ORIGINAL ARTICLE

OPEN ACCESS | PEER REVIEWED

Effects of positioning upon the vertical dimension on cone beam computed tomography

Derya İçöz, Faruk Akgünlü

ABSTRACT

Aims: The present study was performed to investigate the effects of different positioning modalities on vertical dimensional measurements of potential implant sites in cone beam computed tomography (CBCT) images. Methods: Twenty-eight implant shaped stainless steel pins were placed in every tooth location in a dry skull and CBCT images of these pins were obtained with the skull in different positions in lateral and forward-backward planes. The following angles were used in both planes: –10°, –5°, 0°, +5° and +10°. The CBCT images were obtained with the Kodak 9000 CBCT imaging system (Carestream Health Inc, Rochester NY, USA). Panoramic slice views were used for measurement allowing all pins to be viewed on the same slice. The measurements of vertical dimensions of the pins were performed twice on the obtained images by the same observer according to tooth regions and the data was statistically analyzed. Results: Statistical analysis revealed that for forward-backward movements measurement differences were statistically significant in maxillary anterior, mandibular anterior and mandibular premolar regions and for lateral position changes statistically significant differences were observed in the maxillary premolar and maxillary molar regions for imaging modalities changing between the angles of –10° and +10°. Conclusion: Changing the skull position reduces the accuracy of vertical dimensions on CBCT scans. The results of the present study showed that skull movements between –10° and +10° effects the anterior regions significantly, but for other regions of the jaws the measurements are within a clinically acceptable range.

Keywords: Cone beam computed tomography, vertical dimension, Radiographic magnification, Patient positioning

How to cite this article

İçöz D, Akgünlü F. Effects of positioning upon the vertical dimension on cone beam computed tomography. Edorium J Dent 2016;3:40–44.

Article ID: 100018D01OA2016

****

doi:10.5348/D01-2016-18-OA-5

Derya İçöz[1], Faruk Akgünlü[1]

Affiliations: [1]Selcuk University, Faculty of Dentistry, Department of Oral Diagnosis and Radiology, Konya, Turkey.

Corresponding Author: Derya İçöz, Selcuk University, Faculty of Dentistry, Department of Oral Diagnosis and Radiology, Konya, Turkey; E-mail: dyilmaz.icoz@hotmail.com

Received: 28 March 2016
Accepted: 26 May 2016
Published: 15 June 2016

INTRODUCTION

Implant therapy is a widely used dental treatment in modern dentistry and radiographic assessment plays an important role in implant therapy [1]. Implant planning and treatment require a combination of radiographic methods [2]. The measurement error for a radiographic image should be less than 1 mm for implant procedure [3]. Preferred radiographic techniques for implant therapy are intraoral, cephalometric and panoramic radiography; conventional tomography, cone beam and multi-detector computed tomography. Among these techniques cone beam computed tomography (CBCT) is a relatively new imaging technology firstly developed for angiography in 1982 and later used in oral and maxillofacial areas [4]. In CBCT, images are obtained via an X-ray source and detector fixed on a rotating gantry. During the rotation multiple sequential planar projections of field of view (FOV) are acquired [5]. The CBCT scan provides three dimensional (3D) analyses of the maxillofacial region and as well as 3D analysis with high spatial resolution and excellent accuracy of measurements [1–6]. The effective dose of the technique is significantly lower than that of other CT imaging modalities. The CBCT technique provides adequate image quality and fast image processing [7, 8]. A literature review reveals that CBCT is the most accurate dental radiographic method [1].

The relative benefits of a radiographic method depend on the accuracy of its measurements and to reach this issue the most important failure reason is the image distortion [9]. The head position of a patient may change during clinical practice and deviate from the ideal position, which causes image distortion and may cause the images to undergo severe changes [1–7]. These changes have adverse effects on the accuracy of measurements and may cause treatment failure [7].

Nikneshan et al. [6], evaluated the accuracy of linear measurements by changing the reconstruction angles between -12° and $+12^\circ$ on CBCT images, showing that changing the orientation angle decreases the accuracy; nevertheless the measurements may be highly accurate. Hassan et al. [10], compared the measurements of 3D images with 2D slices and 2D projection images and concluded that small variations in the patient's head position do not influence the accuracy of measurements.

The aim of the present study was to evaluate the effects of skull positioning on vertical dimensions according to tooth region in CBCT panoramic slices.

MATERIALS AND METHODS

A human dry skull was provided by the Anatomy Department of Selçuk University for the study. The research project was approved by the Ethical Committee of Selçuk University, Dentistry Faculty of Konya, Turkey.

The age, gender and ethnicity of the dry skull were unknown and the skull was edentulous. Implant-shaped stainless steel pins were inserted in the jaws at each tooth location (28 locations total). Pins were placed as close to parallel to each other as possible and the sizes of all pins were equal at 15.9 mm. The gold standard measurement was obtained by using a digital caliper with a readability of 0.1mm. The dry skull was fixed on a positioner, which was capable of angular movement in lateral and forward-backward planes, with a pipe placed into the foramen magnum and the positioner was fixed on a tripod to aid in positioning (Figure 1). The following angles were used: -10°, -5°, 0°, $+5^\circ$ and $+10^\circ$. Due to the possibility of deviation from ideal position in different planes the angles were changed in both planes for every skull position. For every angular position in the forward-backward plane, the lateral positions of -10°, -5°, 0°, $+5^\circ$ and $+10^\circ$ were applied and vice versa. For lateral movements, positive angles were applied clockwise and negative angles were applied counterclockwise. For the forward-backward position changes positive angles were obtained by tilting the skull forward and negative angles were obtained by tilting the skull backward. However, when the skull was positioned at $+10^\circ$ in both the lateral and forward-backward planes, it was not possible to obtain an image including all the pins. Therefore, this skull position was not included in the statistical analysis.

Imaging and Measurement

The Kodak 9000 CBCT imaging system (Carestream Health Inc, Rochester NY, USA) was used for imaging. To provide appropriate positions of the skull a bite block and light localizer were used. The images were produced using 70 kVp, at 8 mA and for 32.40 seconds. Images were saved in DICOM format using the panoramic slice views which allows evaluating all pins in a single image. The observer measured the pins twice according to tooth location with a one-month interval between the two measurements (Figure 2). All the measurements for every pin were recorded separately and a mean was calculated for each tooth region. For standardization purposes the

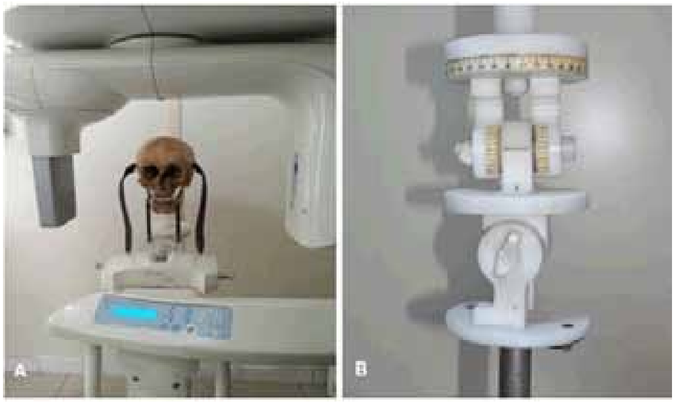

Figure 1: (A) Positioning of the dry skull in the CBCT unit, (B) positioner

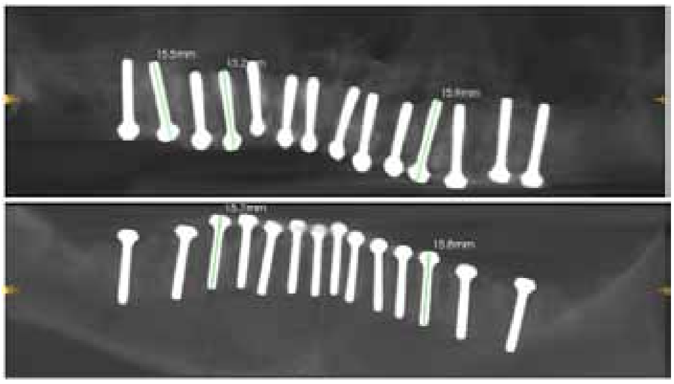

Figure 2: Demonstration of vertical height measurements of the pins on an incorrect positioned CBCT image.

measurements were performed between the midpoints of the coronal and apical edges of the pins. The measured dimensions of the pins were divided into actual size of the pins and magnification factors were obtained for each pin.

Statistical Analysis

The statistical analyses were performed by using SPSS (Statistical Package for the Social Sciences) software version 15. There was high compatibility between the first and second measurements of the observer ($p = 0.992$). The second measurements were used for statistical analysis. The difference between magnification factors in different positions was analyzed by means of one-way analysis of variance (ANOVA) and $p < 0.05$ was considered as statistically significant. For the significant differences post-hoc Tukey tests were performed to determine which positions affected the magnification factors significantly.

RESULTS

In total, 24 different positionings were assessed and 672 measurements were performed (One skull position failed to produce an image including all pins and thus was not included in the results). Data were grouped according to regions (anterior, premolar and molar) and mean values of the measurements were calculated by group.

The data obtained from the dry skull were analyzed according to ANOVA tests of the magnification factors. For forward-backward movements the differences between measurements obtained in different skull positionings are statistically significant in the maxillary anterior, mandibular anterior and mandibular premolar regions. For lateral position changes statistically significant differences were observed in the maxillary premolar and maxillary molar regions. Table 1 gives the mean magnification factors according to tooth regions and assessment of differences between magnification factors of the CBCT images. According to post-hoc Tukey tests of lateral skull position changes for the maxillary and mandibular premolar regions the magnification factors are significantly lower on the side where the head is tilted. For the forward-backward skull position changes of both maxillary and mandibular anterior regions and for the mandibular premolar region magnification factor is significantly lower when the head is tilted forward.

The statistical analysis revealed statistically significant differences between magnification factors of the maxillary molar and maxillary premolar regions with lateral skull position changes ($p = 0.016$ and $p = 0.019$ respectively for right and left premolar regions and $p = 0.00$ and $p = 0.007$ respectively for right and left molar regions). However, for both maxillary molar and maxillary premolar regions the mean error value is smaller than 1 mm. The differences between magnification factors of the anterior regions are not statistically significant for lateral position changes but the mean error value is 1 mm or slightly higher for the maxillary anterior region when the skull is tilted 10° to the right or left side. For mandibular anterior region when the skull is at 0° angle or tilted 5° to the right or left side the mean error value is 1 mm or slightly higher.

For forward-backward position changes the differences between magnification factors are significant in the maxillary anterior, the mandibular anterior and the mandibular premolar regions ($p = 0.00$ for maxillary anterior region, $p = 0.00$ for mandibular anterior region, $p = 0.001$ and $p = 0.00$ respectively for the right and left mandibular premolar regions). For the maxillary anterior region when the skull is tilted backward and for

Table 1: Magnification factors as mean±std.dev and resulted p values of ANOVA.

	Forward-backward		Lateral	
	Mean±std dev	Sig.	Mean±std dev	Sig.
Max. Anterior	0.944±0.006	0.000	0.940±0.033	0.969
Max.Premolar (R)	0.984±0.013	0.081	0.982±0.016	0.016
Max.Premolar (L)	0.989±0.010	0.052	0.987±0.013	0.019
Max.Molar (R)	0.995±0.041	0.622	0.994±0.010	0.000
Max.Molar (L)	0.995±0.018	0.239	0.994±0.009	0.007
Mand. Anterior	0.928±0.009	0.000	0.934±0.039	0.947
Mand.Premolar (R)	0.970±0.014	0.001	0.972±0.022	0.484
Mand.Premolar (L)	0.970±0.014	0.000	0.973±0.024	0.197
Mand.Molar (R)	1.003±0.049	0.252	1.003±0.008	0.265
Mand.Molar (L)	1.000±0.005	0.106	1.000±0.008	0.566

† Significantly difference $p < 0.05$

the mandibular anterior region when the skull is tilted forward the mean value error is slightly higher than 1 mm.

DISCUSSION

The head position of the patient may change before the image is processed which causes measurement discrepancies [7]. In addition, skeletal malformation and malocclusion may also affect the accuracy of measurements because of the relationship of the jaws [11]. In this study the authors investigated the effects of different skull positions on vertical dimensions according to tooth regions in CBCT images. Skull positions likely to occur in clinical practice were selected for assessment.

For the study, pins were inserted in all tooth locations on a dry skull which was fixed on a positioner. The angular position of the skull was changed in lateral and forward-backward planes for imaging. The vertical dimensions of the all pins were measured on the images twice by the same observer with a one-month interval to ensure reproducibility. Magnification factors were obtained for the study by dividing the radiological measurements by digital caliper measurements to compare the proportional changes in the vertical dimension. For statistical analysis mean values were obtained according to tooth regions (anterior, premolar and molar regions) for both jaws to minimize the effect of measurement errors and occurring variations depending on the positions of the pins. The differences between measurements on the mandibular molar regions are not statistically significant for either lateral or forward-backward position changes between -10^{o} and $+10^{o}$.

Nikneshan et al. [6] reported that, when mean absolute error of 1 mm or less is clinically acceptable. The findings of this study show that positioning affects the anterior regions relatively significantly but for other regions of the jaws the measurements are clinically within an acceptable range.

Although these measurements are mostly acceptable for clinical practice, average measurements calculated on the CBCT images tend to be slightly smaller than the determined by a digital caliper. The results of the present study are compatible with the results of a study by Yim et al. [1] which reported that almost no magnification occurred in CBCT images regardless of tooth location. These findings are also similar to those of Baumgaertel et al. [10], who reported that although the measurements are reliable analysis of data slightly underestimate the gold standard. Lascala et al. [8] found that despite the significant differences in the internal structures of the skull the actual measurements are always larger than the measurements of CBCT images and these findings are supported by the present study.

Many studies have been reported that evaluate the accuracy of measured distances in CBCT images. According to a study by Hassan et al. [12], there was no statistically significant difference between ideal and incorrectly positioned image measurements in 3D images or 2D tomographic slices. Ludlow et al. [13] concluded that CBCT measurements are not significantly influenced by different skull positions. Similarly, Hilgers et al. [14] reported that all CBCT measurements were accurate. These findings may be explained by longer distances or the differences in the measured sites.

The results of our study showed that CBCT is a mostly reliable method for linear vertical measurements in dental regions. Lund et al. [15] similarly concluded that linear measurements on CBCT tomograms are highly accurate. According to a study by Kobayashi et al. [16] comparing vertical lengths on CBCT and spiral computed tomography (SCT). The CBCT scan is more accurate than SCT in measuring distances in the mandibular bone. Another study comparing CBCT with multi-detector computed tomography (MDCT) by Al-Ekrish and Ekram [17] showed that CBCT measurements are significantly more accurate than those of MDCT.

CONCLUSION

The present study concluded that changing skull position affects the accuracy of measurements in cone beam computed tomography (CBCT) scans. The measurement inconsistency and deviation from the actual size are more frequent in anterior regions for both the maxillary and the mandibular bones. For the other regions of the jaws mean value error of measurements is within the acceptable range and for the mandibular molar region the differences between measurements and deviation from the actual size are not statistically significant. When we take all these findings into consideration, CBCT is a reliable method for determining vertical dimensions in dental regions.

****

Author Contributions

Derya İçöz – Substantial contributions to conception and design, Analysis and interpretation of data, Drafting the article, Final approval of the version to be published
Faruk Akgünlü – Substantial contributions to conception and design, Analysis and interpretation of data, Drafting the article, Final approval of the version to be published

Guarantor

The corresponding author is the guarantor of submission.

Conflict of Interest

Authors declare no conflict of interest.

Copyright

REFERENCES

1. Yim JH, Ryu DM, Lee BS, Kwon YD. Analysis of digitalized panorama and cone beam computed tomographic image distortion for the diagnosis of dental implant surgery. J Craniofac Surg 2011 Mar;22(2):669–73.
2. Mello LA, Garcia RR, Leles JL, Leles CR, Silva MA. Impact of cone-beam computed tomography on implant planning and on prediction of implant size. Braz Oral Res 2014;28:46–53.
3. Wyatt CC, Pharoah MJ. Imaging techniques and image interpretation for dental implant treatment. Int J Prosthodont 1998 Sep-Oct;11(5):442–52.
4. Benson WB, Shetty V. Dental Implants. In: White SC, Pharaoh MJ eds. Oral Radiology Principles and Interpretation, 6ed. China: Mosby Elsevier; 2009. p. 597–612.
5. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am 2008 Oct;52(4):707–30, v.
6. Nikneshan S, Aval SH, Bakhshalian N, Shahab S, Mohammadpour M, Sarikhani S. Accuracy of linear measurement using cone-beam computed tomography at different reconstruction angles. Imaging Sci Dent 2014 Dec;44(4):257–62.
7. Sheikhi M, Ghorbanizadeh S, Abdinian M, Goroohi H, Badrian H. Accuracy of linear measurements of galileos cone beam computed tomography in normal and different head positions. Int J Dent 2012;2012:214954.
8. Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofac Radiol 2004 Sep;33(5):291–4.
9. Shahidi Sh, Feiz A. Effect of Minor Amendments of Patient's Position on the Accuracy of Linear Measurements Yielded from Cone Beam Computed Tomography. J Dent (Shiraz) 2013 Mar;14(1):1–5.
10. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. Am J Orthod Dentofacial Orthop 2009 Jul;136(1):19–25; discussion 25–8.
11. Sabban H, Mahdian M, Dhingra A, Lurie AG, Tadinada A. Evaluation of linear measurements of implant sites based on head orientation during acquisition: An ex vivo study using cone-beam computed tomography. Imaging Sci Dent 2015 Jun;45(2):73–80.
12. Hassan B, van der Stelt P, Sanderink G. Accuracy of three-dimensional measurements obtained from cone beam computed tomography surface-rendered images for cephalometric analysis: influence of patient scanning position. Eur J Orthod 2009 Apr;31(2):129–34.
13. Ludlow JB, Laster WS, See M, Bailey LJ, Hershey HG. Accuracy of measurements of mandibular anatomy in cone beam computed tomography images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007 Apr;103(4):534–42.
14. Hilgers ML, Scarfe WC, Scheetz JP, Farman AG. Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. Am J Orthod Dentofacial Orthop 2005 Dec;128(6):803–11.
15. Lund H, Gröndahl K, Gröndahl HG. Accuracy and precision of linear measurements in cone beam computed tomography Accuitomo tomograms obtained with different reconstruction techniques. Dentomaxillofac Radiol 2009 Sep;38(6):379–86.
16. Kobayashi K, Shimoda S, Nakagawa Y, Yamamoto A. Accuracy in measurement of distance using limited cone-beam computerized tomography. Int J Oral Maxillofac Implants 2004 Mar-Apr;19(2):228–31.
17. Al-Ekrish AA, Ekram M. A comparative study of the accuracy and reliability of multidetector computed tomography and cone beam computed tomography in the assessment of dental implant site dimensions. Dentomaxillofac Radiol 2011 Feb;40(2):67–75.

Access full text article on other devices

Access PDF of article on other devices