# Computed tomographic measurement of maxillary sinus volume and dimension in correlation to the age and gender (comparative study among individuals with dentate and edentulous maxilla)

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## ABSTRACT

Background : Although development and progress in various diagnostic methods, but still identification of remnants of skeletal and decomposing parts of human is one of the most difficult skills in forensic medicine . Gender and age estimation is also considering an important problem in the identification of unknown skull.

The aims of study: To estimate volume and dimension of maxillary sinus in individuals with dentate and edentulous maxillae using CT scan, and to correlate the maxillary sinus volume in relation to gender and age.

Materials and Methods : This study included 120 patients ranged from (40-69 years), divided into two groups, dentate group with fully dentate maxilla and edentulous group with complete edentulous maxilla, and each group composed of 60 patients (30 males and 30 females) who admitted to spiral CT scan unit in X-ray Institute in Baghdad to have CT of the brain and paranasal sinuses from October 2011 to June 2012, who had complaints of headaches or with suspection of sinusitis but without pathological findings in maxillary sinuses. The maxillary sinus volumes and dimensions (width, depth, and height) were measured with the help of the computer software in Spiral CT scan system.

Results : The statistical analyses of maxillary sinus measurements for dentate and edentulous groups showed that the volume and dimensions of maxillary sinuses in both groups were larger in males than females and they tend to decrease with the older age, in addition it is found that there was no significant differences in measurements of maxillary sinuses between dentate and edentulous groups, but the exception was in height measurements which were significantly higher in edentulous than dentate group for both genders.

Conclusion: It's found that the volumes and dimensions of the maxillary sinuses were larger in males than in females, in addition to that they tend to be less with the older age, so the Computed Tomography measurements of maxillary sinuses may be useful to support gender and age determination in forensic medicine

Key words: Computed Tomography, Maxillary sinus, Volume, Dimension, Dentate individuals, Edentulous individuals.
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## INTRODUCTION

Measurements of the maxillary sinuses in computerized tomography (CT) scans can be used for determination of age and gender when other methods are inconclusive [(1)] .

Determination of gender is extremely important as it can positively rule out a certain percentage of possibilities instantly. The skull, pelvis and femora are the most useful for radiological determination of gender. Radiology can assist in giving accurate dimensions for which certain formulae can be applied to determine gender [(2)]. Age estimation is one of several indicators employed to establish identity in forensic cases. Such estimations of living individuals are made for refugees or other persons who arrived in a country without acceptable identification papers and may require a verification of age, in order to be entitled to civil rights and / or social benefits in a modern society [(3)] .

Pneumatization of the paranasal sinuses begin in the ethmoid sinus and continue sequentially in the maxillary sinuses, the sphenoidal sinuses, and finally the frontal sinuses [(4)] (Figure 1).

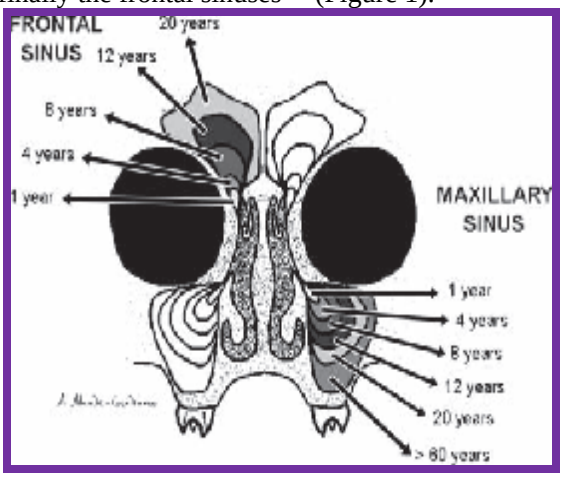


**Figure 1: Diagram showed the development of the frontal and maxillary sinuses according to age in years.**

### Maxillary Sinus Volume and Dimension

The maxillary sinuses reach their mature sizes at the age of about 20 years, when the permanent teeth are fully developed. During adulthood, their

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shapes and sizes change especially due to loss of teeth**.** Then after the maximum growth period, the volume of the maxillary sinus decrease in both genders. This may be caused by the loss of minerals in the bone matrix of the entire body structure that surrounds the maxillary sinus in all directions, which contracts the maxillary sinus and result in a decrease in the maxillary sinus volume [5,6,7] . Smaller maxillary sinuses usually extend from the second premolars to the second molars, while larger sinuses extend from the first premolars or even from the canine and even beyond the third molars [8] .

**The relationship between maxillary sinus and edentulous maxilla**

After a prolonged period of being edentulous, the alveolar ridge that once supported the teeth become atrophic. Extraction of posterior teeth cause an inferior expansion of the maxillary sinus ,thus proving the pneumatization phenomenon after tooth loss. Pneumatization is a physiologic process that occur in all paranasal sinuses during the growth period ,causing them to increase in volume [9]. Pneumatization of the sinus varies greatly from person to person and even from side to side. The expansion of the sinus was larger following extraction of teeth enveloped by a superiorly curving sinus floor, extraction of several adjacent posterior teeth, and extraction of second molars in comparison with first molars [10,11] . (Figure 2,3)

Some authors reported that after tooth loss, the periosteum of the Schneiderian membrane shows increased osteoclastic activity, resulting in resorption of the sinus floor and consequent expansion of the maxillary sinus [12,13] .

**Figure 2: Coronal CT image showed pneumatization of the maxillary sinus into the palatal process of maxilla (arrows).**

**Figure 3: Axial CT image showed pneumatization of the zygomatic process of maxilla (arrows).**

**Relationship between maxillary sinus and teeth**

The anatomical relation between the maxillary sinus and the teeth is a complex one, due to the variable extension of the sinus. Identification of the distance between the dental roots apices and the sinus floor and the establishment of the available bone thickness are imperative requirements in case of surgical procedures of this area [14] .

Knowledge of the anatomical relationship between the maxillary sinus floor and the maxillary posterior teeth root tips is important for the preoperative treatment planning of maxillary posterior teeth [15] . and others found that the buccal roots of the second maxillary molar showed close relations with the sinus in 40.5% of their studied specimen [16] . while The roots of the maxillary first molar were close to the sinus floor in 60% of the studied specimens in addition, the smallest thickness of the alveolar sinus wall was in 1.7 mm at the level of the second molar [17] .

The roots of the maxillary premolar, molar and occasionally canine may project into the maxillary sinus because of the implications this can have on surgical procedures, it is essential for clinicians to be aware of the exact relationship between the apical roots of the maxillary sinus because of the implications this can have on surgical procedures, it is essential for clinicians to be aware of the exact relationship between the apical roots of the maxillary teeth and the maxillary sinus floor [18,19] .

## SUBJECT, MATERIALS AND METHODS

A prospective study consist of (120) patients ranged from (40-69 years), divided into two groups, dentate group (fully dentate maxilla) and edentulous group (complete edentulous maxilla), and each group composed of 60 subjects (30 males and 30 females ) who admitted to spiral CT scan unit in X-ray Institute in Baghdad, from

October 2011 to June 2012. Patients selected with no history of trauma. Patients with facial asymmetry or septal deviation or who had previously undergone surgical procedures or with cleft palate or ectopic & supernumerary teeth were excluded from the study. All patients were examined on Spiral Computed Tomography scanner, (TOSHIBA , Aquillion 64) , Scano angle $90^0$, Slice thickness = 1 mm

**Measurement of maxillary sinus volume**

Maxillary sinus volumes calculated by overlapping CT images (sections) on axial views.

The volume of each section was : $dV = dS \times \Delta h$ where (dS) is the area of the maxillary sinus in a given section which was calculated automatically by the software of CT machine and ($\Delta h$) is the slice thickness of the section.( Figure 4).

The volume (V) of the region from the antral floor to a height of (n) mm was calculated as the sum of the volumes of each section (dV), so the total maxillary sinus volume on both sides from the antral floor to the top of the antrum also computed according Uchida et al in 1998 as described below:

$$v = \sum_{i=1}^{n} dS \times \Delta h$$ (20) .


**Figure 4: Diagram of maxillary sinus showed the method used in this study for measuring maxillary sinus volume using CT images.**

**Measurement of maxillary sinus dimensions**

The three distances (height, width, and depth), were measured on the axial and coronal views, where the width and depth distances measured on axial views while the height distances measured on coronal views .

The depth and width of maxillary sinus was measured above the most apical level of the maxillary sinus floor. The width was defined as the longest distance perpendicular from the medial wall of the sinus to the most lateral wall of the lateral process of the maxillary sinus in the axial view. The depth was defined as the longest distance from the most anterior point to the most posterior point of the medial wall in the axial wall**.** The height was measured away from the inner surface of the anterior border of maxillary sinus. The height of the maxillary sinus was defined as the longest distance from the lowest point of the sinus floor to the highest point of the sinus roof in the coronal view [21] . (Figure 5,6).


**Figure 5: showed CT image included in this study with width and depth measurements of maxillary sinus in this study (Axial view).**

**Figure 6 showed CT image with height measurements of maxillary sinus in this study (Coronal view).**

# RESULTS

Regarding the dentate group, the mean values of the right and left maxillary sinus volume, width, depth and height were for males (23.98 ± 0.81), (23.9 ± 0.83) $cm^3$; ( 24.07 ± 0.62), (24.67 ± 0.63) mm; (36.12 ± 0.62), (39.2 ± 0.61) mm; (39.68 ± 0.61), (39.50 ± 0.63) mm and for females (22.96 ± 0.44), (23.02 ± 0.46) $cm^3$; (22.38 ± 0.95), (22.26 ± 0.94) mm; (35.0 ± 0.9), 35.14 ± 0.82 ) mm; (36.55 ± 1.26), (36.67 ± 1.06) mm respectively and if both sides are considered together, the mean values of the maxillary sinus volume, width, depth and height for males (23.94 ± 0.82) $cm^3$, (24.37 ± 0.62) mm; (36.16 ± 0.61) mm, (39.59 ± 0.62) mm, while for females (22.99 ± 0.45) $cm^3$, (22.32 ± 0.94) mm, (35.07 ± 0.86) mm, (36.61 ± 1.16) mm respectively. No significant difference between the right and left

side for the four variables was found. From these results one can see that the maxillary sinuses in males were larger in volume and wider in width than that of females, as well as the depth and height are higher in males than that of females.

Regarding the edentulous group, the mean values of the right and left maxillary sinus volume, width, depth and height were for males were (24.05 ± 0.38), (23.99 ± 0.3) $cm^3$; (24.87± 0.64), (24.75± 0.63 mm, (36.93 ± 0.53), (36.77 ± 0.51) mm ; (42.07 ± 1.38), (41.89 ± 01.21) mm, and for females (23.01 ± 0.75), (23.9 ± 0.77) $cm^3$, (22.74 ± 1.04), (22.60 ± 0.93) mm; (35.15 ± 1.08) mm ; (37.26 ± 0.63), (37.18 ± 0.69) mm respectively .

If both side are considered together, the mean values of volumes of the maxillary sinus for males (24.02 ± 0.34) $cm^3$, (24.81 ± 0.63), (36.85 ± 0.52) mm, (41.98 ± 1.29) mm and for females (23.05 ± 0.76) $cm^3$, (22.67 ± 0.98) mm, (35.1 ± 1.12) mm, (37.22 ± 0.66) mm respectively. Also no significant difference between the right and left side for the four variables was found. From these results one can see that the maxillary sinuses in males were larger in volume and wider in width than that of females, as well as the depth and height are higher in males than that of females. (Figure 7,8) .

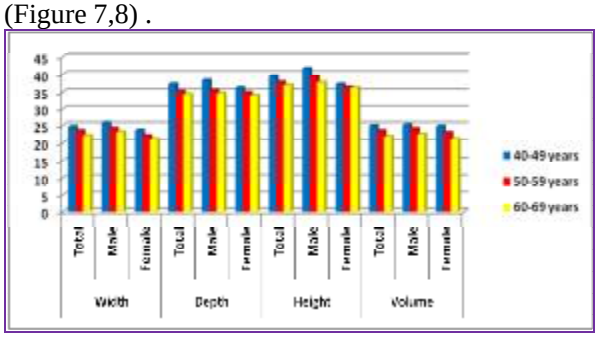


**Figure 7: Age and gender differences of maxillary sinus measurements in dentate group**

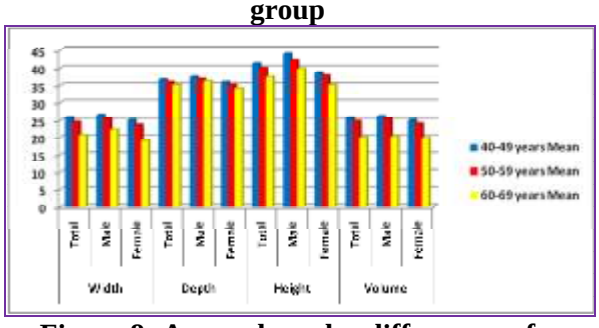


**Figure 8: Age and gender differences of maxillary sinus measurements in edentulous group**

**Comparison of maxillary sinus measurements between dentate and edentulous groups**

For both genders, the mean right and left maxillary sinus volume, width, depth showed no any significant differences between dentate and edentulous group, the exception was in height measurements which were significantly higher in edentulous than dentate group for both genders. But regarding age grouping, there were significant differences between age groups in both dentate and edentulous group, where these four variables tend to decrease with the older age in both dentate and edentulous group ( Figure 9) .

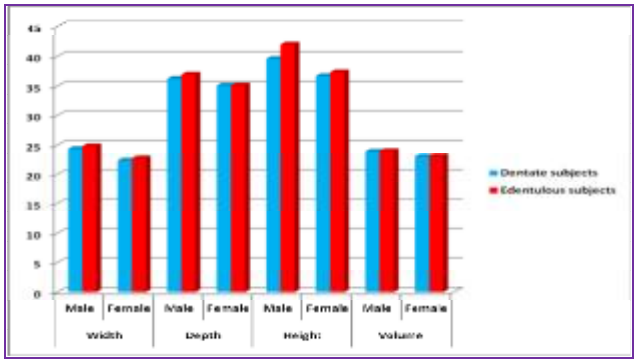


**Figure 9: Gender differences between dentate and edentulous groups**

**Correlation between maxillary sinus volume and the three measured dimensions**

For both genders, the maxillary sinus volumes were positively correlated with the three measured dimensions for both sides ($p<0.01$) in dentate and edentulous group. If both genders considered together, the correlations with the width, depth and height in dentate were (r=0.76, 0.52, 0.64) respectively, while the correlations with the width, depth and height in edentulous group were (r = 0.88, 0.56, 0.86) respectively. (Table 1):

**Table 1: Correlation between maxillary sinus volume and the three measured dimensions**

| | Correlation coefficients in dentate group | P value | Correlation coefficients in edentulous group | P value |
|---|---|---|---|---|
| **Width** | 0.76 | 0.0001 | 0.88 | 0.001 |
| **Depth** | 0.52 | 0.0059 | 0.56 | 0.0067 |
| **Height** | 0.64 | 0.0007 | 0.86 | 0.001 |

# DISCUSSION

Maxillary sinus volumes and dimensions show a wide range in different studies that may reflect the influential effects like human variability and triggering of pneumatization.

**Measurements of maxillary sinuses**

Regarding both the dentate group and edentulous group, the mean values of the right and left maxillary sinus volume, width, depth and height showed no significant difference between

the right and left side for the four variables if both side are considered together. Also it is found that the maxillary sinuses in males were larger in volume and wider in width than that of females, as well as the depth and height are higher in males than that of females .

Previous studies found that there was a significant difference of the maxillary sinus volume between males and females, mainly due to the fact that male exhibit higher and wider maxillary sinuses than females, also they found neither significant difference between the left and right maxillary sinus volume that agree with this study [22].

Some authors have studied the volumetric measurements and anatomical variants of paranasal sinuses in Twenty-four dried skulls of Africans (Nigerians) and they found that the average volume on the right was 11.59 ± 5.36 cm3and 14.98 ± 10.77cm3 on the left, asymmetry of the maxillary sinus was found in 100% of the dried skull, no bony septum was found within the sinuses, these results are too much less than that of this study, this might be due to using dried crania where no bony septum was found within the sinuses and also due to using of small sample, all these might be the cause for decreasing the readings [23] .

Others studied the maxillary sinuses in computerized tomography scans on Turkish people and they found that the mean values of the right and let maxillary sinus width in males were (27.19±5.46mm), (26.89±5.52mm) and in females were (24.44±3.61mm) (24.27±3.98mm) respectively and the right and left maxillary sinus length (depth) in males (42.58±7.9mm), (43.7±7.78) and in females (37.8±5.69), (37.6±6mm) and the right an left maxillary sinus height in males were (47.6±6.4) mm, (47.2±6.5) mm and in females were (45.1±4.6), (43.6 ± 44) mm respectively, these results are higher than that of this study [24] .

Also some authors made measurements of the maxillary sinus volume using Computed Tomography and found that the mean volume ,width, anteroposterior length(depth), and height of the normal Korean adult's maxillary sinuses were 21.90 $cm^3$, 28.33 mm, 39.69 mm, 46.60 mm respectively, these results seem to be higher than that of this study except the volume which is slightly less than of this study that may be due to small sample size or due to anatomical variations, and also he found no significant difference between the right and left side for these variables, as well as he found that the maxillary sinuses in males tend to be larger than females which agree with this study [25] .

**Association of maxillary sinus measurements with the age**

Regarding age grouping, the four variables (Volume, width, depth and height) showed significant difference among the three age group, where all of them found to decrease with the age in both dentate and edentulous group.

Some authors found that the volume decrease with the age which agree with this study, and they stated that this might be related to skeletal size and physique [26,27].

Others reported that the volumes of paranasal sinuses increase regularly with age in both genders, that disagree with current study [28].

**The comparison of maxillary sinus measurements between dentate and edentulous group**

Regarding gender difference, The mean right and left maxillary sinus volume, width , and depth showed no significant differences between dentate and edentulous group except the measurements of height were significantly higher in edentulous group than that of dentate group.

Regarding age grouping, the mean right and left maxillary sinus mean of volume, width, depth and height showed significant differences between dentate and edentulous group.

Some authors studied (101) case and they found no significant difference in maxillary sinus dimension for dentate and edentulous subjects, and this agree with this study ([29,30] .

But others found that The maxillary sinus is significantly larger in adult patients who are edentulous in the posterior maxilla compared with patients with complete posterior dentition, also this disagree with this study [31] .

**Correlation between maxillary sinus volume and the three measured dimensions**

If both genders considered together, the correlations with the width, depth and height in dentate were (r =0.76, 0.52, 0.64) respectively, while the correlations with the width, depth and height in edentulous group were ( r = 0.88, 0.56, 0.86) respectively. From these results one can see that the strongest correlation was with the width ( r = 0.88, 0.86) and height ( r == 0.86 ) in edentulous group , while the weakest correlation was with the depth in dentate group ( r = 0.52 ).

In some studies found that in edentulous patients, the maxillary sinus may expand farther in height and continue to extend into the alveolar bone, this agree with this study**,** others reported that the height of maxillary sinus is the primary determinant of the volume of maxillary sinus, and the depth is the second most important variable,

but this disagree with this study, where it is found that the most important and the strongest correlated variable with the volume was the width of maxillary sinus, and the height is the second [11,20].

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