Comparison of Results of Measurement of Dimensions of the Placed Dental Implants on Cone Beam Computed Tomography with Dimensions of the Producers of the Implants

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ABSTRACT

Introduction: One of the most frequently used method for scanning patients with indication for dental implantation in dentistry is cone beam computed tomography. Implantation, CBCT imaging and implant programme are inevitable when planning a successful replacement of lost teeth. CBCT offers exact information about available bone and its density, adjacent tooth roots, the place of mandibular canal and maxillary sinus and adjacent anatomical structure. **Aim:** The goal of this study is to estimate accuracy of measurements on CBCT images of patients who have implants of different producers and determine if there is any statistically significant correlation between four test groups regardless of the alloy of which implants are made. **Material and methods:** The study was a prospective-comparative, and included fifteen patients with hundred dental implants divided in four groups depending on the producer. **Results:** Over dimensioning in the gained measurements of the whole sample on CBCT images in relation to dimensions of producers is between 0.1006mm and 0.368mm. Even though over dimensioning is measured in millimetres, it has to be taken into consideration in clinical practice when planning an implant placement, and we can recommend safety zone of 0.5mm. There have been no statistically significant differences in the gained results in over dimensioning of implants of different alloys for horizontal and vertical measurements on CBCT images of Astra Tech, Brendet titanium implants and Straumann titanium-zirconium implants. Based on the goals of the study there have been confirmed statistically significant correlations of great value (from 0.841 to 0.936) of high level of importance between manufactured value of dimensions and average dimensions values gained through CBCT imaging in four types of implants (four test groups). The total exactness of measurements on CBCT scan in this research is 96.66% for horizontal measuring and 96.92% for vertical measuring. Therefore, we can conclude that CBCT as radiological method has an unavoidable importance in planning and successful realisation of dental implant procedure. **Conclusion:** Cone Beam Computed Tomography provides exact measurements of dimensions of placed dental implant in relation to dimensions of the producers of the implant because the material from which dental implants have been made does not significantly affect the precision of the measurement.

Keywords: CBCT, implantation, implants, dimensions of measurement.

1. INTRODUCTION

With the appearance of Cone Beam Computed Tomography, CBCT, a new era has started in the area of Dentomaxillofacial Radiology. Thanks to the possibility of obtaining a large number of data in relatively short time period of exposition to X-radiation, as well as low dose of radiation, CBCT represents a desirable way of radiographic Dentomaxillofacial region (1). Craniofacial CBCT scanners have been designed in order to surpass the limitations of conventional CT scanners and to enable daily use of 3D imaging in diagnostics and planning of therapy in implantology, oral and maxillofa-

cial surgery and other branches of dentistry (2). The development of compact, relatively cheap and highly qualitative and sufficiently large panel detectors, as well as highly efficient radiographic tubes with the possibility of multiple expositions, and then the availability of more cost-effective computers with sufficient power for processing and reconstructing CTCT imaging have enabled the creation of commercial Craniofacial CBCT scanners. What also contributed to the foregoing was the possibility of limited volumetric scanning that eliminated the need for the sub-second speeds of rotation of the carrier of radiation source (2). The posi-

Figure 1. Implant placement planning in the Galileos implant program

tion of anatomic structures, such as mandibular canal, maxillary sinus, mental foramen, and teeth roots are defined with greater precision by using CBCT imaging. Dental diagnostics and therapy planning have been significantly improved by the introduction of the three-dimensional CBCT. Implant CBCT program becomes unavoidable segment during planning of compensation of the lost teeth and control of the implant surgeries (Figure 1).

2. AIM

The objective of this study was to assess the accuracy of the measurement on CBCT imaging with patients having dental implants of various producers, regardless of alloys from which implants have been made.

3. MATERIAL AND METHODS

Our research has been conducted as the retrospective-prospective study that was carried out in the X-Ray Cabinet at the Faculty of Dentistry with Clinics of the Sarajevo University. A total of 15 patients were included in the study, and they had been placed a total of 100 dental implants by different producers divided in 4 study groups. The study included patients older than 18 years, who have been subjected to implant surgeries with placed dental implants of Straumann, Bredent, Astra Tech and BioHorizons.

CBCT scanner Galileos comfort plus and face scanner (Sirona the dental company, Germany) with power voltage of 98kV, power intensity of 15-30mAs, scanning time 14 seconds, rotation 200° was used for imaging. Fixed visual field was 15 cm, and resulting scan volume was 15x15x15 cm. Isotropic voxel size was 0.25/ 0.125 mm. Following imaging and data storage, reconstruction of imaging was made in Galileos Implant Program, and also the horizontal and vertical linear measurement of dimensions of the placed implants in mandible and maxilla in sagittal and coronal plane. Linear horizontal and vertical measurements were performed in Galileos Implant program with software envisaged tools for measurements.

Parameters of assessments include the following:

- On dental implants was performed:
 - a. horizontal axis of measurements,
 - b. vertical axis of measurement.
- CBCT measurements were performed on obtained imaging of 2D reconstruction in:
 - a. sagittal reconstructive plane,
 - b. coronal reconstructive plane (Figure 2).
- Comparison of results of measurement was made between two types of implants, specifically:
 - a. implants of titanium alloy and
 - b. implants of titanium and zirconia alloys.
- Obtained results of CBCT measurement of both types of implants were compared with dimensions of the producers.

Statistic analysis included the descriptive statistics, Wilcoxon signed rank test, Whitney test, correlation coefficient. A statistic program SPSS 20.0 was used for data processing.

4. RESULTS

In our study, the average age of patients was 51.8 years (from 27 to 71), out of which total of 26.7% were males and 73.3% were females. A total of 56 dental implants were placed in upper jaw and in lower jaw a total of 44 dental implants.

Horizontal differences between CBCT measurement and original dimensions of Bredent implants were 0.1798 mm, for Astra Tech implant 0.1402 mm, for Straumann implants 1.1006 mm, for Biohorizons implants 0.1240 mm. Vertical differences between CBCT measurement and original dimensions of Bredent implants were 0.3168 mm, for Astra Tech implants 0.3688 mm, for Straumann implants 0.3474 mm, for Biohorizons implants 0.2698 mm. The largest vertical CBCT over measurements was with Astra Tech placed implants 0.3688 mm, and the lowest with Biohorizons implants 0.2698 mm. Results of Wilcoxon signed rank test have not shown that these determined differences in terms of vertical CBCT over measurements in case of 4 different types of placed implants were statistically significant. The largest

Figure 2. Sagittal and coronal reconstructive with measurements

horizontal CBCT over measurements was in case of Bredent placed implants 0.1798 mm, and the smallest one was in case of Straumann placed implants 0.1006 mm. Results of Wilcoxon signed rank test have not shown that these determined differences, in terms of horizontal CBCT over measurements in case of 4 different types of placed implants, were statistically significant. Results of total sample of obtained measurements on CBCT imaging in relation to dimensions of the producers of the sample have over measurements for horizontal measurement 3.34% and for vertical measurement 3.08%. Accuracy of measurement was obtained with regard to total sample of the obtained dimensions at CBCT imaging in relation to dimensions of the producers, for horizontal measurements it is 96.66%, and for vertical 96.92% (Figure 3).

Figure 3. Shows measurement accuracy of the total sample size obtained on the CBCT footage compared to the dimensions of the manufacturer for horizontal measurements

With these 4 types of placed implants, correlation coefficients of high values (from 0.841 to 0.936) of high level of significance from $p=0.01$ (Table 1). This indicates excellent connection and it is noticeable that with the increase of factory dimension it was followed by precise assessment of the dimension with the help of CBCT measurement.

5. DISCUSSION

By using CBCT and sophisticated programmes for planning of implant therapy during planning of the implant surgery, better assessment of the quality of the bone was enabled

Bredent implant			Horizontal measurement arithmetic mean
Spearman's rho	Horizontal fabric dimension	Correlation coefficient	0.876(**)
		Significance	0.000
		N	25
Spearman's rho	Vertical fabric dimension	Correlation coefficient	0.926(**)
		Significance	0.000
		N	25
Astra implantat			Horizontal measurement arithmetic mean
Spearman's rho	Horizontal fabric dimension	Correlation coefficient	0.894(**)
		Significance	0.000
		N	25
Spearman's rho	Vertical fabric dimension	Correlation coefficient	0.881(**)
		Significance	0.000
		N	25
Straumannimplantat			Horizontal measurement arithmetic mean
Spearman's rho	Horizontal fabric dimension	Correlation coefficient	0.841(**)
		Significance	0.000
		N	25
Spearman's rho	Vertical fabric dimension	Correlation coefficient	0.892(**)
		Significance	0.000
		N	25
Biohorizonsimplantat			Horizontal measurement arithmetic mean
Spearman's rho	Horizontal fabric dimension	Correlation coefficient	0.914(**)
		Significance	0,000
		N	25
Spearman's rho	Vertical fabric dimension	Correlation coefficient	0.936(**)
		Significance	0,000
		N	25

Table 1. Results of established statistically significant correlations

as well as length and the width of alveolar ridge, the position of adjacent anatomical structures. CBCT has small dose of ionizing radiation, high resolution of details, precise quantitative and qualitative values and simplicity in use of imaging (3).

Resolution refers to the sharpness or the possibility to show details on the image, and/or possibility of imaging system to scan the image with certain sharpness or details. What impact the resolution is the voxel size, FOV and scanning time.

The voxel size represents dimension of elements in which the volume is divided and it is usually expressed in millimeters or microns. Each voxel is awarded the value that represents the density of the object in the limits defined by attenuation of photons that go through it. It is logical to expect that the use of voxel of smaller dimensions shall allow visualization of smaller variations in density. However, this does not reflect directly the spatial resolution. Scattering of radiation, averaging of volume and artefacts may decrease the spatial resolution of scanning (4). CBCT scanners for detection of X rays use detectors that enable resolution of isotropic voxels between 0.076mm and 0.4mm. This results in multipolar reconstruction of the image (axial, coronal and sagittal) with the level of spatial resolution that is sufficient for measurement in maxillofacial region, where it is important, for the assessment of the position of implants to be precise in all dimensions (5). Due to high contrast resolution, tissues can be seen whose physical density differ for less than 1%. That means that good images are obtained of highly contrastive structures, which makes them suitable for the assessment of the state of bones and teeth. Results of our research indicated constant over measurements of implants on CBCT imaging that moved in range from 0.1006mm to 0.3688mm or 3.34% for horizontal measurement and 3.08% for vertical measurement. Differences between linear measurements on CBCT imaging have increased with the increase of the dimension of the producers implants which can be related to radiation of metals and/or alloy of titanium or alloy of titanium - zirconia. Statistical analysis has been made of the differences between implants with alloy of titanium and implants with alloy of titanium - zirconia, and obtained analyses have not shown that there exist significant differences in measurements, wherefrom it ensues that the material from which implant has been made has no impact on the quality of the image and does not impact the precision of the measurement. Lately, several studies have been published that dealt with examining of the precision of measurement of CBCT imaging. Similar results to our research have been obtained by Moshfeghi and associates who were checking the correctness of CBCT linear measurements in different areas of FOV. Analysis of the measurement has shown that measurements of CBCT are very precise. Average differences between radiological measurements and actual measurements varied from - 0.2781 mm for coronal cross sections (voxel size 0.3 mm) to 0.1418 mm for axial cross sections of high resolution (voxel size of 0.15 mm). Medium difference in their study was smaller than 0.5 mm. Authors have concluded that CBCT is reliable and precise for the measurement (6). Difference of measurement smaller than 0.5 mm may be taken as security zone in planning the placement of implants. Somewhat larger difference of measurement from the one in our research was

obtained by Fatemitabar and associates, who assessed the correctness of CBCT (Planmeca), and they have found out that the average difference varies between 0.37 mm to 0.58 mm for CBCT, and from 0.37 mm to 0.72 mm for 64-detector CT (Siemens) (7). With CBCT imaging, exposure to radiation of patients is much smaller in relation to 64-detector CT, and also the quality of the image and precision in measurement presented in the work of Fatemitabar and associates gives advantage to CBCT radiological method. Pinsky and associates conclude that CBCT (i-CAT) might be correct diagnostic method for small bone defects. They have found that average differences vary from -0.01 mm to 0.27 mm for the width and height of the correctness (8). Stratemann and associates have also found a large precision with CBCT imaging for linear distances in comparison to actual measurements. Errors were small for NewTom 9000 CBCT system and varied from 0.07 mm $\pm$ 0.41 mm and for CB Hitachi MercuRay CBCT system varied from 0.00 $\pm$ 0.22 mm (9). Results of the mentioned research match with the results obtained in this research, in which differences vary between 0.1006 mm to 0.3688 mm.

Comparison of the precision of linear measurements performed with the help of methods CBCT and MSCT is described by Loubele and associates in their study published in 2007. Results have shown that the precision of linear measurements obtained with the help of MSCT method is somewhat larger (0.54 $\pm$ 1.14 mm) in relation to CBCT method (-0.09 $\pm$ 1.64 mm) (10). However, that difference is not statistically significant and authors conclude that CBCT method and MSCT method have good sub-millimeter precision of linear measurements.

Examination of application of CBCT in planning of oral-surgical interventions is conducted by Agbaje and associates, the aim of their study was to assess the precision of the volumetric analysis of extraction wounds with the help of CBCT. Obtained results indicated that there is no significant difference in values of the volume of dental alveoli defined by direct measurement and with the help of CBCT method. Based on that the authors conclude that CBCT method provides absolutely exact data regarding the volume of dental alveoli and it can reliably be used in clinical practice especially for the evaluation of the process of healing of extraction wounds under different conditions (11).

The dimensions of the implants placed in upper and lower jaw were compared in our study, and the results obtained by this comparison have no statistically significant value. Coefficients of correlation with all 4 types of placed implants (4 study groups) are of large value (from 0.841 to 0.936), of relatively high level of significance from $p=0.01$. This indicates that the increase of factory dimensions was accompanied by the precise estimate of the dimension with the help of CBCT measurement.

Image noise, resolution, appearance of artefacts by patients and by devices are the factors that significantly impact the quality of the image, and thereby the precision of linear measurement. Analysis of the obtained over measurements for horizontal and vertical measurement on CBCT image with Astra Tech, Bihorizons, Brendet implants of alloy of titanium and Straumann implants of alloy of titanium zirconia shows no statistical significant differences in obtained over measure-

ments between implants of various alloys. Based on the results obtained we can conclude that the material (alloy of titanium and alloy of titanium zirconia) from which the implant was made does not impact the quality of the image nor the precision of the measurement on CBCT imaging. Over measurements in obtained measurements of total sample on CBCT imaging in relation to dimension of the producer is sub-millimeter and moves in range from 0.1006mm to 0.368mm, and/or 3.34 % do 3.08%. None of the mentioned 4 placed implants (study groups) showed deviations according to the routine form, but they were sporadic and not connected. There were no significant statistic deviations due to the positions of implants in relation to the jaw or region. Based on the aims of the research, statistically significant correlations were found of high level of significance between factory values of the dimensions and average values of dimensions obtained by CBCT measurement of 4 types of placed implants with high coefficient of correlation. Total accuracy of the measurement on CBCT imaging in this research for horizontal measurement is 96.66%, and for vertical measurement is 96.92%, and from obtained results we can conclude that CBCT as radiological method has unavoidable significance in planning of implant surgeries and their successful outcome. Even though differences of over measurements are sub-millimeter ones, they should be considered in clinical application when planning placement of implants. From the mentioned results, it can be suggested that when selecting dimensions of implants and their planning on CBCT imaging, implantologists use safety zone of 0.5mm.

6. CONCLUSION

Cone Beam Computed Tomography provides exact measurements of dimensions of placed dental implant in relation to dimensions of the producers of the implant because the material from which dental implants have been made does not significantly affect the accuracy of the measurement.

• Conflict of interest: none declared.

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