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Assessment of dental implant site dimensions in cone beam computed tomography systems

Avaliação das dimensões da área de implante dentário com sistemas de tomografia computadorizada de feixe cônico

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ABSTRACT

Objective: The aim was to investigate the accuracy of linear measurements of the mandibular ridge recorded using two CBCT systems. **Material and Methods:** Eleven human dry skull were used in which mandibles were chosen to measure width and height in 6 sites. Before scanning, the points were marked using barium sulfate radiopaque contrast media. Mandible imaging was done using two systems: Newtom3G and Cranex3D. Alveolar ridge dimensions were recorded by two observers under uniform condition using special software for each system. The measurement errors and inter-examiner reliability were calculated for each modality and compared with each other and analyzed via SPSS software version 18. The level of significance was set at $P < 0.05$. **Results:** The overall mean was 0.08 mm for Cranex system and 0.5 for Newtom system. The mean of two systems had no statistically significant difference in comparison with each other or with the gold standard. The statistical analysis showed high inter-observer reliability ($P < 0.05$). **Conclusion:** CBCT is highly accurate and reproducible in linear measurements in the different areas of the maxillofacial region.

KEYWORDS

Barium sulfate; Cranex3D; Cone beam computed tomography; Dental implant; Newtom3G.

RESUMO

Objetivo: O objetivo deste estudo foi investigar a acurácia de medidas lineares do rebordo mandibular utilizando dois sistemas de TCFC. **Material e Métodos:** Onze crânios secos humanos foram utilizadas e seis regiões das mandíbulas foram escolhidos para mensuração da largura e da altura. Antes da digitalização, os pontos foram marcados com contraste radiopaco de sulfato de bário. Imagens da mandíbula foram realizadas usando dois sistemas: Newtom3G e Cranex3D . As dimensões do rebordo alveolar foram determinadas por dois observadores em condições uniformes utilizando software específico para cada sistema. Os erros de medição e confiabilidade interexaminadores foram calculados para cada modalidade, utilizando o software SPSS versão 18, e comparados entre si. O nível de significância adotado foi $p < 0,05$. **Resultados:** A média geral para o sistema Cranexfoi de 0,08 mm e 0,5 para o sistema de Newton. As médias dos dois sistemas não apresentaram diferença estatisticamente significativa em comparação entre si ou com o padrão-ouro. A análise estatística mostrou alta confiabilidade interexaminador ($p < 0,05$). **Conclusão:** TCFC é altamente precisa e reprodutível em medidas lineares nas diferentes áreas da região maxilofacial.

PALAVRAS-CHAVE

Sulfato de bário; Cranex3D; Tomografia computadorizada de feixe cônico; Implante dental; Newtom3G.

INTRODUCTION

Provision of dental implants for patients who have lost their teeth is a common practice. Anatomic structures and the surrounding bone must be assessed both clinically and radiographically before placing implants. [1] Imaging options began with two-dimensional (2-D) imaging and now include three-dimensional (3-D) imaging techniques. Diagnostic information, treatment planning and outcome benefits have increased with the use of 3-D imaging techniques. Using 3-D virtual planning techniques before treatment has resulted in optimal implant placement and improved clinical results. [2,3].

Anatomic considerations as determination of bone height and width, determination of bone density and quality, identifying and localizing internal anatomy, determining jaw boundaries, and detecting pathologies are the principal determinants in selecting an optimal implant site. Consequently, clinicians have grown to rely on various imaging modalities to aid them in implant placement. [4-6]

Intraoral and panoramic techniques cannot provide 3-dimensional images in order to determine the dimensions of bone to prepare an ideal treatment plan before implant placement. On the other hand, cross-sections provide useful information in order to determine dimensions of bone. Computerized Tomography (CT) technique provides cross-sections but it exposes the patient to high radiation doses. The principle behind this technique, as its name implies, is a cone-shaped X-ray , with the X-ray source and detector rotating around appoint On field of interest of the patient. The images received by the detector are then complied by the computer into volumetric data. CBCT is a newer technique that are both inexpensive and small enough to be used in the dental office, which yields high-resolution images with favorable accuracy; therefore, it is increasingly used to evaluate different jaw areas and measurements. [7,8]

Cone Beam Computed Tomography can provide submillimeter spatial resolution for images of the craniofacial complex, with scanning time comparable to panoramic radiography. The cone-beam technique uses rotational scanning of an X-ray source, reciprocating an X-ray detector around the patient head. CT/CBCT images are displayed as a matrix of individual blocks called voxels (volume element). CBCT can perform imaging of maxillofacial structures with different voxel sizes. The voxel size in CBCT may be as low as 0.125 mm, smaller than that achieved with conventional CT units. Smaller voxel size provides better image resolution and requires higher radiation dose. CBCT software provide tools to measure distances, angles, zoom, invert the gray scale, adjust contrast, and gamma changes. [9,10]

In the majority of studies, such as studies by Sohrabi et al. [11], Dreiseidler et al. [12], Loubel et al. [13], Suomalainen et al. [14], and Kobayshki et al. [15], in which the accuracy of CBCT has been compared with other systems or different CBCT systems have been compared with each other, the results in general have shown a high accuracy rate for CBCT system.

Two CBCT systems most are used: Newtom3G and Cranex3D. The NewTom 3G is a CBCT machine that specially designed for volume imaging of the maxillofacial region. In this device, the patient lies supine on the couch, as in conventional CT, and head centred in the gantry. [16]

The Cranex 3D is another CBCT device also developed specifically for the purpose of craniofacial imaging. With the patient sitting upright, a rotating source/detector captures a volumetric image of the patient's head, a process similar in nature topanoramic radiography. [16]. The aim of our study was to investigate the accuracy and reliability of linear measurements of mandibular ridge recorded using two systems: Newtom3G and Cranex3D, both independently and in comparison with each other.

MATERIAL & METHODS

Eleven dry human mandibles, which were not identified by gender, age, or ethnicity were used in the present study. The mandibles had no fractures, severe deformities and severe resorption. The Ethical Committee of the School of Dentistry, University of Hamadan, Islamic Republic of Iran, approved this research project. Human dry skulls were used in which mandible site were selected.

The following areas underwent measurements:

1. Two anterior areas of the left and right central incisor teeth

2. Two middle areas of the left and right canine teeth

3. Two posterior areas of the left and right first molar teeth

In these areas 2 measurements were made:

1. The height of the mandible

2. The buccolingual width of the mandible

In this study, width and height of ridge of mandibular bone were measured in marked areas. External surface of mandibular bone is " buccal surface" and inner surface that is close to the tongue, is " lingual surface". Bone width measurement is named "buccolingual width". The maximum distance between the markers in the buccolingual surface were measured.

A digital caliper was used as the gold standard for physical measurements for greater reliability of the study, in a manner similar to that in other studies. The maximum buccolingual diameter which could be measured with the caliper without interference with bony undercuts was designated as the diameter reference and the maximum distance between the buccal margin of the socket and the external border of the inferior cortex was designated as a reference for height, and these references were marked. To prevent placement of the selected areas in an undercut, at first the points were selected in a manner so that the tips of the two arms of the digital caliper (Mitutoyo, Model Cd-6"C, Japan) were exactly placed opposite to each other and then these points were marked by a marker.

Measurements with the caliper were carried out at this stage; two observers measured all the pre-determined areas in all the samples and registered the data in checklist. Then the means of the measurements made by the two observers were calculated as the gold standard.

Barium sulfate radiopaque markers were placed on the points by a very small burnisher so that the points would be visible on radiographic images. A spacer was placed on the areas marked by the markers, using rose wax, with a thickness of 1 mm. Sticky wax was placed on the markers so that they would not be detached.

Imaging of the mandibles

Axial sectional images of the mandibles were acquired with the scanning plane parallel to the long axis of the body of the mandible. (figure 1)

Reference line in all the samples and imaging techniques were applied ; in the Cranex 3D system: inferior border of the mandible was parallel to the horizon and in the Newtom3G system: inferior border of the mandible was perpendicular to the horizon, then laser beam was set for correct position.

Imaging techniques were carried out by Cranex 3D x-ray machine (Soredex, Finland) at 90 kVp, 5 mA, 6FOV and 12.6 s (Figure 2).

Then the images were reconstructed by the special software program of Cranex 3D x-ray machine, with the proprietary name of ON Demand 3D Dental. (figure 3)

Then second radiographic scans from mandibles were obtained using CBCT Newtom VG (Quantitative Radiology, Verona, Italy) at 110 kVp, variable mA, and 6FOV.(Figure 4)

The skull was then centered and fixed in the CBCT system. - in this research, because of mandible was used only, therefore, inferior border of the mandible was as a reference line and Frankfurt plane (line) was not as a reference, so laser light was set on along the inferior border of the mandible. If the position of the mandible was incorrect, scout images were obtained and position were modified, If the position was incorrect yet, all the measurements were standard by three dimensional changing and volume correction.

The raw data were reconstructed using the CBCT software (QR NNT V 2.21 Quantitative Radiology). This system has Smart Beam intelligent program that MA and time will change depending on body size in the Gantry while KVP is constant.

The special ruler of the software program was selected and the areas determined were measured in all the 11 mandibles and data were registered in special checklists.

The images were viewed in a dimly lit room using a 17-inch LG Flatron monitor (LG, Seoul, Korea), with a screen resolution of 1440× 900 pixels and a 32-bit color depth.

Observers were free to choose the settings of the software, including brightness and contrast, with no time limitation.

All the images were evaluated by two observers, an oral and maxillofacial radiologist and a post-graduate student of oral and maxillofacial radiography. Before evaluation the images, the observers were given sufficient explanation about the methodology and study design and observers were quite aware of how to work with NNT viewer and Ondemand 3D dental softwares. By the ruler, bone height and width were measured in marked areas, then data were recorded in the check list by two observer separately. Both observers watched all images and not aware of the another observer recorded or previous measurements. For reproducibility of the results, after two weeks, images were evaluated again by same observers and measurements were recorded in checklist.

For recording the information, a checklist was designed that consist of: type of CBCT systems, number of mandibular bone, width and height measurements in different areas.

Statistical analysis

SPSS software version 18 was used for data analysis. SPSS is among the most widely used programs for statistical analysis in social science. The mean of all radiographic measurements for each image sequence was calculated. T-test was used to compare the means of the measurements made with the gold standard. In order to analyze measurement errors, first the absolute values of the differences between each measurement and the gold standard were calculated. Repeated measures ANOVA was used to evaluate and compare the cumulative effect of the CBCT machine's type, measurements, measurement locations and measurement accuracy and the interactive effect of the variables. The intraclass correlation coefficient was used to determine the accuracy of the radiographic measurements and also inter-observer reliability. The level of significance was set at $P < 0.05$.

Figure 1 - Imaging with the Cranex 3D system and the image of the mandible under study.

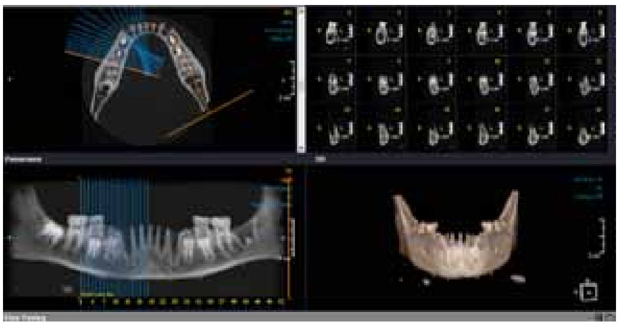

Figure 2 - Sample of images obtained via Cranex 3D system. Axial, panoramic like, crossection views and 3D image of mandible. radiopaque markers are clearly seen.

Figure 3 - Imaging with the Newtom 3G system and the image of the mandible under study.

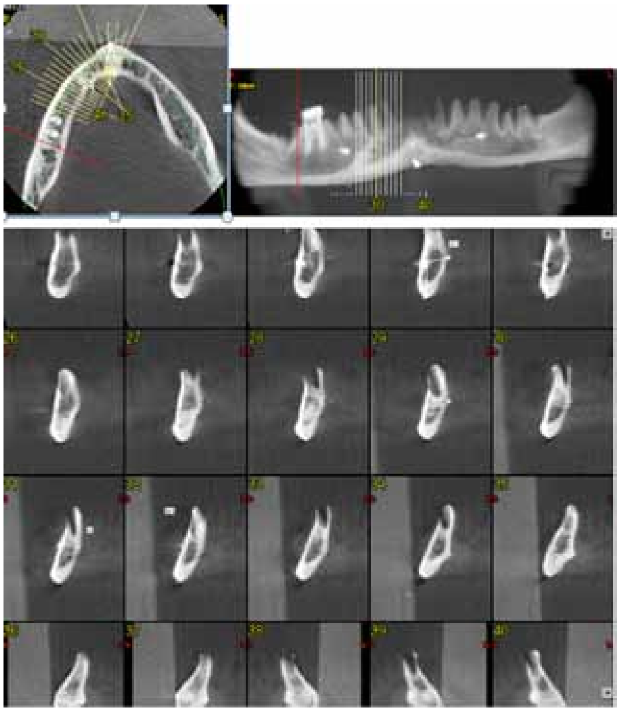

Figure 4 - Sample of images obtained via Newtom 3G system. Axial, panoramic like and crossection views of mandible. radiopaque markers are clearly seen.

RESULT

The data were collected by evaluating measurements made in relation to the buccolingual thickness and height of bone in 11 mandibles in different tooth areas using two systems: Newtom3G and Cranex3D.

The mean difference and standard deviation of the radiographic measurements of Cranex 3D system from the gold standard are summarized in Table 1.

The mean difference and standard deviation of the radiographic measurements of Newtom 3G system from the gold standard are summarized in Table 2.

The overall mean was 0.08 mm for Cranex 3D system and 0.5 for Newtom system. The mean of two systems had no statistically significant difference in comparison with each other or with the gold standard.

Agreement between observers:

Regarding the statistical analysis, no statistically significant difference was seen for both inter-observer reliability in measurements with caliper and two CBCT systems. The ICC

Table 1 - Mean difference and standard deviation of the radiographic (Cranex 3D system) and real measurements

	Mean ± SD	P- Value
height of the mandible	0.086 ± 0.12	P>0.05
buccolingual width of the mandible	0.074 ± 0.18	P>0.05

Table 2 - Mean difference and standard deviation of the radiographic (Newtom 3G system) and real measurements

	Mean ± SD	P- Value
height of the mandible	0.77 ± 0.17	P>0.05
buccolingual width of the mandible	0.24 ± 0.10	P>0.05

for inter-observer reliability varied from 0.996 to 0.999 . The statistical analysis showed high inter-observer reliability ($P < 0.05$).

DISCUSSION

For implant treatments, presurgical assessment to evaluate the dimensions of the available alveolar bone in width and height is important especially when anatomical structures in cases with great bone loss are in proximity. [17,18] Conventional radiography such as panoramic and periapical radiographs do not provide cross-sectional information, and are therefore insufficient for implant site evaluation. Tomographic images are useful for assessing information on ridge measurements three-dimensionally, considered essential for the surgical planning of implant placement. [19-21]

CBCT provides a valuable tool for evaluating craniofacial region. Effective radiation dose from a scan of maxillofacial volume is significantly lower than medical CT and is in the range of conventional dental radiographies. [22]

One of the major uses of CBCT is presurgical implant planning. The linear measurement of distances is often used in presurgical implant planning for the determination of the exact amount of alveolar bone (height and width) and consequently the size of the dental implants. Also, linear measurements are used in orthodontic analysis and in the definition of jaw tumor size. The image data is acquired from a single 360 rotation scan around the patient. [14,23] Image reconstruction provides multiplanar images.

What differentiates the present study from previous studies is the fact that in previous studies different options of CBCT machine, in relation to the accuracy of linear measurements, have not been compared. In the majority of previous studies CBCT has been compared with CT, conventional tomography, digital radiography and panoramic technique rather than being compared with each other.

Another advantage of the present study was the use of a spacer and barium sulfate marker in measurements, which prevented distortion of the external surface of the cortical bone by streak artifacts. Metallic radiopaque markers were not used in the present study because they produce metal artifacts and decrease image quality at areas undergoing measurement. In order to prevent superimposition of the opacity of the marker on the cortical bone so that the area involved can be measured without the thickness of the marker, in previous studies small metallic balls or orthodontic wines have been directly placed on bone; however, they undermine the accuracy of measurements made in these studies because they produce severe metal artifacts. In addition, use of gutta-percha is controversial due to its dimensional instability and low opacity. [24]

In the present study two observers carried out the measurements to increase accuracy; statistical analysis showed no significant differences between the two observers ($P < 0.05$) and there was a high degree of agreement between them.

In the present study, the accuracy of two CBCT systems were evaluated and the results were compared with the gold standard. A digital caliper was used as the gold standard for physical measurements for greater reliability of the study, in a manner similar to that in other studies.

The overall mean was 0.08 mm for Cranex3D system and 0.5 for Newtom3G system. The mean of two systems had no statistically significant difference in comparison with each other or with the gold standard.

Although both systems;Newtom3G and Cranex3D; are high precision in measurement of the buccolingual thickness and height of mandible, but measurement of Cranex D is closer to the caliper and more accurate from

Newtom 3G.These results might be attributed to the following factors:

1. Mandibular position in two systems are different: In Newtown 3G, patient is placed supine mode inside the Gantry and chin upward placed, while in Cranex 3D, patient is standing inside the machine, such as panoramic machine, and his/her chin is almost along the floor. in the Cranex 3D system: inferior border of the mandible was parallel to the horizon and in the Newtom3G system: inferior border of the mandible was perpendicular to the horizon . It is possible to make changes in exposure and get the images that need to be investigated in future studies.

2. The technology is used in the construction of Cranex 3D detector is newer. In this system Amorph silicon Flat Panel(AFP) with Cesium Iodide (CSI) scintillator is used that Leading to a significant increase in Spatial Resolution compared to Newtom 3G system. In Newtom 3G system, the older technology of intensifier +CCD with pixel is used, thus cortex edge detection will be easier and more accurate.

3. In Newtom 3G system, KVP is constant (KVP=110) and Only MA and time will vary slightly with respect to the patient's body and the amount of exposure is adjusted automatically by the device (Smart Beam Technology). Very high KVP and low MAS in Newtom 3G system, Despite a significant reduction in patient dose (the advantage of this system to Cranex 3D), can decrease the contrast and reduce the accuracy of the observers.

So after applying the multivariant tests, the accuracy of Cranex 3D system is close to the gold standard in measurement of the buccolingual width and height of mandible.

In the majority of studies, such as studies by Sohrabi et al. [11], Dreiseidler et al. [12], Loubel et al. [13], Suomalainen et al. [14], and Kobayshki et al. [15], in which the accuracy of CBCT has been compared with other systems or different CBCT systems have been compared with each other, the results in general have shown a high accuracy rate for CBCT system. The slight differences from the gold standard have been attributed to measurement errors with the CBCT machine or the caliper and As a result, might be attributed to the fact that the type of CBCT machine used and therefore the capabilities of their software programs were different in the two studies.

Lund et al. [25] did not report any significant differences between CBCT Accuitomo and the gold standard (digital caliper), which is different from the results of the present study.

Chen et al. [26] compared ridge-mapping measurement before surgical flap reflection and measurement using images from cone beam computerized tomography (CBCT) to direct caliper measurement following surgical exposure of the bone. They found that CBCT was less consistent compared to direct caliper measurements and did not provide any additional, significant diagnostic information. Perhaps it could be attributed to different conditions (in vitro in our study and in vivo in Chen study).

Al-Ekrish et al. [27] investigate the accuracy and reliability of linear measurements of edentulous ridges recorded from 16-row multidetector CT (MDCT) images and cone beam CT (CBCT) images acquired using a flat panel detector (FPD) with a large field of view (FOV), both independently and in comparison with each other. They reported overall mean absolute errors to be 0.75 mm for MDCT and 0.49 for CBCT. This results were closer to measurement from Newtom 3G system (0.5 mm) in our study. We assessed only the mandible for this study but they used both the maxilla and mandible bones for their study. We used a spacer and barium sulfate marker in measurements, while they marked with Gutta percha.

CONCLUSION

According to the findings of the present study both Cranex 3D and Newtom 3G systems, are reliable for use in implant treatment. Therefore CBCT is highly accurate and reproducible in linear measurements in the different areas of the maxillofacial region.

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