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CONE BEAM COMPUTED TOMOGRAPHIC EVALUATION OF THE MAXILLARY SINUS IN DIFFERENT CRANIOFACIAL PATTERNS

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ABSTRACT

Objectives: Evaluation of maxillary sinus dimensions and volume and correlation with different craniofacial patterns.

Methods: This study was done on 67 maxillofacial CBCT scans. Cases were classified skeletally according to Jarabak's ratio, into 3 groups: normal, hyperdivergent / long facial pattern, and hypodivergent / short facial growth pattern. Maxillary sinus dimensions were analyzed as sinus height, width, depth, and volume. All data were collected and statistically analyzed.

Results: There was a statistically significant difference between the three craniofacial groups regarding the height and the width of the maxillary sinus, while sinus depth and volume were statistically non-significant. The correlation between maxillary sinus dimensions with the three craniofacial types was of very weak strength so statistically non-significant. Group 2 (hyper-divergent growth pattern) had statistically significantly lower mean height value and higher mean width value than the other two groups. The difference between the mean height values of group 1 (Normal growth pattern) and group 3 (hypo-divergent growth pattern) was statistically non-significant. The difference between the mean width values of group 2 and group 3 was statistically almost significant. There was no statistically significant difference in depth or volume between either of two groups.

Conclusion: While comparing maxillary sinus dimensions with the craniofacial patterns, sinus height and width are statistically significantly different, while sinus depth and volume are statistically non-significant. However, there is a weak Correlation between maxillary sinus dimensions and the craniofacial patterns.

KEYWORDS: Maxillary sinus; craniofacial; orthodontics; cone beam computed tomography.

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INTRODUCTION

The maxillary sinus is the largest and the first to form of the paranasal sinuses. The alveolar process of the maxilla, which also supports the teeth, forms the inferior border of the sinus. MS develops in direct proportion to the development of the facial bones. The initial phase of both happens early in the first three years of life. Between the ages of 6 and 13, the second phase develops, with inferior growth reaching the level of the hard palate by the age of 9 and lateral extension to the maxillary zygomatic recess. When the permanent molar and premolar teeth erupt, the maxillary alveolus pneumatizes, causing the sinus floor to shift 4-5 mm below the nasal cavity floor and triggering the third phase's subsequent sinus expansion [1].

In general, orthodontics treats misaligned teeth by using orthodontic forces to correct their alignment. The architecture and biomechanics of teeth, as well as the periodontal tissue, correlates with all the surrounding bones and tissues [2]. Maxillary sinus plays a significant role in relation to the craniofacial structures as it is located in close proximity to the maxillary dentition and the adjacent structures, and it influences how the dentition and facial shape develop over time. Understanding the relationships between maxillary sinus dimensions and craniofacial patterns can provide valuable insights for orthodontic treatment planning, implant placement, and surgical procedures [3].

Several previous studies have assessed the correlation between the maxillary sinus and one or all types of craniofacial growth with contrasting results [3-7]. So, the aim of the present study was to find if there is a correlation between maxillary sinus dimensions and different craniofacial patterns using 3D-CBCT.

PATIENTS AND METHODS

Case selection

Patient records for cone-beam computed tomography (CBCT) were retrieved from the archives of the Department of Oral and Maxillofacial Radiology, Ain-Shams University, Faculty of Dentistry. Clearance for the study was obtained from the Institutional Ethics Committee. (Certificate number (FDACU-Rec ER012320).

According to the statistically calculated sample size, 67 cases, with equal male and female ratio, were analyzed meeting the following criteria:

Inclusion criteria:

1- Age - 18 to 30 years.

2- Scans FOV covering the area of maxillary sinus.

3- Full set of teeth with or without the third molar eruption.

4- No apparent craniofacial asymmetry.

Exclusion criteria:

1. Severe craniofacial abnormalities, including cleft lip or palate.
2. Pathologies of the maxillary sinus such as inflammation, mucosal cyst, or tumor.

All CBCT scans were previously obtained using i-CAT CBCT machine (Imaging Sciences International, Hatfield, PA). The DICOM files were transferred to On Demand software (On demand 3D™ , Cybermed, South Korea). All the records were analyzed on both right and left sides by a single observer.

Cases were classified skeletally according to Jarabak's ratio which determines the percentage of the anterior and posterior facial proportions. This ratio is obtained by the formula posterior facial height / anterior facial height x 100. The measurements of facial height were done from the nasion to the menton for the anterior face and from the sella to the gonion for the posterior face [8]. **(figure 1,2)**

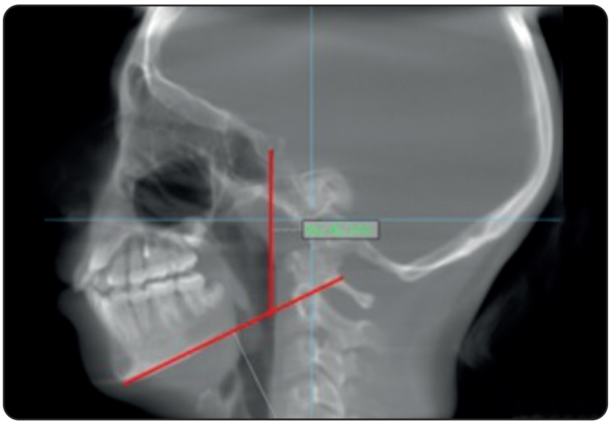

Fig. (1): Posterior facial height measured from sella to gonion.

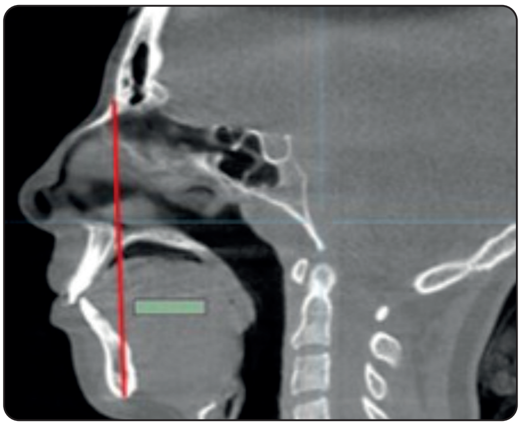

Fig. (2): Anterior facial height measured from nasion to a line tangent to menton.

Cases were classified into 3 groups:

Group 1: Normal growth pattern when the ratio is between 62-65%, Group 2: Hyperdivergent growth pattern/long facial pattern, when this ratio is less than 62%.

Group 3: Hypodivergent growth pattern/short facial pattern, when the ratio is higher than 65% [8,9].

Image standardization:

Each scan was scrolled out till reaching the maximum dimensions of the sinus on the coronal, axial and sagittal views at the first molars level.

Image Analysis:

Maxillary sinus measurements on CBCT were recorded bilaterally as follows:

Height of the maxillary sinus:

This was measured on the coronal view, as the maximum vertical dimension, at the position of first molars **(figure 3).**

Width of the maxillary sinus:

This was measured on the axial view, as the maximum medio-lateral dimension **(figure 4).**

Depth of maxillary sinus:

This was measured on the axial view, as the maximum antero-posterior dimension, perpendicular to the width **(figure 4).**

Volume of maxillary sinus:

Segmentation of the sinus was done using an object mask tool. Points were picked inside the sinus then calculation of the volume was done **(figure 5).**

Statistical analysis

All data were collected, tabulated, and subjected to statistical analysis. Statistical analysis was performed by SPSS (version 20), and presented by Microsoft office Excel.

Quantitative variables were described by the Mean, Standard Deviation (SD), the Range (Minimum – Maximum), Standard Error of the Mean (SEM), 95% confidence interval of the mean, Median and Interquartile Range (IQR).

The Shapiro-Wilk test of normality was used to test normality hypothesis of all quantitative variables for further choice of appropriate parametric and non-parametric tests. For normally distributed variables, one-way analysis of variance (ANOVA) was applied for comparing the three groups while Post hoc multiple comparison Bonferroni method is applied for comparing each two groups together. For variables not normally distributed, non-parametric tests were applied which were Kruskal-Wallis Test for comparing several groups and Mann-Whitney U-Test for comparing two groups.

Kendall's coefficient of rank correlation τb was used for correlation analysis of maxillary sinus dimensions and craniofacial patterns.

Significance level was considered at $P<0.05$ (S); while $P<0.01$ was considered highly significant (HS). Two Tailed tests were assumed throughout the analysis for all statistical tests.

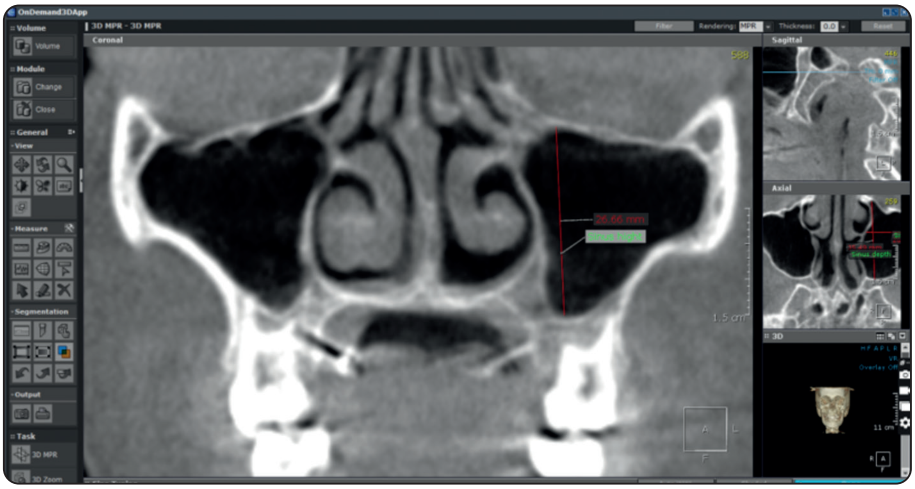

Fig. (3): Height of the maxillary sinus, measured on the coronal view, as the maximum vertical dimension, at the position of the first molars.

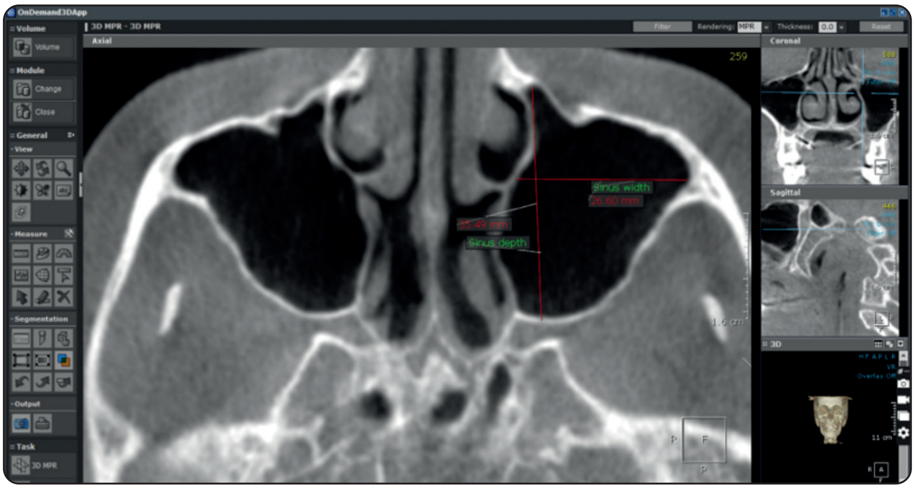

Fig. (4): Width and depth of the maxillary sinus, measured on the axial view, as the maximum horizontal and vertical dimensions.

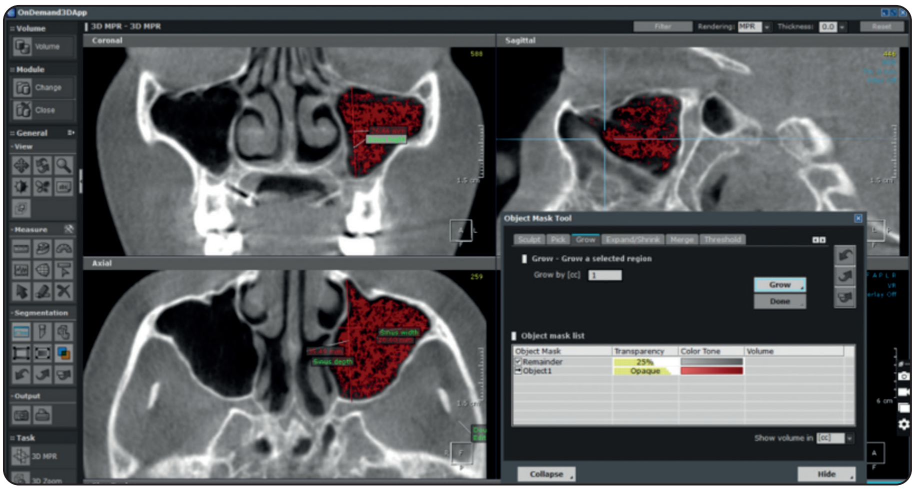

Fig. (5): Volume of the maxillary sinus

RESULTS

Tests of Normality: (table 1)

TABLE (1) Tests of normality for the different parameters in the three groups:

Type		Shapiro-Wilk		
		Statistic	df	Sig.
Height of the maxillary sinus	Group 1: Normal growth pattern	.974	40	.493
	Group 2: Hyperdivergent growth pattern	.963	44	.164
	Group 3: Hypodivergent growth pattern	.983	50	.696
Width of the maxillary sinus	Group 1: Normal growth pattern	.971	40	.378
	Group 2: Hyperdivergent growth pattern	.980	44	.636
	Group 3: Hypodivergent growth pattern	.966	50	.154
Depth of maxillary sinus	Group 1: Normal growth pattern	.877	40	.000
	Group 2: Hyperdivergent growth pattern	.882	44	.000
	Group 3: Hypodivergent growth pattern	.800	50	.000
Volume of maxillary sinus (cm3)	Group 1: Normal growth pattern	.957	40	.133
	Group 2: Hyperdivergent growth pattern	.822	44	.000
	Group 3: Hypodivergent growth pattern	.971	50	.266

Parametric tests were applied for all variables except for depth that was not normally distributed, so nonparametric tests were used.

Height of the maxillary sinus: (table 2,3,4, figure 6)

TABLE (2) Descriptive Statistics for the height of the maxillary sinus

	N	Mean	SD	SEM	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Group 1: Normal growth pattern	40	35.14	4.75	0.75	33.62	36.66	26.00	48.16
Group 2: Hyperdivergent growth pattern	44	32.33	4.27	0.64	31.03	33.62	20.49	40.60
Group 3: Hypodivergent growth pattern	50	34.78	4.74	0.67	33.44	36.13	21.60	44.50

TABLE (3) Comparison of the height of the maxillary sinus between the three groups:

ANOVA table					
	Sum of Squares	df	Mean Square	F	P Value
Between Groups	205.048	2	102.524	4.853	0.00927*
Within Groups	2767.569	131	21.126		
Total	2972.617	133			

There was statistically highly significant difference between the mean values of the three groups. (* P < 0.01 highly significant).

TABLE (4) Multiple Comparison of maxillary sinus height by Bonferroni method:

		Mean Difference	Std. Error	P Value	95% Confidence Interval for Difference	
					Lower Bound.	Upper Bound.
Gr. 1	**Gr. 2**	2.81	1.00	0.01755*	0.38	5.25
Gr. 1	**Gr. 3**	0.36	0.98	1.00000**	-2.01	2.72
Gr. 2	**Gr. 3**	-2.46	0.95	0.03231***	-4.76	-0.15

-Group 2 had statistically significant lower mean height value than the other two groups. (P < 0.05 significant).***
-The difference between mean height values of group 1 and group 3 was statistically non-significant. (*P < 0.05 significant, ** P > 0.05 non-significant).

Width of the maxillary sinus: (table 5,6,7, figure 7)

TABLE (5) Descriptive Statistics for the width of the maxillary sinus:

	N	Mean	SD	SEM	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Group 1: Normal growth pattern	40	26.41	4.58	0.72	24.94	27.87	18.60	35.20
Group 2: Hyper-divergent growth pattern	44	28.43	6.65	1.00	26.41	30.45	14.40	41.00
Group 3: Hypo-divergent growth pattern	50	25.68	5.05	0.71	24.25	27.12	16.80	37.80

TABLE (6) Comparison of the width of the maxillary sinus between the three groups:

ANOVA table					
	Sum of Squares	df	Mean Square	F	P Value
Between Groups	185.384	2	92.692	3.057	0.05040*
Within Groups	3972.146	131	30.322		
Total	4157.530	133			

- The difference between the mean width of the three groups was almost statistically significant. (* P ~ 0.05 Almost S).
- Group 2 had a higher mean width value than the other two groups.

TABLE (7) Multiple Comparison of maxillary sinus width by Bonferroni method:

		Mean Difference	Std. Error	P Value	95% Confidence Interval for Difference	
					Lower Bound.	Upper Bound.
Gr. 1	**Gr. 2**	-2.02	1.20	0.28515*	-4.94	0.89
Gr. 1	**Gr. 3**	0.72	1.17	1.00000*	-2.11	3.56
Gr. 2	**Gr. 3**	2.75	1.14	0.05164**	-0.01	5.51

-The difference between mean width values of group 1, group 2 and group 3 was statistically non-significant. (* P > 0.05 non-significant).

-The difference between mean width values of group 2 and group3 was statistically almost significant. (** P ~ 0.05 Almost S).

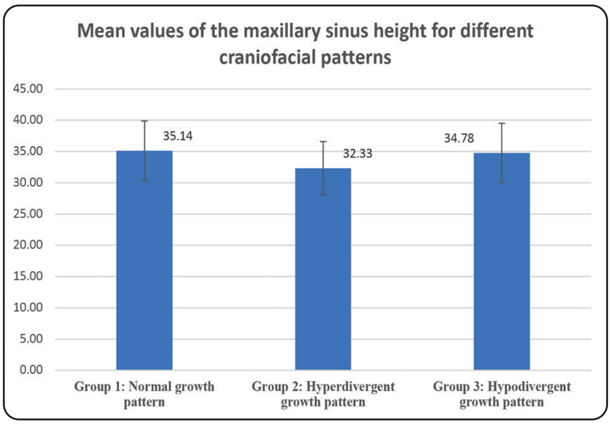

Fig. (6): Bar chart showing mean values of the maxillary sinus height for the different craniofacial patterns.

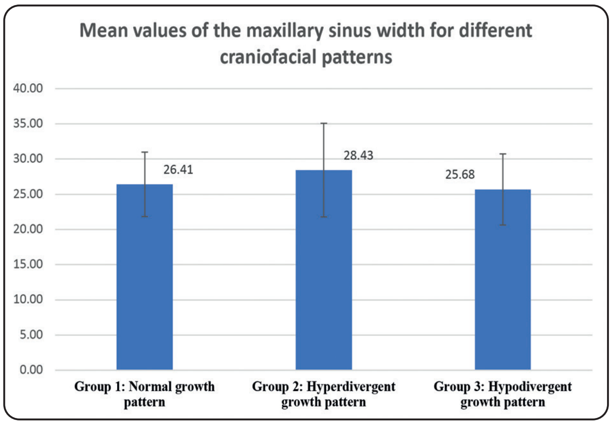

Fig. (7): Bar chart showing mean values of the maxillary sinus width for the different craniofacial patterns.

Depth of the maxillary sinus: (table 8,9,10, figure 8)

TABLE (8) Descriptive Statistics for the depth of the maxillary sinus:

	N	Mean	SD	SEM	95% Confidence Interval for Mean		Min.	Max.	Median	Inter-quartile Range
					Lower Bound	Upper Bound				
Group 1: Normal growth pattern	40	19.54	14.75	2.33	14.83	24.26	1.60	44.58	14.20	28.25
Group 2: Hyper-divergent growth pattern	44	19.07	12.42	1.87	15.30	22.85	2.23	37.30	19.80	25.28
Group 3: Hypo-divergent growth pattern	50	19.18	14.83	2.10	14.97	23.40	1.60	38.80	16.20	30.76

The depth was not normally distributed for the three groups. Non-parametric Kruskal-Wallis test was applied.

TABLE (9) Comparison of the depth of the maxillary sinus between the three groups:

	N	Mean Rank	Chi-Square	df	P Value
Group 1: Normal growth pattern	40	68.44	.077	2	0.96206*
Group 2: Hyper-divergent growth pattern	44	66.20			
Group 3: Hypo-divergent growth pattern	50	67.89			
Total	134				

-There was no statistically significant difference in depth between the three groups. **(P > 0.05 non-significant).**

TABLE (10) Comparison of the depth of the maxillary sinus between the three groups using Mann-Whitney Test for comparing each two groups:

		Mann-Whitney U	Wilcoxon W	Z	P Value
Group 1	**Group 2**	864.00	1854.00	-0.14	0.88604*
Group 1	**Group 3**	978.50	2253.50	-0.17	0.86139*
Group 2	**Group 3**	1059.00	2049.00	-0.31	0.75602*

-There was no statistically significant difference in depth that could be detected between either two groups. (*P > 0.05 non-significant).

Volume of the maxillary sinus: (table 11,12,13, figure 9)

TABLE (11) Descriptive Statistics for the volume of the maxillary sinus:

	N	Mean	SD	SEM	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Group 1: Normal growth pattern	40	5.43	2.46	0.39	4.64	6.22	1.37	10.70
Group 2: Hyper-divergent growth pattern	44	5.34	3.12	0.47	4.39	6.29	0.97	15.72
Group 3: Hypo-divergent growth pattern	50	4.89	2.15	0.30	4.28	5.50	1.29	10.51

TABLE (12) Comparison of the volume of the maxillary sinus between the three groups:

ANOVA table					
	Sum of Squares	df	Mean Square	F	P Value
Between Groups	7.616	2	3.808	0.566	0.56902*
Within Groups	880.915	131	6.725		
Total	888.530	133			

-The difference between the mean volume in the three groups was statistically non-significant. (*P > 0.05 non-significant).

TABLE (13) Multiple Comparison of maxillary sinus volume by Bonferroni method:

		Mean Difference	Std. Error	P Value	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Gr.1	**Gr.2**	0.09	0.57	1.00000*	-1.28	1.47
Gr.1	**Gr.3**	0.54	0.55	0.99394*	-0.80	1.87
Gr.2	**Gr.3**	0.44	0.54	1.00000*	-0.86	1.74

-There was no statistically significant difference in volume between either of the two groups. (*P > 0.05 non-significant).

TABLE (14) Correlation between maxillary sinus dimensions and different craniofacial patterns:

	Kendall's tau_b	P value
Height of the maxillary sinus	**.009**	0.89095*
Width of the maxillary sinus	**-.061**	0.36574*
Depth of maxillary sinus	**.001**	0.98857*
Volume of maxillary sinus (cm3)	**-.053**	0.43323*

*** (P > 0.05 non-significant)**

All Kendall's coefficient of rank correlation τb were of very small values close to zero indicating correlation of very weak strength statistically non-significant.

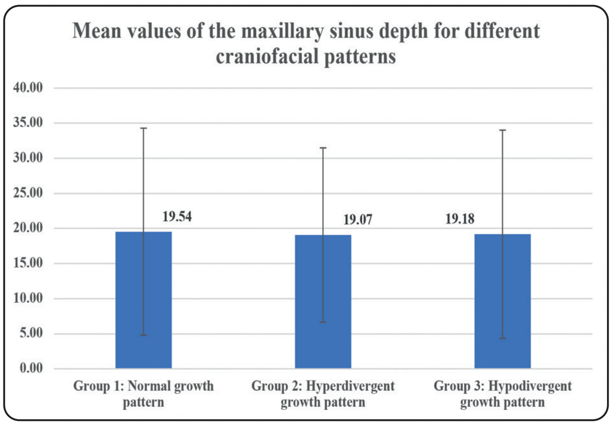

Fig. (8) Bar chart showing mean values of the maxillary sinus depth for the different craniofacial patterns.

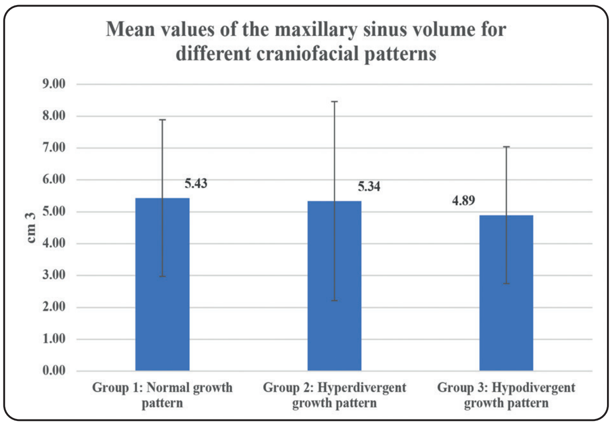

Fig. (9) Bar chart showing mean values of the maxillary sinus volume for the different craniofacial patterns.

DISCUSSION

The maxillary sinus is an important anatomical structure located in the maxilla, or upper jawbone. It is a hollow cavity that plays a crucial role in the respiratory system and is also involved in the development of the face. The maxillary sinus floor can be seen around and between the root apices in the maxillary bicuspid and molar areas. This is an anatomical limitation that may hinder the mobility of teeth during orthodontic treatment and lead to complications. Any change in the maxillary sinus' growth could consequently result in the development of skeletal or dental malocclusion [3].

This study was designed to find if there is a correlation between maxillary sinus dimensions and different craniofacial patterns using CBCT. Different methods in the literature were used to assess the craniofacial type. In our study, we have made this discrimination according to the Jarabak's ratio [8,9].

Craniofacial patterns refer to the unique skeletal structures and proportions of the face and skull. These patterns can vary among individuals and are classified into different types based on the relationship between the upper and lower jaws. The three main types of craniofacial patterns are Class I, Class II, and Class III.

In Class I craniofacial pattern, the maxillary sinus dimensions are generally within the normal range. The size and shape of the maxillary sinus are symmetrical and balanced, providing adequate space for the surrounding structures. While in case of class II or III, sinus dimensions are larger or smaller than normal, which have implications in orthodontic treatment planning, as it may affect the position and angulation of the teeth.

To avoid the bias between the study groups, we have used an equal number of males and females [6,10]. We also restricted the age range between 18-30 years to avoid the age changes related to the maxillary sinus [10].

Maxillary sinus was analyzed according to height, width, depth, and volume. All these parameters were measured bilaterally, the measures were compared between the three study groups.

Parametric tests were applied for all variables except for depth that was not normally distributed, so non-parametric Kruskal-Wallis test was used.

Descriptive statistical analysis showing mean and standard deviation was done. Comparison of each parameter was done between the three groups using ANOVA test, the between each two groups using Bonferroni method except for the depth of the maxillary sinus where Mann-Whitney Test was used. As craniofacial pattern is ordinal categorical variable and sinus dimensions are continuous variables; so that the appropriate measure of association was Kendall's coefficient of rank correlation τb [11].

The results of our study revealed that there was a statistically significant difference between the three groups regarding the height and the width of the maxillary sinus, while sinus depth and volume were statistically non-significant. While the Correlation between maxillary sinus dimensions and the three craniofacial types was of very weak strength so statistically non- significant.

Group 2 (hyper-divergent growth pattern) had statistically significantly lower mean height value and higher mean width value than the other two groups.

The difference between mean height values of group 1 (Normal growth pattern) and group 3 (hypo-divergent growth pattern) was statistically non-significant. The difference between mean width values of group 2 and group3 was statistically almost significant.

There was no statistically significant difference in depth or volume between either of the two groups.

Several research studies have been conducted to investigate the correlation between maxillary sinus dimensions and craniofacial patterns, utilizing various imaging techniques. There are contrasting findings suggesting that the relationship between maxillary sinus dimensions and different craniofacial patterns may not be consistent across all populations or individuals. Moreover, not all studies in the literature were based on CBCT, also most of them relied on two dimensional measurements without analysis of sinus volume.

Some research using CBCT has found no relationship between the vertical development pattern and the maxillary sinus volume [12,13]. Additionally, Shrestha et al. discovered that while there were no significant variations across the groups, High-angle groups tended to have the biggest maxillary sinus capacity among the vertical skeletal groups. These conclusions have many consequences for oral surgery, endodontics, and orthodontics [14].

However, a descriptive CBCT study by Yili et al. discovered a positive correlation between craniofacial characteristics and variables associated with the maxillary sinus. Significant differences were found in the volume, length, and width of the maxillary sinus among the various groups. In patients with low angles, the maxillary sinus volume, length, and width were greater. [15].

In a study by Wang J et al., the researchers used CBCT to assess the position and size of the maxillary sinus in various vertical skeletal patterns in the population of Chinese orthodontic patients with skeletal class I. They concluded that there was no significant difference in maxillary sinus size and location among different vertical skeletal patterns in the skeletal class I population [16].

In contrast, Kumar et al compared and correlated the maxillary sinus dimensions and basal bone height among various facial patterns using CBCT images. They came to the conclusion that there is a relationship between the height of the basal bones and the maxillary sinuses with the facial pattern, which should be taken into account while planning orthodontic treatments and performing facial growth modification procedures on younger patients [3].

Moreover, Przystańska et al retrospective analysis of head CT scans revealed a correlation between midface dimensions and all measurements of the maxillary sinuses [7]. Besides, Paluch Z et al in their study on lateral and posteroanterior cephalometric radiographs concluded that there were strong correlations between the measurement values of the maxillary sinus and the values of facial skeletal classification [17]. In addition, Al–Jumaili et al used cephalometric radiographs with measurements taken involving the maxillary sinus height and depth, maxillary length. They made a correlation with the related dimensions of the craniofacial complex. They concluded that the craniofacial features in the three age groups may be influenced by the growth of the maxillary sinus as a functional matrix role in the growth process. [18].

Overall, the correlation between maxillary sinus dimensions and different craniofacial patterns is complex and inconsistent. Further research is needed to fully understand the underlying factors and mechanisms involved. In summary, multiple studies have shown conflicting results regarding the correlation between maxillary sinus dimensions and different craniofacial patterns. This suggests that there may be other factors at play, such as genetic variations, racial differences, and individual differences, that contribute to the variability in maxillary sinus dimensions.

CONCLUSION

While comparing maxillary sinus dimension with the three craniofacial patterns, sinus height and width are statistically significantly different, while sinus depth and volume are statistically non-significant. However, there is a week Correlation between maxillary sinus dimensions and the three craniofacial patterns.

Abbreviations

List of abbreviations

CBCT cone beam computed tomography

MS maxillary sinus

DICOM Digital Imaging and Communications in Medicine

SD Standard deviation

SEM Standard Error of the Mean

IQR Interquartile Range

FOV Field of view

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