

# The Effect of Head Position on Buccal Cortical Bone Thickness Measurements in CBCT Scans: A Human Dry Mandible Study

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## ABSTRACT

**Objective:** The aim of this study was to compare buccal cortical bone thickness measurements on cone beam computed tomography (CBCT) scans of human dry mandibles with direct measurements and to evaluate the effect of different head positioning on measurements.

**Methods:** In total, direct linear measurements were made at reference points on the buccal bone surfaces in toothless sockets in 26 human dry mandibles. CBCT scans were performed in the central position and with four different types of head position (to the right-left, to the anterior-posterior). Thickness measurements were performed on cross-sectional sections from relevant areas where heated gutta-percha was placed. Measurements were summarized as mean±standard deviation. Differences between measurements were analyzed by ANOVA and Friedmann test.

**Results:** Compared to direct measurements, buccal cortical bone thickness in CBCT scans was higher in the incisor and premolar regions, while lower values were obtained in the molar region. These differences were statistically significant but less than 0.2 mm ( $p<0.005$ ). Different head positions had no effect on measurements on CBCT images ( $p>0.005$ ). Intraobserver agreement for buccal bone thickness was found to be high ( $ICC=0.902-0.976$ ).

**Conclusion:** It demonstrated a clinically acceptable difference between direct measurements and CBCT measurements of mandibular buccal cortical bone thickness. Additionally, no differences in measurements were observed between different types of head positions.

**Keywords:** CBCT, Head position, Buccal cortical bone thickness, Implant

## INTRODUCTION

In dentistry, cone-beam computed tomography (CBCT) is widely used for three-dimensional imaging of the maxillofacial region due to its fast-scanning time, small size, lower cost and radiation doses compared to conventional computed tomography [1-2]. Especially in the recent increase in dental implant treatments [3], radiographic evaluation of the quantity and quality of alveolar bone is of critical importance in preoperative planning, length

and width selection of dental implants, and the success of the treatment [4].

The alveolar bone of the jaws is more difficult to measure than the basal bone due to its thinness and proximity to the teeth and surrounding structures. Since linear measurements of alveolar bone are also used after orthodontic treatment and in the evaluation of periodontal status, the accuracy of the measurements is very

important [5]. Bone thickness measurements in cross-sectional images obtained by CBCT provide high accuracy and reliability [6-9]. However, there are several factors that affect image quality in CBCT scans. Among these factors, the patient's head position is a critical factor that can seriously affect the accuracy of measurements, especially in sensitive evaluations [10].

When the literature is evaluated, the results of studies investigating the effect of head positioning on measurements in CBCT images are controversial [11-16]. Although most authors argue that the measurements are not affected by different head positions [11-13], some authors claim that different positions have an effect on the results [14-16]. Human dry skull bones are frequently used to assess the accuracy of maxillofacial imaging modalities. Direct measurements made on the bones are the gold standard for these evaluations [13]. Many studies in the literature have generally evaluated the measurements of anatomical reference points [11-15]. There are studies evaluating the accuracy and reliability of CBCT measurements of buccal cortical bone with the effect of different factors (such as the use of different devices, different voxel sizes) [5,6]. However, there is only one study evaluating the effect of different head positioning [16].

The aim of our study was to compare CBCT measurements of buccal cortical bone thickness in edentulous sockets with direct measurements in the human dry mandible and to examine the effect of different head positioning on the measurements.

## MATERIALS AND METHODS

This study was approved by the University ethics committee (ID: 2018-52). A total of 26 human dry mandibles that met the following inclusion criteria were used for the study: (1) adult mandible, (2) presence of edentulous socket, (3) absence of metals that may cause artifacts, (4) absence of any pathology and physical damage (such as trauma) to the mandible.

### Main Points:

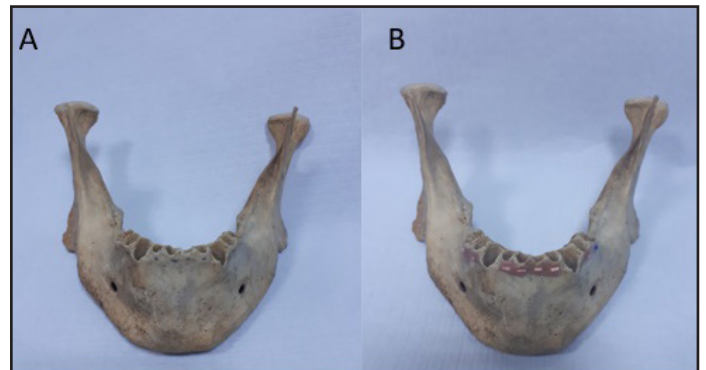
- Dental implant treatment applications have been increasing in dentistry in recent years.
- Accurate measurement of buccal cortical bone thickness on cone beam computed tomography is very important for implant treatment success.
- The minimal difference in patient head positioning does not affect CBCT measurements.

## Direct measurements (Gold standard measurements)

In each mandible, on the buccal bone surfaces of the edentulous sockets, 2 mm below the alveolar bone margin, small points, each representing the area of interest, were marked with a black pencil. (Figure 1). A digital caliper calibrated to 0.01 mm was used to measure horizontally from each marked point perpendicular to the alveolar process. For buccal bone thickness measurements, 2 independent measurements (minimum 1 day apart) were taken from the relevant areas and the mean of these measurements was recorded. These measurements on dry human mandibles were considered as gold standard values.

## CBCT scans

For standardization of CBCT measurements, radiopaque gutta-percha was used as a locator. The 2 mm pieces of gutta-percha cut into sticks were placed just below the marked areas on the bone surfaces as radiographic markers with dental wax (Figure 1).



**Figure 1.** Preparation of bone A. Drawing with a pencil B. Application of heated gutta-percha.

Human dry mandibles were scanned using the Planmeca Promax® 3D Mid (Planmeca, Helsinki, Finland) CBCT device. Scanning parameters were 90 kVp, 8 mA and 0.4 mm voxel size, with a field of view (FOV) of 160x52 mm, where the full mandible was imaged. For scanning, the mandibles were placed in a glass box (20x20x20cm) placed on a styrofoam plate. The box was filled with water before imaging to simulate x-ray attenuation of soft tissues thickness [11,12,17]. Mandibles were stored in a dry environment before imaging to prevent expansion caused by water absorption. To ensure scan standardization, a line was drawn showing the midsagittal line of the box. The box and mandible were adjusted to the laser light of the device showing the midsagittal line (Figure 2A). Five different protocols were created according to movement during scanning:

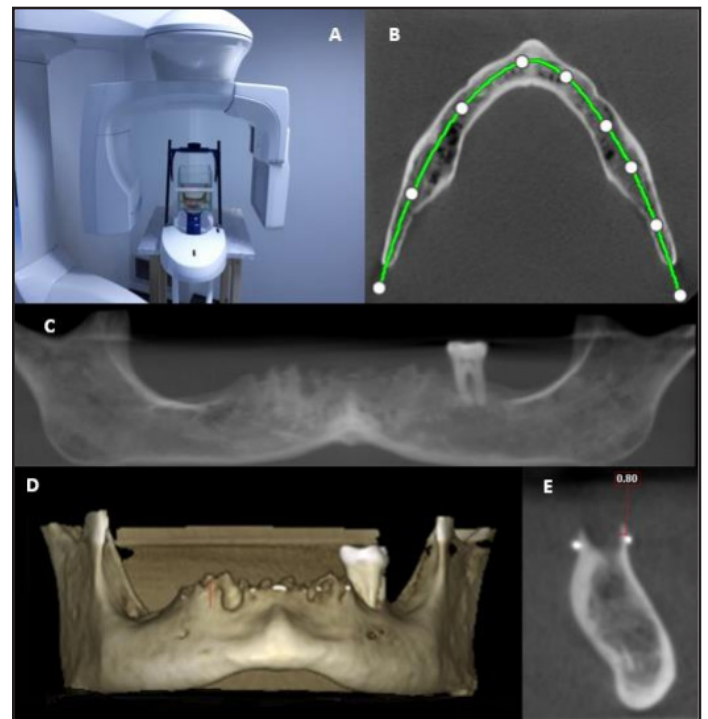
- Protocol A: Central position; The midlines of the box and mandible were parallelized with respect to the CBCT laser light. The sagittal plane of the mandible was made parallel to the vertical plane.
- Protocol B: In right-left position, the box was angulated 10° to the right. 0° Angulation in antero-posterior position.
- Protocol C: In right-left position, the box was angulated 10° to the left. 0° Angulation in antero-posterior position.
- Protocol D: In antero-posterior position, the box was angulated 10° anteriorly. 0° angulation in right-left position.
- Protocol E: In antero-posterior position, the box was angulated 10° posteriorly. 0° angulation in right-left position.

Based on studies in the literature [14,15,18,19] and the pilot test, 10° was determined as the range of motion during CBCT scanning. Inclination in various directions was provided by a preset 10-degree inclined mechanism placed under the box. To prevent movement in positioning, the mandibles were fixed to the box with dental wax. To ensure consistency in rotation angles and orientation, tilt was checked using program tools in the images created after scanning. If there was any artifact in the image, the images were repeated. A total of 155 CBCT images were obtained by scanning 31 bones in five different protocols. Before the analysis, a calibration section was created and pilot measurements were performed on 5 mandibular CBCT images, and these mandibles were not included in the study. CBCT scan data for each mandible were saved as a digital imaging and communications in medicine (DICOM) file. All measurements were performed by a research assistant (with 2 years of experience in CBCT images-B.Ç) under the supervision of an experienced dentomaxillofacial radiologist (with at least 20 years of clinical experience-C.Ö.Ü). Radiographic evaluations were made in a light-reduced environment and from a distance of approximately 50 cm, using a 24-inch medical monitor with a resolution of 1920x1080 pixels, using the original program of the device, Planmeca Romexis 2.7.0.R computer program.

### Cone Beam Computed Tomography Measurements and Evaluation

CBCT images of each bone were evaluated in the same order. Firstly, a panoramic curve was drawn on the axial images showing the sockets in the bone, passing through the center of the alveolar crest (Figure 2B). Panoramic reconstruction images (Figure 2C) and 3D CBCT scans (Figure 2D) were obtained. Cross-sectional sections were obtained from panoramic reconstruction images. For each socket site, cross-sections were determined at

the midpoint of the radiopaque gutta-percha on the buccal bone surfaces. In these sections, linear measurements in mm were made using measuring instruments in a horizontal direction just above the gutta-percha (Figure 2E). Two measurements were made for each region and the average of these measurements was recorded. Due to the different orientations, measurements in the relevant socket regions, right and left, were recorded as anterior, premolar and molar regions. To evaluate intraobserver agreement, 15% of the radiographic measurements made by the observer were repeated 15 days after the first evaluation was completed.



**Figure 2.** CBCT positioning and images A. Central Position, Protocol-A B. CBCT axial image panoramic curve C. Panoramic reconstruction image D. 3D CBCT scan. E. Measurement in cross-sectional section

### Statistical Analysis

IBM SPSS Statistics V22.0 (Armonk, New York, USA) program was used for statistical analysis, calculations and graph drawing. The distribution of buccal cortical bone thickness measurements in the relevant areas were analyzed by Shapiro-Wilk test and normality plots. Measurements were summarized as mean±standard deviation.

The accuracy of CBCT measurements was analyzed by comparing direct measurements, which are considered the gold standard,

and CBCT images obtained with different protocols. While the measurements obtained from the images were compared with direct measurements, a two-way mixed ANOVA model was established, taking into account the type of edentulous socket area (incisor-premolar-molar) and side (right-left). In the model, simple contrast was defined so that the reference measurement was the actual measurement for comparison of each image with direct measurement (simple contrast). In addition, the differences between the measurements obtained from the CBCT images and the direct measurements according to the type of edentulous socket area and side were analyzed by repeated measures ANOVA and Friedman test. The intraobserver agreement between CBCT and direct measurements was evaluated with the intraclass correlation coefficient (ICC). A 95% confidence interval (CI) was given for ICC. Statistical significance level was accepted as  $p < 0.05$ .

**RESULTS**

The buccal bones of a total of 178 edentulous sockets with 72 incisors, 56 premolars and 50 molars in 26 human dry mandibles

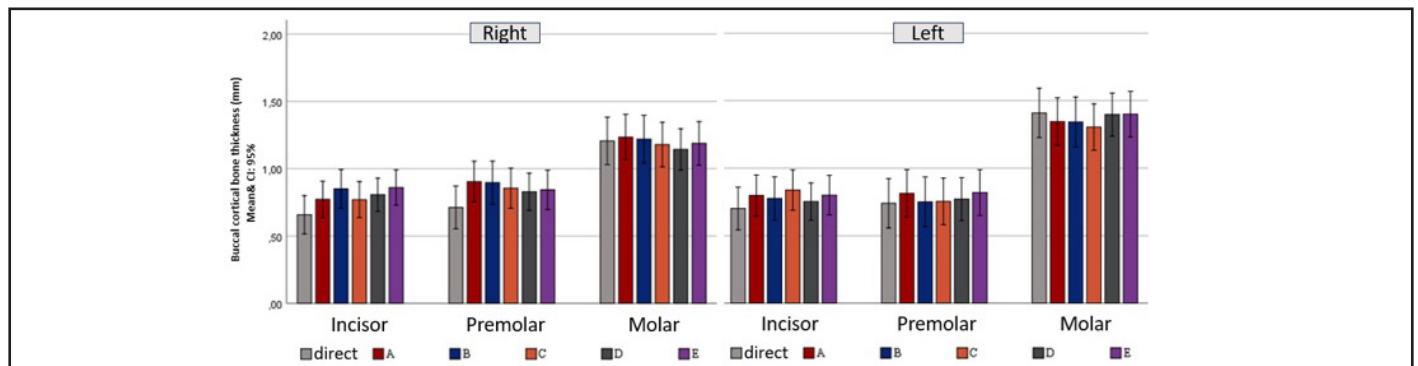
were used in the study. The mean distributions of direct and CBCT buccal cortical bone thickness measurements are given in Table 1 according to edentulous socket area type and side.

In the measurements of buccal cortical bone obtained from CBCT images, higher values were obtained in the incisor and premolar regions, while lower values were obtained in the molar region compared to direct measurements (Figure 3) and this difference was statistically significant. However, the difference was less than 0.2 mm for all regions (A:  $p < 0.001$ , B:  $p = 0.002$ , C:  $p = 0.036$ , D:  $p = 0.028$ , E:  $p < 0.001$ ). The effect of head position on the measurements was examined by comparing Protocol A (Central position) with other protocols on CBCT images. No statistically significant difference was found between the images with changing head position (CBCT,  $p = 0.802$  for B-A,  $p = 0.181$  for C-A,  $p = 0.155$  for D-A,  $p = 0.717$  for E-A). The deviation of CBCT measurements from direct measurements was analyzed according to the type of edentulous socket area. Accordingly, no statistically significant difference was found between the methods in terms of deviation from direct measurements (Table 2).

**Table 1.** Average distributions of buccal cortical bone thickness measurements in the mandible according to the type of edentulous socket area and measurement techniques

| Measurement techniques | Edentulous Socket Area |                    |                    |                    |                    |                    |
|------------------------|------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
|                        | Incisor                |                    | Premolar           |                    | Molar              |                    |
|                        | R, n=40<br>Mean±SD     | L, n=32<br>Mean±SD | R, n=32<br>Mean±SD | L, n=24<br>Mean±SD | R, n=26<br>Mean±SD | L, n=24<br>Mean±SD |
| Direct                 | 0.658±0.229            | 0.701±0.235        | 0.712±0.286        | 0.740±0.286        | 1.206±0.581        | 1.409±0.883        |
| CBCT-A                 | 0.771±0.229            | 0.797±0.205        | 0.903±0.306        | 0.813±0.241        | 1.234±0.410        | 1.345±0.934        |
| CBCT-B                 | 0.850±0.364            | 0.775±0.226        | 0.896±0.242        | 0.750±0.215        | 1.219±0.477        | 1.342±0.932        |
| CBCT-C                 | 0.770±0.306            | 0.838±0.276        | 0.855±0.247        | 0.754±0.246        | 1.179±0.414        | 1.305±0.861        |
| CBCT-D                 | 0.806±0.260            | 0.753±0.170        | 0.828±0.248        | 0.770±0.165        | 1.143±0.353        | 1.397±0.860        |
| CBCT-E                 | 0.860±0.308            | 0.800±0.203        | 0.843±0.235        | 0.819±0.225        | 1.188±0.395        | 1.400±0.878        |

CBCT, cone beam computed tomography, SD, standard deviation, R, right. L, left. n, noun. Unit is mm.



**Figure 3.** Distribution of buccal cortical bone thickness measurements according to edentulous socket type and side (CI: 95%)

**Table 2.** Differences between direct and CBCT measurements of buccal cortical bone thickness in the mandible according to the type of edentulous socket area

| Edentulous Socket Area |             |             |             |             |              |              |
|------------------------|-------------|-------------|-------------|-------------|--------------|--------------|
|                        | Incisor     |             | Premolar    |             | Molar        |              |
| Measurement techniques | R, Mean±SD  | L, Mean±SD  | R, Mean±SD  | L, Mean±SD  | R, Mean±SD   | L, Mean±SD   |
| CBCT-A                 | 0.114±0.206 | 0.096±0.211 | 0.191±0.322 | 0.073±0.168 | 0.028±0.349  | -0.064±0.333 |
| CBCT-B                 | 0.193±0.309 | 0.074±0.194 | 0.184±0.25  | 0.01±0.312  | 0.013±0.252  | -0.068±0.334 |
| CBCT-C                 | 0.113±0.272 | 0.136±0.267 | 0.143±0.251 | 0.014±0.275 | -0.027±0.357 | -0.105±0.275 |
| CBCT-D                 | 0.149±0.246 | 0.052±0.225 | 0.116±0.228 | 0.03±0.228  | -0.063±0.361 | -0.012±0.315 |
| CBCT-E                 | 0.203±0.249 | 0.099±0.227 | 0.131±0.265 | 0.079±0.252 | -0.018±0.402 | -0.009±0.364 |
| p value                | 0.252       | 0.737       | 0.327       | 0.342       | 0.385        | 0.162        |

CBCT, cone beam computed tomography, SD, standard deviation, R, right. L, left. n, noun. Unit is mm. \*P < 0.05.

When the agreement between CBCT and direct measurements was evaluated, it was seen that it had a concordance value of at least 0.857 (95% CI: 0.744-0.881) (Table 3). According to ICC, values between 0.00 and 0.69 indicate unacceptable agreement, values between 0.70 and 0.84 indicate moderate agreement, values between 0.85 and 0.94 indicate high agreement, and values between 0.95 and 1.00 indicate excellent agreement. Accordingly, the agreement of the CBCT measurements with the direct measurements was high. Intraobserver agreement for buccal bone thickness was found to be ICC=0.902-0.976 (Table 3). This result supported that there was high agreement between the measurements and that the measurements were repeatable.

**Table 3.** Compatibility between CBCT and direct measurements and Intraclass correlation coefficient (ICC) for each of the CBCT measurements

|                        | Direct measurement-<br>ICC (95% CI) | Intraobserver<br>agreement-ICC<br>(95% CI) |
|------------------------|-------------------------------------|--|
| Measurement techniques | Buccal cortical bone thickness      |  |
| A                      | 0.857 (0.774-0.881)                 | 0.902 (0.852-0.930)                        |
| B                      | 0.868 (0.764-0.874)                 | 0.976 (0.952-0.988)                        |
| C                      | 0.852 (0.762-0.864)                 | 0.923 (0.815-0.969)                        |
| D                      | 0.885 (0.784-0.897)                 | 0.919 (0.838-0.959)                        |
| E                      | 0.877 (0.726-0.896)                 | 0.975 (0.950-0.988)                        |

## DISCUSSION

In dentistry, determination of buccal bone thickness prior to immediate implant planning is of great importance for treatment success. CBCT is considered as the gold standard for the evaluation of bone quality and quantity in implant treatment planning due to its high dimensional accuracy in cross-sectional bone thickness measurement [20].

There are many studies evaluating the accuracy of CBCT in the literature. Most of the studies evaluated by making various measurements at anatomical landmarks [11,12,14,15]. Other studies have focused on the evaluation of different structures such as horizontal bone loss [21], edentulous socket dimensions and circumferential bone level [22], buccal alveolar bone height measurement [23]. There are studies evaluating the effect of different parameters on the measurements made in CBCT images. In these studies, parameters such as reducing the number of base images [16], using different voxel sizes [21,24], changing the radiation dose [25], using different devices [26,27], different head positioning [10-16,19,28] were examined.

It is noteworthy that these measurements are large in millimeters, as the measurements used in most studies often evaluate the distances between anatomical points. Structures such as cortical bone around the socket are very small and difficult to evaluate, and the number of studies on this subject in the literature is quite limited [16, 23]. In our study, unlike the literature, buccal cortical bone thickness measurements were made in three regions: incisor, premolar, molar, and the difference between CBCT and direct measurements, and the effect of different head positioning

on the measurements were evaluated.

Shokri et al. [14] found that in 3D scans in CBCT, transverse measurements between anatomical points in the maxillofacial region were lower than direct measurements on the skull, but this difference was approximately 1 mm. Timock et al. [23] using 12 cadaver heads evaluated the adequacy of CBCT in buccal cortical bone measurements. The results of the study showed that more than half of buccal bone thickness CBCT measurements were higher than direct measurements, while 41% were lower. Dings et al. [8] found an overestimation of 0.39-0.53 mm in CBCT measurements at different bone thicknesses in the craniofacial region. In our study findings, when compared to direct measurements in buccal cortical bone measurements obtained from CBCT images, higher values were obtained in the incisor and premolar regions and lower values in the molar region.

Our study shows that there is a difference of less than 0.2 mm between direct measurements and centrally located CBCT measurements. It is argued that radiographic measurements are acceptable if the difference between direct and radiographic measurements is one mm or less [28]. In our study, it was concluded that the intraobserver agreement method was highly reliable. Leung et al. [29] measured alveolar bone defect using CBCT with high reliability, which is consistent with the results of our study. The difference in results may be due to different software features of the systems used, calibration processes and the ability of the observer [26]. Additionally, Lund et al. [30] it is argued that voxel size is also effective in different estimations of measurements in CBCT scans.

In a study conducted on 7 dry sheep mandibles with a titanium pin inserted, Nikneshan et al. [28] concluded that angulation of  $-12^{\circ}$  ve  $+12^{\circ}$  on CBCT scans reduce the accuracy of linear measurements, but the margin of error is less than 0.5 mm and is within clinically acceptable limits. Hassan et al. [12] performed CBCT scans on a dry skull with ideal and rotated head positions. Their findings highlight that measurements in 3D images of CBCT scans are accurate and that small differences in head position do not affect measurement accuracy. El-Beialy et al. [13] evaluated the effect of 5 different head positions on different directional measurements in 3D CBCT images and found no change in the measurements of head position. As in most studies [11-13,28], the results of our study showed that different head positions did not affect CBCT measurements.

Unlike the studies in the literature, Nascimento et al. [16] investigated the effect of the number of CBCT basic images and head orientation on the measurements, in which they changed the rotation of the tube detector arm of the CBCT device ( $180^{\circ}$  and  $360^{\circ}$ ) and the direction of the skull ( $90^{\circ}$  and  $180^{\circ}$ ). As a result of their study on thickness measurements of the alveolar bone margin, buccal and lingual cortical bone in the anterior teeth of 11 dry skulls, it was reported that the number of basic images or head orientation did not have a consistent effect on the visualization of the alveolar bone, except for the lingual cortical bone. In this study, different protocols were created from our study by reducing device rotation and changing the head position to a wide angle in the horizontal plane. In our study,  $10^{\circ}$  angles were made, which is the amount likely to be encountered in the clinic [1,15,18,19]. One of the strengths of our study is the use of a larger sample size in this study, especially compared to studies in the literature that use dry human bones in CBCT studies [12-16,23,26,27].

Kamburoğlu et al. [31] evaluated furcation defects in three different voxel sizes (0.076, 0.100, 0.200 mm<sup>3</sup>). Cetmili et al. [21] examined horizontal bone loss on different surfaces of posterior teeth in dry skulls with two different voxel sizes (0.160, 0.250 mm<sup>3</sup>). In both studies, no difference was observed in the evaluations between voxel sizes. Kolsuz et al. [32] evaluated periodontal defects in six different voxel sizes ranging from 0.080-0.200 mm<sup>3</sup>. No statistical difference was found in the detection of all defects up to 0.150 mm<sup>3</sup>. In addition, when the caliper measures the bone from buccal to lingual, some of the volume of each voxel may be lost because each voxel has a volume in 3D images and the software measures the distance from the midpoint of the most buccal voxel to the midpoint of the most lingual voxel [14]. In our study, this may have affected our results, especially in thin structures, since the cortical thicknesses of the relevant tooth regions were different and were made in a single voxel size. Considering the differences between the studies, prospective studies evaluating the effect of voxel sizes can be performed.

### Limitations

Our study has several limitations. First of all, we evaluated a single exposure parameter in our study. Considering that voxel dimensions affect the measurement values, this may have been the reason for the difference in measurements between cortical areas in our results. Another limitation is that the maxilla could not be included in the study due to insufficient number of bones.

In future studies, studies with different voxel sizes including both jaws should be performed.

## CONCLUSION

The results of our study suggest that although there is a statistically significant difference between CBCT and direct measurements, this difference is within clinically acceptable limits (0.2 mm or less). Furthermore, different head positions during CBCT scanning do not affect the measurements. Therefore, we conclude that CBCT measurements can be safely used to assess buccal cortical bone thickness with minimal patient movement.

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**Conflict of interest:** The authors have no conflicts of interest to declare.

**Running Head:** The Effect of Head Position in CBCT Scans

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**Ethics Committee Approval:** The study described in this article was conducted within the framework of the Declaration of Helsinki. Gazi University Ethics Committee approved the study (ID: 2018-52, approval date: 06.03.2018)

**Authors' Contributions:** Conception: BÇ,COÜ; Design: BÇ,COÜ; Supervision: BÇ,COÜ; Materials: BÇ,COÜ; Data Collection and Processing: BÇ; Analysis and Interpretation: BÇ,COÜ; Literature Review: BÇ,COÜ; Writing: BÇ Critical Review: BÇ,COÜ; All authors read and approved the final version.

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