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The accuracy of CBCT in measuring jaws bone density

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Abstract. – BACKGROUND: The cone-beam computerized tomography (CBCT) has become widely used for oral and maxillofacial imaging, providing a good spatial resolution, gray density range, and contrast, as well as a good pixel/noise ratio. In the CBCT the dimensional accuracy is also comparable with Computer Tomography(CT), but in contrast to the CT, the gray density values of the CBCT images (voxel value [VV]) are not absolute.

AIM: The aim of the study was to evaluate if there is a statistically significant difference in bone density values, defined as gray density values(VV), using two different CBCT exposure radiation (8 mAs or 15 mAs).

MATERIALS AND METHODS: 10 dry mandibles were CBCT scanned using two different exposure radiation (8 mAs or 15 mAs). Using software and a radiographic template, the CBCT-scan images were overlapped and two datasets were created, each one giving the respective gray values (VV), of the same area with the same spatial coordinates. The quantified gray density values of the planned volume were measured and expressed as VV in two different exposure radiation scans Groups (Group A: 8 mAs; Group B: 15 mAs). For the statistical analysis, t-test was used.

RESULTS: The differences between the CBCT gray density values(VV) of the Groups (Group A: 8 mAs; Group B: 15 mAs) were statistically significant ($p <= .05$).

CONCLUSIONS: This study demonstrated that the use of a CBCT to evaluate the bone density of jaws is not useful when the values are taken as absolute values. In spite of the lower radiation dose and costs of CBCT, this new technique does not allow an accurate assessment of bone density.

Key Words:
Bone density, Computerized tomography, Cone beam.

Introduction

Osseointegrated dental implant therapy has showed, in the past three decades, successful outcomes, but some clinical reports have indicated a higher survival rate when dental implants were inserted in the mandible rather than in the maxilla[1-3].

Clinical studies have also showed that an highest failure rate is associated with poorer volume and/or density of bone[4].

The mechanical properties of the bone are an important factor for osseointegration reaching, determining the primary implant stability[5-10].

Several studies proposed a variety of methods for assessing the bone density, but these require evaluation either at the time of implant site preparation or subsequent to implant placement[4,11,12].

In the last years, due to the need of less expensive image acquisition protocols or of scanners with lower radiation dose, cone beam computed tomography (CBCT) became widely used for oral and maxillofacial imaging[13] providing a good spatial resolution, gray density range, and contrast, as well as a good pixel/noise ratio[14-17].

In the CBCT the dimensional accuracy is also comparable with CT, but in contrast to the CT, the gray density values of the CBCT images (voxel value [VV]) are not absolute[14].

The purpose of this study was:

- Evaluate if there is a statistically significant difference in bone density values, defined as gray density values (VV), using two different CBCT exposure radiation (8 mAs or 15 mAs).

The hypothesis of this study is that CBCT is not reliable to evaluate the bone density.

Materials and Methods

To evaluate the use of CBCT for bone density determining, the gray density values (VV) of anatomical specimens areas, at the same spatial coordinates, were measured using two different CBCT exposure radiation (8 mAs or 15 mAs).

This method allowed us to obtain comparable images of the same region of interest.

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The protocol employed in this *in vitro* study consisted of an integrated sequences that involved several steps:

1. Creation of a radio-transparent resin template with 9 lead circular radiopaque shots used as landmark to obtain a perfect overlapping;
2. Execution, for all anatomical specimens (10 dry mandibles), of a CBCT scanning using the same template for both two different exposure radiation scans (8 mAs or 15 mAs).
   The CBCT used (Soredex SCANORA® 3D, Tuusula, Finland) was characterized by an amorphous-silicon, flat-panel image detector and offered a cylindrical volume of reconstruction up to 13×14.5 cm with a 14-bit gray density, 0.250 mm pixel size and tube voltage of 90 KV. CBCT scanner employed factory-defined gray density attenuation.
   All acquired data were saved in DICOM (Digital Imaging and Communications in Medicine) format.
   The quantified gray density values of the planned volume were measured and expressed as VV in the two different exposure radiation scans Groups (Group A: 8 mAs; Group B: 15 mAs);
3. Overlapping of the DICOM images in order to have the same spatial coordinates for the both scans. The CBCT DICOM images were imported in a software (Mimics®, Materialise, Leuven, Belgium) and the "image registration" tool was used. The "image registration" tool allows to fuse the two datasets through a landmark point based registration (the lead shots were overlapped) obtaining a perfect overlapping of the CBCT DICOM images.
   The software runs until it finds the exact overlap between images of two and did not require any intervention by the examiner, thus excluding any possible human measurement error.
   The final result was the creation of two datasets, everyone with the respective gray density values, but characterized by the same spatial coordinates;
4. Calculation of the gray density values for the two different exposure radiation scans Groups images. A rectangle with the same spatial coordinates was drawn in both Groups and the gray density value (inside the rectangle) determined. For each anatomical specimens 30 measurements were done (10 in cancellous bone, 10 in cortical bone and 10 in cancellous and cortical bone) and the gray density values shared in six groups:

Group A1: Cortical bone CBCT (8 mAs) gray density values (VV) (Figure 1);
Group B1: Cortical bone CBCT (15 mAs) gray density values (VV) (Figure 2);
Group A2: Cancellous and cortical bone CBCT (8 mAs) gray density values (VV);
Group B2: cancellous and cortical bone CBCT (15 mAs) gray density values (VV);
Group A3: Cancellous bone CBCT (8 mAs) gray density values (VV) (Figure 3);
Group B3: Cancellous bone CBCT (15 mAs) gray density values (VV) (Figure 4).

Statistical Analysis

The volume density values of the study groups was analyzed using *SPSS*® for Windows software (Statistical Package for Social Science, Inc., Chicago, IL, USA).

Descriptive statistics consisting of mean values and standard deviation was calculated for the gray density values (VV) measured.

t-test was used to determine if there is a statistically significant difference among the gray density values (VV) of different Groups. Significance was set at $p \leq 0.5$.

Results

Quantitative data of each Group was described with mean values and standard deviation (Table I).

The differences of the gray density values, using the *t*-test, between the CBCT groups were

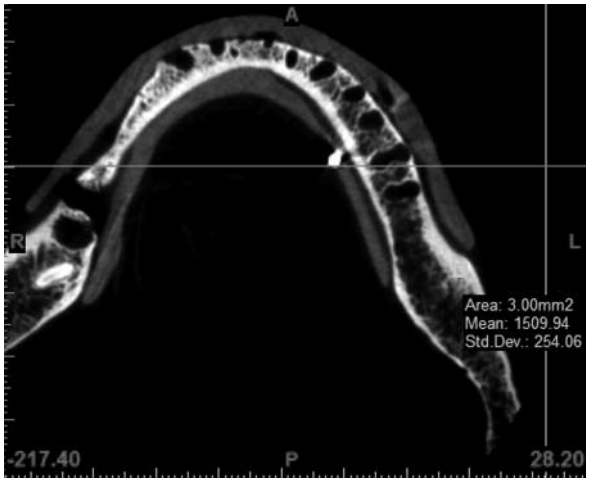

Figure 1. Determination of cortical bone CBCT (8 mAs) gray density values (VV). The drawn square shows a mean value of 1,509.94 VV. The coordinates of the square are indicated below the figure in red.

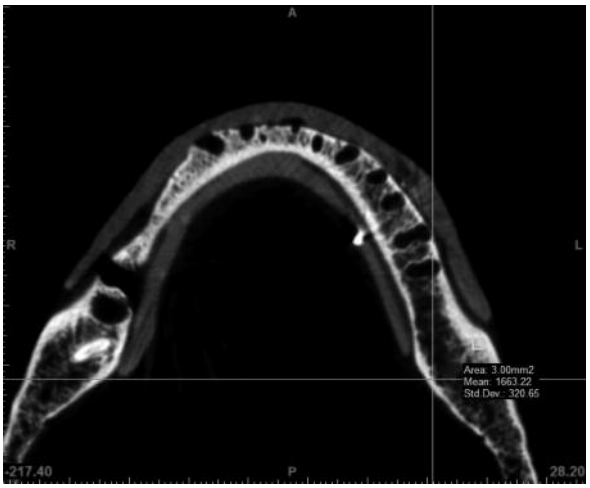

Figure 2. Determination of cortical bone CBCT (15 mAs) gray density values (VV). It should be noted that the coordinates of the drawn square are the same as in the previous figure (-217.40, 28.20). The mean gray density value recorded was 1,663.22 VV.

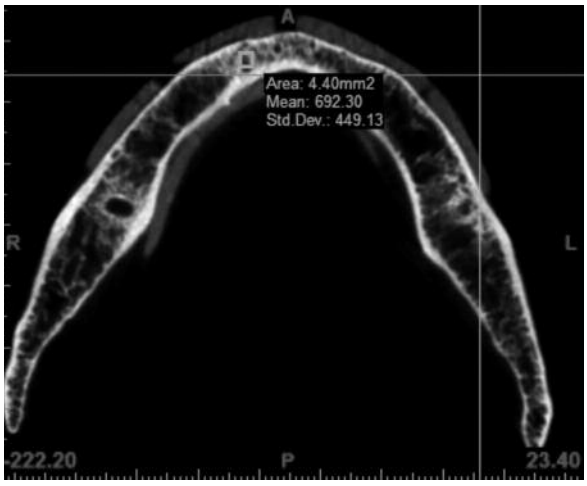

Figure 4. Determination of cancellous bone CT gray density values (VV). It should be noted that the area and the coordinates of the drawn square are the same as the previous figure (-222.20, 23.40). The mean gray density value recorded was 692.30 VV.

statistically significant for comparisons of all Groups (Group A1 vs B1, Group A2 vs B2, Group A3 vs B3) (Table II).

Discussion

The difference in bone density values, defined as gray density values, using two different CBCT exposure radiation (8 mAs or 15 mAs) was analyzed in this study.

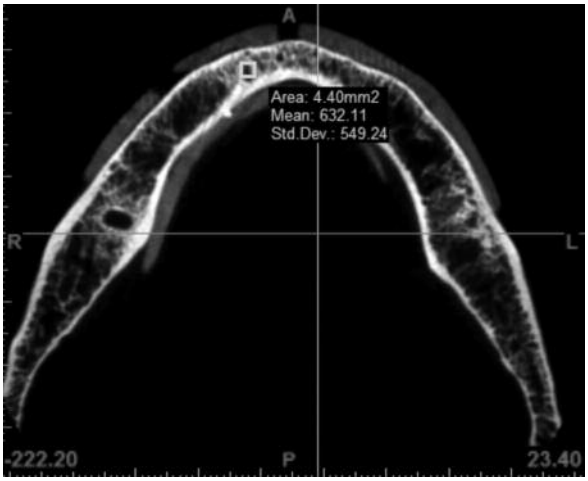

Figure 3. Determination of cancellous bone CBCT gray density values (VV). The drawn rectangle shows a mean value of 632.11 VV. The coordinates of the square are indicated below the figure in red.

In past years, traditional panoramic and periapical radiographs were considered adequate in order to plan oral and maxilla-facial surgery, despite having disadvantages such as a two-dimensional view, magnification, and no quantitative and qualitative information about bone density.

In more recent years, CT has been used to evaluate the dimension and density of bone as it provides quantitative and qualitative data of medullary and cortical bone[18].

With CT, bone density measurements are given in Hounsfield Unit (HU) based on density values for air (-1,000 HU) and pure water (0 HU). The cortical bone ranges from +1,000 to +1,600 HU values[19].

Norton and Gamble[19] evaluated that the mean bone density was 970 HU in the anterior mandible, 669 HU in the posterior mandible, 696 HU in the anterior maxilla and 417 HU in the posterior maxilla. Turkyilmaz et al[20] determined that bone density values ranged from 278 to 1,227 HU in the jaws, with a mean of 751 HU.

Shapurian et al[21] reported bone density values of 559 HU in the anterior mandible, 517 HU in the anterior maxilla, 333 HU in the posterior maxilla and 312 HU in the posterior mandible.

According to Turkyilmaz et al[4], the variability of the values recorded in the literature arises due to the influence of variables such as age and sex.

Thanks to its relatively low cost and reduced radiation dose, cone beam CT (CBCT) has became more widely used for oral and maxillofacial imaging[13].

Table I. Descriptive statistics: mean, standard deviation and minimum-maximum of bone density values, defined as gray density values (VV).

	Mean	Maximum	Minimum	SD
Group A1	1,664.61	2,730.10	1,248.90	336.91
Group B1	1,503.16	2,434.95	836.45	401.16
Group A2	1,012.64	1,248.90	859.00	129.85
Group B2	913.16	1,376.90	679.50	176.17
Group A3	549.06	845.00	307.00	154.40
Group B3	483.85	986.00	251.00	147.84

Table II. *T*-test regarding the differences between the Groups.

	Sig.	Difference between means	Standard error
Group A1 Vs Group B1	.042*	161.44	78.09
Group A2 Vs Group B2	.018*	99.48	40.64
Group A3 Vs Group B3	.022*	65.20	28.06

*Statistically significant. ($p \leq 0.05$)

Song et al[23], using a CBCT machine for presurgical quantification of gray density around 61 implant osteotomy holes, recorded values between 107 and 904VV.

Arisan et al[14], in a recent study aimed at determining the relationship between CT- and CBCT-based gray density values, revealed gray density values ranging from 167 to 989 HU and 229 to 1,042 VV.

In this investigation the gray density values measured in the CBCT using two different CBCT exposure radiation (8 mAs or 15 mAs) were analyzed, but there are no comparable reports in the literature.

The CBCT is a technique widely used in oral and maxillofacial surgery and determination of bone density is an important parameter in surgical planning especially in implantology. On the basis of the present study results an accurate determination of bone density using CBCT requires a better future assessment of the limitations of the use of CBCT.

Conclusions

This study demonstrated that the use of a CBCT to evaluate the bone density of jaws is not useful when the values are taken as absolute values. In spite of the lower radiation dose and costs of CBCT, this new technique does not allow an accurate assessment of bone density.

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