EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

VOL. 71, 1367:1373, APRIL, 2025

PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360

ORAL MEDICINE, X-RAY, ORAL BIOLOGY AND ORAL PATHOLOGY

Submit Date : 14-01-2025 • Accept Date : 29-01-2025 • Available online: 20-04-2025 • DOI : 10.21608/edj.2025.350321.3336

VOLUMETRIC MEASUREMENT OF MAXILLARY SINUS AND ITS CORRELATION WITH CRANIOFACIAL PATTERN IN AN EGYPTIAN POPULATION: A RETROSPECTIVE CROSS-SECTIONAL STUDY

Radwa Haitham Noor El-Din*, Dina Fahim Ahmed**
and Reham Ashraf Hussien***

ABSTRACT

Aim: The aim of this study was to assess the correlation between the volume of maxillary sinus and various craniofacial patterns in a sample of Egyptian population with fully developed maxillary sinus using CBCT scans.

Methodology: 39 craniofacial CBCT scans of healthy individuals who were 18 years or older with complete dentition were collected retrospectively as DICOM (Digital Imaging and Communication in Medicine) file format. Reformatted lateral cephalometric radiographs were obtained from the CBCT scans using PLANMECA ROMEXSIS software to assess the skeletal patterns (class I-II-III) of the individual through Cephalometric angular measurement (ANB). Volumetric measurement of both maxillary sinuses for each individual was conducted by MIMICS medical 21.0 software through semiautomatic segmentation via global thresholding.

Results: For all measurements; there were excellent intra and inter-observer agreement with statistical significance (ICC>0.9, p<0.001). Regardless of side, there were no significant associations between different sinus measurements and craniofacial classification. However, significant correlation between maxillary sinus volume and gender was found.

Conclusion: No significant correlation between maxillary sinus volume and craniofacial pattern was noticed in this sample of Egyptian population. Meanwhile, males showed greater maxillary sinus volume than females.

KEYWORDS: Maxillary sinus, craniofacial patterns, class (I, II, III), CBCT, semi-automatic segmentation, volumetric measurement, segmentation.

* MSc Student, Oral & Maxillofacial Radiology, Faculty of Dentistry, Cairo University
** Associate Professor, Oral & Maxillofacial Radiology, Faculty of Dentistry, Cairo University
*** Instructor, Faculty of Dentistry , Cairo Unviresity

INTRODUCTION

The maxillary sinus (MS) is the largest one of the paranasal sinuses and it is the sinus that is first to be formed. It has a triangular shape and located within the body of the maxillary bone and it comprises three recesses: the alveolar recess which is positioned inferiorly and delineated by the maxillary alveolar process, the infraorbital recess which is positioned superiorly and bounded by the inferior orbital surface of the maxilla, and the zygomatic recess which is positioned laterally and bordered by the zygomatic bone. Since the maxillary sinus is confined within the viscerocranium bones; its growth has paramount anatomical importance in the viscerocranial bones development. It was found that there is a strong correlation between the facial skeleton size and MS volume, since the MS shape and size reflect the development of the bony structures. It has been suggested that the growth of MS is greatly proportional to the facial bones' growth and the shape of mid-face. Moreover, MS can also affect the position of maxilla in relation to the base of the skull and the maxillary development in antero-posterior direction. (1)

Also, the MS is in close relation with the roots of the upper posterior teeth. Thus, it is essential to understand the alveolar process anatomy, morphology of the alveolar recess of the maxillary sinus and the sinus' size and volume for planning surgical intervention of the sinus, oral surgical procedures such as surgical apicectomy, periodontal flap surgery, surgical tooth extraction, and dental implantation or orthognathic surgeries. (2)

During the past years CBCT became an important tool for three-dimensional evaluation of the MS. Moreover, the continuous evolution and updates of CBCT platforms and software gave the user the capability to delineate the MS boundaries and measure its volume. An accurate three-dimensional (3D) segmentation of the MS is important for multiple diagnostic and treatment applications. (3).

In the literature, since only few studies investigated the relation between the craniofacial pattern and MS volume and dimensions, we conducted this study in a group of Egyptians to determine whether there is a correlation between the craniofacial pattern and maxillary sinus volume, and also to evaluate the relation between maxillary sinus dimensions and gender.

SUBJECTS AND METHODS

This retrospective study aims to investigate the correlation between the volume of the maxillary sinus and the skeletal facial pattern on CBCT scans. The sample size calculation was based on a design of the power analysis that has adequate power in order to apply a statistical test of the null hypothesis assuming that there is no difference would be found between various tested groups. By adopting an alpha level of (0.05), a beta of (0.2) (i.e. power=80%) and an effect size (f) of (0.463) calculated that was based on the results of a previous study; the predicted sample size (n) was a total of (39) samples. Sample size calculation was performed using G*Power version 3.1.9.7.

A sample of 39 CBCT scans of Egyptian individuals of both genders of 18 years and older were selected from the CBCT available database at Oral and Maxillofacial Radiology Clinic at the Faculty of Dentistry, Cairo University based on certain eligibility criteria. The sample included good quality Cranio-facial field of view CBCT scans showing the entire maxillary sinus with a full set of maxillary posterior teeth bilaterally. Patients with mucosal thickening, any systemic pathological condition, history of maxillofacial trauma, palatal and/or labial cleft were excluded from this study. The exposure parameters used for the scans were 90 kVp, 8 mA, 13.5 sec exposure time and voxel size of 400 μm.

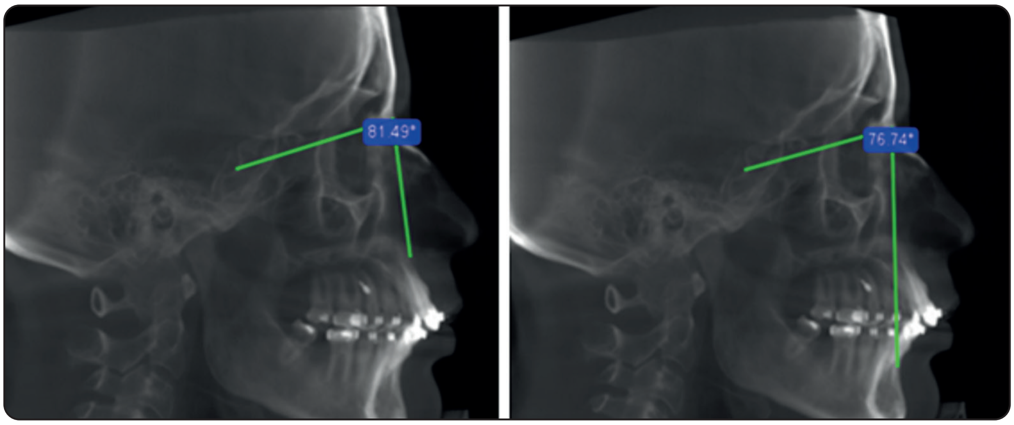


Fig. (1) Reformatted cephalometric image showing SNA and SNB angular measurement.

For craniofacial pattern assessment:

Virtual lateral cephalometric views were obtained from CBCT images to take angular measurements of SNA, SNB & ANB angles in order to classify the patients into the craniofacial patterns (Angle class I, II, III) using Planmeca Romexis 4.6.2R viewer.

Angle SNA stands for the angle that is formed between the Sella-Nasion plane with the Nasion-point A plane and in other words it is the angle formed between maxilla and cranial base, angle SNB stands for the angle that is formed between Sella-Nasion plane with Nasion-point B plane (angle formed between mandible and cranial base), and the angle (ANB) is the result of subtraction of SNA and SNB angles (SNA-SNB). Classification of individuals into the three craniofacial patterns was done according to the score of ANB angle, where Class I was between 2° and 4°, Class II was > 4°, and Class III was < 2° **(2)** (Figure1).

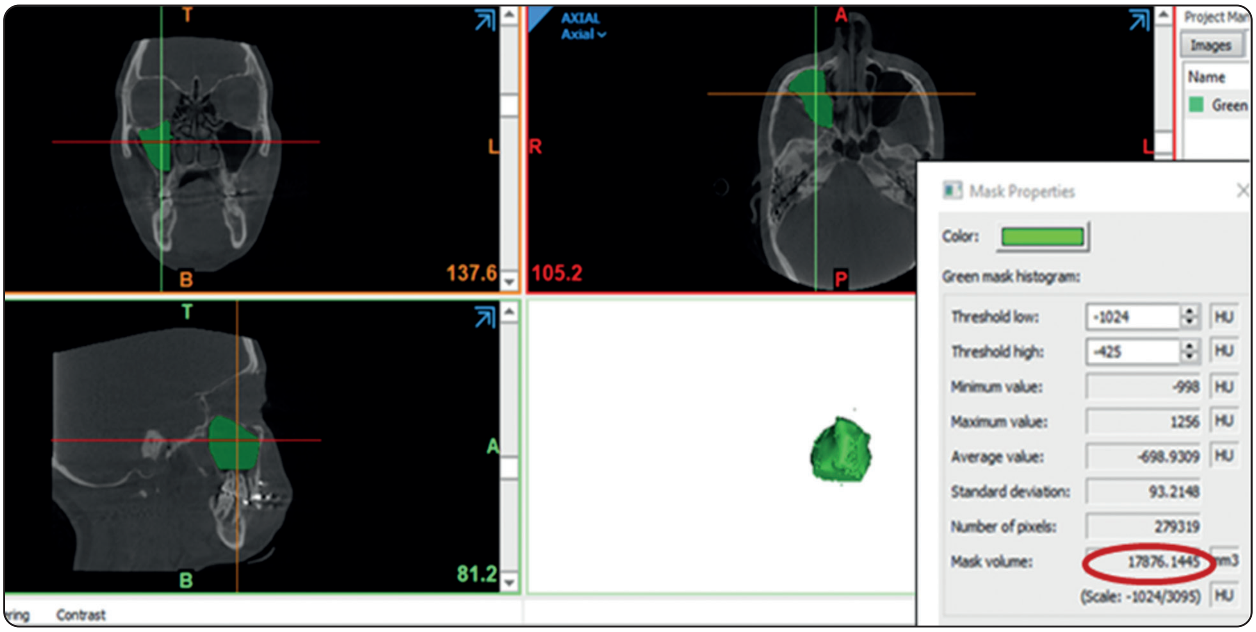
For maxillary sinus volume measurement:

Volumetric measurement of maxillary sinus was obtained via Global thresholding of semi-automatic segmentation using **Mimics Medical 21.0 software**. The three orthogonal planes were used to identify the most medial, lateral, anterior, posterior, superior and inferior points of the maxillary sinus to localize the whole extension of maxillary sinus. Semiautomatic segmentation started by customizing the threshold of air which manually adjusted minimum of -1024 and a maximum of 397 to include the voxels falling within the designated air range and a color-coded mask was automatically created for segmentation. The mask was edited by erasing unneeded threshold or adding deficient threshold and the final mask volume of maxillary sinus was calculated and 3D sinus volume was reconstructed (Figure 2).

CBCT images were interpreted by two Oral and Maxillofacial Radiologists who were blinded from the patients' demographic data and from the results of each other. Each radiologist evaluated the scans for obtaining virtual lateral cephalometric views using PLANMECA ROMEXSIS software in order to classify the participants into the three different craniofacial patterns according to the ANB angle and performed semi-automatic segmentation and volumetric measurement of maxillary sinus using MIMICS 21.0 software.

Statistical analysis:

Numerical data were presented as mean with 95% confidence intervals, standard deviation (SD), minimum (min.), and maximum (max.) values. They were tested for normality by viewing distribution using Shapiro-Wilk's test and were found to be



Fig, (2) Multi-planar reformatted CBCT images presenting the final 3D segmented volume of the maxillary sinus and its volumetric calculation.

normally distributed. Associations were analyzed using a one-way ANOVA test. Correlation analysis was made using Spearman's rank-order correlation coefficient. Inter- and intra-rater reliability were analyzed using the intra-class correlation coefficient (ICC). Multivariable linear regression models were built to analyze the associations between sinus and skeletal measurements. Their residuals were checked and confirmed for normality, and the homogeneity variance assumption was confirmed using Levene's test. The significance level was set at $p<0.05$ among all tests. Statistical analysis was performed with version 4.4.1 for Windows.1 of the R statistical analysis software.

RESULTS

No statistically significant difference was found between measurements of the maxillary sinus volume among the three groups at the right side, the left side as well as mean of the two sides (P-value = 0.991), (P-value = 0.788) and (P-value = 0.899) respectively (Table 1, Figure 3). Regarding gender in relation to volume; values were significantly higher in males than in females at the right side, left side as well as mean of the two sides (P-value = 0.010), (P-value = 0.014) and (P-value < 0.001) respectively (Table 2, Figure 4).

TABLE (1) Associations with craniofacial classification.

Side	Measurement	Mean±SD			p-value
		Class (I)	Class (II)	Class (III)	
Right	**Volume**	15.21±4.40^{A}	15.19±4.97^{A}	15.45±5.79^{A}	**0.991ns**
Left	**Volume**	14.82±3.82^{A}	16.02±5.77^{A}	15.01±5.05^{A}	**0.788ns**
Both	**Volume**	15.02±4.04^{A}	15.61±5.32^{A}	15.23±5.29^{A}	**0.899ns**

ns: Non-significant

TABLE (2)Associations with gender.

Side	Measurement	Mean±SD		p-value
		Male	Female	
Right	**Volume**	17.39±4.94	13.44±4.12	**0.010***
Left	**Volume**	17.40±4.95	13.62±4.25	**0.014***
Both	**Volume**	17.40±4.87	13.53±4.13	**<0.001***

*** Significant (p<0.05).***

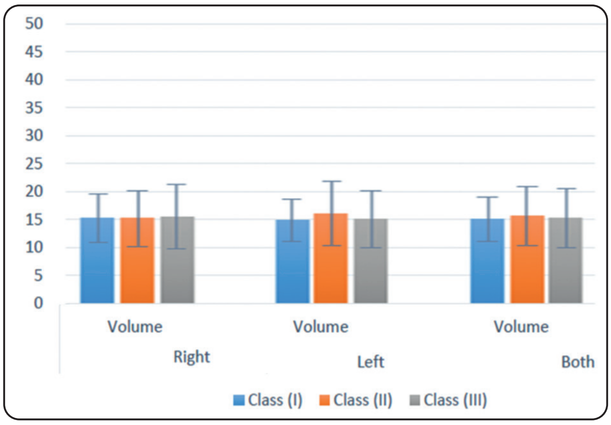


Fig. (3) Bar chart that shows mean and standard deviation (error bars) values for maxillary sinus measurements for different craniofacial classes.

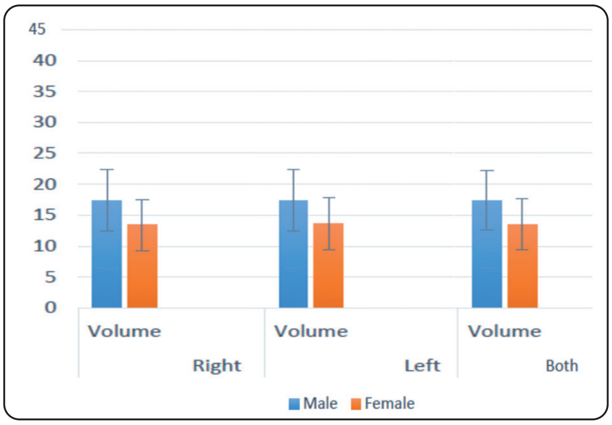


Fig. (4) Bar chart that shows mean and standard deviation (error bars) values for maxillary sinus measurements for different genders.

DISCUSSION

The maxillary sinus measurements are greatly important for maxillofacial surgeons, dentists, ENT surgeons, and dentomaxillofacial radiologists due to its vital position within maxillary bone, its close proximity to the maxillary posterior teeth and its valuable role in facial skeletal growth. Thus, evaluating the relation between the skeletal patterns and maxillary sinus volume (MSV) is extremely essential. The age group selected in our sample was 18 years old and elder because at that age the development of MS is almost completed, and the dimensions are stable [(4)]. Furthermore, as the extraction of maxillary posterior teeth can affect the MSV through pneumatization, only participants with full dentition were included in this study [(5)].

Statistically, no significant difference was found in this present study regarding the maxillary sinus volume of the right and left sides in all three craniofacial patterns (I, II, III). According to the gender, MSV was significantly larger in males than females.

Okşayan et al., 2017 reported that there is no significant difference between the maxillary sinus volume in different vertical growth patterns. However, they evaluated the facial patterns through SN–GoGn angle in contrary to our study which used ANB angle [(6)].

Also, Asantogrol et al., 2021 stated that different skeletal groups are not statistically different concerning the maxillary sinus volume and dimensions using SNA angular measurements and that males and females showed statistically significant difference in sinus volume where males had a larger MS volume than females [(1)].

Moreover, **Abdelhamid et al., 2022** investigated 36 CBCT scans of patients with age range (20-40) years to evaluate MSV and its relation with different vertical growth patterns using Ondemand 3D app 1.0.10.7462 software for MSV measurements. The facial angle, Y-axis angle, gonial angle, and mandibular plane angle were analyzed from reconstructed cephalometric images. Their results were similar to our study as they concluded that no significant differences were found between MSV among different facial growth patterns [(7)].

Also in accordance with our study, the MSV was larger among males in the studied Saudi sample and showed no statistically considerable differences in MSV among the different skeletal patterns in **Alqahtani et al., 2023** although no measurements that included Nasion or Sella points were used as their CBCT scans did not extend beyond the maxilla. They reported that they used the beta angle confirmed by the AXB angle for identifying the sagittal skeletal class and the Frankfort-mandibular plane angle (FMA) for determining the vertical skeletal pattern [(8)].

In contrary to our results **Shrestha et al., 2021** reported that MSV of skeletal class II is remarkably greater than that of skeletal class III group ($P < 0.01$). This may be because they obtained the ANB angular measurement (ANB) from conventional lateral cephalograms while in our study reconstructed cephalometric images were used to obtain the same angle. Regarding relation between gender and MSV, they reported the same results that males showed remarkably larger MSV than females ($P < 0.05$) [(2)].

In 2023, Magat et al. reported that no significant differences were found in MSV in accordance with the various skeletal types ($p>0.05$) as in the presented study. On the other hand, although the males' sinus volume values were higher than those of females, no statistically remarkable differences were found ($p>0.05$). This may be due to that their study did not include individuals with extracted or absent 3rd molars or may be due to unbalanced number of participants of males and females (26 males and 53 females) while in our study they were nearly equal (18 males and 21 females). Also, this might be related to the difference in the age range used in this study (18 years and older) as compared to their study (8-36 years). Considering that MS development is affected by aging, the study population's wide age range may have an impact on the results [(9)].

More investigations is required to assess the correlation between maxillary sinus volume and different craniofacial patterns in order to gain a better understanding and more reliable and precise results owing to the significant importance of maxillary sinus size and location in oral and craniofacial surgeries.

CONCLUSION

In this sample of Egyptian population, no significant correlation between the volume of maxillary sinus and the craniofacial pattern was found. Meanwhile, males showed greater size of the maxillary sinus volume than females.

REFERENCES

1. Asantogrol, F., Etoz, M., Topsakal, K. G., & Can, F. E. (2021). Evaluation of the maxillary sinus volume and dimensions in different skeletal classes using cone beam computed tomography. Ann Med Res 2021;28(4):709-15.
2. Shrestha, B., Shrestha, R., Lin, T., Lu, Y., Lu, H., Mai, Z., & Ai, H. (2021). Evaluation of maxillary sinus volume in different craniofacial patterns: a CBCT study. Oral Radiology, 37(4), 647-652.
3. Morgan, N., Van Gerven, A., Smolders, A., de Faria Vasconcelos, K., Willems, H., & Jacobs, R. (2022). Convolutional neural network for automatic maxillary sinus segmentation on cone-beam computed tomographic images. Scientific Reports, 12(1), 1-9.
4. Bhushan B, Rychlik K, Schroeder JW Jr. (2016). Development of the maxillary sinus in infants and children. Int J Pediatr Otorhinolaryngol;91:146-51

5. Farias Gomes A, de Oliveira Gamba T, Yamasaki MC, Groppo FC, Haiter Neto F, Possobon RF. (2019). Development and validation of a formula based on maxillary sinus measurements as a tool for sex estimation: A cone beam computed tomography study. Int J Legal Med; 133:1241-9.]

6. Okşayan, R., Sökücü, O., & Yeşildal, S. (2017). Evaluation of maxillary sinus volume and dimensions in different vertical face growth patterns: a study of cone-beam computed tomography. Acta Odontologica Scandinavica, 75(5), 345–349. doi:10.1080/00016357.2017.1310294

7. Abdelhamid, N., Nadim, M., & Elkadi, A. (2022). Correlation between maxillary sinus volume and different facial patterns using Cone Beam Computed Tomography in adults. Dental Science Updates, 3(1), 57-64.

8. Alqahtani, Hamad1; Basuhail, Sara1; Alsulaimani, Fahad1; Zawawi, Khalid H1; Barayan, Mohammed2; Al Turki, Ghassan1; Abbassy, Mona Aly1,3. (2023). The Relationship between Maxillary Sinus Volume and Different Cephalometric Characteristics in Orthodontics. Contemporary Clinical Dentistry 14(3): p 191-200, Jul–Sep. | DOI: 10.4103/ccd.ccd_548_22.

9. Magat, G., Taşsöker, M., Lale, B., Güleç, M., Özcan, S., Orhan, K., (2023). Comparison of Maxillary Sinus Volumes in Individuals with Different Dentofacial Skeletal Patterns: A Cone-Beam Computed Tomography Study. Ege Üniversitesi Diş Hekimliği Fakültesi Dergisi, 2023; 44_1, 17-23.