and frontal sinuses in pediatric age groups and proposes a correlation of the volumes with age of the children.

Keywords: Maxillary sinus volume, frontal sinus volume, pediatric age group

Introduction

A comprehensive knowledge with an appropriate visualization of the paranasal sinuses is crucial for performing successful head and neck, skull-base, and maxillofacial surgeries.[1,2] Moreover, the paranasal sinuses exhibit a significant inter-individual variation attributable to a complex anatomy. This renders them as bright areas for exploitation in forensics by aiding in age and sex determination of individuals. Literature mentions a great deal of data supporting the applicability of maxillary and frontal sinus volumes in age and sex determination of individuals.[3-6] The extent of pneumatization of the maxillary sinus varies from person to person, and its volume is influenced by age.[7] It being the first paranasal sinus to form, the development starts as early as in the 17th week of the prenatal period; however, it is only after birth that the majority of growth occurs.[8] Maxillary sinuses remain intact even in explosions, warfare, and other mass disasters such as aircraft crashes, even when the skull and other bones may become badly disfigured, rendering an advantage on the forensic front.[3] Likewise, morphometric dimensions of the frontal sinus have been tested as reliable indicators for forensic purposes. The frontal sinus, generally, is the last sinus to develop, and the formation begins around the fourth or fifth month of intrauterine life, with pneumatization reaching the frontal bone by around the second year of life.[9] The size becomes more conspicuous by the second or third year of life, and further expansion into the vertical portion of the frontal bone begins around the fifth year, with most children over the age of six demonstrating vertical projection radiographically. Enlargement of the sinuses occurs during puberty with a small additional increase in height several years after this growth spurt in some individuals, and frontal sinus growth is generally completed by the 20th year of life. However, the morphology remains practically unchanged during one's entire adult life. Moreover, the low frequency of maxillary and frontal sinus hypoplasia and/or aplasia dictates a highly significant morphological characteristic for a reliable identification of an individual based on the comparison of ante-mortem and postmortem radiographs.[10,11] Various methods have been prescribed in literature for deriving frontal and maxillary sinus volumes, including computed tomography (CT) and magnetic resonance imaging (MRI).[12-15] However, all the mentioned diagnostic aids have been reported to have disadvantages namely invasiveness, lack of availability, expensiveness, and high radiation exposure. Recently cone-beam computed tomography (CBCT) has been used as a method to evaluate maxillary and frontal sinus volumes.[14-16] Although, there are extensive studies producing data on the maxillary and frontal sinus volumes, those involving pediatric age groups are scarce. Thus, the aim of the present study was to evaluate the volumetric measurements of the maxillary and frontal sinuses in 9–14-year-old children using CBCT, which is considered to be the most effective tool for evaluation, thus raising the platform of the volumetric data of these sinuses in the lesser studied age-group of population and aiding in further extensive studies.

Methods: This retrospective pilot study was conducted with the clinical and CBCT records of 30 children (18 males and 12 females) in the age range of 9–14 years. The subjects were divided into three groups: Group A, comprising children in the age range of 9–10 years; Group B, comprising those in the age range of 11–12 years; and Group C, comprising those in the age range of 13–14 years, with 10 children in each group. Children with a history of mid-facial trauma or cleft lip or palate were excluded from the study. Likewise, children with a history of orthodontic treatment or orthognathic surgery, trauma or any surgery of the skull, any systemic disturbance, or hereditary facial asymmetry were excluded from the study. A thorough clinical examination of the children was performed, and a written informed consent was obtained from parent/guardian of each of them. The CBCT scans were performed with Planmeca ProMax 3D Mid (Planmeca, Helsinki, Finland), and the acquisition protocol was tailored to include the anatomical areas of interest corresponding to the maxillary and frontal sinuses. The obtained images were exported in DICOM (.dcm) format into a laptop and analyzed using the Romexis 4.4.0. Software (Planmeca, Helsinki, Finland). Maxillary (right and left) and frontal sinuses were marked using an ellipsoid tool in the coronal section, and then, using the air cavity tool, the volume of each of the sinuses was calculated (Figures 1 and 2).

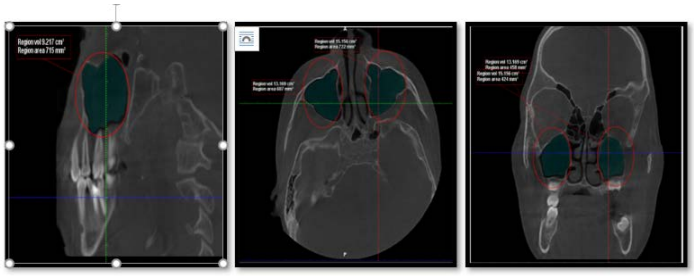

Figure 1: Volumetric measurement of the maxillary sinus in sagittal, coronal, and axial planes in a 12-year-old male child. Note the sinus mucosa with normal thickening, lining the walls of the cavity.

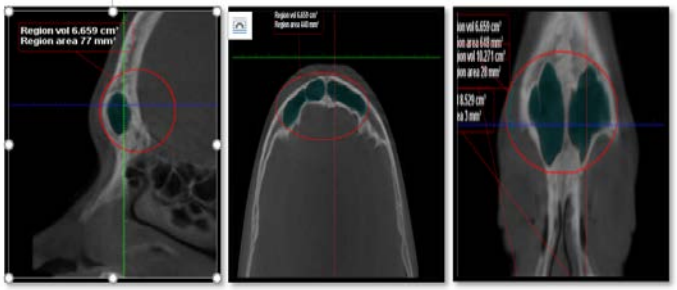

Figure 2: Volumetric measurement of the frontal sinus in sagittal, coronal, and axial planes in a 12-year-old male child. Note the sinus mucosa with normal thickening, lining the walls of the cavity.

The study was approved by the institutional ethical committee and was conducted in accordance with the Declaration of Helsinki (2000). Statistical Analysis: For statistical purposes, we documented the age and sex of each patient. All statistical analyses were performed using the SPSS software, version 22 (SPSS Inc., Chicago, IL, USA). One way ANOVA test was used to compare within the groups, and unpaired t-test was used to compare the difference in the sinus volumes between males and females and between the right and left maxillary sinuses.

Results

The study comprised of 18 males and 12 females (Table 1).

Table 1: Sex-wise distribution of the children included in the study

	Frequency	Percentage
Male	18	60.0
Female	12	40.0
Total	30	100.0

The mean values of volumes of the right and left maxillary sinus, total maxillary sinus, and frontal sinus in Group A were 8.4940 ± 1.1966 cm3, 8.3774 ± 1.2047 cm3, 16.8714 ± 2.1212 cm3, and 2.1903 ± 0.8870 cm3, respectively; in Group B were 8.7553 ± 0.9067 cm3, 8.3937 ± 1.1461

cm3, 17.1490 ± 1.5732 cm3, and 3.0469 ± 1.5907 cm3, respectively; and in Group C were 11.9895 ± 2.230 cm3, 12.6164 ± 1.6797 cm3, 24.6059 ± 4.38536 cm3, and 7.6546 ± 1.7763 cm3, respectively. The difference in the values among all the three age groups was statistically significant ($p < 0.001$) (Table 2).

Table 2: Comparison of the maxillary and frontal sinus volumes among the different age groups

	Group	N	Mean (cm^3)	Std. Deviation (cm^3)	ANOVA	Post-hoc
Right Maxillary Sinus	A (9–10 years)	10	8.4940	1.19668	<0.001	(A=B)<C
	B (11–12 years)	10	8.7553	0.90679		
	C (13–14 years)	10	11.9895	2.23309		
	Total	30	9.7463	2.20495		
Left Maxillary Sinus	A (9–10 years)	10	8.3774	1.20479	<0.001	(A=B)<C
	B (11–12 years)	10	8.3937	1.14615		
	C (13–14 years)	10	12.6164	1.67970		
	Total	30	9.7958	2.41842		
Total Maxillary Sinus	A (9–10 years)	10	16.8714	2.12123	<0.001	(A=B)<C
	B (11–12 years)	10	17.1490	1.57320		
	C (13–14 years)	10	24.6059	3.49481		
	Total	30	19.5421	4.38536		
Frontal Sinus	A (9–10 years)	10	2.1903	0.88700	<0.001	(A=B)<C
	B (11–12 years)	10	3.0469	1.59074		
	C (13–14 years)	10	7.6546	1.77637		
	Total	30	4.2973	2.82232		

The mean value of total maxillary sinus volume in males was 19.2679 ± 4.4043 cm3 and in females was 19.9533 ± 4.5182 cm3, and the difference was statistically insignificant ($p = 0.68$). Likewise, the mean value of frontal sinus volume in males was 3.8889 ± 2.3688 cm3 and in females was 4.9098 ± 3.4126 cm3, the difference being statistically insignificant ($p = 0.34$) (Table 3).

Table 3: Comparison of the mean volumes of maxillary and frontal sinuses among males and females

	Sex	N	Mean (cm^3)	Std. Deviation (cm^3)	P value
Total Maxillary Sinus	Male	18	19.2679	4.40431	0.68
	Female	12	19.9533	4.51828	
Frontal Sinus	Male	18	3.8889	2.36880	0.34
	Female	12	4.9098	3.41261	

The mean value of right maxillary sinus volume was 9.7463 ± 2.2049 cm^3 and of left maxillary sinus volume was 9.7958 ± 2.4184 cm^3, and the difference was statistically insignificant ($p = 0.934$) (Table 4).

Table 4: Comparison of the mean values of right and left maxillary sinus volumes

	N	Mean (cm^3)	Std. Deviation (cm^3)	P value
Right Maxillary Sinus	30	9.7463	2.2049	0.934
Left Maxillary Sinus	30	9.7958	2.4184	

Discussion

Evaluation of the volume of the paranasal sinuses is not only simple, but also a significant parameter for exploitation of these sinuses in pathological and forensic sciences. Although such volumetric studies have been performed in all age groups, those including the pediatric age groups are relatively scarce.[12, 18-20] Thus, we included children in the age group of 9–14 years in our study, to present and expand data in pediatric age groups. Measurement of sinus volumes has been performed using various methods in the past, including injections of various materials into the sinuses, stereology, use of the ellipsoid formula, etc. Recently, programs allowing segmentation and modeling based on semi-automatic processing of CT and MRI have been extensively used for volume measurements. These methods are compatible with three-dimensional imaging techniques and enable morphometric measurements. The technique of CT of the paranasal sinuses has already become a cornerstone in the evaluation and management of patients with sinus disease as well as in the age and sex determination of individuals in forensic sciences.[17] Moreover, it has expanded our vision into the anatomical features and variations of the sinus system, allowing a better assessment of pneumatization of the paranasal sinuses.[12] During the last decade, CBCT, first reported in the literature by Mozzo et al. [21], has been proposed for maxillofacial imaging and has gained recognition worldwide. A CBCT scan differs from CT in the type of image acquisition process that it employs. Rather than capturing an image as separate slices, as in CT, CBCT produces a cone-shaped X-ray beam making it possible to capture the image in a single shot. The resultant volume can be reformatted to provide multiple reconstructed image perspectives such as sagittal, coronal, and axial views. Furthermore, CBCT offers an advantage of a lower dose of radiation than CT, especially in limited field of view, and particularly, while evaluating maxillary sinuses.[22] Thus, we

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