Influence of Cone-beam CT Volume Orientation on the Proximity of Maxillary Sinus to the Alveolar Crest at Dental Implant Sites

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ABSTRACT
Aim: The aim of the study was to investigate the effect of cone-beam CT (CBCT) volume orientation on the proximity of maxillary sinus to the alveolar crest at dental implant sites.

Materials and methods: CBCT images for 54 posterior maxillary implant sites were selected for the study. Vertical distance between the floor of maxillary sinus and the alveolar crest was measured in two different volume orientations: occlusal plane and mandibular base parallel to the horizontal plane. The measurements were repeated and compared using paired sample t-test.

Results: The vertical distance between the floor of maxillary sinus and the alveolar crest was significantly greater when the CBCT volume was oriented with the mandibular base parallel to the horizontal plane (p ≤ 0.05).

Conclusions: If the CBCT volume was oriented with the mandibular base parallel to the horizontal plane, this will result in increase of the vertical distance between the floor of maxillary sinus and the alveolar crest. Subsequently, this will lead to selecting longer dental implants.

Clinical significance: CBCT volume orientation is paramount for implant planning at maxillary sinus area. Incorrect volume orientation might result in choosing implants with incorrect dimensions, this will lead to unacceptable complications at time of implants insertion.

Keywords: Cone-beam computed tomography; Dental implants; Maxillary sinus; Patient positioning.

INTRODUCTION
In recent decades, the use of implants in dentistry has been expanding to solve clinical challenges that were difficult to treat before. Because of this expansion, there has been an increased interest in attaining accurate measures to determine the residual alveolar bone quality, quantity and morphology to facilitate diagnosis and treatment planning. Cone-beam computed tomography (CBCT) offers the ability for the three-dimensional assessment that is necessary for implant dentistry but with a much lower radiation dose compared to conventional CT scans,¹ which made it the imaging modality of choice for many clinical situations in this field.² In addition, it has been established by extensive research that CBCT is an accurate and reliable tool for diagnosis and treatment planning in implant cases.³

Despite the aforementioned information, research still shows that there is a wide range of inaccuracy when linear measurements for the alveolar ridge are taken from CBCTs, which can be either more or less than what the real dimensions of the ridge are.⁴ Underestimations can lead to compromised implant length, resorting to more invasive approaches that might actually be unnecessary for the specific case being treated (such as sinus-lift or ridge augmentation) or even resorting to treatments other than dental implants. On the other hand, overestimations can lead to endangering vital structures, such as the inferior alveolar canal and the maxillary sinus among others.

Some of the postulated causes of CBCT linear measurements inaccuracies are the type of the device and the software program used, patient movement during scanning, and errors in automated and manual procedures.³ One of the factors that have come under focus is the CBCT volume orientation or patient head position. Studies that investigated the effect of this factor on the accuracy of linear measurements taken from CBCT have mixed results. Some of the studies found that there was no statistically significant difference between measurements made on tilted,⁴,⁵ rotated⁴,⁶,⁷ and tipped⁴,⁵ images compared to measurements taken in a central position. Others found that there was a statistically significant difference between measurements taken physically and CBCT measurements taken in various head positions.⁶ This statistically significant difference, however, was judged to be clinically insignificant in some of the studies⁹-¹¹ or described as “clinically acceptable” in others.¹² Out of the studies that reported in the height and width of the alveolar bone, one found a significant difference in the measurements of bone width but not height,¹³ but others found a difference in bone height but not in width,¹⁴,¹⁵ or found a difference in both height and width.¹⁶

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As evident from above, the question of whether the volume orientation significantly affects the linear measurements is an important one to answer and still largely controversial. Due to this, this study was conducted for further investigation of this issue. Moreover, this study will be the first one to investigate the effect of CBCT volume orientation on the proximity of maxillary sinus to the alveolar crest at dental implant sites.

**Materials and Methods**

**Patients**

34 patients with 54 posterior maxillary implant sites who consulted our dental clinics between January 2018 and January 2019, and underwent CBCT examination were included in this study. The patients comprised 16 males and 18 females (mean age 51 years, range 28–77) and the implant sites comprised 32 first molars and 22 second molars sites. All of implant sites included in the study were free of artifacts and pathologies. The present study is part of a protocol which was approved by the Local Ethical Committee with protocol number 319/2015.

**CBCT Examination**

As a CBCT apparatus, KODAK 9500 Cone Beam 3D System (Carestream, USA) with flat panel detector was used. The imaging area of CBCT is a cylinder with a height of 15–20.6 cm and a diameter of 9–18 cm providing isotropic cubic voxels with sides approximating 0.2–0.3 mm. Only cases examined with 0.2 mm of voxel size were included in the study. The exposure parameters were 90 kV tube voltage, 10 mA tube current and exposure time of 10.8 seconds. Examinations were performed by 360 degree rotation in occlusal position while the patient was standing and closing his/her mouth.

**Evaluation of Images**

After exporting CBCT data as Dicom files into InVivo software 5.2.3 (Anatomage, San Jose, California, USA), one calibrated oral radiologist with 13 years of experience with CBCT, measured the vertical distance between the floor of maxillary sinus and alveolar crest on a cross sectional slice generated at the center of each implant site after adjusting the volume orientation into two positions: occlusal plane parallel with the floor and mandibular base parallel with the floor (Figs. 1 to 4). In the aforementioned orientations, the center of the implant site was determined on a panoramic radiograph that was generated at maxillary alveolar crest as a reference horizontal level. After a 1-month interval, the same oral radiologist repeated all measurements. All images were evaluated on LCD monitor with the installed imaging viewer. When necessary, the window settings were adjusted to optimize the images for evaluation.

**Statistical Analysis**

The required sample size was calculated using statistics software (GPower v. 3.1.9.2; Heinrich-Heine-University at Dusseldorf, Germany). A power analysis using the matched pairs t-test, with an alpha-level of 0.05 showed that 54 implant sites would be adequate to obtain 95% power in detecting a statistical difference between measurements. Pearson’s correlation coefficients were calculated to evaluate intra-observer agreement for the vertical measurements taken after one month under two volume orientations depending on the following criteria: a value of less than 0.40 was considered to indicate poor agreement, from 0.40 to 0.59 fair agreement,
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Results
The intra-observer agreement was excellent for the vertical measurements under two volume orientations; Pearson’s correlation coefficients were 0.79 and 0.78, respectively. The vertical distance between the floor of maxillary sinus and the alveolar crest was significantly greater when the CBCT volume was oriented with the mandibular base parallel to the horizontal plane ($p \leq 0.05$, Table 1).

Discussion
Sometimes it is difficult to properly seat the patient head inside the CBCT machine, especially if the patient is obese or having movement disorders. Therefore, several studies have investigated the effect of volume orientation or patient head position on CBCT measurements at dental implant sites. Among these studies, only Sabban and Visconti et al. compared horizontal and vertical measurements of maxillary dental implant sites under different head orientation with the standard position. The focus of all other studies was only the mandible.

In Sabban et al. study, the head orientation significantly affected the vertical measurements in CBCT scan, especially when the head was extended. However, a direct comparison with our study is not possible since the head position resulting in mandibular base parallel to the horizontal plane was not considered. Moreover, they did not consider the vertical distance between the alveolar crest and the floor of maxillary sinus as the height, and it was unclear if only first or second molars implant sites were used since they use the term upper posterior implant sites.

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Table 1: Descriptive statistics of vertical measurements under two volume orientations

| Volume orientation                              | Mean  | N   | Std. deviation |
|-------------------------------------------------|-------|-----|----------------|
| Occlusal plane parallel with the floor          | 7.8504| 54  | 3.09932        |
| Mandibular base parallel with the floor         | 8.7054| 54  | 3.29477        |
Similar to our study, Visconti et al.\textsuperscript{16} showed that the majority of implant site measurements were underestimated when compared with the standard position in which the occlusal plane parallel to horizontal plane. The largest variations in maxillary bone height measurements took place when the head rotated superiorly by 20 degrees. Although there was no attempt in our study to measure the angle between both volume orientations, rotating the head superiorly to make the mandibular base parallel to horizontal plane might result in 15 degree positive vertical angulation as reported by Costa et al.\textsuperscript{13}

As reported in previous studies,\textsuperscript{5,15} to obtain accurate measurements of dental implant sites, it is recommended to orient the CBCT volume in order to make the occlusal plane parallel to the horizontal plane. Applying this to our sample of study, this will result in wider safety margin and proper implant planning. Therefore, we recommend using such softwares in order for the patients not to repeat the examination and to avoid unnecessary radiation.

**CONCLUSION**

In conclusion, if the CBCT volume was oriented with the mandibular base parallel to the horizontal plane, this will result in increase of the vertical distance between the floor of maxillary sinus and the alveolar crest. Subsequently this will lead to selecting longer dental implants which might result in damage or perforation of maxillary sinus.

**CLINICAL SIGNIFICANCE**

CBCT volume orientation is paramount for implant planning at maxillary sinus area. Incorrect volume orientation might result in choosing implants with incorrect dimensions, this will lead to unacceptable complications at time of implants insertion.

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