Volumetric Changes of Maxillary Sinus Post Augmentation using CBCT

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DECLARATION

I declare that *Volumetric Changes of Maxillary Sinus Post Augmentation using CBCT* is my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Tineke van Zyl :

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DEDICATION:

This thesis is dedicated to:

My wonderful and supportive parents over all my years of studying, my kind-hearted mother, Karien and my gentle giant of a father, Fanie.

To my big brother, Stephan, for always listening to me and giving me advice wherever he can, even if he is more than 10 000kms away.

I love you all very much and thank you for everything!

ABSTRACT:

Aim:

To measure the changes induced by maxillary sinus augmentation surgery by retrospective analysis of 3D virtual models of the maxillary sinus air volumes.

Background:

By evaluating the air volume of the maxillary sinus pre-operatively (Reading 1 – V1) and postoperatively, 3-6 months later (Reading 2 – V2) the changes using different augmentation materials will be ascertained. Additionally, the difference between maxillary sinus air volumes using Cone Beam Computed Tomography CBCT between readings 1 (V1) and 2 (V2) will be determined (preoperatively and postoperatively) and lastly the relationship between CBCT reading at V1 and V2 according to age and gender will be determined.

Materials and methods:

Twenty-five observations were selected for this cohort study. The results for reading 1 (V1) were recorded. Reading 2 (V2) was obtained 3-6 months later and compared to reading 1 (V1) on the same spreadsheet.

Results:

A two-way Anova test showed no difference between age and gender with either pre- or post-operative sinus augmentation.
Further investigation made use of two models with both still having a statistically insignificant result. A Qualitative comparison was also made after the mean difference

had been calculated between the different materials used and the air volume of the maxillary sinuses.

Conclusion:

The study resulted in a demographically no statistically significance difference for determining a volumetric change of air in the sinus, pre- and post -augmentation.
The volumes compared using CBCT and a software showed that there were sinus changes in air volume and in bone volume, thus if bone volume increase, air volume decrease, irrespective of the type of bone graft used.
Literature suggests that there are some parameters and limitations that can have an effect on the air volume changes of the maxillary sinus in using different augmentation materials.

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KEYWORDS:

Maxillary sinus

Sinus Augmentation

Bone grafting materials

CBCT

Airway

LIST OF ABBREVIATIONS:

CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
SCC	Squamous Cell Carcinoma
RF	Radio frequency
T	Tesla
TMJ	Temporomandibular Joint

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Data sheet: Volumetric changes of Maxillary Sinus Post Augmentation using CBCT

CHAPTER ONE: INTRODUCTION

Replacing a missing tooth is vital in restoring form and function to the human dentition. Implant prosthesis procedures are a fast growing and rapidly progressing field in dentistry. The planning of this procedure is important for the success of the prosthesis and depends on the quality of bone, bone volume in three dimensions and imaging to allow avoidance of anatomically structures.

In the posterior maxilla, the maxillary antrum is anatomically positioned superior to the alveolar ridge. In the event of permanent tooth loss, there is often a downwardly directed pneumatization of the maxillary sinus. Pneumatization is the process of growth and expansion of an air filled structure in bone and is mostly due to tooth loss as a result of the alteration of bone architecture; inflammation and abnormal pathology.

In the last two decades, sinus augmentation has been used preoperatively to prepare sites for subsequent dental implant placement in the posterior maxilla.

Maxillary sinus floor augmentation was introduced in the late 1980's with the use of autogenous bone for the increasing vertical bone height. In 1986, Tatum considered the preparation of a trap door to access the Schneiderian membrane in the lateral wall of the sinus. This area of space created between the membrane and sinus wall was then filled with bone substitute, autogenous bone or a mixture of these for future dental implant treatment (Rickert *et al*. 2011).

1.1. Sinus graft material

An important factor for implant success depends on sinus graft height. These include the categories of bone substitute used by surgeons and include xenogenic grafts (from other species), allogenic grafts (from same species) and alloplastic grafts (synthetic materials).

With regard to evaluation of the effect of graft material and the volume used of new bone, no correlation was found between the volume of bone created in the sinus floor, and the volume of bone grafting material used for sinus augmentation (Bensaha *et al*. 2016).

Therefore special imaging modalities are needed for the assessment of height quality and volume of newly regenerated bone.

1.2. Radiographic examination

It is essential to assess the amount of bone available prior to deciding sinus augmentation treatment. In the past, two-dimensional imaging, notably panoramic radiographs, could not evaluate the bone volume at the augmented site, thus three dimensional, Cone Beam Computed Tomography (CBCT), was introduced.

If we look back at the early radiographic examinations, they made use of panoramic radiographs that served to quantify vertical alterations of any grafted materials, however, no volumetric investigations could be obtained (Dellavia *et al*. 2013). Panoramic images have magnification whereas CBCT is what you see is what you get, thus dimensionally accurate. Therefore CBCT is proposed for providing the most accurate results of volumetric changes in sinus augmentation, either pre operatively or post operatively (Urooge, 2017).

Analysis of the graft material on CBCT is quite difficult and is only a subjective assessment from the point of the interpreter. In some cases the use of screws and mesh frameworks cause metal artifacts and beam hardening and this can obscure the detailed examination of the augmentation site and material. In an attempt to overcome this, the author considered looking at air volume changes instead of the osseous changes. One wants to know if the volume of air in the antrum is significantly altered post sinus augmentation.

This study served to ascertain volumetric changes before and after sinus augmentation and the importance of using appropriate imaging modalities whilst investigating if demographics made any difference.

CHAPTER TWO: LITERATURE REVIEW

One of the conundrums in modern dentistry as the consequence of tooth loss is the change seen in the alveolar bone. This is also evident in the maxillary bone, where the maxillary sinus floor migrates inferiorly in an apparent size increase due to maxillary molar tooth loss. Bone and alveolar resorption continue after maxillary posterior tooth extractions, leaving only a thin wall of bone between the maxillary sinus and the oral cavity (Tatum, 1986).

Aldelaimi et al, 2016 discussed that the most common finding of pneumatization of the maxillary sinus is secondary to posterior maxillary tooth loss. Due to this phenomenon, an atrophic maxillary alveolar process prevents implant placement. Therefore sinus augmentation has been used for several decades to enhance sites for dental implant placement.

Sinus floor augmentation was first introduced by Boyne, James and Tatum using autogenous bone for increasing the vertical bone height to aid in implant insertions (Rickert *et al*, 2011).

With the trans-alveolar and lateral antrostomy approaches, which are the main techniques for increasing vertical bone height at the posterior maxilla, the success rates have been high, but any clinician must be aware of potential complications and how to manage them (Jensen *et al*. 2012)

Furthermore, Tatum suggested that the treatment process for augmentation of the maxillary sinus floor includes the preparation of a trap door, the Schneiderian membrane, in the lateral sinus wall, by using a lateral approach. This was then followed by filling the space created between the lifted trap and sinus mucosa with either: autogenous bone, bone substitute, or a mixture of these materials (Tatum, 1986; Rickert *et al*, 2011).

While autogenous bone grafts are still considered the gold standard of treatment today in sinus augmentation with regards to bone regeneration, some ‘problems’ have been documented using a type of autologous bone grafts. These include blood loss, pain, infection in the donor site and morbidity. Consequently the choice of bone substitutes like xenogenic grafts, allogenic grafts and alloplastic grafts were made available for clinicians. They all share positive outcomes and are readily available (Ueda *et al.* 2001)

The following findings also add to a growing body in the literature:

- Volumetric changes of the maxillary sinus after sinus lift procedure
- Changes in maxillary sinus observed on radiographs following augmentation
- Parameters influencing graft resorption
- Different materials used for bone augmentation.

2.1 Maxillary sinus volumetric changes after sinus lift procedure

The success of a sinus lift procedure is measured by the increased volumetric changes in the bone as well as the sinus airway. Measuring the volume of these materials and quantifying the amount of material remaining after given periods, has been the focus of previous studies (Johansson *et al*. 2001).

The study has promoted six-month clinical measurements of the volumetric changes together with the volume of bone grafts in the atrophic maxilla. Only ten severely atrophic edentulous maxillary patients received autogenous bone as well as bilaterally particulate bone grafts to the maxillary sinus.

The volumetric changes were then captured using 2mm contiguous axial Computed Tomography (CT) scans after one to two weeks and again six to seven months postoperatively. After six months, the two different methods seemed similar in both the buccal onlay and the sinus inlay grafts. However, the above small study sample required further investigation (Johansson *et al*. 2001)

In a more comprehensive six year study using medical CT, an evaluation of the volume changes of autogenous post sinus lifting and grafting was performed (Sbordone *et al*. 2013). The evaluation of long-term bone remodeling of autografts was recorded annually to compare the block and particulate bone procedures for sinus floor elevation; and the survival of positioned dental implants (Sbordone *et al*. 2013). To compare and evaluate the volume and density of inlay grafts over time, pre and post CT scans, using a software program was also used. The conclusion of this study showed that the bone block underwent a negative remodeling of volume and an increase in density in the spongious area during the initial healing period. The autogenous bone block procedures resulted in. resorption of 21.5%, whereas sinus grafts produced 39.2% bone resorption (Sbordone *et al*. 2013).

2.2 Maxillary sinus augmentation changes observed on radiographs

Panoramic radiographs were proposed to quantify vertical alterations of the grafted materials; however, no volumetric investigations could be obtained from the analysis of two-dimensional data. In addition, magnification and/or distortion of images that do occur even in perfectly positioned panoramics or those caused by operator error (Dellavia *et al*. 2013).

In 2008, Kirmeier *et al* stated that panoramic radiographs should not be the only radiographic tool and proposed using medical CT. They assessed the sinuses pre operatively, two weeks post operative and again six months post operative. They found a significant reduction in the volume of bone augmented after six months. The grafted bone could be clearly distinguished from the original bone by assessing the density and structure on 1mm CT slices. The dose consideration for repeated CT scans should warrant a substitution for CBCT that has markedly lower radiation dosages (Kirmeier *et al*. 2008).

The radiographic gold standard for the maxillary sinus by ear, nose and throat (ENT) specialists is thus a multi-slice CT. However, with the CBCT available for more than a decade, it is understood that CBCT has several advantages over medical CT scans (Vogiatzi *et al*. 2014).

Panoramic radiography has little use for volumetric assessment, as only two-dimensional images are produced (Gray *et al*, 2000). Therefore panoramic radiography cannot be eliminated in cases where the number of uncomplicated implants is considerably low (Georgescu *et al*. 2010). Panoramic imaging also has limitations in the assessment of the implant site and any identifying pathology in the maxillary sinus, because it cannot display the three dimensional architecture (Mohan *et al*. 2011).

Three-dimensional modalities are simply superior in detecting changes in the maxillary sinus pre- and postoperative sinus augmentation (Neugebauer *et al*. 2011). Thus they have become more important for assessment of the jaws and include radiographic imaging like Computed tomography (CT) and Cone Bean Computed Tomography (CBCT).

2.2.1 Sinus augmentation changes pre, immediately after and post augmentation radiographically evaluated:

A large number of studies have been undertaken to assess the efficacy of a bio-absorbable membrane, a three-dimensional volumetric analysis after sinus grafts, using cone beam computed tomography (CBCT) to protect the sinus membranes and guide bone regeneration has been proposed by Kim Moon *et al* (2013). In their study CBCT scans were performed before, immediately after surgery, six months after surgery and one year after surgery. Thus the average volume of graft material remaining six months after placement and one year, no difference were found among these materials. While only slight differences among the data indicating volumetric CBCT analysis were observed. The authors concluded that there was no significant relationship between the resorption of grafted bone and the success rate were noted.

There have been a number of longitudinal studies involving the evaluation of CT images to compare bone grafting resorption in the maxilla and the particulate bone (case) to bone blocks (control). Dasmeh et al treated with iliac bone grafts and maxillary oral implants, followed by CT scans directly post grafting and after two years. The volumetric changes after six months were extensive, as were the changes in the particulate bone, which tends to be larger after just two years, than that of block bone. Their conclusion was that despite extensive graft resorption, radiographically complete integration and embedding of implants installed in the bone occurred. Therefore the amount of volumetric reduction between particulate bone and block bone grafts showed no significant difference (Dasmeh *et al*. 2011).

A new method to evaluate volumetric changes in sinus augmentation procedure, in clinical practice as well as in dental research, together with evaluating the filling material features was proposed (Dellavia *et al*. 2013). A study was done by evaluating Maxillary CBCT at one week and then at six months postoperatively. The calculated augmented sinus volume on the CBCT data was replicable in the standardized and automatic masks-based methods. Therefore the proposed computation procedure was effective for both expert and non-expert operators. They concluded that their technique could be applied in both clinical and research settings (Dellavia *et al*. 2013).

2.3 Parameters influencing maxillary sinus graft resorption

Few studies were available providing parameters influencing the resorption after maxillary sinus augmentation until Klijn et al in 2011 conducted a study with three-dimensional analysis of the ridge dimensions and the bone graft volume changes in the atrophic posterior maxilla, using CBCT imaging. Ridge dimensions were assessed before the maxillary sinus augmentation, whereas bone graft volumes were compared after maxillary sinus floor augmentation surgery with a graft interval of several months. These researchers used multi-variate extension of linear regression including independent variables, such as patient, gender, age, alveolar crest height and width, and graft time interval to analyze the relationship between changes in bone volume.

They concluded that resorption thus occurred when autologous bone grafts for maxillary sinus augmentation were used (Klijn *et al*. 2011).

An analysis of surgical procedures of maxillary sinus lift was done to assess the influence of different grafts used in maxillary sinus lift. Most of their subjects had different grafting materials, including fresh, frozen allogenic particulated bone; hydroxy apetite (Endobon®); Bone Ceramic (60% hydroxyapatite and 40% beta-tricalcium phosphate); and Bone Ceramic and Emdogain®. No correlation between dimensional changes and the total maxillary sinus volume. They concluded that insufficient evidence was found to support the suggestion that the maxillary sinus volume influences graft contraction (Favato *et al*. 2014).

More recent literature in gender comparison of about 100 patients' (50% male and 50% female) measuring maxillary sinus length, height, area, volume and perimeter were not statistically significant for the differences of both males and females, using CBCT. CBCT imaging is characterized by rapid volumetric image acquisition with high resolution, low dose and precise information about complex anatomical structures provides accurate results (Urooge, 2017).

The criteria for the success of maxillary sinus augmentation showed some limitations, such as small patient population and variance in statistical analysis (Fuggazzotto *et al*. 1998). The differentiation between a surviving implant and a successful implant has been demonstrated in only a limited number of reports. Many of these studies were done in a controlled environment, with a selected number of clinicians performing surgical, restorative and maintenance procedures. The results of such ideal therapeutic conditions are not necessarily transferable to the clinical milieu of the everyday practitioner (Fuggazzotto *et al*. 1998).

2.4 Different materials used for bone augmentation

The most commonly used xenograft that was introduced in 1995 for sinus lift is Deproteinized Bovine Bone Mineral (DBBM). It can be either used alone or with autogenous bone or Platelet Rich Plasma (PRP). Allogenic grafts, which are derived from the same-species donors, Demineralized Freeze-Dried Bone (DFDB) and Fresh-Frozen Bone (FFB) are also used. Allogenic are regarded as the best-documented graft materials for sinus augmentation. Alloplastic grafts on the other hand consist of synthetic biocompatible materials such as hydroxyapatite (HA), tricalcium phosphate (TCP) or bioactive glasses (Sehn *et al*. 2015).

Suprastructure survival, including implant placement after maxillary sinus augmentation procedures can be obtained using different materials. Hatano et al assessed the radiographic evaluations of graft height changes after maxillary sinus floor augmentation with a 2:1 autogenous bone/xenograft (Bio-Oss®) mixture and simultaneous placement of dental implants.

Implant length, original sinus height and the changes in sinus-graft height were calculated and divided into three groups:

1. Grafted sinus floor above implant apex
2. Implant apex level with grafted sinus floor
3. Grafted sinus floor below implant apex

Within 3 years after augmentation, all implant losses were documented with the clinical survival rate of implants at 94.2%.

Hatano et al reported that an important factor for the success of implants and long term stability of sinus-graft is the height and progressive sinus pneumatization after augmentation, with a recommended 2:1 autogenous bone/xenograft mixture needed.

Another study (Zizelman et al), compared bone formation after sinus augmentation. Engineered bone was used to assess volume measurements with autogenous bone grafts from iliac crest to compare commercially produced transplants of human cells. Autologous transplants showed a minimal resorption rate, whilst tissue engineered bone had a resorption rate of 90%, only three months post operatively. These authors concluded that autologous cancellous bone grafts in sinus augmentation therefore are more reliable than that of cultured osteoblasts.

Autographs are reported to be the popular treatment of choice, due to the consistency of osteogenic, osteoinductive and osteoconductive properties, which are all extremely rich in growth factors (Rickert *et al*, 2011).

When there is insufficient bone to place osseo-integrated dental implants in the posterior maxilla, a sinus lift procedure is preformed to increase vertical bone height. Various materials have been used, including bone substitutes obtained from numerous sources. For successful implant placement, the surgeon must know the volume of bone graft needed to obtain the correct implant site bone volume following sinus augmentation (Gray *et al*. 2000).

Further prospective studies have been suggested to evaluate the quantitative changes of different bone graft materials, age and gender for maxillary sinus augmentation procedures to improve long-term implant stability. Investigation of the current protocol of criteria used to evaluate successful sinus augmentation prior to implant placement in posterior maxillary region is advised (Kirmeier *et al*, 2008).

CHAPTER THREE: RESEARCH AND METHODOLOGY

3.1 Aim

The aim of this study is to analyze 3D virtual models of the maxillary sinus air volumes and to measure the changes induced by maxillary sinus augmentation surgery.

3.2 Objectives

All patients selected for the study had already received treatment and no radiographs were exposed for the purpose of this study.
The objectives of the study are to:

- evaluate air volume of the maxillary sinus at pre-operative (Reading 1-V1) and postoperative 3-6 months later (Reading 2-V2)
- measure the air volume changes of the different material used for the bone augmentation procedure
- determine the difference between maxillary sinus air volumes using CBCT between readings 1 (V1) and 2 (V2) (preoperatively and postoperatively)
- determine if there is a relationship between CBCT reading at V1 and V2 according to age and gender

3.3 Study design

This was an historical cohort study.

3.4 Study sample

Records of all sinus augmentation procedure patients in the Oral Health Clinic, referred or residential (location) and inpatient or outpatient (level of care) were assessed for implant placement. The main inclusion criteria were that the CBCT examinations were completed and available for review.

An appropriate sample size of 25 was deemed required, however this sample size was unobtainable within the study duration at the primary collection site requiring the remainder to be drawn from private practitioners affiliated with the University. The same consent, ethics and information was relayed personally to the patient, via the researcher. Sample cases met the following inclusion and exclusion criteria:

3.4.1 Inclusion criteria

All selected subjects in the sample were required to have had a:

- pre-operative CBCT for implant planning and a postoperative CBCT before the end of July 2018, with a 3-6 months interval between pre and post operative scans.
- complete sinus anatomy captured in the FOV (field of view).

3.4.2 Exclusion criteria

All selected subjects in the sample with:

- previous sinus surgery
- changes in the sinus unrelated to pathology, infection or trauma
- a medical history of bleeding disorders, immune-compromising conditions, bone disorders, pregnancy, malignancies, radiation, chemotherapy, or diabetes
- an age under 18 years old

3.5 Ethical clearance

Permission was obtained from the Dean and the relevant Heads of departments to analyze the records of all sinus augmentation cases treated from 2010. A list of planned implant cases to be treated have been compiled and documented, while also assigning numbers to the patients. This corresponding number has been kept by the chief researcher (in a secure location via password protected PC.) The postoperative CBCT volumes (reading 2) were assessed again, using the corresponding number and same side. Anonymity was maintained at all times and only numbers were conveyed when transferring data.

No additional scans were required for this study other than the normal evaluation for prosthetic treatment, i.e. one scan preoperatively and the final scan 3/6 months post-operatively. All reconstructed studies were deleted at the end of the study.

Ethics approval for this study were obtained from the University of the Western Cape's Biomedical Research Ethics Committee (BMREC).

No personal information of any patient has been recorded or divulged in this study.

No conflict of interest was declared.

3.6 Data collection

All records from 2010 until July 2018 were utilized

First reading and second readings:

The records of all sinus augmentation procedures done were evaluated. Over 200 observations that met the inclusion/exclusion criteria were categorized and evaluated for baseline volumetric measurements of the right/left maxillary sinus.

All readings for the study were obtained from the following CBCT machines and corresponding software:

- NewTom® with NNT® software (version-8)
- Carestream® (Kodak) with Carestream® Image/Utility viewer program.

25 observations were identified for the study and the cases were anonymously numbered and the corresponding volumetric measurement of the right/left or both sinuses was recorded.

3.6.1 Details of image acquisition:

3D CBCT Modalities used included:

- Carestream® (Kodak) CS 9300 with Carestream® Image/Utility viewer program were used to evaluate axial, sagittal and coronal views of maxillary sinuses. Sensor type TFT Scan mode with continuous and pulse Scanning time of 12-28 seconds (+/- 10%) and Voxel size (µm) 90 to 500 depending on the area needed for reconstruction of images.

Field of view (cm) 5x5 and 17x13.5 subsequently, were used for pre operatively and post operatively acquisition, depending on the observation needed. Reconstruction time were less than 2 minutes based on the recommended computer system configuration requirements.

X-Ray Generator and Other Specifications:

Tube voltage 60 - 90 kV

Tube current 2 - 15 mA

Frequency 140 kHz

Tube focal spot 0.7 mm (IEC 60336)

Input voltage (AC) 110/110/130V – 50/60Hz

- Newtom® VGI®, Verona, Italy was also used to evaluate full field-of-view (Full mode) scans (15 x 15 cm). Tube voltage and current was captured at 110 kV and 3-7 mAs, Time/X-ray emission time: 18s/3.6s. The reconstructed data was analyzed with a voxel size of 0.30 mm^3.

The observations were converted to Digital Imaging and Communication in Medicine (DICOM) format. The DICOM files were analyzed into a three-dimensional image by multiplanar reformatting (MPR) and volume rendering using imaging software (OnDemand 3D® software version1.0 (build 1.0.10.751), Cybermed Inc, South Korea.

These converted DICOM files were then stored on a hard drive system, which was converted into a computer software that were used for data capturing under a specific folder.

The computer specifications used were (Thinkcenter ® M73 Desktop Intel (R) Core ® i5-4590 CPU @ 3.30 Ghz, (4CPU's), 8139 physical RAM). The usage of two monitors include; the first monitor was Philips Brilliance MNS 1190T [(aspect ratio: 5:4, screen size: 19inch, display type: LCD – TFT active matrix, native resolution: 1280 x 1024 at 60 Hz, contrast ratio – 800:1/25000:1 (dynamic), color support: 24 bit (16.7 million colors)]. The second monitor was the Philips® UltraClear 4K UHD (BDM435OUC)[(LCD panel type: IPS LCD, aspect ratio: 16:9, optimum resolution: 3840 x 2160 @ 60 Hz, brightness: 300 cd/m^2, contrast ratio (typical) - 1200:1, display colors: colour support – 1.07 billion colors (10 bit)].

To obtain the data for the volumetric changes of the maxillary sinus, pre and post operative, the following was done:

Reading one (V1):

The data collection involved the following steps:

- Preoperative scans were viewed by opening the specific CBCT volume in the dedicated software of the CBCT machine to analyze the maxillary sinus
- The maxilla were viewed with one or both sinuses in full view and included the areas of bone augmentation treatment
- This reconstructed study saved in DICOM (Digital Imaging and Communications in Medicine) format, transferred to a software package (OnDemand3D®), which was used to assess the sinus volume.
- While in OnDemand3D®, the icon 3D was chosen, then the Profile icon were used that allowed measurement of the intensity of the sinus from a superior to inferior aspect
- The intensity were then displayed on a graph (Fig. 1) with a y-axis and x-axis in distance (mm), and were then configured in the minimum and maximum densities of the area interested
- With this minimum and maximum densities, the icon 3D picker, under segmentation were chosen
- This threshold then allowed one to change the upper and lower densities obtained previously, but for action to take place, the start function was pressed
- Saved as a new object under the mask operation icon
- The next step involved the fine tuning bar

- The operator had already an object 1 (standard), next an object 2, that were created, where the threshold procedure was used
- The operator then chose the colors icon above and pressed on Independent Opacity icon
- Next step involved the color gradient on the top, a right click was indicated which allowed the deletion of all colors with the result only one color was left
- The window was maximized for better sight
- With the hand tool, the gradient scale was dragged to minimize the gray scale to +- 650 for exclusion of soft tissue and inclusion of air
- The sinuses appeared hyper intense on 3D slice
- Under segmentation icon, the 3D picker were used, sculpted and smartpen was selected
- The action was then to remove/cut out any unwanted areas so that just the sinus, either left or right were visible for total volume measurement
- This third-party software allowed the user to identify the airspace and then merged the entire airspace with similar relative density to give a volume reading (reading one)

Reading two (V2):

The data obtained involved:

- Postoperative scans 3 - 6 months after augmentation that were evaluated by opening the specific CBCT volume in the dedicated CBCT machine software to analyze the maxillary sinus (as per reading one)
- The same right/left or both maxillary sinuses previously evaluated were included in the area(s) of bone augmentation treatment
- The reconstructed study were converted and saved in DICOM format and transferred to the same software package (OnDemand3D®) as in reading one.
- Under the icon 3D, the Profile icon allowed you to measure the intensity of the sinus from a superior to inferior aspect
- The intensity was then showed on a graph of y-axis and x-axis in distance (mm),

which were configured in the minimum and maximum densities

- With this minimum and maximum densities the icon 3D picker under segmentation were chosen
- The threshold then allowed you to change the upper and lower densities obtained previously, for action to take place, start was selected
- This was then saved as a new object under the mask operation icon
- The next step involved the fine tuning bar
- The operator had an object 1 and an object 2, which were made using the threshold procedure
- Then clicked on the colors above and selected on Independent Opacity icon
- Next step involved the color gradient on the top, a right click were performed and thus deleted all the colors, with the outcome of all is white
- The window was maximized for better sight
- With the hand tool, the gradient scale were dragged to minimize the gray scale to +- 650 for exclusion of soft tissue
- The sinuses appeared hyper intense on 3D slice
- Under segmentation icon, the 3D picker were used, sculpted and smartpen were chosen
- The action was then to remove/cut out any unwanted areas so that just the sinus, either left or right were visible for total volume measurement
- This third party software allowed the user to identify the airspace, so the entire airspace with similar relative density was merged to give a volume reading (reading two).
- These new volumetric measurements (of the corresponding right/left or both sinuses) was recorded

3.7 Examples of the measurements carried out

The images below indicate the way we determine the volume on the maxillary sinus with the OnDemand3D® software system.

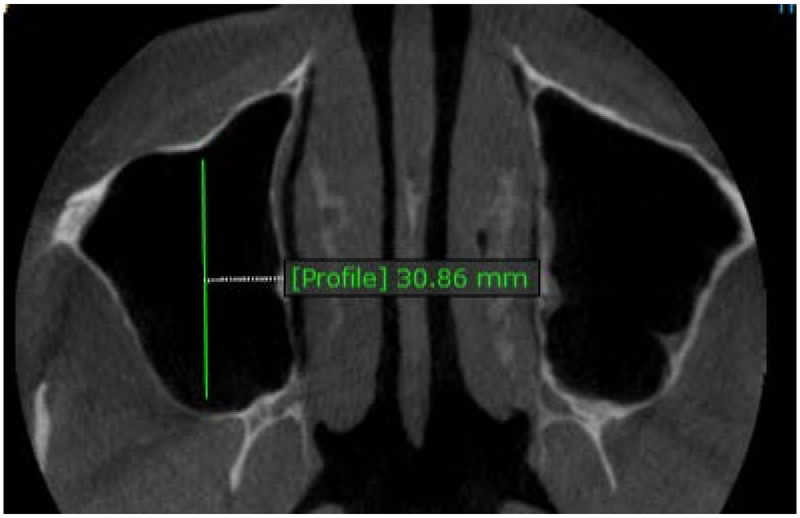

Figure 1. Profile picker tool

After each observation, Dicom files were converted into the software database of 3-D demand; and a profile picker tool (Fig 1) was used to measure the internal density of left- or right-hand side of the maxillary sinus.

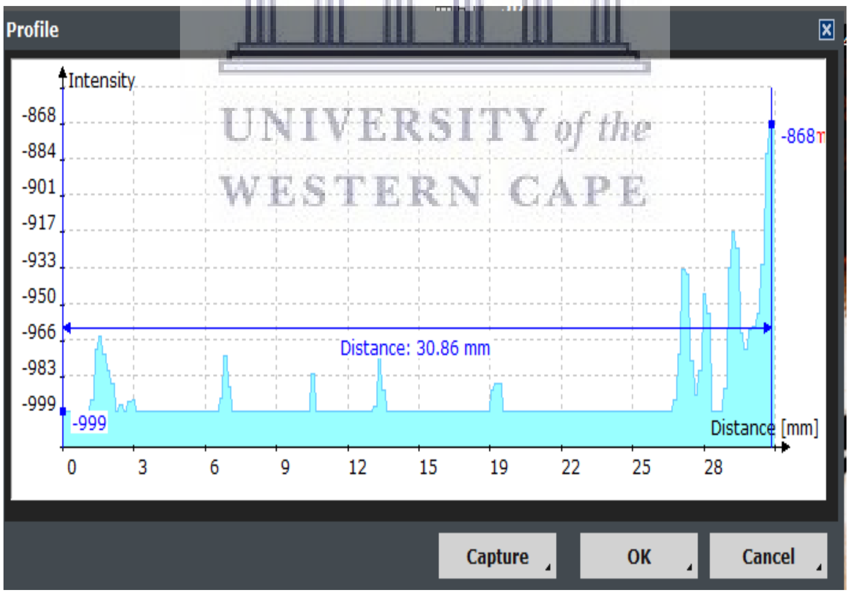

Figure 2. Measurement of intensity of sinus density to determine threshold

The above image is then used to determine the threshold, which in turn produces a three-dimensional volume image of the maxillary sinus shown in Fig. 3

Figure 3. After threshold was determined and before cutting the sinuses with the tool, smartpen, Antero-Posterior view

Figure 4. Head view after threshold has been implemented and before cutting maxillary sinus

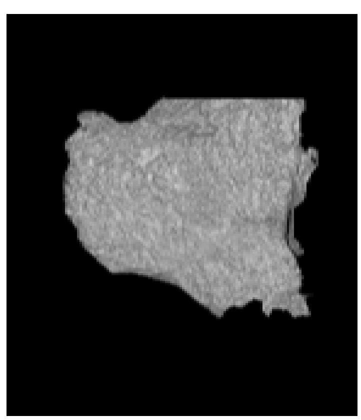

Figure 5. Example of the right handside maxillary sinus cut with smartpen

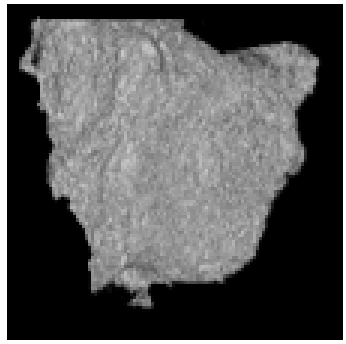

Figure 6. Example of left handside maxillary sinus cut with smartpen

A tool in the software system, called the smartpen was used to cut the sinus, which determine the volume measurement.

Lastly, to determine the volume (mm^3), each observation, either left or right maxillary sinus were measured using the object mask tool (Fig 7) where the threshold values have already been determined by Fig 1 and Fig 2.

The total volume of each observation was documented on an Excel spread sheet (Appendix A).

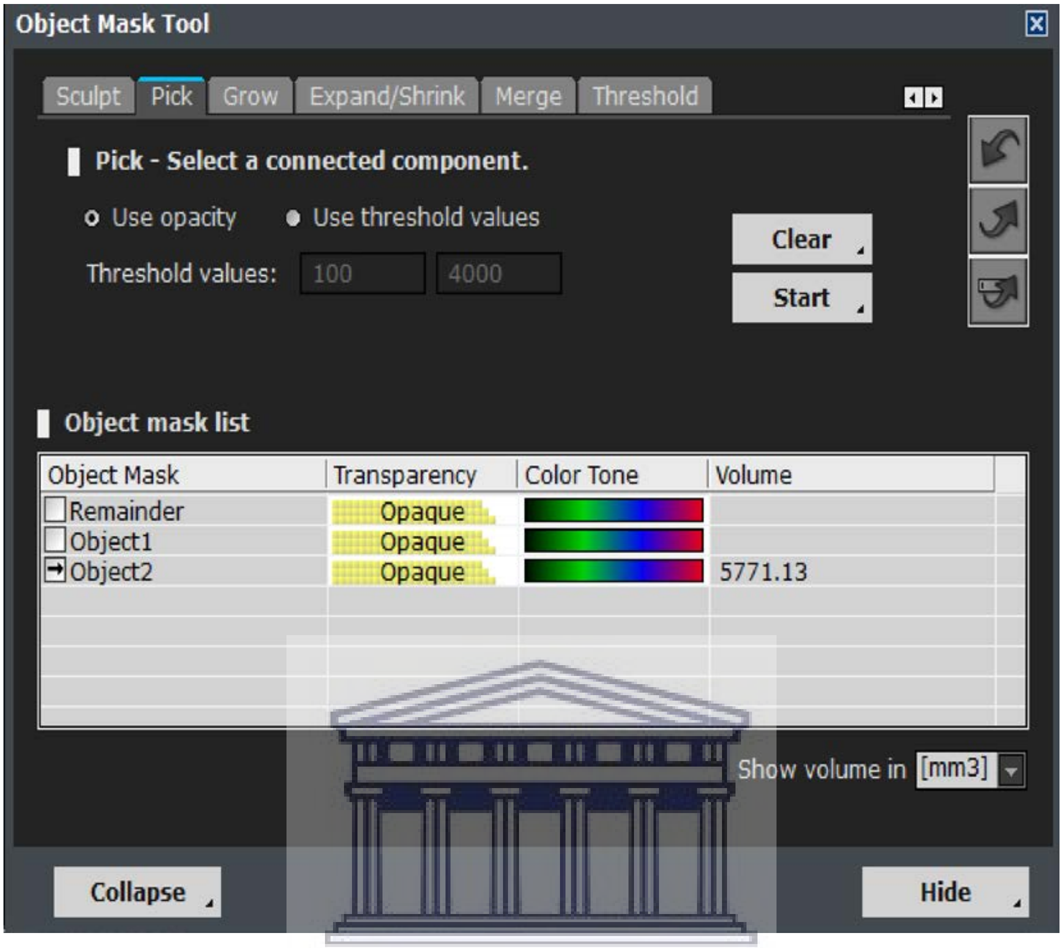

Figure 7. Left hand maxillary sinus volume measurement with object mass tool

CHAPTER FOUR: RESULTS AND DATA ANALYSIS

The following steps of how the results were obtained were:

- The results for reading 1 (V1) were recorded on the spreadsheet. Reading 2 (V2) were obtained 3-6 months later and compared to reading 1
- All categorical data was analyzed using a chi-squared test, or an appropriate non-parametric equivalent test
- Differences between reading 1 and 2 was assessed using an Anova or a non-parametric equivalent test

- Correlations was assessed using a Pearson's correlation coefficient or a non-parametric equivalent
- All analysis was deemed statistically significant at $p < 0.05$
- All the data collected for readings 1 and 2 was be captured on the Excel spreadsheet as per Appendix A and data was analyzed with the Statistical Package for Social Sciences (SPSS® Version 12.0 or later, Chicago, IL, USA)

4.1 Results:

In this cohort study, a total of 25 observations were evaluated. The measurements of maxillary air volume pre operatively and post operatively were analyzed and recorded. The data were interpreted undertaking different variables below:

i. Age and Gender in volumetric changes of the maxillary sinus:

These results were obtained using an ANOVA, a two-way ANOVA was conducted to examine the effects of gender and age category levels on volume difference. Data are a mean ± standard error, unless otherwise stated. Residual analysis was performed to test for the two-way ANOVA assumptions. Outliers were assessed by an inspection of a boxplot. Normality was assessed using Shapiro-Wilk's normality test for each design cell. Homogeneity of variances was assessed using Levene's test. There were no unusual outliers, residuals were normally distributed ($p > .05$); and there was homogeneity of variances ($p > 0.05$).

```
. . table Agecat Gender, contents (mean VolumeDifference sd VolumeDifference)
```

Agecat	GENDER F	GENDER M
45-54	6068.363	8967.3725
	2028.785	643.7537
55-64	7660.6873	2023.577
	2826.433	1570.857
65+	7139.9242	5570.9025
	944.9116	820.0552

Table 1. Age category table showing gender and age contents of mean volumetric differences

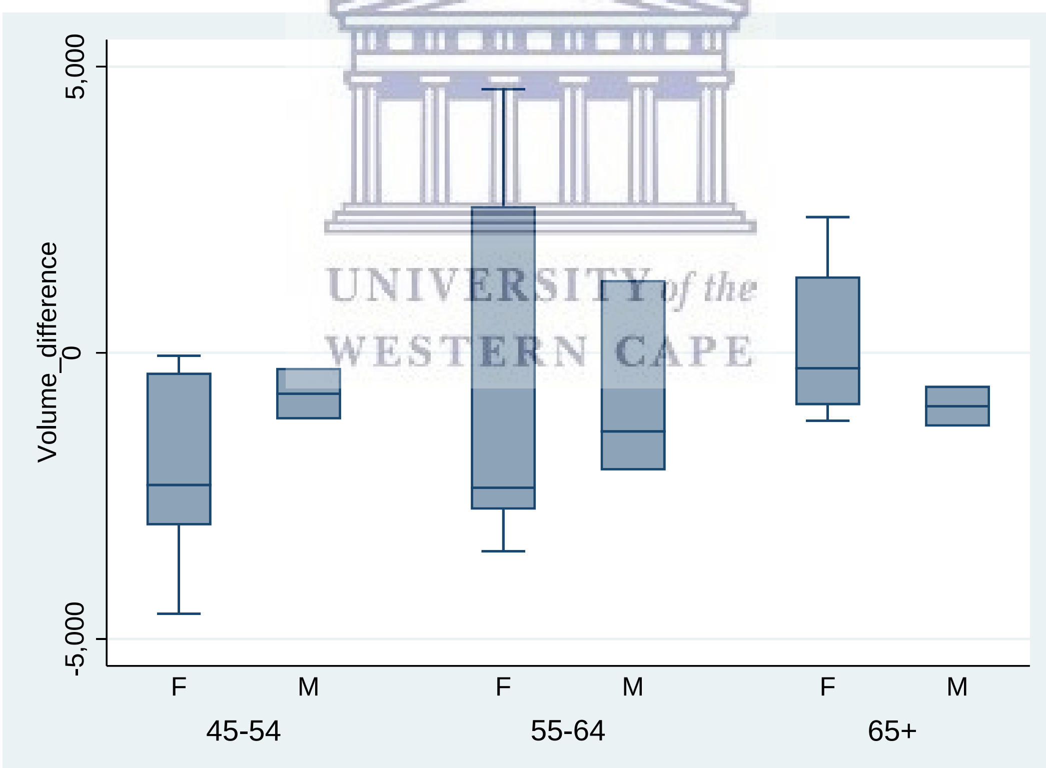

Figure 8. Box plot showing the outliers observations

```
. swilk Volume_difference

                   Shapiro-Wilk W test for normal data

    Variable |        Obs       W           V         z       Prob>z
-------------+------------------------------------------------------
Volume_dif~e |         25    0.96211      1.053     0.105    0.45814
```

```
.  anova Volume_difference Gender##agecat

                        Number of obs =         25    R-squared     =  0.1359
                        Root MSE      =    2150.45    Adj R-squared = -0.0915

                  Source | Partial SS         df         MS        F    Prob>F
              -----------+----------------------------------------------------
                   Model |   13821269          5   2764253.9      0.60  0.7021
                         |
                  Gender |  14591.686          1   14591.686      0.00  0.9558
                  agecat |  3134660.4          2   1567330.2      0.34  0.7168
           Gender#agecat |  4430750.8          2   2215375.4      0.48  0.6266
                         |
                Residual |   87864375         19   4624440.8
              -----------+----------------------------------------------------
                   Total |  1.017e+08         24   4236901.9
```


The interaction effect between gender and age category on volume difference was not statistically significant, F (1, 19) = .48, p = 0,6266. Therefore, an analysis of the main effect for Gender was performed, indicating that the main effect was not statistically significant, F (2, 19) = 0, p < 0.9558. The main effect for age category was also found to be not statistically significant, F (2,19) = 0.34, p = 0.7168.

```
. pwcompare Gender#agecat, mcompare(bonferroni) effects

Pairwise comparisons of marginal linear predictions

Margins      : asbalanced
```

	Number of Comparisons
Gender#agecat	15

	Contrast	Std. Err.	Bonferroni t	Bonferroni P>|t|	Bonferroni [95% Conf.	Interval]
Gender#agecat						
(F#55-64) vs (F#45-54)	1406.331	1259.175	1.12	1.000	-2816.988	5629.651
(F#65+) vs (F#45-54)	2233.271	1302.163	1.72	1.000	-2134.231	6600.773
(M#45-54) vs (F#45-54)	1342.831	1799.197	0.75	1.000	-4691.74	7377.402
(M#55-64) vs (F#45-54)	1337.153	1570.468	0.85	1.000	-3930.252	6604.558
(M#65+) vs (F#45-54)	1123.601	1799.197	0.62	1.000	-4910.97	7158.172
(F#65+) vs (F#55-64)	826.9396	1196.401	0.69	1.000	-3185.832	4839.711
(M#45-54) vs (F#55-64)	-63.50043	1724.197	-0.04	1.000	-5846.519	5719.518
(M#55-64) vs (F#55-64)	-69.1781	1483.952	-0.05	1.000	-5046.408	4908.052
(M#65+) vs (F#55-64)	-282.7304	1724.197	-0.16	1.000	-6065.749	5500.288
(M#45-54) vs (F#65+)	-890.44	1755.836	-0.51	1.000	-6779.578	4998.698
(M#55-64) vs (F#65+)	-896.1177	1520.599	-0.59	1.000	-5996.261	4204.025
(M#65+) vs (F#65+)	-1109.67	1755.836	-0.63	1.000	-6998.808	4779.468
(M#55-64) vs (M#45-54)	-5.677667	1963.084	-0.00	1.000	-6589.934	6578.579
(M#65+) vs (M#45-54)	-219.23	2150.451	-0.10	1.000	-7431.921	6993.461
(M#65+) vs (M#55-64)	-213.5523	1963.084	-0.11	1.000	-6797.809	6370.704

ii. Air volume changes of different materials used in the sinus augmentation procedure

MATERIALS	Mean of material type	Mean of V1 = mm^3	Mean of V2 = mm^3
A	4.6	5670.9	7330.4
B	2.5	6206.9	3150.0
C	14.5	5683.2	4469.9
D	8.5	6036.9	5104.8
E	16.5	6438.5	7875.5
F	12	5401.7	5350.6
G	13.5	7432.4	6819.4
H	15.5	9186.7	5401.2
I	17	11501.0	11001.2
J	18.5	9860.5	7312.3
K	20.5	5852.9	4524.5
Grand Total	**13**	**6862.2**	**6094.0**

Material keys:
A - Bio-oss mixed with PRP
B - Iliac crest bone harvesting (spongy and cortical bone)
C - Bio-oss
D - Fuse-on mixed with blood and bone mixed with PRP
E - Bone SA mixed with PRP
F - Bone mixed with PRP and PRF with PRP membrane
G - Biogide and PRP mixed with Bone SA
H - Bone SA mixed with platelet-rich plasma taken from patient blood
I - Bone SA with harvested bone of patient
J - Bone SA
K - Bone retrieved from bonetrap mixed with Bio-oss covered with Bio-guide membrane

Table 2. Comparison of different materials vs. maxillary sinus air volume changes

The table above indicate the different materials used in all 25 observations. A qualitative analysis result was obtained by calculating the average of materials preoperative and postoperative sinus augmentation.

iii. The difference between maxillary sinus air volumes (Pre operatively and Post operatively)

OBSERVATIONS	V1	V2	TOTAL
1	3.06337	4.33465	1.27128
2	5.99212	2.53121	-3.46091
3	6.41463	3.76887	-2.64576
4	2.33179	0.278333	-2.053457
5	1.75349	0.379829	-1.373661
6	6.99169	8.32679	1.3351
7	6.95792	9.32985	2.37193
8	5.35351	4.7751	-0.57841
9	6.72046	5.43213	-1.28833
10	7.03891	11.6439	4.60499
11	5.22296	4.78191	-0.44105
12	5.40178	5.35067	-0.05111
13	7.85614	6.66753	-1.18861
14	7.00914	6.97138	-0.03776
15	10.2705	7.25702	-3.01348
16	8.10308	3.5455	-4.55758
17	11.501	11.0012	-0.4998
18	9.91369	7.17432	-2.73937
19	9.80734	7.45038	-2.35696
20	6.75789	4.4487	-2.30919
21	4.94798	4.60048	-0.3475
22	6.857	5.9432	-0.9138
23	6.6351	6.1333	-0.5018
24	9.1836	8.02114	-1.16246
25	9.46408	9.20067	-0.26341

Table 3. Difference in maxillary sinus air volumes

CHAPTER FIVE: DISCUSSION AND CONCLUSION

This study was the first that was conducted in South Africa. The results indicate that no statistical differences were encountered, however a number of important limitations need to be considered:

a. Access to data regarding inclusion and exclusion criteria
b. Small sample size
c. Not representative sample due to the cohort of patients
d. Variation between clinician and the software

The results of our study showed that age and gender had no effect on the volume changes either pre- nor post- operative sinus augmentation using CBCT, which indicated similarities in literature done by Urooge, 2017.

Further literature suggests that there were some parameters and limitations that can have an effect on the air volume changes of the maxillary sinus in using different augmentation materials. The maxillary sinuses volumetric changes can either be changed by an increase or decrease in air volume or bone that has been placed during sinus augmentation. The majority of the literature looked at bone dimensions, the percentage left after a specific time period after sinus augmentation and what radiographic modalities were used. All studies differed with respect to the materials used like xenogenic, allogenic and alloplastic grafts. Previous studies by Kim Moon *et al* (2013) and Favato *et al* (2014) found similar outcomes where no correlation between dimensional changes and the total maxillary sinus volume was found. Overall, these studies only highlighted some of the different grafts and material used, thus insufficient evidence was therefore found to support the suggestion that the maxillary sinus volume influences graft contraction.

Although the difference in air volume using different materials also showed that most observations had a decrease in air volume and an increase in bone height/volume after sinus augmentation. Literature by Bensaha *et al*, (2016) found no correlation between the volume of bone created in the sinus floor, and the volume of bone grafting material used for the sinus infiltration technique, or the lateral sinus lift.

In some of the studies we noted medical CT was used pre-operatively 2 weeks after and again 3/6 months and then for follow up. An alternative could have been the use of CBCT with its markedly lower radiation dose. The problem with CBCT is that it does not provide true density but rather a relative density. However in a study that Reeves et al (2012) concluded that the grey scale levels used in a CBCT could be used to derive Hounsfield Units (HU) clinically. CBCT should thus be the image of choice due to decreased patient radiation exposure, ease of access, greater resolution than that of medical CT imaging and the affordability.

The present study showed changes in volume when the pre-operative CBCT (V1) were compared with the postoperative CBCT (V2) (Table 3). It is a normal variation if the reading of V1 is larger than V2, although in extreme cases the author found V2 is larger than V1. This can be due to V1 that had some soft tissue thickening or slight inflammation, which caused a discrepancy in the reading, not ascertainable by the human eye. The software might have distinguished V1 greater than V2 and after surgery the discrepancy might have cleared, so that V2 was larger. This means that the software can still display even a small change in the density of mucous/sinus lining, the discrepancy. While the approximate volumes were measured by choosing patients with no sinus changes as stipulated in the inclusion and exclusion criteria, the software system can still document this discrepancy. Due to the operator’s opinion related to pathology, the gray scale of 3D radiographic techniques was then considered. This highlights the importance and value of 3D imaging and its capabilities.

The aim of this study was to analyze 3D virtual models of the maxillary sinus air volumes and to measure the changes induced by maxillary sinus augmentation surgery.

Based on limitations of this study a bigger sample size and a comparison of different software systems appears indicated. An area of future research would be to see if one or another of these graft materials are more resistant to resorption and pneumatization than another.

BIBLIOGRAPHY:

Abrahams, J.J., Hayt, M.W., Rock, R., (2000). Sinus lift procedure of the maxilla in patients with inadequate bone for dental implants: radiographic appearance. *Am J Roentgenol*, May; 174(5):1289-92.

Aldelaimi, T.N., Khalil, A.A., (2016). Maxillary sinus augmentation. *Journal of Craniofacial Surgery;* 27(6)

Ardekian, L., Mactei, E., (2006). The clinical significance of sinus membrane perforation during augmentation of the Maxillary Sinus. *J Oral Maxillofac Surg; 64: 277-282*

Arora, S., Kau, R., Lamba, A., Faraz, F., Tandon, A., Ahad, A., (2013). Role of Cone Beam Computed Tomography in Rehabilitation of a Traumatised Deficient Maxillary Alveolar Ridge Using Symphyseal Block Graft Placement. *Case Reports in Dentistry* Article ID 7488405

Balaji, S.M.,(2009).*Textbook of Oral and Maxillofacial Surgery*., Elsevier India

Bensaha, T.E.I., Mjabber, H., (2016), Evaluation of new bone formation after sinus augmentation with two different methods, *International journal of Oral and Maxillofacial Surgery;* 45(1) 93-98

Clemen, R. T., & Winkler, R. L. (1999). Full @ Onlinelibrary.Wiley.Com. *Risk Analysis*.

Close, L.G., Merkel, M., et al (1986): *Computed tomography in the assessment of mandibular invasion by intraoral carcinoma.* Ann Otol Rhinol Laryngol ;95(4-1):383-88.

Dasmah, A., Thor, A., Ekestubbe, A., Sennerby, L., & Rasmusson, L. (2012). Particulate vs. block bone grafts: Three-dimensional changes in graft volume after reconstruction of the atrophic maxilla, a 2-year radiographic follow-up. *Journal of Cranio-Maxillofacial Surgery*, 40(8), 654–659.

Dellavia, C., Speroni, S., Pellegrini, G., Gatto, A., & Maiorana, C. (2014). A new method to evaluate volumetric changes in sinus augmentation procedure. *Clinical Implant Dentistry and Related Research*, 16(5), 684–690.

Emirzeoglu M, Sahin B, Bilgic S, Celebi M, Uzun A.(2007). Volumetric evaluation of the paranasal sinuses in normal subjects using computer tomography images: A stereological study. *Auris Nasus Larynx [Internet]*.;34(2):191–5.

Favato, M. N., Vidigal, B. C. L., Cosso, M. G., Manzi, F. R., Shibli, J. A., & Zenóbio, E. G. (2015). Impact of human maxillary sinus volume on grafts dimensional changes used in maxillary sinus augmentation: A multislice tomographic study. *Clinical Oral Implants Research*, 26(12), 1450–1455.

Fugazzotto, P. a, & Vlassis, J. (2000). Long-term success of sinus augmentation using various surgical approaches and grafting materials. *The International Journal of Oral & Maxillofacial Implants*, 13(1), 52–8.

Georgescu, C., Mihai, A., Didilescu, A., Moraru, R., Nimegean, V.R., Nimegean, V., Tanase, G., (2010). Cone beam computed tomography as a method of quantitative analysis of alveolar crest in the frontal mandibular area. *Romanian Journal of Morphology & Embryology;* 51(4): 713-717

Ghom, A.G, (2008), *Basic Oral Radiology.,*JP Medical Ltd

Gray C, Redpath T. (2001).Magnetic resonance imaging assessment of a sinus lift operation using reoxidised cellulose (SurgicelR) as graft material. *Clin oral Implant[Internet*].;526–30.

Gray, C. F., Staff, R. T., Redpath, T.W., Needham, G., Renny, N.M.P., (2000), *Assessment of maxillary sinus volume for sinus lift operation by three-dimensional magnetic resonance imaging;* Dentomaxillofacial Radiology 29, 154 -158; Macmillan Publishers Ltd.

Hallman M, Thor A. (2008), Bone substitutes and growth factors as an alternative/complement to autogenous bone for grafting in implant dentistry. *Periodontol 2000 [Internet]*. 2008;47(1):172–92

Hu, K., Choi, D., Lee, W., Kim, H., Jung, U., Kim, S., (2012). Reliability of two different presurgical preparation methods for implant dentistry based on panoramic radiography and cone-beam computed tomography in cadavers. *J Periodontal Implant Sci; 42*: 39-44

Janner, S., Caversaccio, M., Dubach, P., Sendi, P., Buser, D., Bornstein, M., (2011). Characteristics and dimensions of the Sceneiderian membrane: a radiographic analysis using cone beam computed tomography in patients referred for dental implant surgery in the posterior maxilla. *Clin Oral Impl Res*; 22: 1446-1453

Jensen, T., Schou, S., Stravropoulos, A., Terheyden, H., Holmstrup, P.,(2012). Maxillary sinus floor augmentation with Bio-Oss or Bio-Oss mixed with autogenous bone as graft in animals: a systemic review, *International Journal of Oral and Maxillofacial Surgery,* 41(1),114-120

Johansson, B., Grepe, A., Wannfors, K., & Hirsch, J. M. (2001). A clinical study of changes in the volume of bone grafts in the atrophic maxilla. *Dentomaxillofacial Radiology*, *30*(3), 157–161.

Klijn, R. J., van den Beucken, J. J. J. P., Bronkhorst, E. M., Berge, S. J., Meijer, G. J., & Jansen, J. A. (2012). Predictive value of ridge dimensions on autologous bone graft resorption in staged maxillary sinus augmentation surgery using Cone-Beam CT. *Clinical Oral Implants Research*, *23*(4), 409–415.

Karjodkar, F.R. (2000) *Textbook of Dental and Maxillofacial Radiology*.,2nd Edition Jaypee Brothers Medical Pub

Lana J., Rodrigues, P., Machodo, V., Souza, P., Manzi, F., (2011). Anatomic Variations and lesions of the maxillary sinus detected in cone beam computed tomography for dental implants.*Clin Oral Implants* (23):1398-140

Lawson, W., Patel, Z., Lin, F., (2008). The Development and Pathologic Processes that Influence Maxillary Sinus Pneumatization. *The Anatomical Record;* 291: 1554-1563

Meleo, D., Mangione, F., Corbi, S., Pacifico, L., (2012). Management of the Scheiderian membrane perforation during the maxillary sinus elevation procedure: a case report. *Annali di Stomatolgia;* III (I):24- 30

Miles DA., (2005). Clinical Experience with Cone-beam Volumetric Imaging—Report of Findings in 381 Cases. *US Dent [Internet]*. 2006;(2005):2–7.

Monje, A., Diaz, T. K., Aranda, L., Insua, A., Garcia-Nogales, A., Wang, H-L.,(2016), Scheiderian Membrane Thickness and Clinical Implication for Sinus Augmentation: A Systemic Review and Meta-Regression Analysis. *J Periodontal,* August: 87 (8):888

Mohan, R., Singh, A., Gundappa, A., (2011). Three-dimensional Imaging in periodontal diagnosis-Utilization of cone-beam computed tomography. *J Indian Soc Periodontal,* Jan-Mar: 15 ;(1):11-17

Neugebauer, J., (2010). Evaluation of Maxillary Sinus Anatomy by Cone-beam CT prior to sinus floor elevation. *Int J Oral Maxillofac; 25*: 258-265

Pompa, V., Galasso, S., Cassetta, M., Pompa, G., De Angelis, F., Di Carlo, S., (2010). A Comparative study of the Magnetic Resonance and Computed Tomography in the pre-implant evaluation. *Annali di Stomatolgia; 3*: 33-38

Rasmusson, L., Kahnberg K-E, Tan A. (2001).Effects of Implant Design and Surface on Bone Regeneration and Implant Stability: An Experimental Study in the Dog Mandible.

*Clin Implant Dent Relat Res [Internet].;*3(1):2–8.

Reeves, T.E., Mah, P., Mc David, W.D., (2012) Deriving Hounsfieldunit using grey levels in cone beam CT: A clinical application. *Dentomaxillofac Radiol [Internet].*,41:500-8

Rege, I., Sousa, T., Leles, C., Medonca, E., (2012). Occurrence of Maxillary sinus abnormalities detected by cone beam CT in asymptomatic patients. *BMC Oral Health*; 12:30

Riachi F, Naaman N, Tabarani C, Aboelsaad N, Aboushelib MN, Berberi A, et al. (2012). Influence of material properties on rate of resorption of two bone graft materials after sinus lift using radiographic assessment. *Int J Dent [Internet]*.

Rickert D, Slater JJRH, Meijer HJA, Vissink A, Raghoebar GM.(2012). Maxillary sinus lift with solely autogenous bone compared to a combination of autogenous bone and growth factors or (solely) bone substitutes. A systematic review. *Int J Oral Maxillofac Surg [Internet]*.;41(2):160–7.

Sehn FP, Dias RR, de Santana Santos T, Silva ER, Salata LA, Chaushu G, et al. (2015). Fresh-frozen allografts combined with bovine bone mineral enhance bone formation in sinus augmentation. *J Biomater Appl [Internet*].;29(7):1003–13.

Serkerci, A., Sisman, Y., Etoz, M., Bulut , D., (2013). Aberrant Anatomical Variation of Maxillary sinus Mimicking Periapical Cyst: A report of two cases and Role of CBCT in diagnosis.

Sbordone, C., Toti, P., Guidetti, F., Califano, L., Bufo, P., & Sbordone, L. (2013). Volume changes of autogenous bone after sinus lifting and grafting procedures: A 6-year computerized tomographic follow-up. *Journal of Cranio-Maxillofacial Surgery*, *41*(3), 235–241.

Suresh, K.M., Chong, V., *Atlas of Head and Neck Imaging.* New York, Thieme, 2004

Testori, T., (2012). Prevention and Treatment of Postoperative Infections after sinus elevation Surgery: Clinical Consensus and Recommendations. *International Journal of Dentistry*

Vogiatzi, T., Kloukos, D., Scarfe, W. C., & Bornstein, M. M. (2014). Incidence of anatomical variations and disease of the maxillary sinuses as identified by cone beam computed tomography: a systematic review. *The International Journal of Oral & Maxillofacial Implants*, *29*(6), 1301–14

Ueda, M., Tohnai, I., Nakai, H., (2001) Tissue engineering research in oral implant surgery. *Artificial organs*, 25(3),164-171

Urooge, AB; (2017); Sexual dimorphism of maxillary sinus: A morphometric analysis using cone beam computed tomography. *Journal of Clinical and Diagnostic Research* 11(3)

Wallace, S.S., Froum, S.,J.,(2003) Effect of maxillary sinus augmentation on the survival of endosseous dental implants: a systemic review, Annals of Periodontology, 8(1),328-343

Westbrook, C., Talbot, J. (2011) MRI in practice.,4th Edition Wiley-Blackwell

Whaites, E., & Drage, N., (2013), *Essentials of Dental Radiography and Radiology.*, 5th Edition, Churchill Livingstone

White, S.C., & Pharoah, M.J.(2009)*Oral Radiology: Principles and Interpretation.,*5th Edition, St. Louis, Mo: Mosby/Elseriver.

Appendix A:

VOLUMETRIC CHANGES OF MAXILLARY SINUS POST AUGMENTATION USING CBCT

Obser-vation	**Material used**	**Age**	**Gender**	**V1**	**V2**
1					
2					
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