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RELATIONSHIP BETWEEN TOMOGRAPHIC BONE DENSITY AND PRIMARY STABILITY OF OSTEOINTEGRATED IMPLANTS

Tatiana Helena Brunelli Caldas
Brazilian Dental Association
Petrópolis, Rio de Janeiro
http://lattes.cnpq.br/6333388249352034

Mariana Ribeiro de Moraes Rego
Universidade do Estado do Rio de Janeiro, Dentistry Course, Department of Prosthesis
Rio de Janeiro, Rio de Janeiro
http://lattes.cnpq.br/2431394853212384

Eduardo José Veras Lourenço
Universidade do Estado do Rio de Janeiro, Dentistry Course, Department of Prosthesis
Rio de Janeiro, Rio de Janeiro
http://lattes.cnpq.br/0024836844885547

Mayra Cardoso
Universidade do Estado do Rio de Janeiro, Dentistry Course, Department of Prosthesis
Rio de Janeiro, Rio de Janeiro
http://lattes.cnpq.br/7882632501333995

Abstract: The objective of this study is to correlate the primary stability of implants, given by the insertion torque obtained during installation, to the tomographic bone density measured on cone beam tomography (CBCT), in the same region, considering factors such as age, gender, location, length and diameter of the implants. Data were collected from medical records of 19 patients attended in the specialization course in Implantology at ABO/Petrópolis-RJ, who underwent implant installation surgery between 2011 and 2015. From a total of 114 implants, the insertion torques were obtained, measured by the surgical torquemeter, immediately after insertion into the receptor site. In each patient's CBCT, using the Dental Slice® software, virtual implants were installed in the same positions corresponding to the implants described in the care record. Using the "Hounsfield line" tool present in the program, bone density values were recorded in 3 positions around the implant (buccal, apical and lingual/palatal), in 3 trans-axial sections of the tomography, obtaining an average which was considered the bone density in the region. The results were analyzed using parametric and non-parametric tests, with a significance level of 0.05. Density and torque were greater in the mandible than in the maxilla (p=0.000), and greater in type I and II bones than in type III and IV bones (p=0.000). A moderately significant correlation was found between bone density and implant torque (Spearman correlation coefficient=0.439; p=0.000), suggesting that CBCT can be used to predict insertion torque during surgical planning.
Keywords: Cone beam tomography, CBCT, bone density, torque, dental implants

INTRODUCTION

The concern with carrying out more precise surgical planning has led dentistry professionals to make use of technological resources that are more advanced than conventional radiographic exams, and opt for Cone-Beam Computed Tomography (CBCT) as the essential work tool. According to Bou Serhal et al. (2002), Guerrero (2006) and Turkyilmaz et al. (2007), the overlap of various tissues on conventional radiographs is a limitation that prevents appropriate assessment in some cases. In addition to locating important anatomical structures, CT scans can provide us with essential data such as width, height, density and structures of bone tissue. They allow the visualization of non-overlapping anatomical structures, thus generating a highly reliable image, in addition to being a low-cost resource with little exposure to radiation, compared to multislice tomography (Arandayarachkul et al., 2005).

The quality of the bone tissue of the maxilla and mandible can be assessed on tomography based on its density, based on macroscopic characteristics of the cortical and trabecular bone (Lekholm & Zarb, 1985; Misch et al., 1998). Bone density can be assessed using the Hounsfield tomodensitometric scale. Godfrey Hounsfield, in 1972, quantitatively described bone density, obtaining a scale based on the amount of gray tones in computed tomography (CT) images, thus creating the Hounsfield unit (HU). The scale is based on two criteria: attenuation in dry air, set at -1000 HU, and attenuation in water at 25°C, set at 0 HU. On this scale, the average HU values of cortical bone range from +1000 HU to +1600 HU, in CT. Based on this, Shapurian et al. (2006) established a relative scale of values in different bone types: >600 HU: very dense cortical bone, 400 to 600HU: dense cortical bone, and <200HU: low-density cortical bone. These values vary between CT and CBCT. Hao et al. (2014) observed statistically significant differences in mean bone density between different regions of the jaw, concluding that HU must be better understood as "relative" density rather than "real" density.

Bone density is a fundamental parameter for carrying out immediate loading, which is the restoration of the dental element and its putting into function within 72 hours after installing the implant. Immediate loading represents a reduction in treatment time, but requires minimal initial primary stability of the installed implant. Primary stability is one of the prerequisites for achieving osseointegration and the main indicator of success for dental implants.

The initial or primary stability of an implant can be measured by the clinical insertion torque during its installation, being a non-subjective and non-invasive method (Pagliani et al. 2010). According to Friberg et al. (1999) and Sakoh et al. (2006), the preparation of the bone bed receiving the implant also influences primary stability, and it is important to evaluate the bone density of the site to be operated on to define the surgical approach in order to favor this stability.

The possibility of correlating bone quality (density) with primary stability can be an interesting resource for surgery, as it provides preoperative data that determine greater treatment predictability (Isoda et al., 2011). Marquezan et al. (2012) stated that there is a positive association between primary stability and bone density. According to Norton and Gamble (2001), Shapurian et al. (2006), and Loubele et al. (2007), the variation between bone density values in different regions of the jaw bones is extremely important for preoperative assessment, and accurate information on bone density in these regions is data that must be taken into consideration.

Jaysankar et al. (2012) correlated the shades of gray found in volumetric tomography with the subjective assessment of bone quality at the time of surgery. They concluded that the gray values found on CBCT can be used as an aid to predict bone quality. According to Lee et al (2007), bone density as determined by CT and CBCT is related to the resistance to implant insertion, suggesting that this method can be used to predict the primary stability of the implant.

Salimov et al. (2013) observed a statistically significant correlation between the density values found in CBCT and the stability of the implant, reaching the conclusion that the assessment of bone density using CBCT is an efficient method to predict the initial stability of the implant prior to surgery, as well as such as the possibility of immediate loading.

Thus, the objective of this work is to correlate the primary stability of implants, given by the insertion torque obtained during installation, to the tomographic bone density measured on CBCT, in the same region, considering factors such as age, gender, location, length and diameter of the implants.

MATERIAL AND METHODS

This research was approved by the Research Ethics Committee, under registration number 61138316.0.0000.5256 and was carried out using data collected from the medical records of patients treated in the specialization course in Implantology at ABO/Petrópolis-RJ, from 2009 to 2015. 112 medical records were initially examined and, following the inclusion and exclusion criteria, 19 medical records were selected, totaling 114 implants.

Medical records of patients with implants already installed and with prosthetic treatment completed were included in this study. Preoperative CBCT scans saved in the Dental Slice® software must also be available.

Records of patients who were still undergoing treatment, patients who only had x-rays as an initial examination, tomography

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saved in a program other than Dental Slice®, and records that did not have at least one of the data that were used in the research were excluded.

The following data contained in the medical records were collected: (1) data regarding the patients' general health; (2) implant insertion torque value measured by the surgical torquemeter; and (3) implant data, such as model, brand, length and diameter.

Implants with the same geometric characteristics described in the patients' records were virtually installed in the tomographic examination, using the Dental Slice® software, in order to reproduce the surgical procedure. Then, using the "Hounsfield line" tool in the program, bone density values were obtained in three different cross-sections (mesial, central and distal), with three regions surrounding the implant being measured in each section (buccal, lingual and apical). The average of these measurements was considered the bone density of the region corresponding to each implant, and determined the type of bone found.

Data were analyzed using the SPSS 20.0 program. The results were subjected to the Shapiro-Wilk and Kolmogorov-Smirnov normality tests, using parametric statistical tests for normal distributions (Student's t test or Anova) and non-parametric tests (Mann-Whitney or Kruskal-Wallis) for non-normal distributions. normal. The correlation between bone density and insertion torque was assessed using the Spearman correlation test. The significance level adopted was 5%.

RESULTS

The patients' ages ranged from 35 to 80 years. Of 114 implants installed, three men received 24 implants and 16 women received 90 implants, both in the maxilla (62 implants) and mandible (52 implants).

Four distinct regions of implant installation were considered to observe the distribution in the dental arches: anterior maxilla (corresponding to the region between elements 13 to 23), posterior maxilla; anterior mandible (region between the 2 emergences of the mental foramina); and posterior mandible.

The installed implants were classified according to the following characteristics: length (short – up to 10 mm – and long – above 10 mm); diameter (narrow – 3.3 mm –, regular – 3.75 mm to 4 mm – and wide – 5 mm); and design (cylindrical, cylindrical-conical and conical). The bone type, determined by the "Hounsfield line" tool, was classified as: type I (above 2300 HU); type II (from 1900 to 2299 HU); type III (from 1400 to 1899 HU); type IV (from 500 to 1399 HU).

Bone density and insertion torque were evaluated in relation to the variables gender, age, implant installation region, type of bone, length, diameter and implant design, and are described in Table 1.

In general, density and torque were greater in the mandible than in the maxilla. The average densities of the anterior and posterior regions of the maxilla were similar to each other, and the same occurred in the mandible. The torque in the anterior maxilla was similar to that in the posterior mandible, being greater than in the posterior maxilla and smaller than in the anterior mandible.

In relation to bone type, the densities of types I and II were similar to each other, and greater than type III, which in turn was greater than type IV. Torque was similar between types I, II and III, and lower in type IV.

There was no significant difference in density or torque in relation to gender, age, or length, design or diameter of the implants.

A significant moderate correlation was found between bone density and implant torque (Spearman correlation coefficient=0.439; p=0.000).

Variables	N	Density (HU) mean ± standard deviation median; Minimum; maximum	Torque (NCm) mean ± standard deviation median; Minimum; maximum
Gender		*P=0,237*	*P=0,452*
Male	24	1559,33 ± 655,46	43,54 ± 14,02
		1516,41; 449,21; 2599,00	45; 20; 70
Female	90	1745,56 ± 421,21	40,11 ± 17,40
		1688,51; 827,16; 2869,00	45; 10; 80
Age		*P=0,385*	*P=0,144*
Up to 50 years	24	1596,2 ± 503,11 1674,27; 449,21; 2566,75	36,66 ± 13,64 40; 10; 60
Over 50 years	90	1735,73 ± 475,68 1688,51; 630,36; 2869,00	41,94 ± 17,38 45, 10, 80
Jaw		*P=0,000*	*P=0,000*
Jaw	62	1436,21 ± 396,43	34, 35 ± 15,43
		1436,67; 449,21; 2708,30	35; 10; 60
Mandíbula	52	2028,45 ± 365,76	48,55 ± 14,99
		1961,15; 1501,77; 2869,00	50; 20; 80
Region		*P=0,000*	*P=0,000*
anterior maxilla	32	1452,74 ± 272,77	40,46 ± 12,97
		1511,52; 745,88; 1838,29	42,5; 10; 60
posterior maxilla	30	1418,58 ± 500,42	27,83 ± 15,35
		1327,11; 449,21; 2708,30	20, 10, 60
anterior mandible	8	2189,42 ± 431,95	65,00 ± 7,55
		2325,22; 1665,19; 2678,12	60; 60; 80
Posterior jaw	44	1999,18 ± 350,14	45,56 ± 14,06
		1956,97; 1501,77; 2869,00	45; 20; 70
Bone type		*P=0,000*	*P=0,000*
Type I	13	2542,38 ± 149,28	52,69 ± 16,02
		2545,11; 2352,00; 2869,00	60; 20; 80
Type II	22	2029,25 ± 175,08	46,13 ± 13,35
		2041,09; 1701,77; 2290,67	45; 20; 70
Type III	50	1690,87 ± 205,85	42,10 ± 15,68
		1213,48; 1407,99; 2693,79	45; 10; 70
Type IV	29	1113,33 ± 250,08	29,31 ± 10,16
		1213,48; 449,21; 1367,63	25, 10, 60
Length		*P=0,932*	*P=0,895*
Up to 10 mm	25	1699,07 ± 423,70	40,60 ± 16,54
		1690,26; 903,57; 2599,00	40; 20; 70
Over 10 mm	89	1603,03 ± 500,21	40,89± 16,89
		1681,48; 449,21; 2869,00	45; 10; 80
Diameter		*P=0,911*	*P=0,945*
Narrow	2	1531,77 ± 337,62	45,00 ± 7,07
		1531,77; 1293,04; 1770,51	45, 40, 50
Regular	106	1712,95 ± 490,85	40,75 ± 16,71

		1684,68; 449,21; 2869,00	45; 10; 80
Wide	6	1647,96 ± 407,45	40,83 ± 17,72
		1731,97; 903,57; 2108,06	42,5; 20, 70
Project		*P=0,066*	*P=0,157*
Cylindrical	64	1732,09 ± 485,82 1731,12; 449,21; 2708,30	39,06 ± 15,98 40,00; 10,00; 70,00
Conical	19	1879,20 ± 560,81 1699,64; 903,57; 2869,00	39,47± 20,40 40,00; 10,00; 80,00
Cylindrical-conical	31	1547,29 ± 383,13 1582,29; 745,88; 2405,92	45,32 ±15,54 50,00; 20,00; 70,00

Table 1 - Descriptive statistics of density and torque in relation to the analyzed variables

DISCUSSION

When evaluating the results obtained in this research, it is possible to confirm the importance of using CBCT as a surgical planning tool, mainly aiming at immediate loading. Our results corroborate the findings of Fuster-Torres et al. (2011), who concluded that measuring bone density using preoperative CBCT can be a useful tool for diagnostic purposes, especially in suspected cases of low bone quality.

CBCT has established itself as an essential exam for surgical planning, and can be used to plan not only the length, diameter and distribution of implants to be installed, as well as to evaluate preoperative bone quality.

A study carried out by Parsa et al. (2013), with the aim of exploring the effectiveness of CBCT-derived bone density value, evaluated its correlation with implant stability parameters, including insertion torque value, in relation to different clinical variables such as gender, age, bone quality and implant diameter. Statistically significant correlations were found between CBCT bone density values and implant stability parameters in relation to all variables, leading to the conclusion that bone density assessment using CBCT is an efficient method and significantly correlated with the stability parameters. implant stability and the Lekholm & Zarb index (1985). Thus, it is possible to predict the initial stability of the implant and the possibility of immediate or early loading using CBCT before implant installation.

Based on the hypothesis that the density is the same between both genders, we conclude that this applied to this study, however, Bassi et al. (1999) and Solar et al. (2010) reported discrepancies between the genders related to bone changes due to hormonal factors and chewing muscle strength.

When evaluating the results obtained in this study in relation to bone type, torque and density, we confirm the statements of the study carried out by Lekholm & Zarb (1985), when a bone type classification was created based on the amount of cortical and medullary bone in a given area, thus confirming that CBCT is a reliable method for assessing bone quality.

A major question arises from the lack of standardization of density values obtained from different tomographs. However, according to Salimov et al. (2014), the use of this exam is an efficient method and significantly correlated with the primary stability and the classification of Lekholm and Zarb (1985).

The analysis carried out in this study between density and torque, where we obtained a moderate correlation between these two variables, may have been influenced by several factors inherent to the surgical procedure, such as the use of extremely long implants in a low density region, to obtain immediate loading, a factor that generates a positive result clinically, as the use of long and inclined implants can be a device to achieve better locking and, consequently, better primary stability in the apical region of the implant, maintaining the three-dimensional prosthetic position ideal platform and thus obtaining immediate loading.

Since the primary stability of implants is a determining factor for their success, as well as immediate loading, Arisan et al. (2012) carried out a study on edentulous mandibles where they considered the primary stability parameters measured by the insertion torque value and resonance frequency analysis. The radiographic and subjective classification of bone quality was also used as one of the factors for analysis in CBCT, comparing with this same criterion in multislice tomography (CT). They concluded that, similar to CT gray density values, CBCT could also be predictive for the subjective radiographic assessment of bone quality and primary implant stability. The results must be confirmed on different CBCT devices.

In order to objectively evaluate the reliability of CBCT as a tool for the preoperative determination of bone density, González-García et al. (2013) analyzed the histomorphometric relationship with the bone. Density was expressed as bone volumetric fraction assessed by micro-CT of bone biopsies at the insertion site of dental implants in the maxillary bones. To do this, they analyzed 39 bone biopsies from 31 patients, which made it possible to determine in the preoperative phase the average density of the long bone axis where the implants would be installed. Then, the bone volume fraction was measured using micro-CT of the extracted biopsies, concluding that radiographic bone density assessed by CBCT has a strong positive correlation with the bone volume fraction assessed by micro-CT at the site of dental implants in maxillary bones. Preoperative estimation of density values by CBCT is a reliable tool for objectively determining bone density.

CONCLUSION

There is a moderate correlation between bone density obtained by CBCT and implant insertion torque, suggesting that CBCT can be used to predict insertion torque during surgical planning. The mandible has higher values of density and insertion torque than the maxilla. Factors such as patient gender or age, or implant-related factors such as design, length or diameter, are not directly linked to bone density or insertion torque.

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