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Maxillary sinus volume in different facial patterns

A Project
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Bachelor of Dental Surgery

By

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Certification of the Supervisor

I certify that this project entitled "**Maxillary sinus volume in different facial patterns**" was prepared by **Soumaia Mourad Falih** under my Supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervisor's name: Assistant Professor Dr. Shaymaa Shaker Taha

Dedication

I would like to dedicate my humble effort to:

My sweet and lovely **(Father & Mother)** their affection, love, encouragement and prays of day and night make me able to get success and honor.

My beautiful sisters **(Mina& Deena).**

My supportive man & best friend **(my fiance Belal).**

All friends for their unlimited encouragement and help.

Especially Talar & Teeba for helping me

Finally, to all who encouraged me even through a word.

Soumaia Mourad

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First and foremost, praises and thanks to Allah Almighty for helping me fulfill my dream, for his blessings throughout my work to complete it successfully.

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List of Abbreviations

(2D)	**Two dimensional**
(3D)	**Three dimensional**
(CBCT)	**Cone beam computed tomography**
(MS)	**Maxillary sinus**
(MSF)	**Maxillary sinus floor**
(OSA)	**Obstructive sleep apnea**
(OTM)	**Orthodontic tooth movement**
(PAS)	**Pharyngeal airway space**
(Pg)	**pogonion**
(PNS)	**Posterior nasal spine**
(TADs)	**Temporary anchorage devices**
(TMTMS)	**Teeth moving through the MS**

Introduction

The maxillary sinus (MS) is one of the anatomical limitations during orthodontic treatment. The maxillary sinus has a pyramidal shape and is the largest paranasal sinus **(Baker *et al.,* 2011)** It usually represents a single chamber cavity, but in some cases two sinuses separated by bone septa can be found. It has a shape of four-walled pyramid with a base located medially to the NC (the lateral wall of the nose) and an apex directed towards the zygomatic arch.Orthodontics generally deal with the correction of misaligned teeth under the application of orthodontic forces. Tooth movement triggered by orthodontic force is affected by the biomechanics properties and anatomy of teeth and the periodontal tissue. The MS is an air-filled cavity lined with mucosa between the floor and the posterior teeth **(Masri *et al.,* 2013)**.

It may extend laterally and inferiorly due to growth, absence of teeth, or other factors. For around 50% of adults, the maxillary sinus floor (MSF) extends close to the maxillary posterior teeth **(Livas *et al,* 2013)** . The root apices of premolar, molar, and canine teeth can penetrate into the MS in some cases **(Al-Ani *et al.,* 2016;Gu *et al.,* 2018; Zhang *et al.,* 2019; Oishi *et al.,* 2020; Choi *et al.,* 2020)** and lose the support of the alveolar bone.

The MSF is a hard high density bone similar to the cortical bone **(Chaiyasang *et al.,* 2010)**. Bone remodeling for the MSF is more difficult than that for the cancellous bone. These factors generally affect orthodontic tooth movement (OTM) and treatment outcome.For patients with a low MSF, teeth moving through the MS (TMTMS) becomes inevitable in some cases, such as in canine distalization **(Kuroda *et al.,* 2016)** or when the spaces closes after a tooth extraction **(Oh *et al.,* 2014)**. Bodily movement is generally expected but is difficult to achieve in these cases. When roots penetrate into the MS, moderate apical root resorption **(Wehrbein *et al.*, 1995)** , considerable tipping **(Park *et al.*, 2014)** abnormal pulp vitality, or perforation of the sinus membrane can be observed during OTM. Careful modification of the orthodontic force system for the tooth penetrating into MSF is helpful in reducing these side effects. Several successful practices of TMTMS have been reported in recent years . On the basis of clinical experience, it is universally recognized that light constant force can move teeth through the sinus floor. However, few researchers have addressed the effect of MS anatomy on tooth movement in more detail.

Aims of the study

1-To explore the correlation between the maxillary sinus volume and the vertical growth pattern.

2-To explore the correlation between the maxillary sinus volume and the sagittal jaw relation.

3-Test gender difference.

Chapter one: Review of Literature

1.1Correlation Between Maxillary Sinus Volume and Different Facial Patterns Using Cone Beam Computed Tomography in Adults.

Evaluation of the maxillary sinus during orthodontic diagnosis is crucial since it may affect the orthodontist's treatment plan. Precautions should be taken so that the line of treatment chosen not encroach on the integrity of the maxillary sinus (**Oishi *et al.*, 2020)**. Orthodontic treatment plan is affected by the size and position of the maxillary sinus. Likewise, the maxillary sinus may be affected by different malocclusions either dental or skeletal, anteroposterior or vertical in terms of size and position (**Cappellette *et al.*, 2017; Oz *et al.*, 2017)**. With the emergence of cone beam computed tomography (CBCT) and its advantages in the world of radiography appreciated, orthodontists are using it more and more frequently. Studying the maxillary sinus becomes more accurate and with a 3D approach and the volume of the sinus could be evaluated (**Carrascal *et al.*, 2017)**. Several researches were made to pinpoint whether there is a relation between maxillary sinus volume and malocclusion. Some studies show that there was a correlation between the maxillary sinus volume and vertical malocclusion however there were other studies that contradicted that finding **(Tikku *et al.*, 2013; Okşayan *et al.*, 2017).** The purpose of the present study was to find out if there is a correlation between the maxillary sinus volume and vertical growth pattern in adults using cone beam computed tomography. Studying the maxillary sinus is of great value to orthodontist. This is due to its close proximity to the teeth in the upper arch in a way that the upper alveolar process forms its lower border. Many studies were conducted to show the relationship between the maxillary sinus and different orthodontic applications. It was found that some of orthodontic treatment modalities affect the volume of the maxillary sinus such as rapid maxillary expansion, Orthognathic surgery, Uprighting upper molars and traction of deeply impacted canines increase the volume of the maxillary sinus ***(*Ozbilen *et al.*, 2019; Faur *et al.*, 2019)**. Another relation between the maxillary sinus and orthodontic treatment is that when moving teeth through the sinus. When moving teeth through the maxillary sinus there was increase in the risk of root resorption and undesired tipping also treatment time was prolonged. Orthodontists also must be aware of the maxillary sinus especially during mini-implant placement either buccal or infra-zygomatic to avoid maxillary sinus perforation which may lead to sinusitis or mini-implant failure **(Motoyoshi *et al.*, 2015; Jia *et al.*, 2018)**. In the present study there was no statistically significant difference between the left and right maxillary sinus volume in all three groups. Likewise,Okşayan et al **(Okşayan *et al.*, 2017)** found no significant difference between the right and left maxillary sinus volume when they studied it in patients with different vertical growth patterns. Also, when the extension of the maxillary sinus was studied and its relation to posterior teeth there was no statistically significant difference between the right and left side **(Kosumarl *et al.*, 2017*)*** Moreover, **Tikku *et al.*,** found significant difference in the volume of the maxillary sinus on the right and left sides in the mouth breather group when they were comparing the maxillary sinus volume in normal and mouth breathers. They claimed that this difference is caused by chronic inflammation thickening the bony walls of the sinus. The results of the previous study showed that there was no statistically significant difference in the volume of the maxillary sinus volume when comparing individuals with normal facial pattern, hyperdivergent facial pattern and hypodivergent facial pattern with both software programs. This is in accordance with **Okşayan *et al.*,** who likewise compared the maxillary sinus volume in adults with vertical malocclusion using CBCT. Their findings confirm the results of this study and they concluded that there is no correlation between maxillary sinus volume and vertical growth pattern. However;

they also found that there was decrease in the length and width dimensions in the high angle group. In this study the length, width and height were not compared.

On the other hand, in another research it was found that patients with short anterior facial height or in other words with hypo-divergent faces had decreased volume of the maxillary sinus when the upper airway and maxillary sinus volume were compared in different dental and skeletal malocclusions. This can also be explained by the age difference in the sample of that study and the present study. That study evaluated the CBCTs of children between 5 and 13 years old **(Kula *et al.*, 2013)** however, **Ryu *et al.*,** found that the cranio-caudal height of the maxillary sinus as well as the cross-sectional area were greater in those with skeletal open bite, while in the anteroposterior and mediolateral dimensions there were no significant differences between those with skeletal open bite and those with skeletal normal overbite. In previous study the total volume was not measured opposite to this study the measurements were obtained from certain cuts and the overall volume was not put into consideration. In addition to that **Tikku *et al.*,** and **Agacayak *et al.*,** found that adult and growing mouth breathers who mostly have hyperdivergent faces had smaller sinuses than nasal breathers. However; the conflict in the results between these studies and the previous study can be explained that unlike the present study the vertical growers in both studies were originally mouth breathers. As a consequence of the mouth breathing habit there is decrease in the function of nasal cavity thus decreasing the development of the maxillary sinus. Furthermore, mouth breathers are more prone to pathological conditions decreasing the sinus volume.

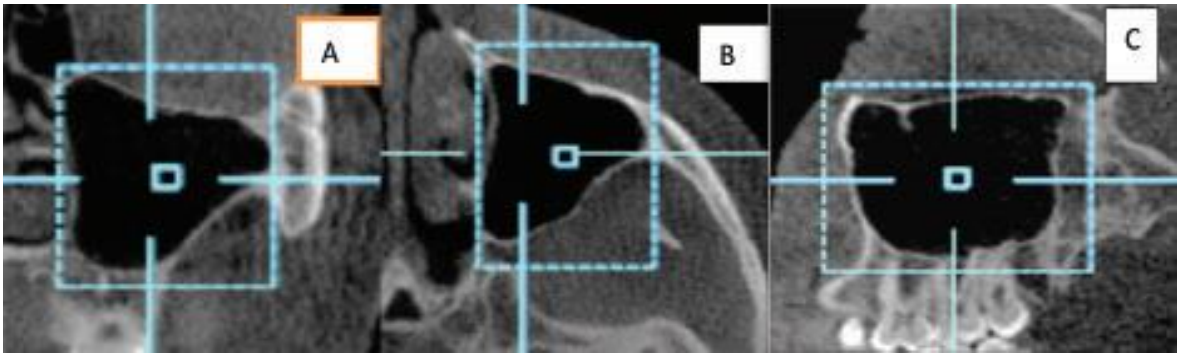

Figure 1: Cone beam CT; Magnification of outlined and selected Maxillary

(Nada *et al.*, 2022).

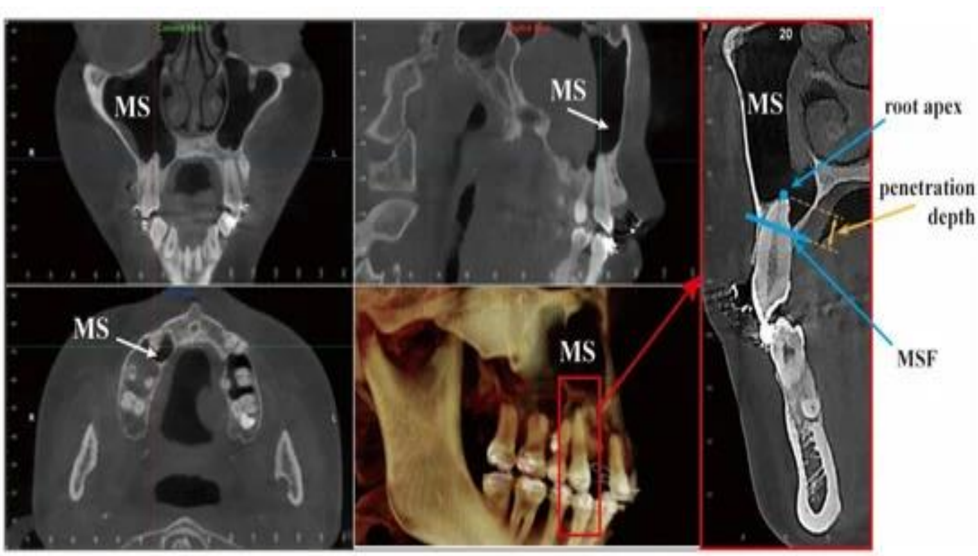

Figure 2: Tomography images of a patient with a low MSF. Penetration depth is the distance between the root apex and the MSF; MS is the maxillary sinus; MSF is the maxillary sinus floor.

(Nada *et al.*, 2022).

1.2 Evaluation of the maxillary sinus in panoramic radiography

The development of two-dimensional (2D) panoramic imaging techniques began in the first half of the 20th century, but the first device applying this technology was only described in 1959 **(Paatero *et al*., 1959)** Since then, this radiographic technique has steadily been improved and has become a standard diagnostic tool in a clinician's daily practice. In parallel, cone beam computed tomography (CBCT), first described in 1982 **(Robb, 1982)**, was introduced as a tool for dental and maxillofacial diagnostics. The advantages of three-dimensional (3D) CBCT over 2D conventional panoramic tomography include an excellent imaging quality of high-contrast structures like the maxillofacial bone anatomy, no geometric distortion, and no superimposition of surrounding anatomic structures. **(Price *et al*., 2012)** The advantages of panoramic radiography, on the other hand, are comparatively low-radiation doses, its general availability, and the comparatively low costs.

Further, it is especially useful in the initial diagnostic phase of implant planning because it relates information on both dental arches, the inferior alveolar canals, and the maxillary sinuses to its pathologic conditions **(Tyndall *et al*., 2012)** However, limitations include the lack of visualization of structures like the bucco-lingual ridge pattern and the visual loss of cortical plates or undulating concavities **(Jaju and Jaju, 2014)** moreover, the fact that more than 80% of measurements from the crest of the residual alveolar ridge to the inferior alveolar canal have errors of more than 1 mm renders panoramic radiography unsuitable as a single imaging source for dental-implant site assessment **(Tyndall *et al*., 2012)**. Furthermore, it is well known that an average magnification factor of 1.25 can be expected in panoramic radiographs. This demands calibration of the image with the help of a defined reference device when determining the appropriate implant size

(Schropp *et al.*, 2009) Precise assessment of the maxillary sinus is mandatory when planning a lateral or internal sinus floor elevation **(Bornstein *et al.*, 2014; Dula *et al.*, 2014)**. It has been claimed that, besides clinical examination, evaluation of the maxillary sinuses is possible by panoramic radiography **(Mathew *et al.*, 2009)** and CBCT **(Bornstein *et al.*, 2014; Neugebauer *et al.*, 2014)** Though it is known that millions of sinus lift operations were performed with panoramic radiographs without any problems, especially due to the superimposition of different structures, precise assessment of a maxillary sinus finding is difficult in 2D panoramic radiography **(Shahbazian *et al.*, 2014)**. This difficulty implies that, as a clinical consequence, patients are often referred to specialists on the basis of a suspected maxillary pathology visualized on a panoramic image. This further requires a CBCT, and the question arises whether a primary CBCT should be performed in cases of maxillary sinus diagnostics instead of an initial panoramic radiography. Moreover, the inter- and intra-examiner variation in the interpretation of 2D radiographs may exceed the variation in imaging techniques and diagnostic yield **(Helminen *et al.*, 2000)** leading to a rather examiner-dependent assessment of panoramic images.

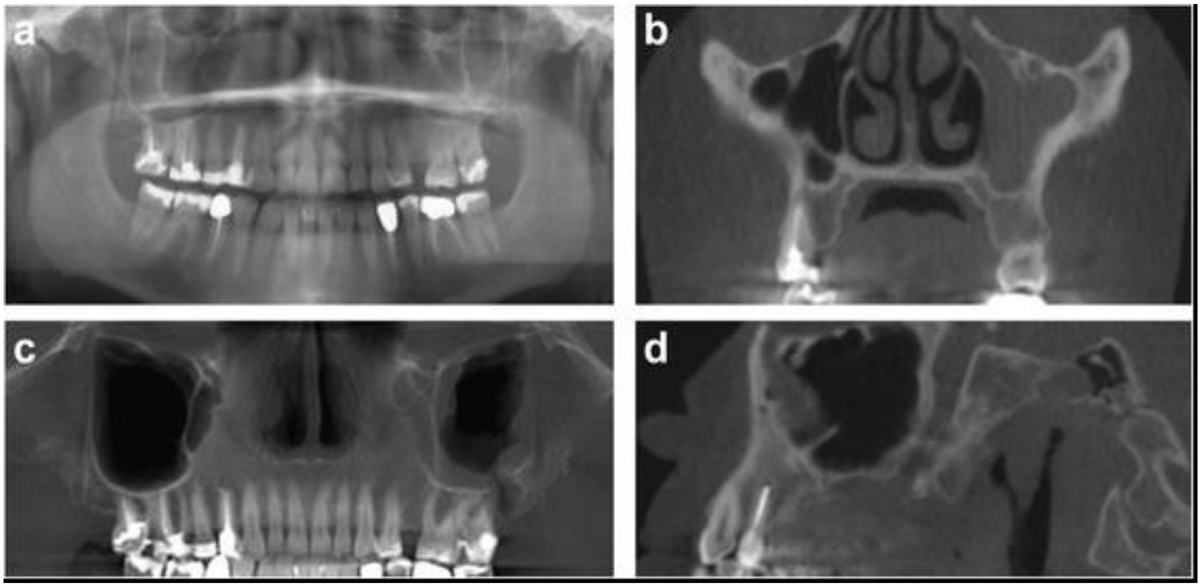

Figure 3: Radiographic findings of patient 19: oro-antral communication, basal opacity, basal septa; a panoramic radiography (Soredex, Cranex); b–d CBCT images (KaVo 3D eXam): coronal plane (b); panoramic reconstruction view (c); CBCT sagittal plane, right sinus (d).**(Malina-Altzinger et al., 2015)**

1.3 Dimensional changes of maxillary sinuses and pharyngeal airway in Class III patients undergoing bimaxillary orthognathic surgery

criteria of CLIII based on skeletal deficiency and the result illustrate the maxillary sinus area is the most important one in development of this type of malocclusion. This come in agreement with **Al-Ani *et al*.**, The mean value of male group is CLI larger than CLIII, this may be due to the inclination of maxillary plane, while mean value of female group is CL I larger than CL III with very high significant difference, additionally, there is very high significant difference between both gender, this result totally agree with **Emirzeoglu *et al*.**, and **Urabi** generally due to the fact that male exhibit higher and wider maxillary sinus than female.

For cases in which both mandible and maxilla are responsible for the Class III skeletal deformity, bimaxillary surgery is indicated.A very important aspect of the surgical correction of a skeletally Class III relationship is that it causes changes in the position of the hyoid bone and the tongue. The posterior shift of the tongue base is associated with an increase in the contact length between the soft palate and the tongue. This change appears to push the soft palate posteriorly and to decrease the pharyngeal airway space (PAS) **(Muto et *al*., 2008).** As a result of these changes in hard and soft tissues, it has been suggested **Riley *et al*.,** that mandibular setback surgery produces a shift in oropharyngeal characteristics to a morphology commonly associated with sleep-disordered breathing, typified by obstructive sleep apnea (OSA). In bimaxillary surgery during which the maxilla is advanced, in addition to mandibular setback, this effect may be less pronounced, as shown by the conflicting results among the authors.**(Chen *et al*., 2007; Degerliyurt *et al*., 2008)** It has also been noted **(Halawa, 2005)**. That maxillary impaction surgery may influence the maxillary sinus. The superior positioning of the maxilla obtained by removal of bone in the vertical direction may result in a decrease in the maxillary sinus area. The clinical implications of such a decrease in sinus area are unknown. In the past, the majority of research has measured airway and maxillary sinuses mainly in 2D ; however, these structures are 3D .The purpose of the previous study was to evaluate using CBCT the pharyngeal airway and maxillary sinus volume changes following bimaxillary surgical treatment of Class III skeletal deformities. In addition, we also aimed to determine if a correlation exists between the amount of the surgical movement of the jaws and the amount of change in the volumes of the pharyngeal airway and maxillary sinus.

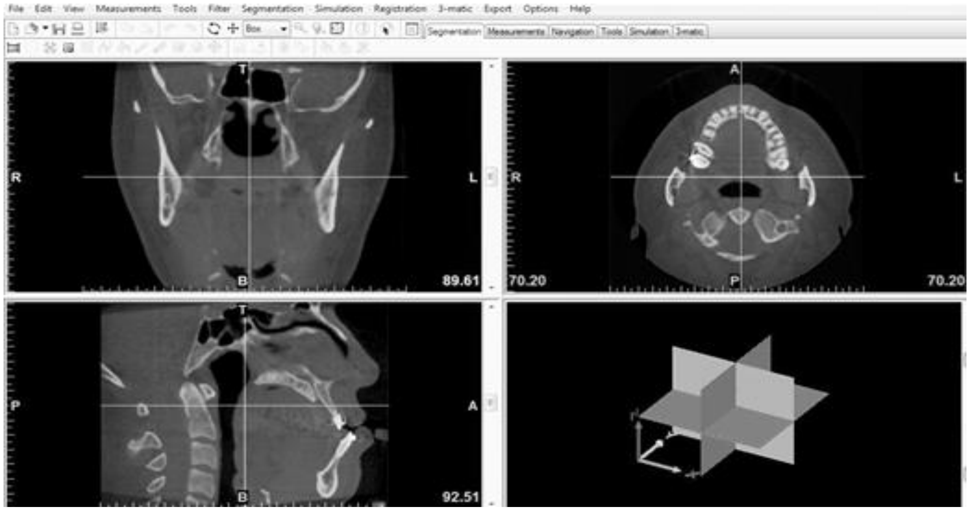

Figure 4: Image before thresholding **(Panou *et al.*, 2013).**

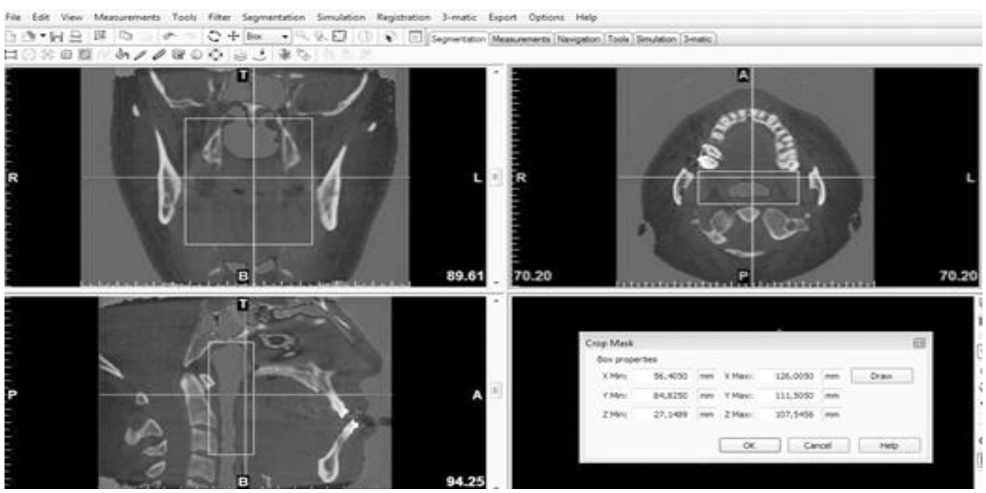

Figure 5: The pharyngeal airway, cropped. The defined borders are clearly seen in the sagittal view **(Panou *et al.*, 2013).**

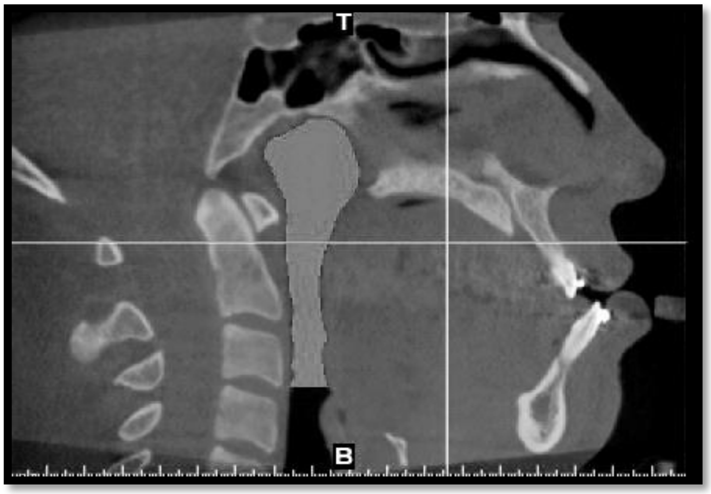

Figure 6: Sagittal view. The connections of the pharyngeal airway with the external air are removed **(Panou *et al.*, 2013).**

The structures that failed to connect with the outer airway were separated, and the 3D image of the pharyngeal airway was constructed and calculated. The 3D image of the pharyngeal airway was divided into upper and lower parts by a plane drawn from PNS to the most anterior and inferior point of the first vertebrae (Figure 7). The volumes of upper, lower, and total pharyngeal airway were calculated (Figure 7). In addition, the smallest cross-sectional airway area was measured in each CT.

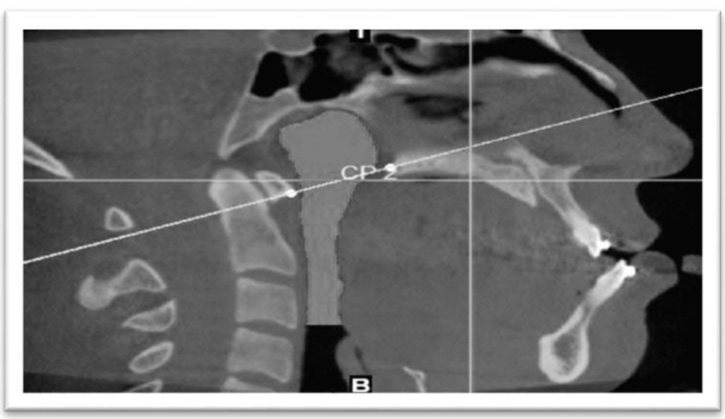

Figure 7: Sagittal view. The plane that divides the pharyngeal airway into upper and lower compartments is visible **(Panou *et al.*, 2013).**

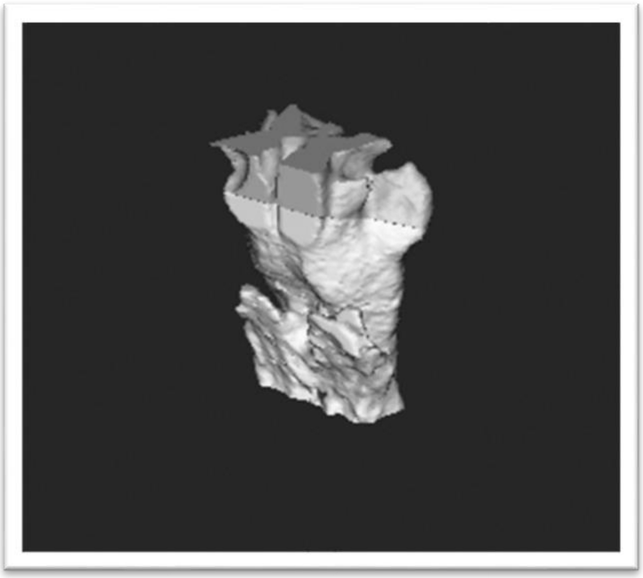

Figure 8: Three-dimensional model of the pharyngeal airway (lateral view) **(Panou *et al.*, 2013)**

For the assessment of maxillary sinus volumes the coronal image was selected. The same thresholding limits were applied as in the pharyngeal airway assessment, and the sinuses were cropped in the slice in which their widest size was apparent (Figure 9). Cropping was also done in axial and sagittal views. Any connection with the outer air was eliminated; 3D images of the left and right sinus were constructed, and their volumes were calculated (Figures 10 and 11).

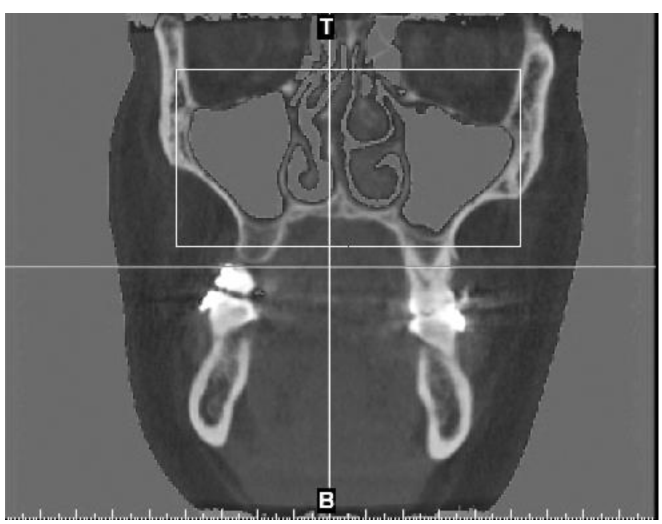

Figure 9: Maxillary sinuses, cropped **(Panou *et al.*, 2013).**

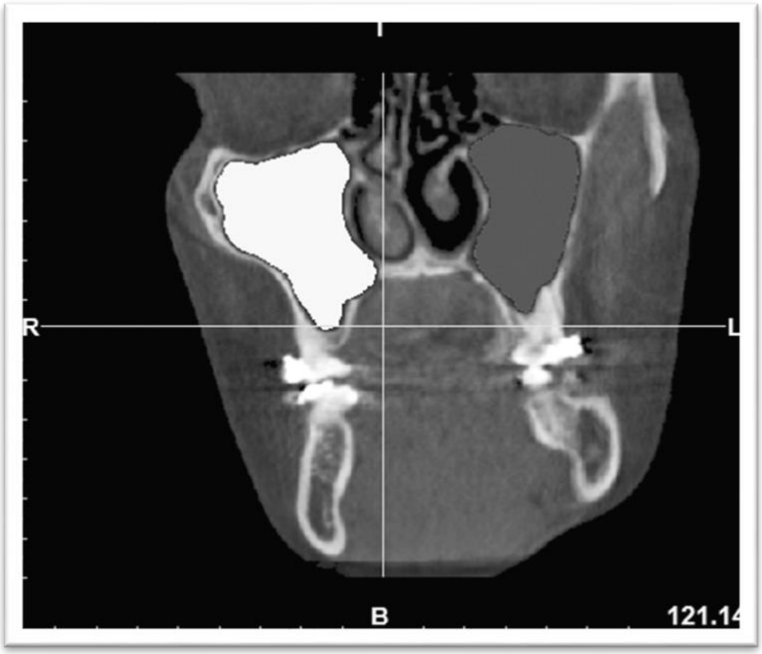

Figure 10: Maxillary sinuses, coronal view. The isolated maxillary sinuses are clearly visible **(Panou *et al.*, 2013).**

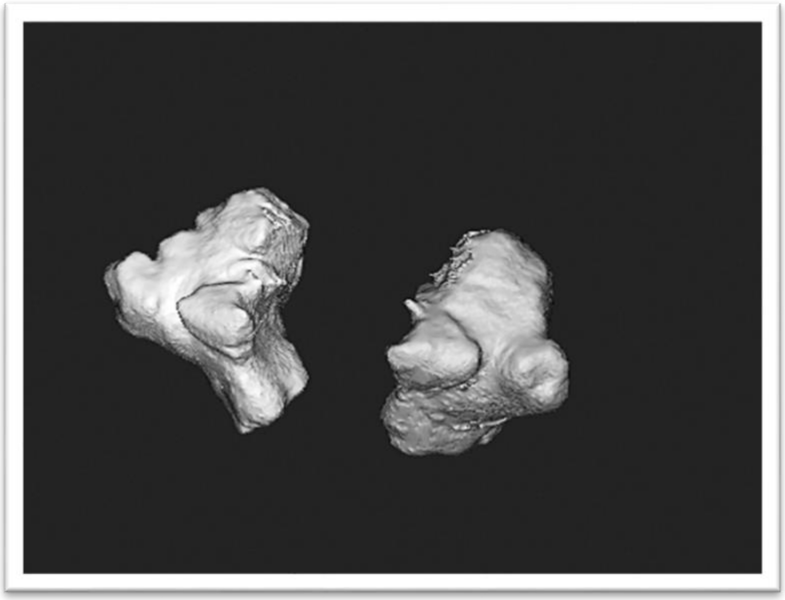

Figure 11: Three-dimensional image of the maxillary sinuses **(Panou *et al.*, 2013).**

The initial values of all the parameters related to pharyngeal and sinus dimensions were evaluated for gender differences using the Mann-Whitney U-test. There was no statistically significant difference between the two genders except for the parameters of LPA and TPA. For these parameters, preoperative and postoperative comparisons were made separately in males and females using the Wilcoxon test. For the rest of the parameters, all of the comparisons were made in the whole sample using a paired samples t-test. The amounts of mandibular setback in female and male patients were compared with the Mann-Whitney U-test as well. Pearson's correlation was used to determine if a relationship existed between the amount of the surgical movement and the volumetric changes observed between the time points. **(Panou, 2013).** The positional changes resulting from the movements of the jaws have been shown to be responsible for airway narrowing **(Katakura *et al.*, 1993)** and to be associated with sleep-related breathing disorders, such as OSA **(Riley *et al.*, 1987).**

Conversely, it has been reported that there is no decrease of the upper airway with bimaxillary correction of Class III malocclusion **(Chen *et al.*, 2007)** and that pharyngeal airway volumes are increased as a result of the surgery. In the previous study the average interval between the surgery and the second CBCT scan was 3.90 ± 0.87 months. This interval was chosen in order to avoid the postsurgical tissue swelling as well as inflammation of the tongue, uvula, and hypopharynx that may occur immediately after surgery, thereby leading to biased results. Additionally, in order to be able to assess the immediate changes induced by surgery, before any significant relapse or remodeling could occur, no scan was taken after a period of 6 months after surgery **(Gu *et al.*, 2000)**. stated that the maximum forward relapse of the (Pg) occurred mainly within 6 months after the surgery.

Most of the previous studies dealing with the influence of orthognathic surgery on pharyngeal airway and maxillary sinus volume have been conducted on lateral cephalometric film **(Chen *et al.*, 2005; Chen *et al.*, 2007)** which does not give an accurate indication of the complexity of these structures or of their true size. They chose to conduct their study using CBCT because of its advantages over the Multi-sllice-CT scans (MS-CT), the most important being their lower radiation dose, reduced artifact, and lower costs. With CBCT, it was possible to perform the scanning with the patients sitting upright, which is a benefit, since the supine position used in MS-CT imaging causes significant morphologic changes of the airway because gravity affects the soft tissues surrounding the oropharyngeal cavity. In the present study the pharyngeal airway was divided into upper and lower parts according to the method described by **Grauer *et al.*,** It has been shown that anatomically the sizes of the pharyngeal airway and maxillary sinus may differ between males and females.**(Grauer *et al.*, 2009)**. For this reason, in the present study ,Dimensional changes of maxillary sinuses and pharyngeal airway in Class III patients undergoing bimaxillary orthognathic surgery , they chose samples and evaluated initial values of the variables were compared between males and females. A statistically significant difference was found only for the parameters of lower and total pharyngeal airway. For those two variables they performed separate statistics, dividing the sample according to the gender. In an effort to find an explanation for this difference in LPA and TPA volume changes between males and females, the mean setback amounts of males and females were compared to see if the males had a significantly greater amount of setback than females. However, there was no significant difference between the setback amounts for males and females. In a CT-based study, **Degerliyurt *et al.*,** found that after bimaxillary surgery, only midsagittal anteroposterior dimensions were significantly decreased at the level of the soft palate and the base of the tongue for males and females. In the previous study , they observed a significant decrease only in the male group for the lower and total pharyngeal airway volumes. Recently, **Hong *et al.*,** conducted a study that consisted of preoperative and postoperative CBCT scans of 21 skeletal Class III patients who were assigned to either mandibular setback surgery or bimaxillary surgery. They reported that the pharyngeal airway showed significant narrowing after mandibular setback and bimaxillary surgery. However, the amount of narrowing was smaller in patients undergoing bimaxillary surgery than in patients undergoing mandibular setback surgery. They also found that the amount of change in the anteroposterior dimension and cross-sectional area on the posterior nasal spine plane and the length of the pharyngeal airway presented significant differences between the two groups. The study of **Hong *et al.*,** includes a larger group divided into two subgroups depending on the type of surgery. In this previous study, all of the patients in the group underwent bimaxillary surgery. The results of the study **Hong *et al.*,** are in agreement with the results of the male subgroup in the present study. **Halawa** studied the maxillary sinus size before and after Le Fort I impaction surgery on the basis of lateral cephalometric radiographs of 36 patients obtained before and after the surgery. Additionally, for 12 patients, lateral cephalometric films were also taken, on average 15 months after surgery. They concluded that maxillary sinus area decreased significantly by $1.69\ cm^2 \pm 1.07\ cm^2$ after surgery, followed by an increase of $0.52\ cm^2 \pm 0.53\ cm^2$ during the average postsurgical period of 15 months. The use of lateral cephalometric radiographs in **Halawa's** study results in a limitation for that investigation, since structures were being assessed by a 2D method.

Additionally, in a lateral cephalometric radiograph the left and right sinuses are superimposed, making the evaluation of the sinus dimensions more inaccurate.

1.4 Maxillary Sinus Dimensions in Skeletal Class I and class II Chinese Population with Different Vertical Skeletal Patterns: A Cone-Beam Computed Tomography Study.

In the previous study the skeletal class II population, there was no significant difference in the maxillary sinus size within different vertical skeletal patterns in the skeletal class I population. However, males tend to have larger maxillary sinuses than females. in males, it differs among different vertical patterns with an increase from low to normal to high-angle.

Jingyi *et al.*, team recently revealed that, in the skeletal class II population, the skeletal high-angle patients have statistically significantly larger maxillary sinuses than the low- and normal-angle patients in both genders **(Syverson *et al.*, 2022)** while no significant difference was found in sinus size between genders. Interestingly, it has been reported by other groups that women generally have a smaller sinus volume than men. **(Aktuna *et al.*, 2019; Maspero *et al.*, 2020).** In addition, other groups have different conclusions regarding the correlation between the vertical skeletal patterns and the maxillary sinus size. For example, **Endo *et al.*,** found that maxillary sinus length, maxillary sinus height, and total maxillary sinus area showed significant positive correlations with upper anterior facial height by evaluating the lateral cephalometric images **Ryu *et al*.,** also found that the patients with an anterior open bite have greater maxillary sinus height and more vertical pneumatization of the maxillary sinus floor in the posterior tooth root region than the patients without anterior open bite.

On the other hand, **Göymen *et al*.**, stated there was no difference in maxillary sinus sizes among patients with different vertical patterns **Kosumarl *et al.*** also did not find a significant difference in the distance from the maxillary root apices of posterior teeth to the floor of the maxillary sinus between subjects with a skeletal open bite or skeletal normal bite

However, **Oksayan *et al.*,** concluded that patients with a low-angle vertical facial pattern have larger maxillary sinus dimensions than patients with a high-angle vertical facial pattern **.** The disagreements may be due to overlooked sagittal skeletal patterns in the study designs. Nevertheless, several previous publications utilized 2D lateral cephalometric or panoramic images, which introduced systematic error during the measurement due to the overlapping of anatomic structures and built-in magnification in the 2D X-rays **(Kadioglu, *et al.*, 2019)**.

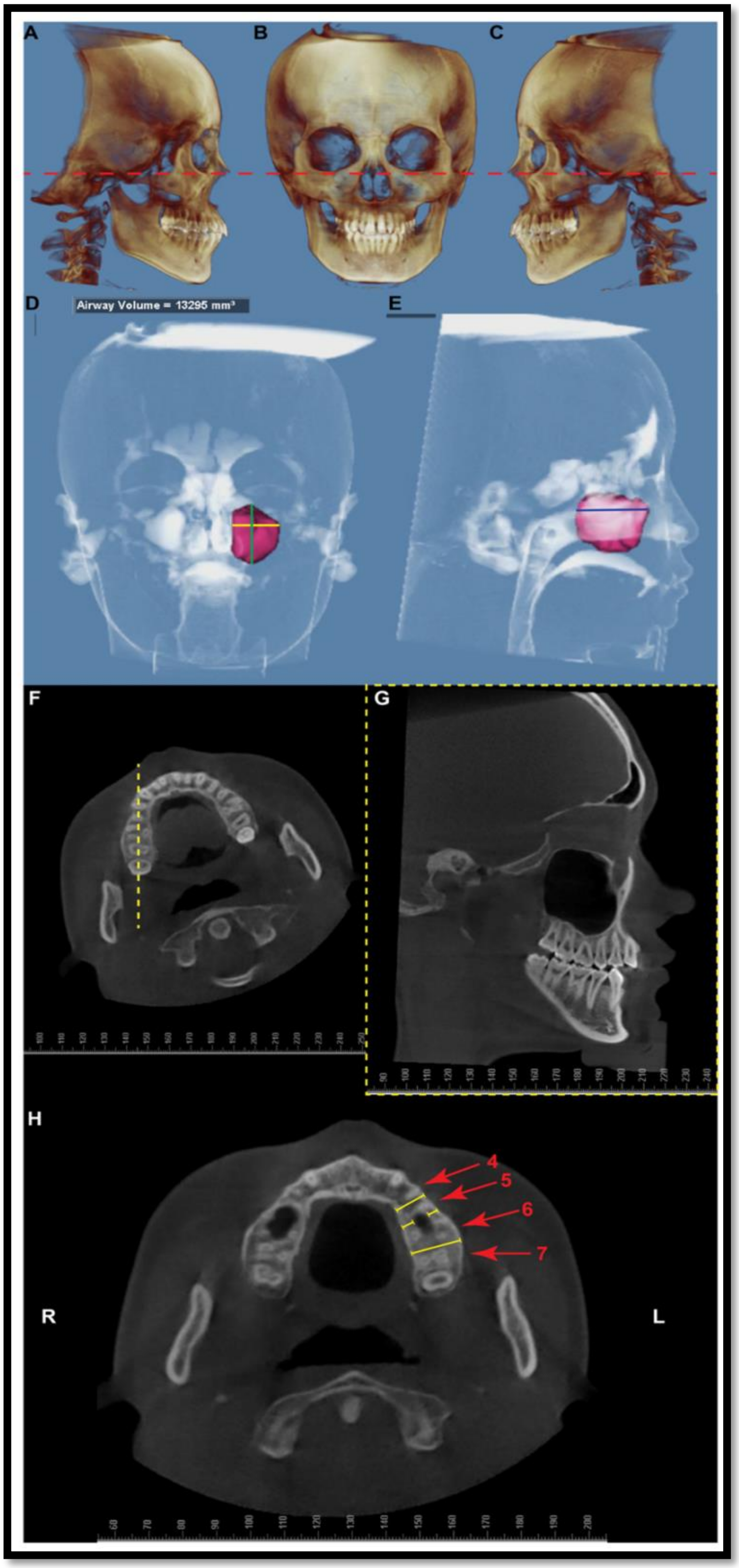

Figure 12: The CBCT image was oriented to Frankfort horizontal plane (red dash line) using

right and left porions (A, front view) and the right orbitale (B, right view), then verified on the left view (C). (D) Dolphin Software 3D airway/sinus rendering module was utilized to measure the volume of the maxillary sinuses. The sinus volume was directly reported by the software. The image showed the left maxillary sinus of this patient. The height (solid green line) and width (solid yellow line) of the maxillary sinus were measured on the front view. (E) The depth of the maxillary sinus (solid blue line) was measured on the side view. (F) The CBCT image was oriented to have the sagittal cut (yellow dash line) midway between the buccal and palatal cortices for the alveolar bone height measurement between every two posterior teeth. (G) The sagittal view generated from the orientation shown in panel F for the alveolar bone height measurement between every two posterior teeth. (H) The demography of alveolar bone thickness measurement buccally and palatally to the maxillary sinus on the left side of the patient. An axial slice of a CBCT image at the level apical to the maxillary posterior alveolar bony crest. The red numbers and arrows indicate the roots of the posterior teeth—4, first premolar; 5, second premolar; 6, first molar; 7, second molar. The alveolar bone thickness measurements on this slice were marked as yellow lines. Between the right first and second premolars, and between the first and second molars, no maxillary sinus penetration was noticed. Thus, the measurements were made from the buccal cortex to the palatal cortex in this location to represent the alveolar bone thickness—R, right side; L, left side **(Jingyi Wang *et al.*, 2022).**

Several studies have been done to relate the maxillary sinus size to the sagittal and vertical skeletal patterns, while controversial conclusions were reached in these pioneered investigations. For example, from the sagittal perspective, **Oktay *et al.***, concluded that females with class II have relatively larger sinuses while **Endo *et al.*, 2010** did not find the same tendency.

regarding the vertical patterns, **Ryu *et al.***, found that there was greater sinus height and less basal bone in subjects with open bite; however, **Kosumarl *et al.***, concluded that there was no difference in sinus height between subjects with a skeletal open bite and those with normal open bite The discrepancy could be attributed to multiple limitations, such as only using 2D imaging, small sample size, and, more importantly, not always having clear skeletal classification in both vertical and sagittal dimensions.By only focusing on the skeletal class II population, as previous study demonstrated a strong correlation between the vertical skeletal pattern and the maxillary sinus size and dimension, as well as a correlation to the amount of alveolar bone around the sinus **(Syverson *et al.*, 2022)**.

When evaluating the amount of alveolar bone around the maxillary sinus in these skeletal class I subjects, again, unlike the skeletal class II population, no significant difference was found regarding the distance between the alveolar bone crest to the sinus floor within different vertical skeletal patterns, nor on the alveolar bone thickness at the level of 5 mm from the alveolar bone crest. In addition, differences were noticed in the superior levels at 8 mm and 10 mm at the premolar regions but not posterior in the skeletal class I population. These observations are also different from those observed in the skeletal class II population, in which vertical skeletal pattern-associated differences were in the molar region instead of the anterior region. Among the skeletal class I subjects evaluated in the previous study, the different incidence of alveolar bone less than 5 mm thick in relation to skeletal vertical patterns was only observed in males but not females. However, the incidence of alveolar bone with a thickness less than 5 mm in female subjects with high-angle is lower in the skeletal class I population than the skeletal class II counterparts.

There are certain limitations of the previous study that need to be taken into consideration. Firstly, the previous study involved subjects from 15 to 40 years old. Most maxillary sinus postnatal growth happens during the first three years of life and between 7 and 12 years of age. The adult sinus size is usually reached between 12 and 15 years of age, and its development overlaps with the peak of growth in both males and females. After 18 years of age, the maxillary sinus volume usually decreases with age **(Aktuna *et al.*, 2019; Maspero *et al.*, 2020)** Therefore, in this study they picked age range representing the matured size of the maxillary.

However, the sinus size and the distance between the sinus floor and alveolar crest are dynamically changing during aging or when there is posterior tooth loss **(Jun *et al.*, 2005; Velasco-Torres *et al.*, 2017).** Thus, the findings from the previous study may not be applied to the patient with an age out of the age range used in this study.

1.5 Maxillary sinus floor extension and posterior tooth inclination in adolescent patients with Class II Division 1 malocclusion treated with maxillary first molar extractions.

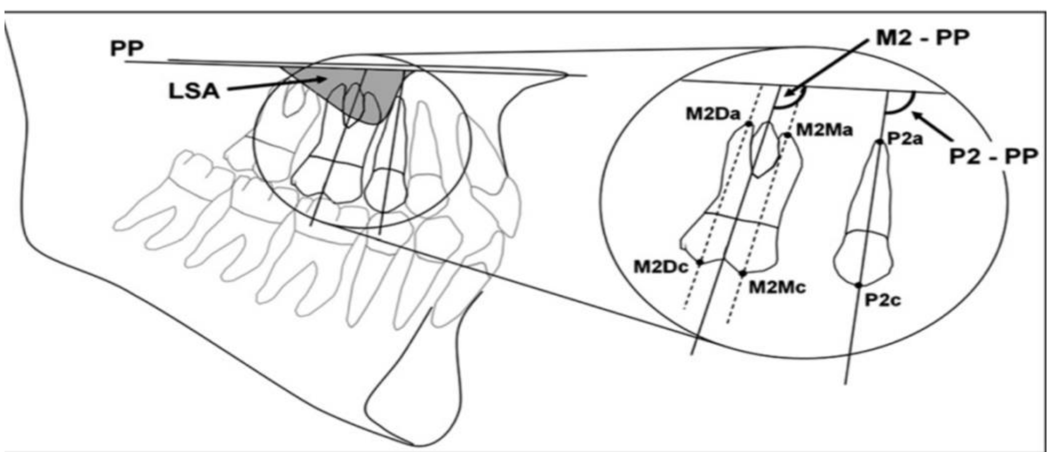

figure 13: Representation of cephalometric points and measurements (P2-PP, M2-PP, LSA) used in the study (in magnified image: M2Mc, Mesial cusp of the maxillary second molar; M2Ma, mesiobuccal root apex of the maxillary second molar; M2Dc, distal cusp of the maxillary second molar; M2Da, distobuccal root apex of the maxillary second molar; P2c, midpoint of the cusp of the maxillary second premolar; P2a, root apex of the maxillary second premolar). (This figure.13) shows the situation after treatment. During treatment with maxillary first molar extractions, it is known that a close relationship between the dental roots and the inferior wall of the sinus can impede orthodontic tooth movement **(Wehrbein *et al.*, 1990; Fuhrmann *et al.*,**

1997). Despite the increasing popularity of 3D radiographic techniques, such as computed tomography and cone-beam computed tomography in orthodontic research, the systematic use of 3D imaging for diagnostic procedures and treatment planning is still not considered standard care, and it is limited to selected clinical conditions **(Pazera *et al.*, 2011) .** On the other hand, lateral cephalograms are prescribed for most orthodontic patients on a routine basis. When this previous study was conducted, a limited number of cephalometric studies on maxillary sinuses were indexed in electronic data bases, **(Robinson *et al.*, 1982).**

by measuring the maxillary sinuses on cephalometric radiographs of patients with cleft palate and normal subjects, found no significant differences with respect to size, shape, and rate of development. Similarly, a recent cephalometric study in adolescents with different malocclusion classes reported no significant association between maxillary sinus size and sagittal skeletal jaw relationship. **(Endo *et al.*, 2010).**

However, cephalograms have inherent disadvantages for measuring 3D structures; distortion, superimposition, and differential magnification can lead to misidentification of the sinus outline and measurement errors**. (Farronato *et al.*, 2010) .** Measurement accuracy can also be compromised by volumetric differences between the right and left sides. **(Spaeth et al., 1997).** To minimize such errors, they chose to consider only the sinus outline that extended below the palatal plane. This lower sinus component is closely related to the periapical region of the maxillary posterior teeth and, therefore, was considered to be the most related to orthodontic intervention. If we had selected the total sinus area, we would not have been able to differentiate between potentially relevant area changes close to the teeth and changes at other distant locations, not related to the dentition. Statistical analysis showed no evidence of an association between sex and second premolar inclination and molar inclination. The lack of sexual dimorphism on sinus size is consistent with the results of previous cephalometric studies**. (Endo *et al.*, 2010;**

Oktay, 1992; Barghouth *et al.*, 2002). but computed tomography volumetric evaluation has shown sex-specific differences. **(JunBC *et al.*, 2007).**

Chapter Two: discussion

Several studies have been done to relate the maxillary sinus size to the sagittal and vertical skeletal patterns, while controversial conclusions were reached in these pioneered investigations. For example, from the sagittal perspective, **Oktay *et al.***, concluded that females with class II have relatively larger sinuses while **Endo *et al.*,** did not find the same tendency, and regarding the vertical patterns, **Ryu *et al.***, found that there was greater sinus height and less basal bone in subjects with open bite**.**

However, **Kosumarl *et al.*,** concluded that there was no difference in sinus height between subjects with a skeletal open bite and those with normal open bite The discrepancy could be attributed to multiple limitations, such as only using 2D imaging, small sample size, and, more importantly, not always having clear skeletal classification in both vertical and sagittal dimensions and also studying the maxillary sinus is of great value to orthodontist. This is due to its close proximity to the teeth in the upper arch in a way that the upper alveolar process forms its lower border. Many studies were conducted to show the relationship between the maxillary sinus and different orthodontic applications. It was found that some of orthodontic treatment modalities affect the volume of the maxillary sinus such as rapid maxillary expansion, Orthognathic surgery, Uprighting upper molars and traction of deeply impacted canines increase the volume of the maxillary sinus **(Ozbilen *et al.*, 2019; Faur *et al.*, 2019).**

Another relation between the maxillary sinus and orthodontic treatment is that when moving teeth through the sinus. When moving teeth through the maxillary sinus there was increase in the risk of root resorption and undesired tipping also treatment time was prolonged **(Sun *et al.*, 2018; Cha *et al.*, 2020).**

Chapter Three

3.1 Conclusion

1- From this study it was concluded that there is no correlation between the maxillary sinus volume and the vertical growth pattern. Also, that the right and left maxillary sinuses are corresponding to each other in volume.

2- A recent cephalometric study in adolescents with different malocclusion classes reported no significant association between maxillary sinus size and sagittal skeletal jaw relationship and for the skeletal class II and skeletal class I there was no significant difference in the maxillary sinus volume within different vertical skeletal patterns . The skeletal class II high angle patients have significantly larger maxillary sinuses than the low and normal angle patients Also for the class III patient found that the Class I has largest sinus than class III due to the inclination of maxillary plane, for the male and female group with high significant difference.

3- The both genders have no significant difference found in sinus size. Interestingly, it has been reported by other groups that women generally have a smaller sinus volume than men .

3.2 Suggestions

1. Dimension of Maxillary sinus in cleft lip and palate patient.
2. Tooth movement through the maxillary sinus.
3. The effect of the maxillary expansion treatment on maxillary sinus volume.

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