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Computerized tomographic pre–implant evaluation of bone density

Florian - Constantin Dogioiu [1,*], Rodica Luca [2], Dragoș Epistatu [3]

[1] Department of General Radiology and Dentistry, University of Medicine and Pharmacy "Carol Davila" Bucharest, Romania
[2] Department Pedodontics, University of Medicine and Pharmacy "Carol Davila" Bucharest, Romania
[3] Department of General Radiology and Dentistry, University of Medicine and Pharmacy "Carol Davila" Bucharest, Romania

*corresponding author e-mail address: ***florian.dogioiu@gmail.com***

ABSTRACT

Determination of bone density is indispensable to any objective and realistic preimplant assessment of bone supply. Objective: determining the role and informational contribution of the computerized tomographic imaging examination (CT) at the stage of pre-implant assessment through qualitative determinations (maximum and minimum density) of the edentate alveolar ridges of the jawbones, at the level of the potential dental implant sites. Retrospective study conducted on a sample of 46 patients to whom have been identified [clinically and radiologically on ortho-pantomography (OPG)] a number of 200 possible implant sites, which were explored by additional imaging with computerized tomographic multi-detector (MDCT) examination. Thus, we extracted a number of 600 data regarding: minimal density (Dmin) and maximum density (Dmax), measured at the tomographic examination sections and the average density (Dmed) was calculated as the arithmetic mean between Dmin and Dmax, being classified in one of five classes (D1-D5) of Misch classification. The number of negative values (NNV) recorded in the age group of 45 to 60 years were 7.68 (total), 8.25 (LMx) and 9.8 (LMd). Primary stability and success rate of implants is much higher in lateral maxillary zones in men than in women in the age group between 45 to 60 years. Women have lower D3 and higher D4 incidence than men in both lateral maxilla (LMx) and lateral mandible (LMd) zones. In the age range between 45 to 60 years, decreasing of bone density is more pronounced at women compared to men, at both maxilla and mandible, as evidenced by lower D3 and increased D4 percentages. With respect to the proper determination of bone density, the value of information supply of MDCT is superior to other radio-imaging commonly used examinations in medical dentistry (including CBCT).

Keywords: *pre-implant, bone density, dental imaging, ortho-pantomography.*

1. INTRODUCTION

Dental imaging has had a considerable role in the development of dental implantology in the past 35 years, allowing for more realistic assessments of the chances of success and therapeutic alternatives best suited to each particular case. In the practice of global dental implant are used radio-imaging techniques such as: retro-alveolarnradiography, OPG, CBCT or nuclear magnetic resonance (MRI), but the most accurate spatial information are provided by MDCT (as stipulated in EC's Issue no. 136/2004 concerning european guidelines on radiation protection in dental radiology1). There is also the ultrasounds evaluation of bone quality technique, but it is not yet available for the practice of dentistry and is less known in implantology.

These treatments have become, over the past 30 years, a routine therapeutic method with a high degree of predictability, the reported success rate exceeding 95%4-6. To obtain such results, it requires, in addition to the thorough knowledge of the general state of health of the patient, an accurate assessment of the local conditions regarding the quantity and quality of bone – the bone supply.

Pre-implant imaging evaluation has quantitative (the height and width of the alveolar ridge in the edentate zone), qualitative (bone density and homogeneity) and strategic objectives (choice of the shape, position, size and optimal dimension of the implant, according to the bone supply and anatomical neighborhood structures). From the analysis of all of these information results a personalized surgical guide. Quantitatively, the bone is assessed in terms of height H (in apical-coronal direction, vertical), length (in mesiodistal direction) and width L (in oral-vestibular sense) of the edentulous alveolar ridge. Crestal atrophy designates the loss of normal alveolar bone consecutive to the loss of one or more teeth5. The length can be easily determined by intraoral clinical examination, unlike H and L which can be properly evaluated only through imaging. If we consider that in addition to these two parameters (H and L) we must as well take into account the spatial positioning of the implants to surrounding anatomical elements (mandibular canal, mental foramen, maxillary sinuses, nasal fossa), then it is obvious that 3D imaging techniques are the most accurate and reliable solutions for the pre-implant evaluation.

Bone quality, one of the main factors that can influence the success of implant therapy (higher rates of failure and lower values of primary stability of implants were recorded in zones with poor bone quality7,8), includes multiple aspects related to the degree of mineralization, bone physiology, morphology and type of trabecular pattern, but there is no clear consensus to define the concept. Factors that may adversely affect the osseointegration of implants are pre-existent bone local inflammatory lesions (local osteosclerotic scars or remaining osteolytic lesions, both being a chronic apical periodontitis consequence)9 or intravenous bisphosphonates, which blocks bone renewal process, making it more friable and prone to fracturing. Moreover, Marx10 have demonstrated that bisphosphonates have the half life of 11 years and that, administered intravenously, accumulates in bone 143 times faster than by oral administration. The bone density as a medical term is defined as the index amount of mineral per cm2 of bone structure. This medical definition differs from the physico-chemical definition of the term density expressed by the ratio of mass and volume.

Bone density of the maxillary bone in edentulous zone is a determining factor in choosing the treatment plan, implant design, surgical approach, healing time and bone loading in prosthetic treatment. For example, in the treatment with implants, low quality of the bone tissue associated with reduced bone volume leads in 65 % of the time to failure of implant therapy. This failure is most common in the jawbone and posterior areas (16).

Bone density changes depending on several factors: the mechanical influences and biomechanical parameters, hormones, vitamins, as well as duration of the edentulous status, having a predominant influence on bone change. Reduction of bone density can be seen on the radiography when demineralisation exceeds 30%. On the other hand, bone tissues on overexposed films may appear as demineralised, when they are, in reality, a normal structure11. The greatest difficulties encountered by physicians in the preoperative stage of the prosthetic–implant treatment are the bone quality and width (in oral vestibular sense) assessment of the edentulous alveolar ridge. They cannot be determined by OPG examination either not at all (ridge width) or only approximately (bone density), with a fairly large dose of subjectivity from the examiner.

In a 2011 study, Wirth & col.11 believes that the success of an implant insertion can be predictable only by assessing the bone density. A large bone density does not always correspond to elevated trabecular microstructure parameters such as trabecular number (Tb.N) or size of trabeculae (Tb.Th) 12, for which is recommended the use of CT with peripheral quantitative high physicochemical definition resolution (HR–pQCT)13 or micro-CT (μ-CT). However, comparative studies between MDCT and μ-CT aiming trabecular structure analysis concluded that MDCT technique although has limited spatial resolution, provides acceptable information and is recommended for bone density evaluations14.

Currently, there is a widespread tendency at global level of using CBCT for pre-implant imaging assessment, thanks to very good quality images obtained through exposure to a much smaller dose of radiation, than MDCT, to the three-dimensional character of the images and a greater accessibility for doctors and patients (lower purchase price of the equipment and lower cost price of the exploration). There are, however, studies15-17 that challenges CBCT's ability to determine correctly the bone density. The conclusion of a study published by Armstrong (2006)15 is that "Hounsfield units produced in identical anatomical zones with CBCT and MDCT, are not identical". Experience has shown that the shades of gray in the images obtained with a CBCT scanner are different (sometimes very much!) than those obtained with a scanner of another manufacturer. Furthermore, shades of gray from one CBCT scan may differ from those obtained at another scan with the same scanner. The results of a study conducted by Katsumata & col.18 were that shades of gray for bone, in a CBCT image, ranged from – 1500 to 3000, concluding that CBCT's capacity for evaluation of bone density or quality is limited and because the margins of the shades of gray is so broad, obtained density data are insignificant. This makes difficult, if not impossible, to compare data on bone density.

In this retrospective study we aimed to analyze the data on bone density (essential index of assessment phase of opportunity and implicitly of the chances of success of the prosthetic-implant treatments) measuring in CT sections Dmax and Dmin and calculating (as arithmetic mean between the two values) Dmed of crestale edentate zones.

For the demonstration of computerized tomography exploration information intake, the cases have been analyzed comparatively, using two types of imaging tests, OPG and MDCT.

2. EXPERIMENTAL SECTION

2.1. Selection of cases and projection of the study.

To achieve their goals, the authors of the paper have designed and performed a retrospective study on a series of cases. The population of the study consisted of patients who were present in the dental medicine cabinets of the authors in 2008–2013 to carry out specialized treatments. Patients were clinically examined in detail, investigated and diagnosed, and it was designed a treatment plan adapted to the particular clinical situation and in accordance with the wishes of the patient. To be included in the study, patients were required to have at least an edentulous area and to show their explicit desire to restore the integrity of the dental arches by prosthetic implant treatments. There were removed from the study the cases having poor quality imaging examinations, which made impossible the correct and safe assessment of radiological criteria for analysis. All patients included in this study have been explained the details of imaging examination, planned surgical interventions and possible complications of the surgery they are subjected to and each patient gave his consent in written form. This study was conducted in accordance with the Helsinki/Fortaleza Declaration (2013).

2.2. Radiographic examination.

Digital panoramic radiographs were taken by CRANEX NOVUS (manufacturer SOREDEX – Tuusula, Finland), with the following technical characteristics: generator voltage of 60/70 kV, current intensity of 7 mA, CCD sensor, generator-sensor distance of 500 mm, magnification of 1.25, exposure time 9 sec., focal spot size 0.5 mm and pixel-sensor size 96 μm. The MDCT scanner was SIEMENS EMOTION type 16 (manufacturer SIEMENS, Germany) with the following characteristics: current intensity of 45 mA, voltage of 130 kV and exposure time between 8–10 seconds. It is a high performance hospital scanner with 16 sensors.

2.3. Radiographic evaluation.

Each case contained in this study was imaging documented by two (2) examinations, OPG and MDCT. We used OPG examination to get general information guidance on the studied case, and from the MDCT examinations we extracted data on Dmax and Dmin at the level of implantation sites. Dmed was calculated as the arithmetic mean between Dmax and Dmin. Medium bone densities were then included in one of the 5 categories of **Misch**[19] scale**:** D1 > 1250 HU, D2 = 800–1250 HU, D3 = 350–850 HU, D4= 150–350 HU and D5 < 150 HU.

2.4. Statistical analysis of the data. The obtained data in this study were statistically analyzed using the program Origin Pro8 produced by OriginLab Corporation, Northhampton, Massachusetts, USA (2007), running on Microsoft Windows. Because the studied groups did not have large amounts of data for the sensitivity and the record track, we used in this program statistics on columns.

3. RESULTS SECTION

This retrospective study consisted of analyzing the data obtained by imaging exploration of a number of 46 patients whom, due to objective reasons that will be outlined below, we divided into two groups: a group composed of 29 female patients (63.05 %) and a group consisting of 17 male patients (36.95 %). In this survey, during the data collection phase, we observed lower values of bone density in women, especially in the age group of 45 to 60 years. Therefore we decided to split the two groups mentioned above in three age groups (< 45, 45-60 years and > 60 years).

Analizing OPG and MDCT in each of the 46 patients we have extracted a number of 200 determinations of implant sites, at each site being performed a number of two measurements (Dmax and Dmin). Based on the values obtained for Dmax and Dmin, it was calculated the Dmed as arithmetic mean of the two. Thus, we realized a table with 600 data which were then statistically analyzed and interpreted. In addition to this classification, we studied the distribution of the cases by simultaneously applying two criteria : sex and the analyzed topographic zone (**see Table 1**). Given the practical importance of accurate evaluation of bone density of an implant site, we calculated the mean of the average values on topographic zones in both groups. Within the female team, the highest value was obtained in the anterior maxilla (548.71 HU), the smallest (236.75 HU) in the anterior mandible and intermediate values in posterior maxilla (358.75 HU) and posterior mandible (371.75 HU). In contrast, within the male group, the average Dmed was extremely balanced: the anterior maxilla 440.1 HU, the posterior maxilla 422.37 HU and posterior mandible 445.96 HU.

Comparing these data, on the one hand, one can notice "spreading" values for the 4 topographical zones at women and concentration of values of the male group. On the other hand, it is surprising that the mean of the average density of anterior maxilla at the female team patients has the highest value, while the lowest value was recorded in the anterior mandible. These data contradict those of the studied literature, which argue that bone density is greater in the mandible (especially anterior zone) than in the maxilla, with direct consequence on the success rate and osseointegration of implants[20,21].

We believe that small values of the average Dmed of anterior mandible area in women is explained also by the small number of studied cases for this zone (2 cases = 1 % for women and no case for men). The average density differences between different topographic zones may explain the differing rates of osseointegration of dental implants, as claimed by Kido & col.[22] After these results, we made a comparative analysis of the Dmed in the lateral maxilla zone at both groups, for the age group between 45 and 60 years. Thus, we observed that the mean in the male group (434.93 HU) is higher by 43% than the same indicator in the female group (303.82 HU). Considering that the range of values of the recommended average bone density for implant insertion is in the range of 150 ÷ 850 HU (D3 and D4 density on **Misch** scale), analysing densitometry values falling within this value range, we observed differences between the two groups (male / female) (see **Table 2**).

Table 1. Distribution of the studied cases analysed by gender and topographic zone (Total number of measurements = 200 (100 %)).

Group	Anterior maxilla	Posterior maxilla	Anterior mandible	Posterior mandible
M	5 (2.5%)	33 (16.5%)	0	25 (12.5%)
W	14 (7%)	84 (42%)	2 (1%)	37 (18.5%)

Table 2. Percentage expression (by gender) of D3, D4 densities frequency in the lateral maxilla zone. The values D3 (45 ÷ 60) and D4 (45 ÷ 60) are in the age group of 45 to 60 years old.

Group	D4	D3	Total number of cases	D4 (45÷60)	D3 (45÷60)
M	9 (27.28%)	24 (72.72%)	33 (100%)	1 (3.03%)	7 (21.21%)
W	31 (36.9%)	42 (50%)	84 (100%)	22 (26.19%)	17 (20.23%)

Analyzing the data in this table, we can see that the frequency of D3 density incidence is about the same for men and women, while lower values of density (D4) are for over 8.5 times more common for women! In contrast, incidence of D4 is nine times lower in patients aged between 45 to 60 years compared to the D4 percentages of the entire group LMx men. These differences were not previously reported in the studied literature.

Comparing Dmedium values that have great topographic variability at women, with the same parameter analyzed in the male group reflecting high values concentration, we may conclude that this indicator has to be analysed carefully and precisely from the imaging point of view in the planning stage of the prosthetic-implant treatment. This is achieved under optimal conditions, with maximum accuracy by MDCT method, which provides sensitivity within unanimously accepted limits and outstanding reproducibility data.

Considering the direct proportionality between bone density and the amount of bone in contact with the implant surface (percentage wise, bone contact with the cortical bone being higher in trabecular bone, preserving the proportion between the compact mandible bone and the maxilla spongy one23) by studying Table 2 we may conclude that primary stability and success rate of implants is much higher in the lateral maxilla in men than in women, aged between 45÷60 years segment.

Women (compared to men) in the age group between 45 to 60 years have a lower incidence of D3 density and over 8.6 times higher D4 that can be explained by the decrease until cancellation of estrogen compensation during menopause and post-menopause.

After the third decade of life, the cortical bone loss in a year is on average 0.3-0.5% of its structure. For women, due to estrogen deficiency, menopause is followed by a rate loss of cortical bone by 2-3% per year for 8-10 years and of trabecular bone by 4.8% per year for 5-8 years. To make comparison, we have done similar calculations for the LMd in both groups. The results are found in Table 3, where we see that in the age segment between 45 to 60 years, women have the D4, 2 times more frequent than men.

Table 3. Percentage expression (by gender) of the frequency of D3, D4 densities (and separately for the age group between 45 and 60 years) in the lateral mandible area.

Group	D4	D3	Total number of cases	D4 (45÷60)	D3 (45÷60)
M	9 (36%)	15 (60%)	25	4 (16%)	4 (16%)
W	16 (43.24%)	16 (43.24%)	37	12 (32.43%)	5 (13.51%)

In the male group, the scattering of the D3 values is quite high because the incidence of D3 (45 ÷ 60) is about 3.5 times lower than the D3 for all 25 cases LMd. Seeing these results, we considered necessary to deepen research by studying comparatively the Dmin average in both groups (M / W) for LMx and LMd, extracting these values separately for the age group between 45 to 60 years. We have summarized in Table 4 the data, where we observed greater differences than those recorded in Tables 2 and 3. In the case of the male group we obtained higher values in LMd than in LMx and the average Dmin has higher values in all analyzed cases than in the women group which has a negative average LMD in 45 ÷ 60.

Table 4. Comparison table M/W with average Dmin in LMx and LMd, including the category 45÷60 years.

Group	Dmin LMx	Dmin LMd	Dmin LMx 45÷60	Dmin LMd 45÷60
M	85.22	102.64	101.37	184.22
W	66.96	33.1	33.22	-16.9

The predominance of negative values within women group led us to evaluate the two groups in terms of negative values of minimum density, obtaining the values from **Table** 5, where the percentage distribution of the number of negative values (NNV) of the lateral maxillary zone was over 1.4 times higher at women (34.52%) than men (24.24%). Truly spectacular figures were recorded in the age group between 45 to 60 years, the ratio between the percentage NNV at women (26.44%) towards men (3.44%) is 7.68, the one in the lateral maxilla area (W / M) is higher (8.25), the largest being in LMd (9.8) !!! These results confirm previous data from this study, showing large differences in average density values between the two groups at the expense of women.

Table 5. Comparison table M / W with NNV of Dmin in: LMx and LMd, including the category 45 to 60 years. The percentage values in parentheses for **Total** and **45 ÷ 60** columns are reported (see **Tab.1**) to the total number of cases LMx + LMd (M = 58, W = 121) and those of the columns L**Mx, LMd, LMx 45 ÷ 60 and LMd 45 ÷ 60** are reported to the number of cases LMx (M = 33, W = 84), respectively LMd (M = 25, W = 37).

Group	Total	LMx	LMd	45÷60	LMx 45÷60	LMd 45÷60
M	14 (24.13 %)	8 (24.24 %)	6 (24.00%)	2 (3.44 %)	1 (3.03 %)	1 (4.00 %)
W	46 (38.01 %)	29 (34.52 %)	16 (43.24 %)	32 (26.44 %)	21 (25.00 %)	11 (29.72 %)

4. CONCLUSIONS

Comparing the average of the values of the medium density (with a large topographic variability at women) with the same parameter analyzed in the male group (reflecting a *high concentration of values*) we may conclude that this indicator must be carefully and precisely analyzed from the imaging point of view in prosthetic-implant treatment planning stage. This is done in optimal conditions, with the highest accuracy, using the MDCT method which provides an acceptable *sensitivity* and remarkable *reproducibility* data. Primary stability and implant rate of success is much higher in the lateral maxillary at men than at women, aged between 45 and 60 years. A surprising result is that the average medium density of the frontal maxillary zone in the women group of patients have the highest value, while the lowest was recorded in the front mandible. These data contradict those of the studied literature, which argue that bone density is greater in the mandible (especially the front zone) than in the maxilla, with direct consequence of the success rate and osseointegration of implants. A possible explanation for this surprising difference could be the small number of studied cases with implant sites in the anterior maxilla/mandible.

Women have lower D3 incidence and higher D4 than men, at both LMx and LMd. In the age range between 45 to 60 years, decreasing of bone density is more pronounced in women compared to men, at both maxilla and mandible, as evidenced by the lower percentages D3 and high D4. The results obtained in the study reflect percentage values of the bone density higher on the LMx than on the LMd, which is contrary to the literature data. Thorough imaging investigation (CT techniques) is mandatory for patients in the age group between 45 and 60 years, to accurately determine the bone density at the level of envisaged implantation sites. With respect to proper bone density determination, the informational exploration input value MDCT is incomparable to other radio-imaging examinations currently used in dentistry (including CBCT). MDCT provides practitioners accurate, reproducible, constant data and with an acceptable resolution on osseus trabecular microstructure.

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