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VOLUMETRIC AND LINEAR ASSESSMENT OF MAXILLARY TUBEROSITY BONE AS A DONOR SITE FOR ALVEOLAR RIDGE AUGMENTATION USING CBCT A CROSS SECTIONAL ANALYTICAL STUDY

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ABSTRACT

Introduction: Maxillofacial bone defects occur as a result of various causes as infections, tumor and cysts or natural loss of bone after extraction of teeth. There are a lot of disputation among dental practitioners in the material that should be utilized to fill up bone deficiencies in order to increase bone volume and improve implant placement. Because autogenous bone has osteogenic, osteoinductive, and osteoconductive properties, it is considered the gold standard for bone reconstruction.

Purpose: The aim of this study was preoperative CBCT assessment of maxillary tuberosity as an intraoral donor site for purpose of autogenous block graft.

Materials and methods: 20 volunteers were included in the study, and each one signed an informed consent form. Participants were chosen based on predetermined eligibility criteria. CBCT images were interpreted using Planmeca Romexis software version 6.4 by one of oral and maxillofacial radiologist of more than 10 years' experience. Linear and volumetric measurements of maxillary tuberosities using segmentation (manual and semiautomatic segmentation) were done.

Results: Results showed the difference between real and segmented volumes to be statistically significant with real volume being significantly higher than manual and semi-automatic segmentation ($p<0.001$). However, the difference in measurements' error was not statistically significant ($p=0.102$).Method reliability analysis showed that there was a moderate agreement between semi-automatic and manual segmentation that was statistically significant ($ICC=0.693$, $p<0.001$) and there was a strong agreement between both observations that was statistically significant ($ICC>0.9$, $p<0.001$).

Conclusion: CBCT is a valuable tool to assess the linear and volumetric measurements of the block grafts for maxillary tuberosity as an intraoral donor site. According to this study maxillary tuberosity could be a suitable source of autogenous bone graft for the treatment of small and limited defects of the alveolar process.

KEYWORDS: Intraoral autograft, implant planning, maxillary tuberosity, CBCT

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INTRODUCTION

Finding dependable donor sites for autogenous bone harvesting is crucial due to the rising popularity of dental implants and the need of adequate alveolar bone support. Alveolar bone resorption may be started or made worse by long-term edentulism, aging, trauma, congenital defects, periodontal disease, infection, and systemic disorders **(Yavuz et al. 2009 &Diarjani et al. 2023).** The most common transplanted tissue in the human body is bone. In order to restore the lost space, maintain the shape of the bone, improve the soft tissue, and regenerate and augment bone; surgical bone grafting is performed **(Diarjani et al. 2023).** Grafts from a variety of sources, including xenografts, allografts, alloplastic grafts, and autografts, have been utilized to augment existing bone defects (**Abdeltawab et al. 2022**). The degree of atrophy, the nature of the bone defect, and the quantity of existing bony walls all have a role in the technique and material choice for bone grafting (**Diarjani et al. 2023**). Both autogenous and allograft bone are derived from humans, however allograft bone is extracted from a donor rather than the transplant recipient, it's gotten and kept in a bone bank. Bone used in an autogenous bone graft comes from the recipient of the graft,while xenografts one transplants from animals such as bovine **(Deluiz et al.2015)**

Autogenous bone has been the only source of osteogenic cells making it an ideal material for grafting with osteoinductive, osteogenic and osteoconductive property, with less graft rejection and with a success rate of over 95% even in cases with severe vertical and horizontal bone resorption. Because of this, it is considered as the gold standard for oral reconstructions **(Nkenke et al. 2014, Sakkas et al. 2017 and Abdeltwab et al. 2022)**. The need for a second surgical site, postoperative discomfort, and problems are potential drawbacks of autogenous graft **(Esmaeili et al. 2023 and Gnanasagar et al. 2023)**. The volume of bone needed for reconstruction, the type of defect, and the type of bone graft (cortical, medullary, or corticomedullary) are all factors that must be taken into consideration when choosing suitable donor site (**Faverani et al. 2014).** Both intraoral and extraoral donor sites are acceptable sources for autogenous bone grafts. Higher volumes of bone can be obtained from extraoral donor sites from the ileum, ribs, cranial vault (parietal), and tibia; however, these locations have a number of disadvantages, including higher treatment costs, significant donor site morbidity, and the need for a second surgical site. For oral and maxillofacial bone grafting, the lateral and anterior parts of the mandibular ramus, the region buccal to the third molars, the mandibular lingual cortex, the zygomatic bone, the maxillary tuberosity, the hard palate, the coronoid process, and the mandibular symphysis can be obtained as an intraoral donar sites (**Safi et al. 2021&Diarjani et al. 2023**). The advantages of intraoral grafts include much less bone needed, close proximity to donor and recipient sites, shorter surgical times due to easy access, less anesthesia needed, lower morbidity, shorter hospital stays, and less discomfort for the patients. **(Reininger et al. 2017 &Abdeltawab et al. 2022).**

The mandibular ramus and the symphysis (chin) are the two primary intraoral donor sites. However, access to these locations is restricted, and they are linked to significant postoperative morbidity and consequences include neurovascular damage and neurological dysfunction (**Hassani et al. 2005, Khojasteh et al. 2013 and Zuffia and Sans 2022).**

The maxillary tuberosity has been used as a source of bone for augmentation surgeries for a number of years, and it offers advantages over other intraoral donor sites in that the harvesting process is straightforward and causes few difficulties. Tolstunov, to our knowledge, was the first to discuss the possibility of using a maxillary tuberosity block graft to address specific maxilla bone abnormalities needed for implant insertion**(Tolstunov 2009 & Zuffia and Sans 2022).** It offers small to medium amounts of bone depending on the anatomy, it can be removed bilaterally, depending on the architecture. It is used to fill in minor fenestrations where teeth have been lost for placement of implants as well as grafts in the maxillary sinus cavity. **(Faverani et al. 2014).** Despite these positive traits and benefits, careful preoperative planning and analysis of the amount of grafts to be collected are still crucial to reducing postoperative problems at the donor site throughout autogenous graft procedures **(Nagla'a & Bahammam 2018 and Abdeltawab et al. 2022)**. Cone-beam computed tomography can correctly measure the intraoral donor site's size, the volume of harvestable bone, and the proximity of the intraoral donor site to anatomical structures **(Spin -Neto et al. 2013 and Esmaeili et al. 2023**), also it provides submillimeter resolution in images of excellent diagnostic quality, interactive features, quick scanning times, and affordable costs. Additionally, compared to traditional CT, the overall radiation dose is significantly lower (**Scarfe & Farman 2008, Adibi et al. 2012, Park et al. 2017, Jacobs et al. 2018, and Abdeltwaab et al. 2022).** This study was aimed to preoperative CBCT assessment of maxillary tuberosity as donor site for purpose of autogenous block graft.

MATERIAL AND METHOD

In this cross sectional analytical study twenty participants were included in the study and an informed consent was signed by each participant, from Egyptian patients who attended the Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University for CBCT scanning for different dental purposes. The study was approved by Research Ethical Committee, faculty of Dentistry, Cairo University (reference number 23/3/23).

Eligibility criteria

Inclusion criteria: Normal (volunteering) Egyptian population has normal facial morphology, age range 25 to 60 years old, high-quality CBCT images of the maxilla, or both jaws with maxillary third molar not extracted or missed, free from implant or surgical intervention in the donor sites, as well as free from any systemic condition affecting the jaws. No gender preference in selection of the patients

Exclusion criteria: Individuals who have developmental malformations, fractures, or lesions at donor sites, patients with extracted or missed maxillary third molar, pregnant females and edentulous patients.

Radiographic data

Radiographic scanning was done at the Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University. CBCT Planmeca Promax 3D Mid machine (Planmeca, Helsinki, Finland) was used to scan the patients using 90 kVp, 10 mA, 14 seconds and 200×60 mm FOV with 0.4 mm voxel size. CBCT scans were saved anonymously and interpreted using Planmeca Romexis software version 6.4 by one of oral and maxillofacial radiologist of more than 10 years' experience. The scans were evaluated twice with a period of two weeks between the two reading sessions for intra-observer reliability.

Image Analysis

In all cases, adjustment of the volume orientation was done, where the axial plane was aligned with the hard palate and the sagittal plane was aligned with the nasal septum. Then, determination of the anatomical boundaries of the maxillary tuberosity of both sides were plotted according to **Reininger et al. 2017**, just distal to the last molar and the maxillary sinus membrane superiorly. The linear measurements of maxillary tuberosity were performed using the coronal and sagittal CBCT views. In the coronal plane, the length and thickness were measured **(Fig.1**), but the width was measured in the sagittal plane at half the length just distal to the last molar **(Fig.2**). For volumetric measurements, the manual and semiautomatic segmentation were done, the manual segmentation was done on successive axial cuts for accurate selection of volume **(Fig.3 & 4)** and the semiautomatic segmentation was done at the axial cut and adjusted from the other 2 planes **(Fig.5**).

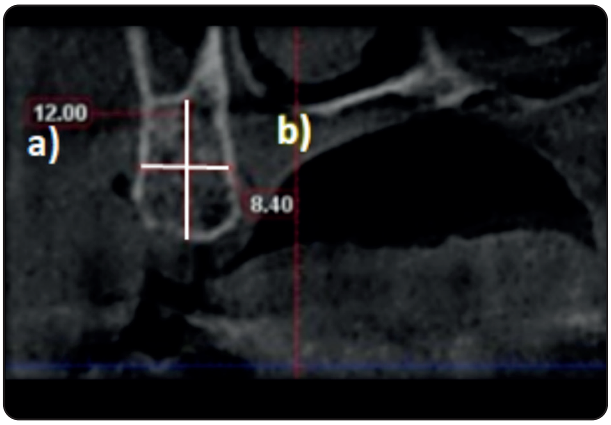

Fig. (1): Coronal cut showing the linear measurements of the maxillary tuberosity: a) the length (12.00 mm), b) the thickness (8.40 mm).

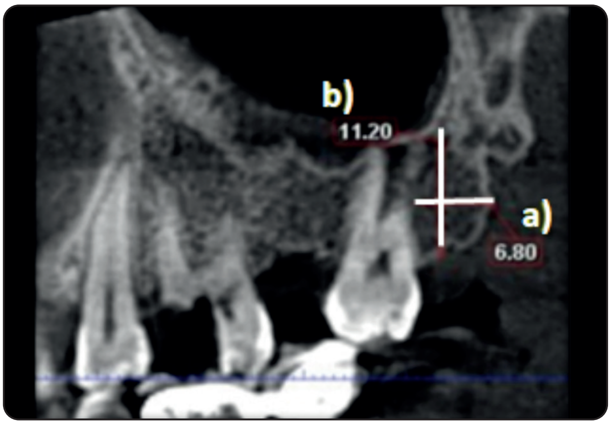

Fig. (2): Sagittal cut for the measurement of maxillary tuberosity length: a) the width (6.80 mm), b) the length (11.20 mm).

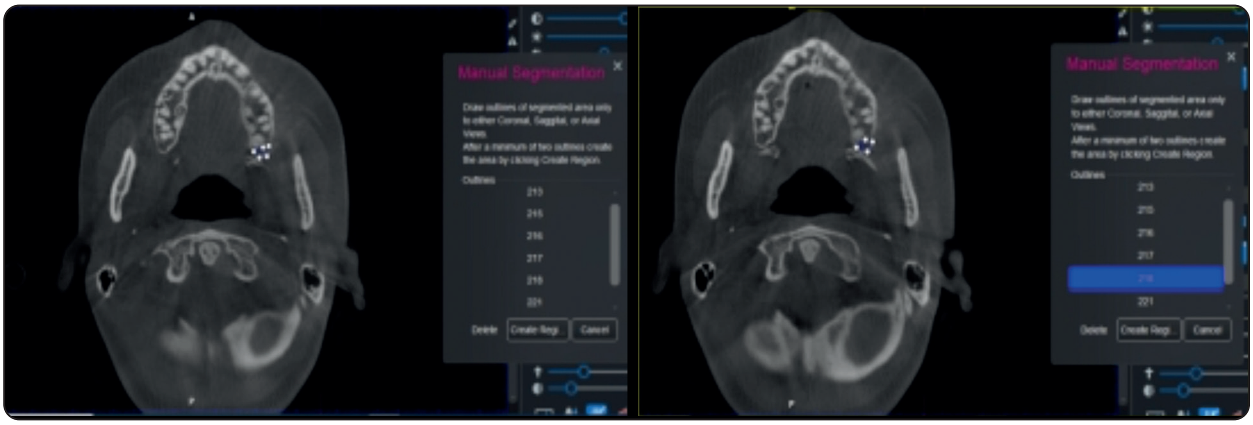

Fig. (3) Two axial cuts showing manual segmentation of maxillary tuberosity by tracing dots on successive axial cuts.

Fig. (4): Axial cut showing the volume of the maxillary tuberosity of (0.149cm3) by manual segmentation.

Statistical analysis

Frequency and percentage values were used to present categorical data. The mean with 95% confidence intervals (CI), standard deviation (SD), minimum (min.) and maximum (max.) values were used to depict numerical data. Shapiro-Wilk's test was used to test for normality . Data were normally distributed and were analyzed using paired t-test and repeated measures ANOVA followed by Bonferroni post hoc test. Correlations were analyzed using Spearman's rank order correlation coefficient. Reliability analyses were done using Intraclass correlation coefficient (ICC). The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.1 for Windows.

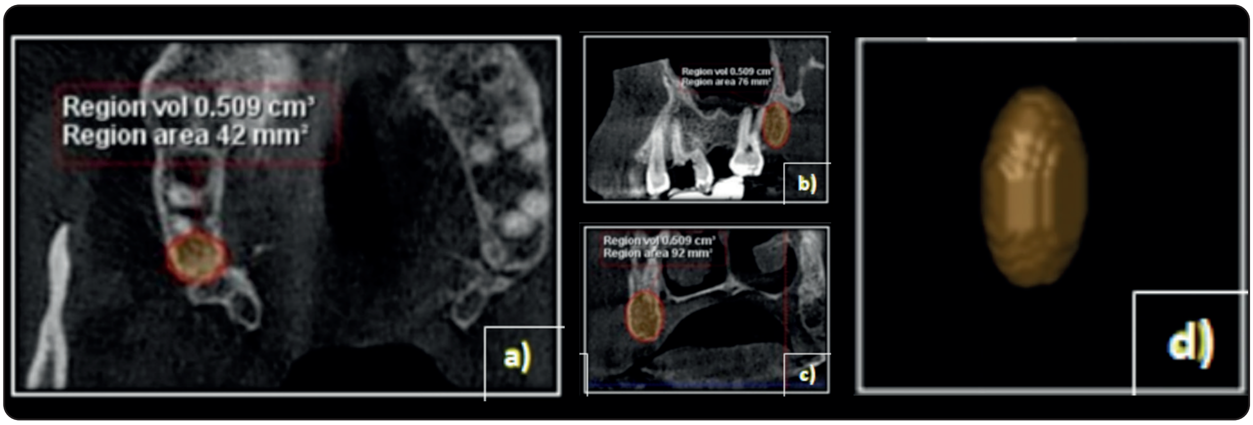

Fig. (5): Axial(a), sagittal (b) and coronal(c) cuts showing the volume of the maxillary tuberosity of (0.509 cm3) , with the resultant 3D representation (d) by semiautomatic segmentation.

RESULTS

The study was conducted on 20 cases on both sides (8 males and 12 females) with the mean age of (26.60±5.32) years. Descriptive statistics of linear and volumetric measurements of maxillary tuberosity were presented in **table (1)**. There was no significant association between gender and different measurements ($p>0.05$) also there was no significant correlation between age and different volumes ($p>0.05$). By comparing the real volume and segmented volumes by manual and semiautomatic segmentation, results showed that the real volume being significantly higher than manual and semi-automatic segmentation ($p<0.001$) **(Fig.6)**. However, the difference between manual and semiautomatic segmentation in measurements' error was not statistically significant ($p=0.102$) **(Fig.7)**. Method reliability analysis showed that there was a moderate agreement between semi-automatic and manual segmentation that was statistically significant (ICC=0.693, $p<0.001$). For each measured parameter and overall, there was a strong agreement between both observations that was statistically significant (ICC>0.9, $p<0.001$).

TABLE (1) Showing descriptive statistics for linear and volumetric measurements

Parameter	*Mean*	*95% CI*		*SD*	*Min.*	*Max.*
		Lower	***Upper***			
Length (coronal cut)	9.63	8.81	10.46	2.67	4.5	16
Thickness (coronal)	8.16	7.64	8.68	1.68	5.8	12.01
Width (sagittal cut)	6.31	5.96	6.67	1.15	4	8.4
Real volume	0.50	0.43	0.56	0.2	0.21	0.95
Semiautomatic segmentation	0.24	0.21	0.26	0.09	0.09	0.43
Manual segmentation	0.21	0.18	0.24	0.1	0.06	0.48

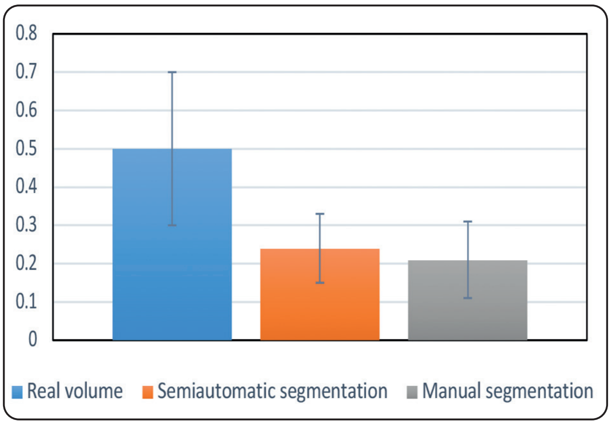

Fig. (6): Bar chart showing mean and standard deviation (error bars) values for different volumes

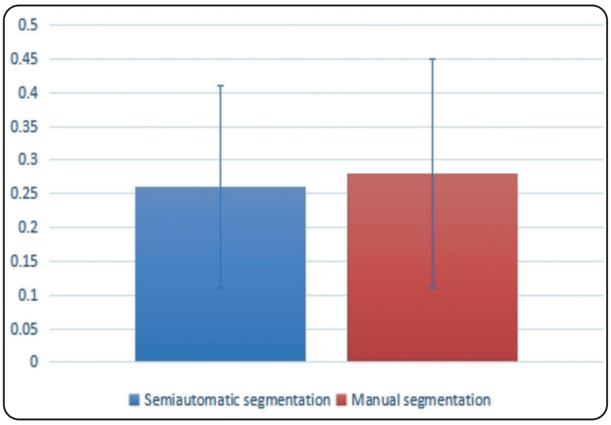

Fig. (7): Bar chart showing mean and standard deviation (error bars) values for measurement error

DISCUSSION

Bone grafting procedures are commonly needed when there is a lack of bone volume especially in implant surgery procedures**.** Autogenous bone grafts are stated to be the gold standard in the alveolar ridge augmentation procedures due to its osteogenic, osteoinductive and osteoconductive properties **(, Pourabbas & Nezafati 2007, Desai et al. 2013, Nkenke et al. 2014 and Stoyanov & Deliverska 2018).** Autogenous bone grafting constitutes intraoral and extraoral types of grafting, where each of which has their own pros and cons. **Titsinides et al. 2019** stated that, intraoral sites outweigh extra-oral sites due to the relative proximity between the donor and the recipient site, ease of surgical access, lack of permanent skin scarring and minimal postoperative morbidity. The main target of this research was to quantify the amount of bone harvested from maxillary tuberosity of Egyptian population to be able to use it in jaw defects filling instead of extraoral ones. Regarding our patients' selection criteria, although the age range was written from 25 – 60 years, nevertheless, we realized during sample selection that at older age groups, there might be multiple teeth extractions with concomitant loss in bony structure. Moreover, systemic diseases affecting the bone quantity and quality usually accompany older age groups.

Although there is a plethora of studies performed on dry mandibles or in vitro concerned with the evaluation of intraoral autografts such as **Pikos 2005, Yates et al. 2013 and Sakkas et al. 2015** , yet the presence of 3D assessment using CT and CBCT is still scarce in literature especially in the relatively new sites. CBCT evaluation and assessment of donor sites are very important to attain proper planning for surgical treatment and hence avoid or decrease the postoperative Complications **(López et al., 2015, Stoyanov & Deliverska 2018).**

Stoyanov & Deliverska 2018 and Safi et al. 2021 reported that the use of cross-sectional imaging improved the understanding of the analysis of donor sites in vivo.

In this study, CBCT technology and the Planmeca Promax 3D Mid machine were used to assess maxillary tuberosity in-vivo using linear and volumetric measurements (manual or semi-automatic segmentation techniques). Our primary outcome was the assessment of maxillary tuberosity volumes using the segmentation technique. Nevertheless, we added the linear measurements as well to identify the linear dimensions to give an insight about the whole graft shape and if it can be handled without further refinement in bony defects**.**

Several studies have confirmed that CBCT is a reliable tool for accurate linear and volumetric measurements of graft dimensions to determine the relative position of anatomical structures and delineate safety zone delineation for ultimate safe bone harvesting. **García-Sanz et al. in 2017** analyzed mandibular condyles CBCT scans of seven cadavers in the presence of the surrounding soft tissue component. The reliability of CBCT imaging for taking linear and linear-volume calculation was found to be high. This was in agreement with **Hamdy & Hussien 2020,** who also reported the same conclusion in a maxillary sinus study. Despite the discrepancy reported by **Park et al. 2017** and **Nagla'a & Bahammam 2018** between the segmented volumes (by manual segmentation, Mimics software) versus the real or actual volume, it was concluded that CBCT is reliable and can give 3D segmented object providing an ideal preoperative guide for the clinician. **Park et al. 2017** evaluated CBCT on phantoms and provided satisfactory volume measurements as well. Although they reported volume error values in comparison to the real anatomic structures, nevertheless. The segmented volume was smaller than the actual one due to noise and presence of more artifacts making segmentation of the object from the surrounding structures more difficult. The accuracy of semiautomatic segmentation relies on the grey value and threshold value defined by the operator. Structural variability and the frequent absence of a strong grey gradient near the boundaries make the segmentation step difficult, which leads to an overextension or underextension of the segmentation with the semi-automatic procedure **(Vallaeys et al. 2015). M**anual segmentation is supposed to be more accurate, although being much more time consuming, and is highly subjective depending on the operator. Moreover, its accuracy is compromised if boundaries are not sufficiently dense or discriminating. **Younes & Khairallah 2020** in his study stated that the maxillary tuberosity usually consists of a thin cortical layer with a mixture of marrow spaces, adipose tissue, and vital osteogenic cells, needed for bone formation. These affect the dimensional stability of the graft and revascularization positively. Moreover**, Reininger et al. 2017 and Younes & Khairallah 2020** concluded that tuberosity harvesting showed no complications and good accessibility. A limitation to its usage is the reduced available amount of bone.

Most of the published studies were in-vivo surgical ones, with a very few focusing on the preoperative planning of the graft site using CBCT, both linear and volumetric measurements were standardized by using reference lines and defined boundaries as Similar to **Faverani et al. 2014, Reininger et al. 2017 and Younes & Khairallah 2020,** we took the boundaries of the maxillary tuberosity, just distal to the last molar and up to the schneiderian membrane. They also reported that this area was relatively safe with very low complication rate.

Maxillary tuberosity was reported as a relatively recent intraoral block donor site that was suitable for minor and limited bone augmentations particularly in the maxilla.It was claimed to augment from 4 to 6 mm bone loss or 1 to 2 teeth loss. This was stated by **Gellrich, et al. 2007**, **Sakkas et al. 2015 and Reininger et al. 2017 .** In the present study the maxillary tuberosity was 9.63 and 6.31 mm (mean) for length and width respectively, indicating that prominent tuberosity could be harvested as a block graft. However, caution must be taken to prevent Schneider membrane puncture and the ensuing creation of a fistulous defect as stated by **Faverani et al. 2014**. It can be stated that the maxillary tuberosity, in spite of its contribution with a small block graft, it was described by **Younes & Khairallah 2020,** that it shows minimum or even no complications and good accessibility. In agreement with a study done by **Khojasteh et al. 2016 and Aboushara et al.2018** stated that tuberosity alveolar block bone grafts is a valuable source of bone in augmentation of alveolar ridges deficient in width **.** Regarding implant stability and graft thickness, the maxillary tuberosities showed acceptable thickness (mean 8.16 mm) in the present study, which may ultimately help in implant stability that was in agreement with study done by **Abdeltawab et al. 2022,** with mean thickness was 10.16 mm.

When it comes to the confounding factors affecting the volume of bone grafts, **Safi et al. 2021)** performed a study on 78 CBCT scans, 39 females and 39 males (20 and 70 years) with median age of 45years. They reported significantly larger values in male patients, and a difference among different age groups. On the other hand, **Agthong et al. 2005** found no significant inter-gender difference in linear measurements but this finding was not conclusive due to their small sample size (110 candidates in their anatomical cross section study). In our study, there was no association to both factors. Males didn't show larger segments than females and age differences had no effect on the graft volume. It's worth noting that our sample size was based on graft volume calculation not considering the age and gender as confounding factors.

The volume in the current study was done in two ways, volumes calculated from linear measurements and volumes extracted by the segmentation tool(manual and semiautomatic segmentation). The difference between the two volume techniques was relatively wide 0.21±0.10, 0.24±0.09 and 0.50±0.20 for real volume ,semiautomatic and manual segmentation respectively, where segmentation showed underestimated values.This was in agreement to **Park et al. 2017, Nagla'a & Bahammam 2018 and Abdeltawab et al. 2022** who concluded that despite the inaccuracy of the semi-automatic and manual method in comparison to the real or actual volume; it is reliable and should be used as a guide and the resulting 3D shapes provide an ideal preoperative guide for the clinician according to the following reported defect sizes quantified by **Reininger et al.2017,** a small defect is named to an alveolus with maximum dimensions of 7 mm of length, 5 mm depth, and 12 mm height with a required volume of bone of 0.42 ml. A medium defect dimensions is 14–21mm length, 5mm depth, and 12mm height and this is the length of 2 to 3 teeth and an amount of bone ranging from 0.84 to 1.26 ml, whereas a large defect is with a length of over 21 mm, corresponds to 3 or more teeth span and bone volumes greater than 1.26 ml. In the present study, the volumes calculated by the semiautomatic was almost close to the volumes calculated by manual segmentation 0.26±0.15 and 0.28±0.17 respectively, so for more saving time, it would be preferred to use semiautomatic segmentation as there no difference in accuracy between the two segmented volumes. **Sahlstrand-Johnson et al. 2011** found that the results of automatically calculated volume of the sinus were 14-17% higher than the manually calculated. We believe that the clinical significance of such difference of error will ultimately rely on the structure segmented and reason for segmentation. **Alsufyani et al 2016** concluded that semiautomatic segmentation of the pharyngeal and nasal airways was found to be reliable, valid, and time efficient. **Andersen et al 2018** segmentation is accurate with small mean errors of no clinical relevance. In the current study a correlation between the dimensional measures of the graft to be harvested and a defective site in an enrolled patient did not apply. As a result, it is advised to do a prospective study on individuals who actually have alveolar defects, showing segmented volumes of the defects in comparison to volumes of the suitable donor locations.

CONCLUSION

CBCT is a valuable tool to assess the linear and volumetric measurements of the block grafts for maxillary tuberosity as an intraoral donor site. According to this study maxillary tuberosity could be a suitable source of autogenous bone graft for the treatment of small and limited defects of the alveolar process. Regarding to implant stability and graft thickness, maxillary tuberosities showed acceptable thicknesses, which will ultimately help in implant stability. However, further research comparing different intraoral bone block grafting sites for implant treatment would help to weigh up the benefits against the shortcomings of one graft over another.

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