Maxillary sinus size in different gender and sagittal skeletal classes: orthodontics and forensic interests

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ABSTRACT

Background: Evaluation of the maxillary sinus dimensions by using lateral cephalograms for treatment planning, sex determination and forensics purposes is still wanting in the literature. However, none has been performed in Lebanese population.

Methods: A retrospective study on 115 lateral cephalograms of healthy young Lebanese male and female adults, age ranged from 22 to 26, was orthodontically conducted in order to investigate the maxillary sinus size in different gender and sagittal skeletal classes, and its distribution within vertical facial types. Five measurements were used to assess the maxillary sinus size: two linear and three areas. Maxillary sinus size parameters were compared between males and females using Mann-Whitney U tests. The outcome measures were assessed across the different categories of sagittal and vertical malocclusion using Kruskal-Wallis tests, it has been followed by a post-hoc pairwise comparaisons. Statistical significance was set at 0.05.

Results: All measures of maxillary sinus size displayed significant gender differences. When subjects were categorized into Class I, II and III only the lower sinus area differed significantly between the three groups. Only Class II hyperdivergent subgroup subjects were found to have significantly greater sinus length, total sinus area and upper sinus area when the assessment was based on ANB angle.

Conclusion: The findings were in agreement with recent studies done on CTs and CBCTs regarding the presence of a sexual dimorphism in the maxillary sinus size. The novelty of this research was the inclusion of the vertical dimension as a variable that showed significance in Class II hyperdivergent subjects. These results are also of interest to the forensic context when involving adult subjects.Key words: Groove, root, attachment, concavities, acquired deformities.

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INTRODUCTION

Limited researches have studied the Maxillary Sinus Size (MSS) on lateral cephalometric X-ray for diagnosing airway problems, treatment planning, sex determination and human identification in forensics. The maxillary sinus is an anatomical structure that is centrally located in the maxillary bone; its development affects the craniofacial skeleton.[1] The MSS assessment plays an important role in teeth movement in proximity with the sinuses, Temporary Anchorage Devices (TAD) placement,[2] some surgeries where the maxillary sinus contour is involved[3] in the vertical and sagittal dimensions and the orthognathic treatment planning.[4,5] In forensic dentistry, the MSS provides important information about human recognition and gender determination since the maxillary sinuses maintain their anatomical shape and structure intact following accidents where the skull and other bones are badly disFig.d[6]. In airways assessment, correlations between the airway pressure in the nasopharynx and the paranasal sinuses sizes have been demonstrated.[7]

(b)

Since the last decades, the size of the sinuses has been studied with Computed Tomography (CTs),[1,8,9,10,11,12] Magnetic Resonance Imaging (MRIs).[13,14] Lately, Cone Beam Computed Tomography (CBCTs)[15] represents the gold standard in the evaluation of MSS because it overcomes the lack of cross-sectional information, superimposition, distortion, and magnification noted in the conventional radiography.[16,17,18,19] However, conventional radiographies such as panoramic, lateral and frontal cephalograms (LCs and FCs) are most commonly utilized in dentistry. These two dimensional tools can be used for screening the sinus during treatment planning in order to prevent some complications such as root resorptions during orthodontic treatment, perforation of the maxillary sinus during TAD placement, alteration of the sinus function in orthognathic surgeries where the maxillary sinus contour is within the limit of the cut as well as the evaluation of treatment outcome.

The purpose of this study was to investigate on lateral cephalograms, in a Lebanese Caucasian population, the maxillary sinus size in different gender and skeletal sagittal classes, taking into consideration both the sagittal and the vertical skeletal facial types. The results of this study will highlight the importance of the MSS in assessing airways, orthodontics related treatment planning, sex determination and human identification in forensics.

MATERIALS AND METHODS

One hundred and fifteen lateral cephalograms were used for this study. The X-rays were for healthy young Lebanese male and female adults, age ranged from 22 to 26 years. The Lebanese origin was confirmed by the family tree and lack of interethnic marriages in the preceding 3 generations.

Cephalometric analysis

The digital lateral cephalograms were carried out in a standardized manner and then transferred into a computer and analyzed using the Viewbox Cephalometric tracing software (Viewbox Version 4.0.1.7, 2013, dHAL Software, Kifissia, Greece). Cephalometric skeletal landmarks and structures were identified and digitized simultaneously (Table 1). The rectangular coordinates, with the x-axis parallel to the Frankfort horizontal plane and the y-axis perpendicular to the Frankfort horizontal plane through the Sella, were used for maxillary sinus measurement. Five measurements describing the MSS were evaluated (Fig. 1): two linear were the Maxillary Sinus Length (MSL) and Maxillary Sinus Height (MSH), and three areas were the Upper Maxillary Sinus Area (UMSA), the Lower Maxillary Sinus Area (LMSA) and the Total Maxillary Sinus Area (TMSA) as described by Endo et al[2] in Table 1.

Statistical analysis

The sagittal skeletal classes I, II and III were classified on the basis of the ANB angle and the vertical hypo, normo and hyperdivergent facial types according to the Frankfort mandibular plane angle FMA. Sagittal and vertical facial type measures were each classified into three categories within the established norms and standard deviations. Maxillary sinus size parameters were compared between males and females using Mann-Whitney U tests for independent samples. Similarly, the outcome measures were assessed across the different categories of sagittal and vertical facial type using Kruskal-Wallis tests for independent samples. When Kruskal-Wallis tests showed statistical significance, post-hoc pairwise comparisons were performed using Dunn's procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values were presented for post-hoc comparisons. Statistical significance was set at 0.05.

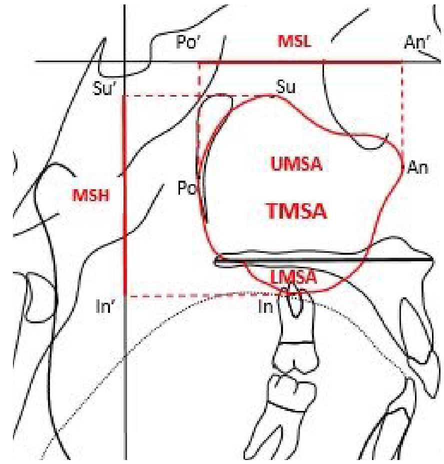

Fig 1. Reference points and maxillary sinus measurements

RESULTS

Descriptive statistics

Maxillary sinus size parameters varied considerably within the assessed population (Table 2). The greatest variation was noted for measures of maxillary sinus size

Table 1: Reference points, measurements and definition

Maxillary Sinus Reference Points	Definition
An	Point An, most anterior point of maxillary sinus
An′	Point An′, point projected vertically from An to the x-axis
Po	Point Po, most posterior point of maxillary sinus
Po′	Point Po′, point projected vertically from Po to the x-axis
Su	Point Su, most superior point of maxillary sinus
Su′	Point Su′, point projected vertically from Su to the y-axis
In	Point In, most inferior point of maxillary sinus
In′	Point In′, point projected vertically from In to the y-axis
Maxillary Sinus Measurements	**Definition**
MSL (mm)	Maxillary sinus length, distance between An′ and Po
MSH (mm)	Maxillary sinus height, distance between Su′ and In′
TMSA (mm^2)	Total maxillary sinus area, area outlined by maxillary sinus surface
UMSA (mm^2)	Upper maxillary sinus area, upper area of maxillary sinus from palatal plane
LMSA (mm2)	Lower maxillary sinus area, lower area of maxillary sinus from palatal plane

Table 2. Descriptive Statistics for Maxillary Sinus Size Parameters (N=115)

	Minimum	25th percentile	Median	75th percentile	Maximum
Maxillary sinus length (mm)	31.04	41.87	43.77	46.93	61.83
Maxillary sinus height (mm)	26.81	40.80	44.00	47.12	59.22
Total maxillary sinus area (mm2)	791.17	1279.02	1387.46	1589.73	2824.36
Upper maxillary sinus area (mm2)	791.17	1163.02	1263.69	1381.17	2528.29
Lower maxillary sinus area (mm2)	0.00	130.45	130.45	202.10	393.62

Table 3. Distribution of Maxillary Sinus Size Parameters by Gender (N=115)

	Males (n=46)		Females (n=69)		Mann-Whitney U	
	Median	Mean rank	Median	Mean rank	Test statistic	p value
Maxillary sinus length (mm)	45.60	66.26	43.17	52.49	1,207.00	0.030*
Maxillary sinus height (mm)	46.56	73.23	42.51	47.85	886.50	<0.001**
Total maxillary sinus area (mm^2)	1530.79	73.23	1348.27	47.85	910.00	<0.001**
Upper maxillary sinus area (mm^2)	1338.05	72.04	1231.77	48.64	941.00	<0.001**
Lower maxillary sinus area (mm^2)	164.24	70.93	120.08	49.38	992.00	0.001**

** Statistically significant at $p < 0.05$; **Statistically significant at $p < 0.01$.*

area. Total maxillary sinus area and lower maxillary sinus area ranged from 791.17 to 2824.36 mm^2 and from 0.00 to 393.62 mm^2, respectively. Upper maxillary sinus area contributed towards 85-90% of the total area of the sinus.

Gender differences

All measures of maxillary sinus size displayed significant gender differences (Table 3). Median measures of maxillary sinus length and height in addition to median measures of upper, lower and total area were statistically significantly larger in males than in females (p-value =0.03 for maxillary sinus length; p-value ≤ 0.001 for remaining measures).

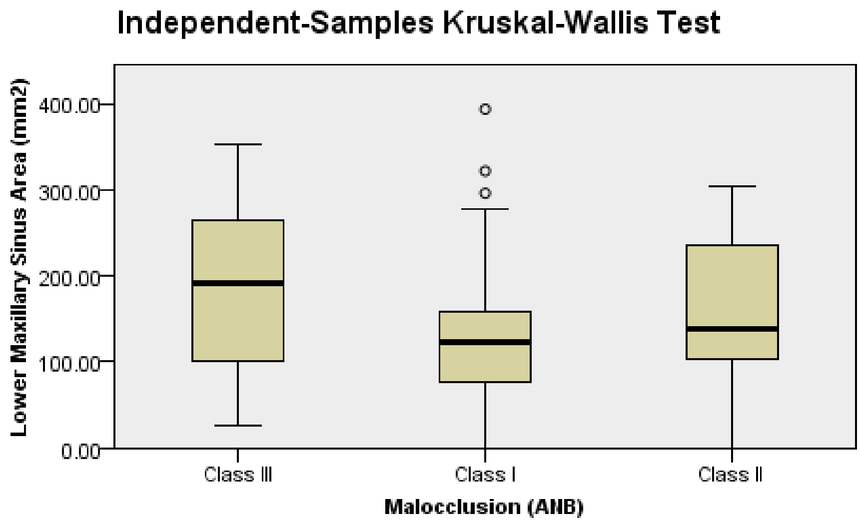

Fig 2. Distribution of lower maxillary sinus area (mm2) by malocclusion assessed by ANB angle (N=115). Independent-samples Kruskal-Wallis H(2)= 7.291, p = 0.026. Class I vs. Class III comparison statistically significant at p = 0.039 (IBM® SPSS® version 20.0).

Table 4. Distribution of Maxillary Sinus Size Parameters by Sagittal Malocclusion Categorized by ANB angle (N=115)

	Class III (n=20)		Class I (n=63)		Class II (n=32)		Kruskal-Wallis		Dunn's post-hoc§		
	Median	Mean rank	Median	Mean rank	Median	Mean rank	Test statistic ǂ	p value	I vs. III	I vs. II	II vs. III
Sinus length (mm)	44.02	53.38	43.17	53.44	45.70	66.75	3.387	0.184			
Sinus height (mm)	44.62	63.45	43.60	54.32	44.68	61.84	1.728	0.421			
Total sinus area (mm^2)	1424.55	64.50	1332.79	51.43	1512.43	66.88	5.475	0.065			
Upper sinus area (mm^2)	1264.43	59.05	1238.27	53.03	1336.12	67.13	3.816	0.148			
Lower sinus area (mm^2)	190.85	72.05	122.35	50.83	137.68	63.34	7.291	0.026*	0.039*	0.251	1.000

Note. Class III: ANB < 0 degrees; Class I: 0 ≤ ANB ≤ 4 degrees; Class II: ANB > 4 degrees.

ǂ Kruskal Wallis test statistic evaluated at 2 degrees of freedom and adjusted for ties.

§ Dunn's post-hoc statistic with Bonferroni adjustment of p values to account for three pairwise comparisons.

** Statistically significant at p < 0.05; **Statistically significant at p < 0.01.*

Table 5. Distribution of Maxillary Sinus Size parameters by Sagittal dimension assessed by ANB angle in Hyperdivergent subgroup (FMA>28 degrees, N=42)

	Class III (n=8)		Class I (n=19)		Class II (n=15)		Kruskal-Wallis		Dunn's post-hoc§		
	Median	Mean rank	Median	Mean rank	Median	Mean rank	Test statistic	p value	I vs. III	I vs. II	II vs. III
Sinus length (mm)	43.54	20.50	42.55	16.37	46.68	28.53	8.308	0.016*	1.000	0.012*	0.404
Sinus height (mm)	44.62	23.38	42.51	17.58	44.87	25.47	3.696	0.158			
Total sinus area (mm)	1407.03	24.00	1301.83	15.32	1520.97	28.00	9.371	0.009**	0.279	0.008**	1.000
Upper sinus area (mm^2)	1260.21	21.25	1184.67	16.32	1349.61	28.20	7.870	0.020*	1.000	0.015*	0.587
Lower sinus area (mm^2)	198.99	28.00	125.01	17.95	135.59	22.53	3.946	0.139			

Note. Class III: ANB < 0 degrees; Class I: 0 ≤ ANB ≤ 4 degrees; Class II: ANB > 4 degrees.
ǂ Kruskal Wallis test statistic evaluated at 2 degrees of freedom and adjusted for ties.
§ Dunn's post-hoc statistic with Bonferroni adjustment of p value to account for three pairwise comparisons.
** Statistically significant at p < 0.05; **Statistically significant at p < 0.01.*

Differences related to the sagittal dimension

Maxillary sinus measures were examined and compared in different malocclusions in the sagittal and vertical planes. When the sample was categorized into Class I, II and III according to ANB angle only the lower sinus area differed significantly between the three groups (p = 0.026), the median area being larger in subjects with Class III maxillo-mandibular relationships compared to those with Class I jaw relationships (p = 0.039) (Table 4, Fig. 2).

Further explorations were carried out to assess associations between maxillary sinus size and sagittal malocclusion while controlling for the vertical pattern. The relationship between sagittal malocclusion and maxillary sinus variables was assessed in hypodivergent, normodivergent and hyperdivergent subjects separately. Only Class II hyperdivergent subgroup subjects were found to have significantly greater sinus length, total sinus area and upper sinus area when the assessment was based on ANB angle (with adjusted p values of 0.012, 0.008 and 0.015, respectively) (Table 5).

DISCUSSION

Of the 115 lateral cephalograms included in this study, 60 % (n = 69) were for female and 40 % (n = 46) were for male subjects. The outcome parameters of maxillary sinus size were not normally distributed between which necessitated the use of non-parametric statistical tests.

Our results show a wide range of maxillary sinus dimensions even though our sample is derived from the same age (22-26 years) and ethnic group (Table 2). MS dimensions are in relation to multiple factors such as the ethnicity, the craniofacial and skeletal dimensions, the environmental conditions and the breathing pattern.

The study also demonstrated that the variation of dimension is also significantly associated with the gender difference since the median of male subjects show greater values compared to female (Table 3). Maxillary Sinus Size needs to be assessed carefully where a large amount total maxillary impaction is recommended, especially in females, taking into consideration the sinus position, the Total Maxillary Sinus Area, and the fact that the Maxillary Sinus Size decreases after the third decade. Trying to correlate our results to those of the literature, we conclude that the gender association with Maxillary Sinus Size becomes more relevant in adult subjects whatever is the radiographic tool used[20]: LC,[21] CT,[22-29] and CBCT.[6] Our results were not in accordance with those obtained by Endo et al (2010) who also used LCs and a sample age ranged between 12 to 16 years and the results of Oktay[30] who used panoramic X-rays and a sample age ranged between 6 to 30 years. This might be explained by the sample age since the Maxillary Sinus Size grows till the second decade in females and the third decade in males.[31]

The results of the sample also showed that adult subjects with Class III skeletal relationships have larger LMSA compared to those with Class I jaw relationships (Table 4 and Fig. 2). This might be due to the fact that in Class III skeletal subjects there is a tendency of a downward growth of the normal or narrow maxilla into a wider mandible. Positive air pressure in the maxillary sinus may explain the development of the lower maxillary sinus below the palatal plane. In other words the LMSA might be relatively larger in Class III than Class I subjects.

When the vertical dimension was included in the present study, only Class II hyperdivergent subjects were found to have significantly greater Maxillary Sinus Length, Total Maxillary Sinus Area and Upper Maxillary Sinus Area than Class I hyperdivergent subjects, with adjusted p values of 0.012, 0.008 and 0.015 respectively (Table 5). To our Knowledge, no previous studies in the literature, have combined the vertical dimension to the sagittal when assessing the Maxillary Sinus Size.

CONCLUSION

The presence of a sexual dimorphism in the maxillary sinus size was demonstrated in this study, where males showed greater values compared to females.

The results are of interest to the forensic context when involving human identification, gender determination in adult subjects and orthodontic and orthognathic surgery treatment planning.

The novelty of this research was the inclusion of the vertical dimension as a variable that showed significant differences in Classes I and II hyperdivergent subjects for the first time. More studies are warranted to explain these findings and explore the incrimination of the cranial base, the palatal and occlusal plan in these results.

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