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Current Concept of Densitometry in Dental Implantology

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1. Introduction

Bone density measurement have an important clincal role in the evaulation of bone quality and volume pre-operative and bone loss during dental implant treatment. It can be based on intra-oral and panoramic radiographs, cone beam and micro-computed tomography (CBCT and CT), dual-energy X-ray absorptiometry (DEXA), magnetic resonance imaging (MR), quantitative ultrasound and laser Doppler flowmetry. DEXA is recognized by some clinicians as the gold standard for bone density analysis. Bone densitometry performed by DEXA have provided the foundation for treatment of patients with osteoporosis. However, the equipment needed is usually not available in dental clinics and its units are quite expensive. A major challenge is to develop a widespread, low cost, user- and patient-friendly tool for bone density evaulation. The most widely used densitometric method in implantology is Computer Assisted Densitometric Image Analysis (CADIA). CADIA is computer program based on densitometric interpretion of digitalised radiografic images. CADIA is most commonly used for periapical and panoramic images. Due to inexpensive, non-invasive diagnostic method, CADIA is capable to detect minimal variations of the mineralized tissue density, such as bone remodeling after flap surgery, peri-implant tissue variations after flap surgery, the healing process in the furcation area after regenerative procedures. Before digital era was introduced in clinical diagnostic practise (where images are automatically digitalized), conventional radiographic images were digitalized mostly using scanner or video camera, which resulted in 10% reduced quality of images. CADIA analysis has been reported to be highly sensitive and specific, showing a diagnostic accurecy of 87%. Digitalized 2D images are presented in pixels and 3D images in voxels. A image quality (i.e. resolution) changes according to increasing or decreasing pixel/voxel size. The three parameters of image quality are contrast, sharpness and noise. The contrast describes differences in dose, brightness or intensity in an image, the sharpness refers to the transitions between the different densities. Since densitomeric evaluation is used for comparing images, in attempt to achieve more objective and precise interpretation, it is of utmost importance to standardize criteria in radiografic imaging. For the standardisation of the intraoral radiogfraphs following criteria should be considered:

- The procjection used should minimize distortion of the anatomic structures of interest
- The method should provide information about the degree of standardization achieved

- The ionizing radiation exposure should be the minimum necessary to provide diagnostic information
- The method should be flexible enought to allow monitoring of all sites in the mouth
- The method should not be uncomfortable to the patient
- The method should not require extensive training for use
- The method should use readly avaible meterials

The most common method in standardizing densitometric technique is by using a copper calibrating stepwedge which consists of 5 layers, with the first layer presented by 0,1 in width and visible on a particular and predetermined site of the image (Figure 1). Copper is chosen due to its effective atomic number which is similar to bone. In the past aluminium

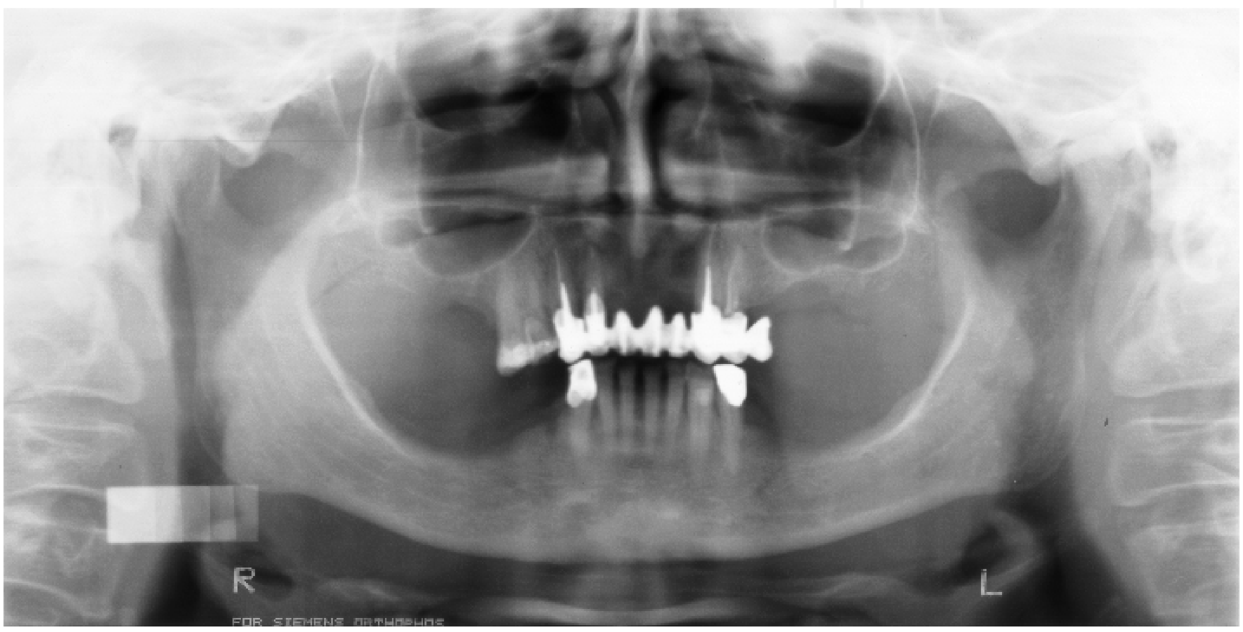

Fig. 1. Position of copper calibrating stepwedge on digital panoramic image.

was used instead, but was found to be too massive for positioning when used in retroalveolar images. In the manner of the easiest X-ray-film manipulation, many other materials such as a nickel in various thicknesses, hydroxyapatite, barium sulfate or some solutions such as CsCl or CaCl2 to simulate bone density, ethanol for fat and water for soft-tissue equivalent are in use. Stepwedge is used for linearisation, contrast-brightness adaptation and contrast optimisation for every measured image. Densitometric evaluation is based on intensity of gray shadows, which is predetermined on a scale varying from 0 (zero=black) to 255 (white) for intra-oral and panoramic radiographs. Recent CT scan devices can distinguish up to 4000 different gray shadows and therefore are far more precise, objective and reliable in comparison with periapical and panoramic images. Gray shadows determined by CT machines and its software programs are called Houndsfield Units (HU) representing a radiation attenuation for every pixel of the computer slice image. An HU value of 0 is equivalent to the radiation attenuation value of water, while an HU scale starts at value of -1000 corresponds to the value of air and generaly ends at around 3000 HU corresponding to the enamel. The density of structures within the images using CT scan is absolute and quantitative and can be used to differentiate tissuas in a region (i.e. muscle, 35-70 HU; fibrous tissue, 60-90 HU; cartilage, 80-130 and bone 150-1800 HU depending of the gradation of the bone quality). CT enables the evaulation of proposed implant sites and provides diagnostic information that other imaging methods could not. Recent CBCT scans have few advantages in a comparasion to CT witch are lower effective dose of the radiation, better device avaibility for dentist (size and price), 3D view of images insted of 2D, simple computer software device and better tool for implant placement. A lack of CBCT ,due to lower effective dose, is resolution of images compared to CT device. MR is used in implant imaging as a secondary imaging technique when primary imaging techniques such as CT or CBCT fails. MR is a technique to image the protons of the body using magnetic fields. MR depicts trabecular bone as a negative image by virtue of the strong signal generated by the abundant fat and water protons in the sorrounding tissue, whereas bone mineral lacks free protons and generates no MR signal and its not useful in charecterizing bone density. It is reasonable to say that the preoperative densitometric evaulation of bone undergoing implant placement using CT scans are far more precise than any avaible devices. When it comes to postprosthetic imaging whose purpose is to evaulate the status and prognosis of dental implant, method of choice is CADIA. Periapical or panoramic radiography produces high resoultion images of the dental implant and sorounding alveolar bone (Figure 3). CADIA have limitations in determining buccal and linqual changes in alveolar bone and depiction of the 3D relationship between dental implant and soruonding bone. CT is able to determine that changes but it cannot match the resolution of periapical image due to artifacts which produse titanium implant (Figure2).

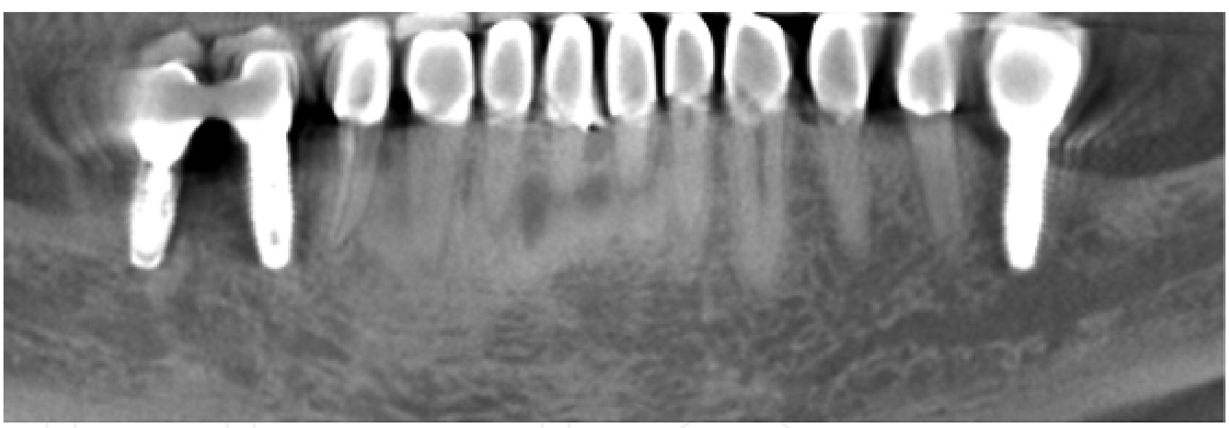

Fig. 2. CBCT scan used after implant placement shows lower resoultion of bone around dental implant due to interaction with titanium implant

2. CADIA modification

In this chapter densitometric measurement will be shown throught the modification of conventionally used CADIA and DIGORA software. Digital periapical and panoramic images were used, due to their minimal radioactive emission and high image quality that are not lost upon digitalization. Main task was to measure bone density around inserted dental implants using titanium implant itself as a stepwedge. This modification contains 12 measurement points for periapical and 10 points for panoramic images. They are precisielly located in positions in and around dental implants. The measurement of bone density is obtained automatically due to performed software package after entering the RVG image. Positions of the 12 points are specified in advance and inserted in the software database,

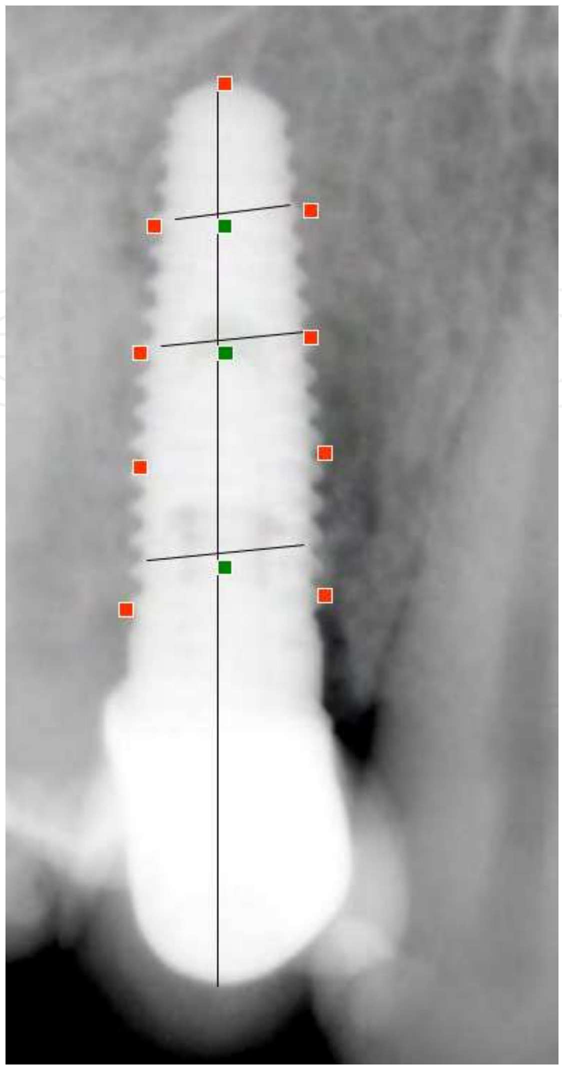

Fig. 3. Position of the correction (green) and measurement (red) points.

so the points remain in the same location for all evaluated images (Figure 3). The first 3 points are regarded as correction factors (modified stepwedge) which are situated on different parts of the implant. The first correction point is located in the apical part of the implant, where density of the gray shadows was the highest; the second correction point is located in the middle part of the implant where density of gray shadows have minimal intensity due to the perforated structure of the implant and the third correction point is located in the cervical part of the implant where density of gray shadows have midium intensity in the position where the crown screw is attached to the implant. Correction points served for revision of density change in measurements which occured due to discontinuity of the x-rays (i.e. distortion of x-rays present in each image in the series of follow-ups, as well as difference in exposition in the same series of images that were taken during a follow-up period). Measuring points are positioned as follows: the first point was placed in the middle line 1mm apically to the implant, and the remaining 8 points were placed in the bone surrounding the implant in precisely determined positions. This CADIA modification is designed to monitor changes in bone density around implants and to compare it with other images. If there is a need to precisely determine a densitometric value, original stepwedge is inevitable.

3. Usage of modificated CADIA in clinical purpose

Current modification of CADIA is in use since 2008. and there are few publications describing its use in clinical purpose about various tehniques of implant placement. In the first study complete densitometric measurement with images, grapfhs and tables will be shown while in the other cases only final images will be presented.

3.1 Comparison between flapless and two-stage techique of dental implant placement

Minimally invasive surgical techniques are a current trend, not only in dental implantology but in all surgical fields. It gives an atraumatic approach for the patients which results in better and easier accomplishment of treatment, not only for the patient but for the surgeon as well. Both of surgical techniques, two-stage and flapless, are safe methods with a long

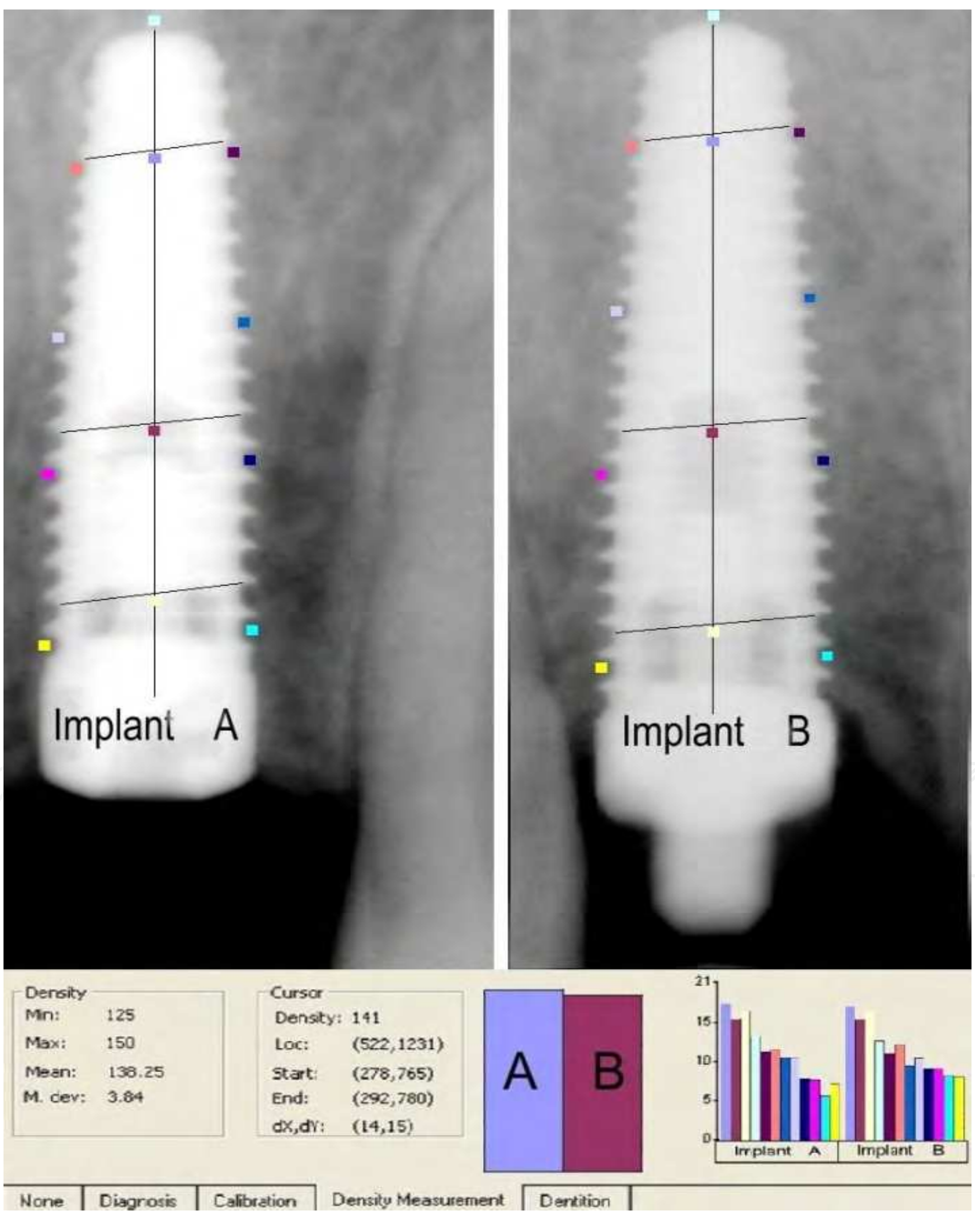

Fig. 4. CADIA comparison between two stage(left) and flapless (right) technique.

term success and satisfaction for the patients. Further cases describes radiographic assessment of flapless technique and determination of its clinical values in comparison with two-stage dental implant technique through computerized densitometric analysis. Values of densities were measured in all 10 patients through 3 months in certain time interval in 12 determined points. The first point was placed in the middle line 1mm apically to the implant, and the rest of 8 points were placed on the precise positions between 4. and 5., 9. and 10., 13. and 14., and between 18. and 19. of the screw thread, on each side of the dental implant (Figure 4).
The validaity of results in measured densities for all 5 patients, in which the implants were inserted using two-stage technique, throught all 3 measurements are shown in Table 1. The validaity of results in measured densities throught 3 measurements in all 5 patients, in which the implants were inserted using flapless technique are shown in Table 2. For easier analogy of measured densities, we used average densities for each technique according to stage of measurement.
Due to pilot study, the results were notstatistically analyzed, but compared through the values of average densities. Average value of density in period of 3 months (first measurement) in two-stage technique was 174.1, and in flapless technique were 158.8. Second measurements were done 12 months after the implants were inserted, and the results were: 172.18 in two-stage technique, and 158.47 in flapless technique. Average value of density after 18 months (third measurement) was for two-stage technique 170.86, and for flapless technique 157.57. All these results are shown in Figure 5. After mutual comparison of average densities, the results showed approximately the same decrease of density for both surgical techniques in the follow-up period of 18 months, conventional two-stage technique shown 3.24 and flapless technique 1.23. It shows minimal loss of density in both surgical techniques, as it is shown in the Figure 6.

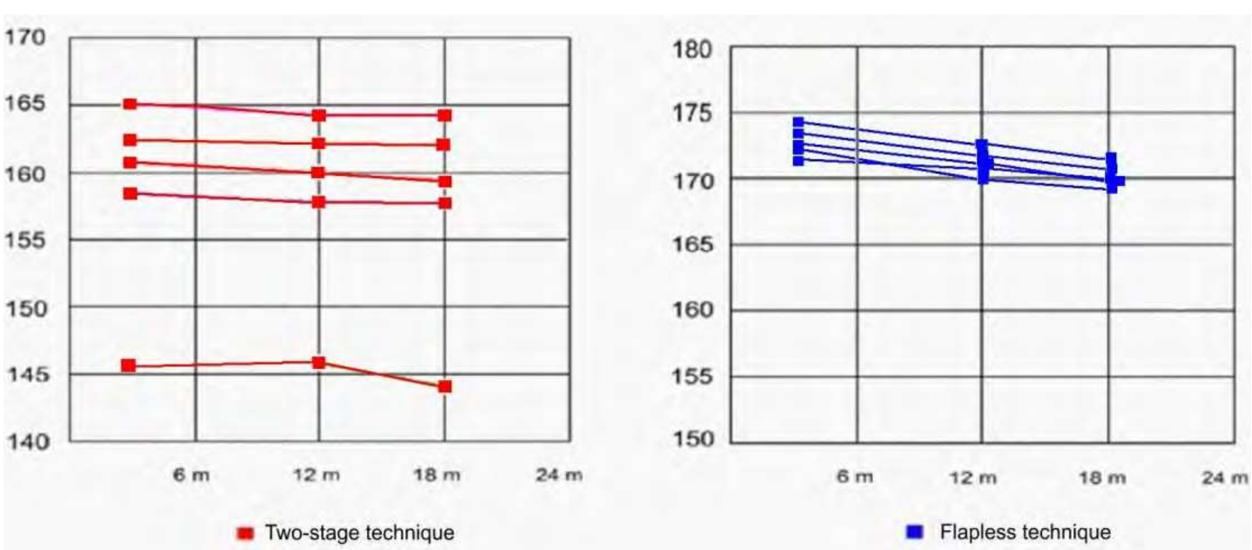

Fig. 5. Average values of bone density around inserted implants throught all 3 measurements.

After dental implant loading, values of density changes due to masticatory forces. Effect of masticatory forces can be enrolled in the changes of the bone around inserted implant with the help of densitometric analysis.

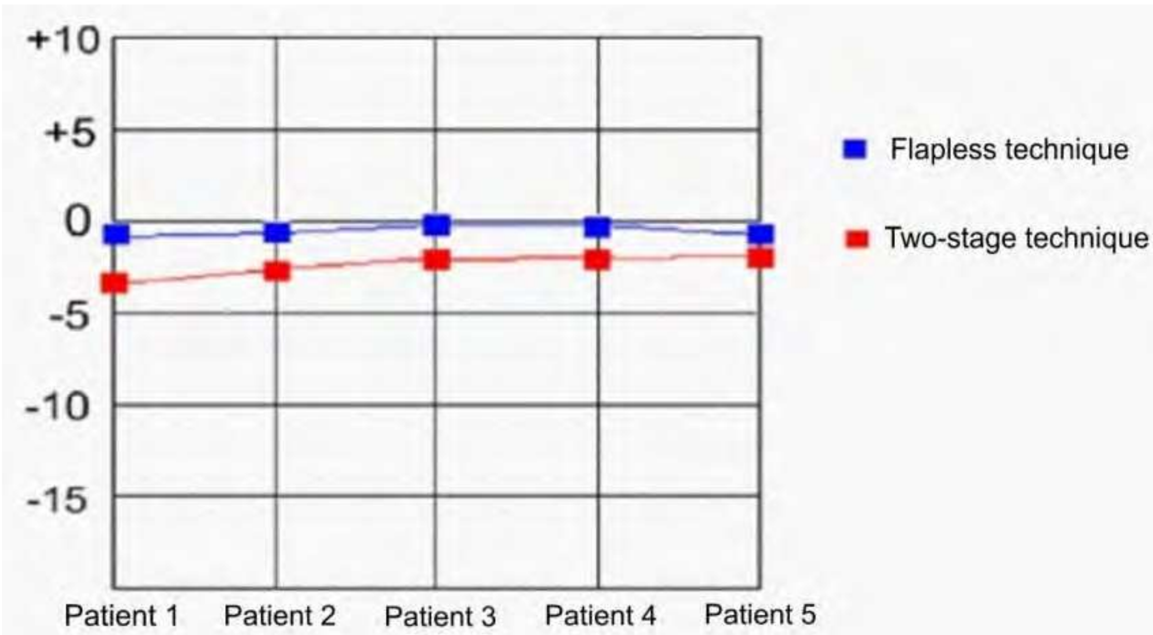

Fig. 6. Comparation of average bone densities showed approximately the same decrease of density for both surgical techiques in the follow-up period.

	Patient 1			Patient 2			Patient 3			Patient 4			Patient 5		
Point	3. month	12. month	18. month	3. month	12. month	18. month	3. month	12. month	18. month	3. month	12. month	18. month	3. month	12. month	18. month
1	254.96	255.14	254.19	254.52	255.41	254.99	254.42	254.85	254.12	253.99	254.12	254.01	253.84	254.04	253.94
2	248.23	244.21	245.74	247.91	244.82	245.83	248.35	247.68	246.07	244.25	244.58	244.56	242.38	243.15	242.67
3	247.43	251.25	250.69	249.95	251.36	251.44	250.81	251.04	251.83	248.08	247.84	247.92	247.09	246.44	246.89
4	204.16	200.31	198.22	204.16	203.54	202.38	194.69	192.42	192.1	200.74	199.86	197.94	198.53	197.69	196.99
5	190.12	187.21	183.72	191.29	189.36	188.45	193.53	191.34	189.79	185.65	186.41	184.27	184.33	183.04	182.85
6	192.82	216.23	205.14	190.21	191.24	190.41	193.74	190.95	190.41	193.54	192.85	192.41	186.37	184.65	184.22
7	177.2	179.43	179.12	172.28	174.67	173.56	177.6	177.52	177.08	174.91	175	173.57	180.7	178.31	177.68
8	180.74	176.78	172.1	181.84	180.05	179.68	184.9	182.37	181.69	184.67	180.49	179.62	182.57	179.91	179.56
9	171.4	155.62	151.12	170.69	167.66	166.95	168.67	167.44	166.55	168.55	167.21	165.74	174.39	171.24	170.77
10	166.53	162.23	169.72	169.88	163.59	160.06	174.18	175.73	174.28	178.79	177.12	174.83	174.95	172.58	171.72
11	144.71	132.87	134.21	141.41	138.48	134.59	144.69	140.25	134.52	134.07	133.43	132.07	140.55	138.69	137.41
12	143.42	137.44	140.59	140.97	137.26	133.08	141.64	138.92	136.95	144.61	140.81	138.4	139.84	138.29	137.59
Average	174.57	172.01	170.44	173.64	171.76	169.91	174.85	172.99	171.49	173.95	172.58	170.98	173.58	171.6	170.98

Table 1. Bone densities throught 3 measurements for 5 patients in the two-stage technique group.

Changes of the bone around inserted implant were mostly expressed on the points 7, 8, 9 and 10 which are located on the 9., 10., 13. and 14. thread of the implant. In the two-stage and flapless surgical technique, average values of bone density change (with the same indications) were approximately the same. Decrease of 3.24, and in flapless technique was 1.23. Due to our knowledge, there are no published results in the recent literature regarding densitometric comparison between these two surgical techniques. Most of the authors use the minimally invasive surgical techniques in everyday practice, including the flapless

	Patient 1			Patient 2			Patient 3			Patient 4			Patient 5		
Point	3. month	12. month	18. month	3. month	12. month	18. month	3. month	12. month	18. month	3. month	12. month	18. month	3. month	12. month	18. month
1	231.76	228.05	232.8	255	251.56	253.21	254.17	254.56	254.8	254.8	253.73	254.01	253.88	254.2	253.65
2	208.79	219.69	217.45	226.07	227.22	226.69	229.3	229.44	230.04	231.59	230.67	231.58	235.67	236.47	232.91
3	222.6	215.41	212.92	240.13	242.42	240.9	240.08	241.42	242.17	244.12	243.77	243.99	247.53	248.33	247.93
4	189.65	185.35	185.01	196.96	185.56	184.54	197.58	196.96	196.35	190.37	188.38	188.17	190.77	188.2	187.69
5	188.84	187.3	186.92	169.11	169.65	163.01	180.42	178.6	178.22	185.9	184.93	184.56	185.39	184.62	183.74
6	186.97	185.63	184.9	171.36	180.13	178.63	181.64	181.04	180.74	184.55	183.41	183.2	184.06	183.93	183.53
7	164.52	164.08	163.96	157.68	155.75	155.44	163.27	164.28	164.16	174.71	175.36	175.06	173.61	173.07	171.49
8	157.15	160.43	158.24	159.76	159.13	158.41	164.88	164.58	164.4	173.43	174.11	173.58	171.94	172.38	171.15
9	151.28	150.27	149.53	120.07	120.46	118.3	141.09	140.9	140.84	163.27	163.24	162.89	155.07	154.75	153.57
10	149.71	150.42	148.71	122.76	125.58	123.17	142.37	141.89	141.79	160.76	161.39	160.85	153.26	153.57	152.94
11	133.1	132.07	130.56	105.01	108.06	107.63	125.99	125.74	125.47	127.69	126.5	126.23	130.43	129.76	128.4
12	131.58	130.01	128.72	108.5	109.5	107.21	126.07	125.94	125.86	124.95	125.49	124.73	128.82	128.7	128.07
Average	161.42	160.62	159.62	145.69	145.98	144.04	158.15	157.77	157.54	165.07	164.76	164.36	163.71	163.22	162.29

Table 2. Bone densities throught 3 measurements for 5 patients in the flapless technique group.

approach in dental implantology. Becker et al. have found that implants placed without flap reflection remained stable and exhibited clinically relevant osseointegration similar to when implants were placed using conventional flap procedures. Campelo and Camara have published the most extensive study about using one-stage flapless surgical technique in dental implantology. In their 10-year retrospective study the cumulative success rate, for 770 implants using a flapless surgical technique, have varied from 74.1% to 100%, relative to the year of placement, which can be explained with a learning curve combining technology and material development in dental implantology. Survival rates in other reported studies, for flapless surgical approach, are between 91% and 98.7%5 which indicate successful results of this technique application. Based on our results, we can say that both of examined groups, and two different techniques in dental implantology show the same clinical values after 18 months of follow-up.

3.2 Comparation between two different techniques of sinus floor elevation

Prior to planning implant surgery and prosthetic reconstruction in the posterior maxillar region, it is not uncommon not to consider sinus floor elevation surgery first, which can be achieved using either open or closed technique approach, or minimal invasive baloon sinus lifting thechnique which has recently been in use. Two clinical cases presented in the literature, in which densitometric measurements were compared by both techniques of sinus elevation, the baloon sinus lifting with open and closed access. In the first case elavation of the right maxillary sinus was done by the balloon controled technique (transcrestal approach). The augmentation was done with alloplastic bone filler (tricalcium phosphate). Lifting of the left maxillary sinus was performed by forming lateral fenestration on the buccal cortical plate followed by augmentation with the mixture of xenogenic bone filler and autologous bone graft. After 6 months of augmentation 3 implants on each side were placed and prosthetic suprastructure was completed within next 4 mounths. Values of bone density were measured in 10 points around each inserted implant compared with RFA measurements of implant stability before loading and 3 and 12 mounths after prosthetic loading. After mutual comparison of average densities, the results showed approximately the same decrease of density for both surgical techniques in the follow-up period of 12 mounths. It shows minimal loss of density around inserted implants in grafted maxillary sinus areas elevated by both surgical techniques. Gained data results are showing that sinus lifting method with enclosed balloon approach techique can result in gaining enough area for implant placement as well as with opened approach technique. Furthermore balloon technique is more over less traumatic experience for patient with a much fewer side effects and postoperational problems. In addition if there is a sufficient bone width for the purpose of sinus lifting in favour of placing of two up to 3 implants in that area it can equaly sufficient use enclosed balloon technique instead of open lateral approach which is causing much more traumatised experience for patient and much more postoperative problems (Figures 7, 8 and 9).

Fig. 7. Initial radiograph before surgical treatment

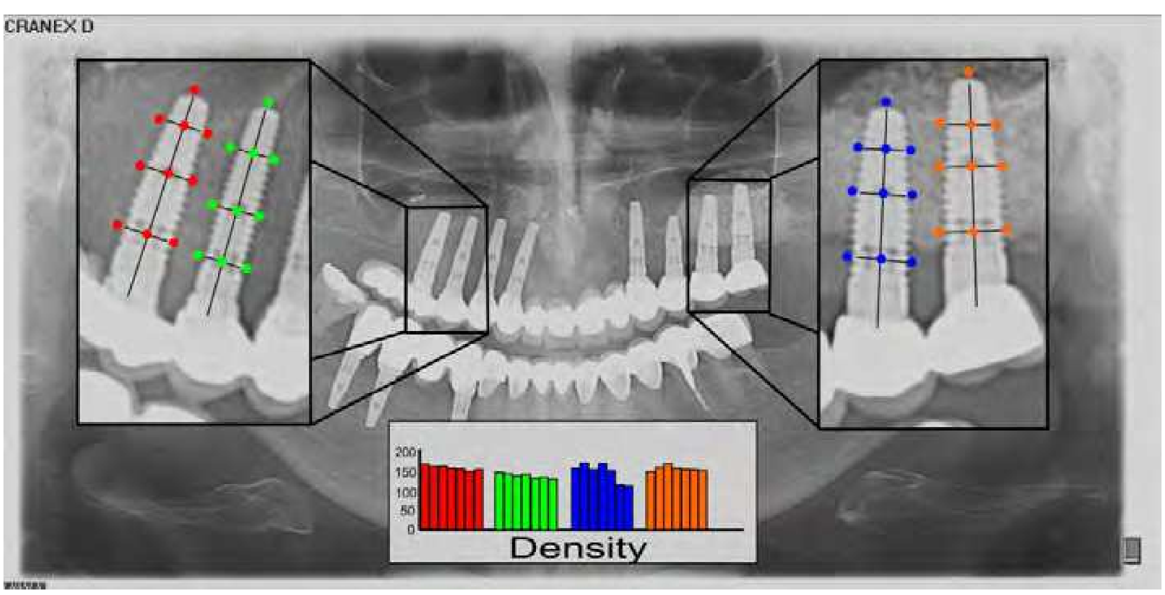

Fig. 8. Densitometric measurement of two different approaches, open sinus lift technique (red and green points) and ballon technique (blue and orange points).

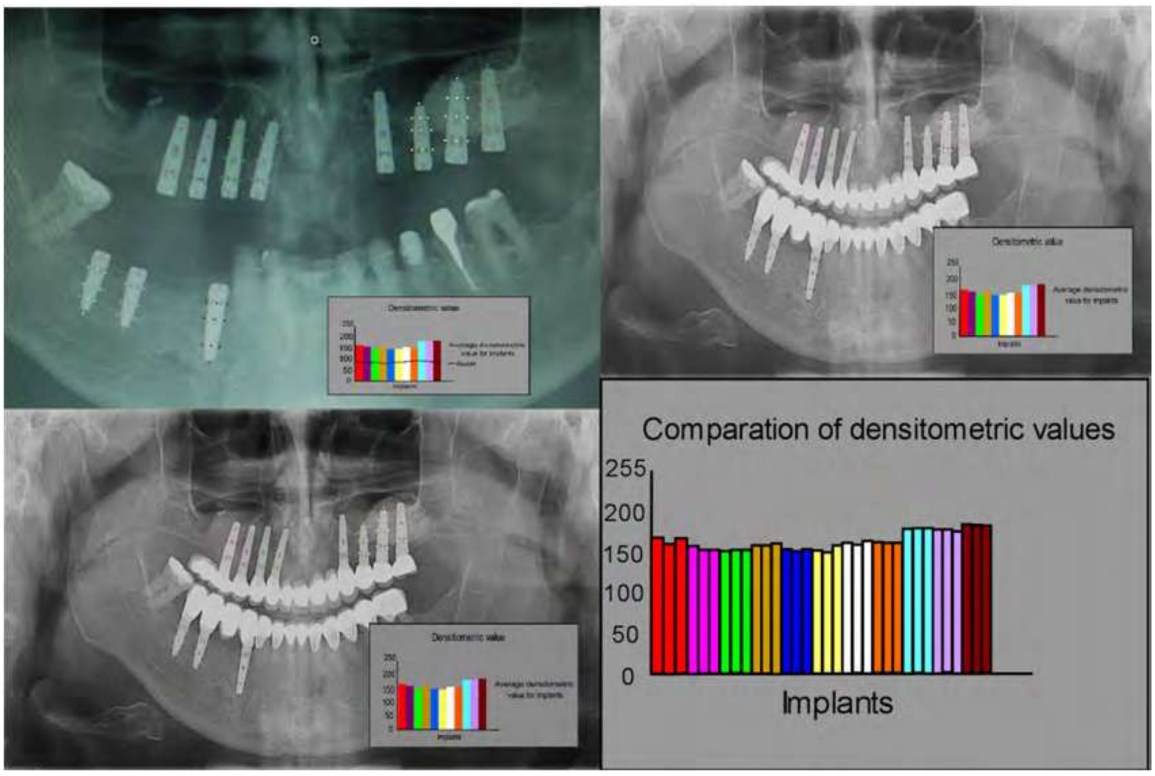

Fig. 9. Densitometric comparison between two different approaches, open sinus lift technique (left upper molar region) and ballon technique (right upper molar region). Lower right molar region was augmented using splitting technique (2 implants)

In the second case elevation of the right maxillary sinus was done by close sinus lift technique and on the left side by the ballon controled technique filled with alloplastic material (tricalcium phosphate). After 6 months of augmentation one implant on each side were placed and prosthetic suprastructure was completed within next 4 mounths. Values of bone density were measured in 10 points around each inserted implant compared with RFA measurements of implant stability before loading and 3 and 12 mounths after prosthetic loading, same as int he first case. First densitometric measurement showed, that the bone

Fig. 10. Initial radiograph before surgical treatment

around dental implants augmented by ballon sinus lift technique, had twice more value in comparation with close sinus lift techinque due to bone filler. After follow-up period of 12 mounths, like in the first case, the same decrease of density for both surgical techniques were observed (Figures 10 and 11).

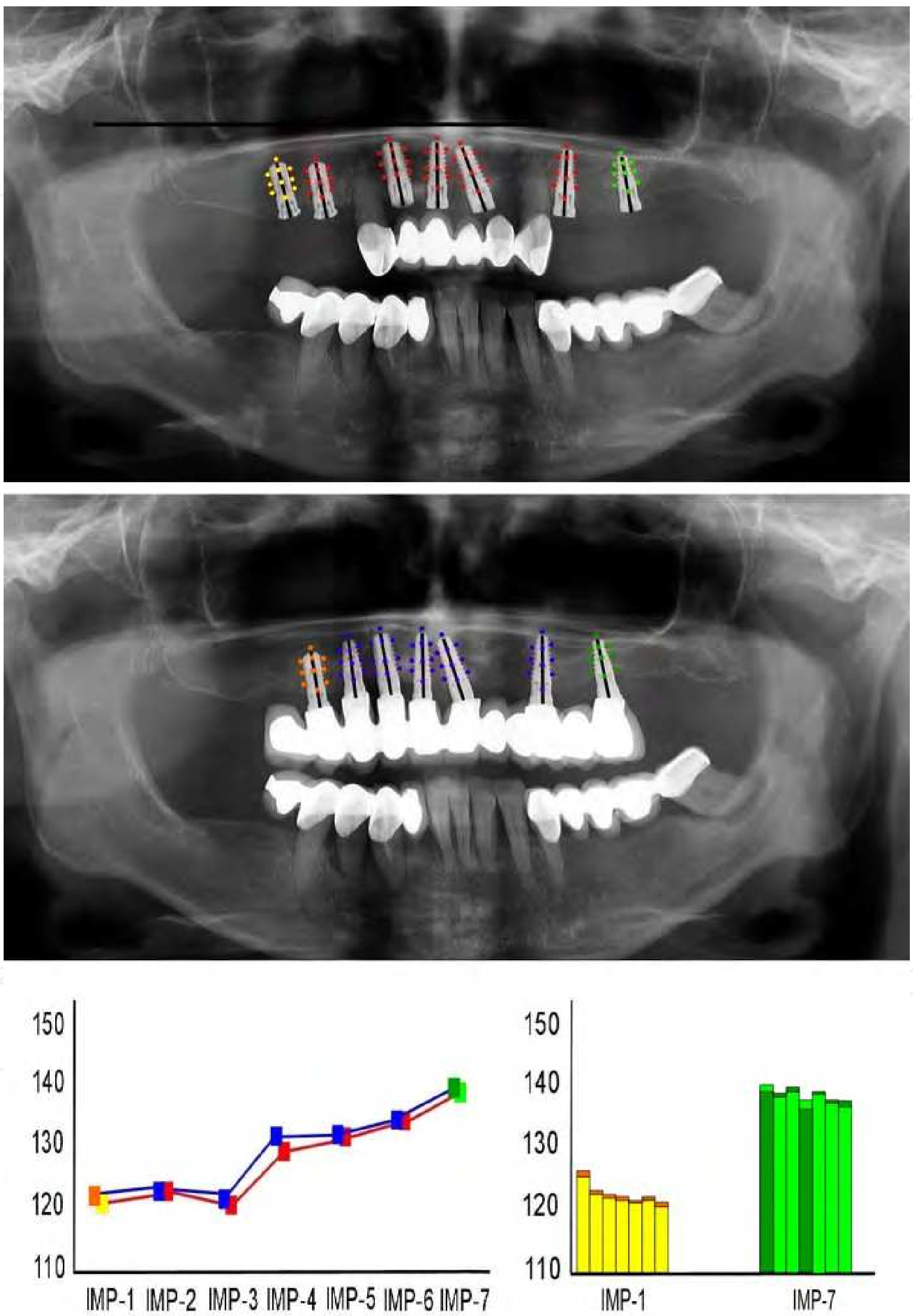

Fig. 11. Densitometric comparison between two different transcrestal approaches, close sinus lift technique (left implant and yellow graph) and ballon technique (right implant and green graph).

3.3 Alveolar ridge augmentation using splitting technique

In oral implant surgery, in order to widen the alveolar ridge and avoid horizonatal ridge augmentation by using autologous bone transplants, splitting and spreading techniques are indicated instead. These two methods are regarded as minimally invasive surgical techniques which reduce the number of surgical interventions, and result in minimally present postoperative complications, such as the patient's discomfort during the procedure. They also minimize the healing period in which it is expected to accomplish final prostetic reconstruction. Two clinical cases are shown in which densitometric measurements were compared by splitting technique and cllasic two-stage technique of dental implants placement. In the first case two implants in lower molar region using splitting technique and one implant in premolar lower region using two-stage technique were placed (Figure 8). Prosthetic suprastructure was completed within next 4 mounths. Values of bone density were measured in 10 points around each inserted implant after placement, after 4 and 12 mounths. After mutual comparison of average densities, the results showed almost nearly the same decrease of density for both surgical techniques in the followup period of 12 mounths. In the second case splitting technique is used in lower premolar and molar region, placing 3 dental implants (Figure 12). Values of bone density were measured in 10 points around each inserted implant after placement, after 4 and 12 mounths. The results showed again the same decrese of density compared with two-stage technique.

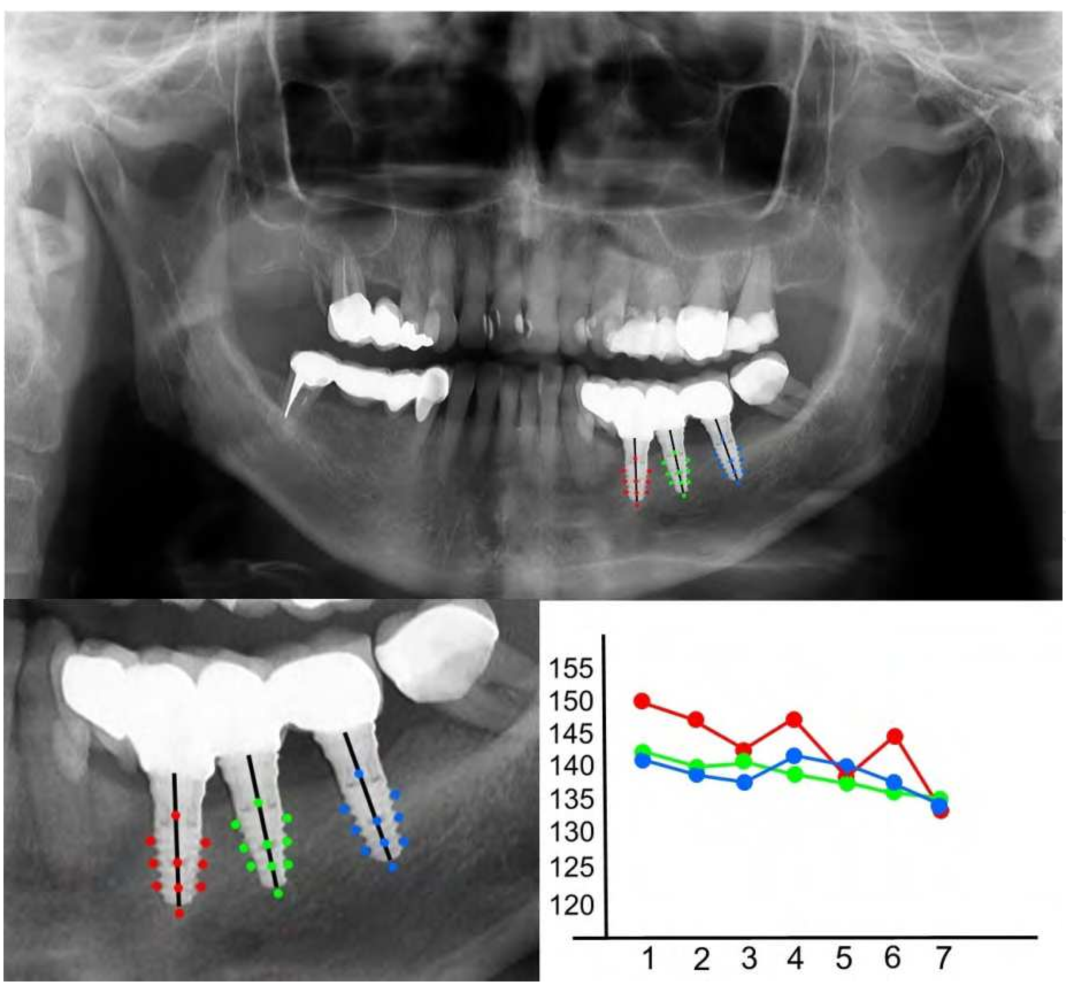

Fig. 12. Densitometric measurement of bone around 3 implants using splitting technique

3.4 Augmentation with autologous bone graft with simultaneous dental implant placement

Defect of the alveolar ridge of the left maxilla remained after extractions of the central and lateral incisors due to vertical root fractures (Figure 13) were augmented with the autologous bone block harvested from the retromolar area after two dental implants placement. Primary stability of the inserted implants was satisfactory. The gap between autologous graft and bone defect walls were filled with autologous bone chips harvested with bone scraper from the same harvesting site in the retromolar area. Augmented area was covered with the xenogenic bone substitude and resorbable collagen membrane. Densitometric measuremnt was performed six months after surgical procedure (Figure 14).

Fig. 13. Initial radiograph before surgical treatment

The results showed the higher decrese of density on bone grafts in comparation with bone alone.

3.5 Spreading technique in combination with autologous bone graft

Dental implant was placed after spreading the alveolar ridge bone due to long edentulous period (Figure 15). After implant placement infraction of the buccal cortical plate has remained. Defect was augmented with the autologous bone chips harvested with the bone scraper from the retromolar area, covered with β-tricalcium phosphate bone substitude and resorbable collagen membrane. Densitometric measurement was performed six months after surgical procedure, directly before final prosthetic restoration, and 12 months after surgery and 6 months after loading (Figures 16 and 17).

3.6 Alveolar ridge augmataion using rhBMP-2

In recent years, the delivery of osteoinductive factors such as bone morphogenic proteins (BMPs) have become an alternative approach to traditional bone grafting due to their capacity to enhance the natural ability of the surrounding tissues to produce bone healing and new bone and cartilage formation. In following case densitometric measurements were compared between bone induced by rhBMP-2 and normal bone (Figure 19). Substantial loss of vertical ridge height was noted bilaterally in both the mandibular molar regions and were deemed insufficient without augmentation to enable placement of dental implants. Bone was augmented using human recombinant BMP-2 and 3 dental implant were placed 6 mounths after. Values of bone density were measured in 10 points around each inserted

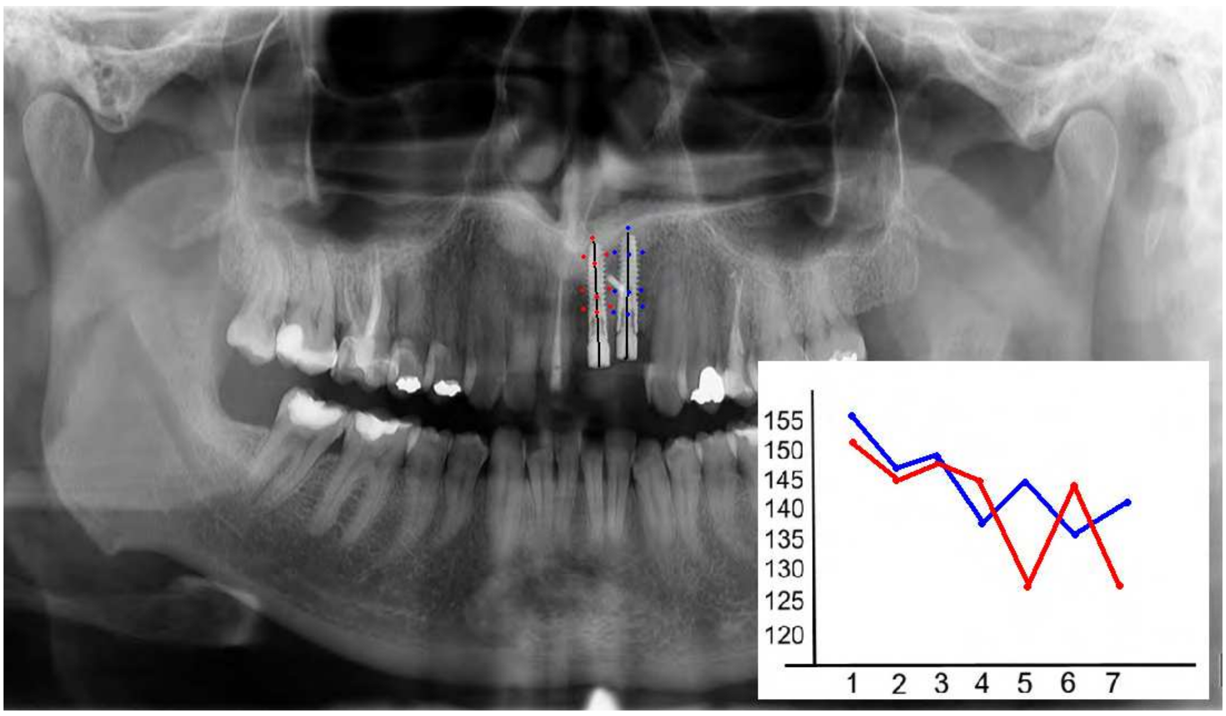

Fig. 14. Densitometric measurement of augmented bone around 2 implants placed simultaneouslly with the autologous bone graft (the fixation screw is positioned between the osseointegrated implants)

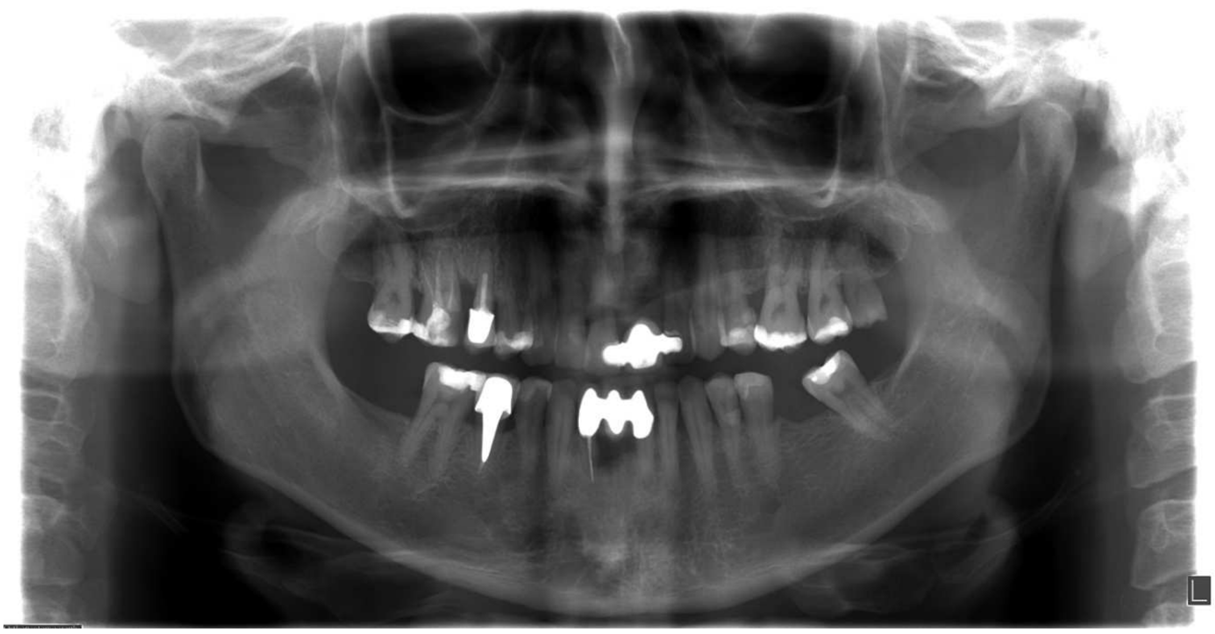

Fig. 15. Initial radiograph before surgical treatment

implant after placement, after 4 and 12 mounths. In this case, the results shows slighty decrease of density in bone induced with rhBMP-2 in comparison with classic two-stage technique of dental impalnts placement in the follow-up period of 12 mounths.

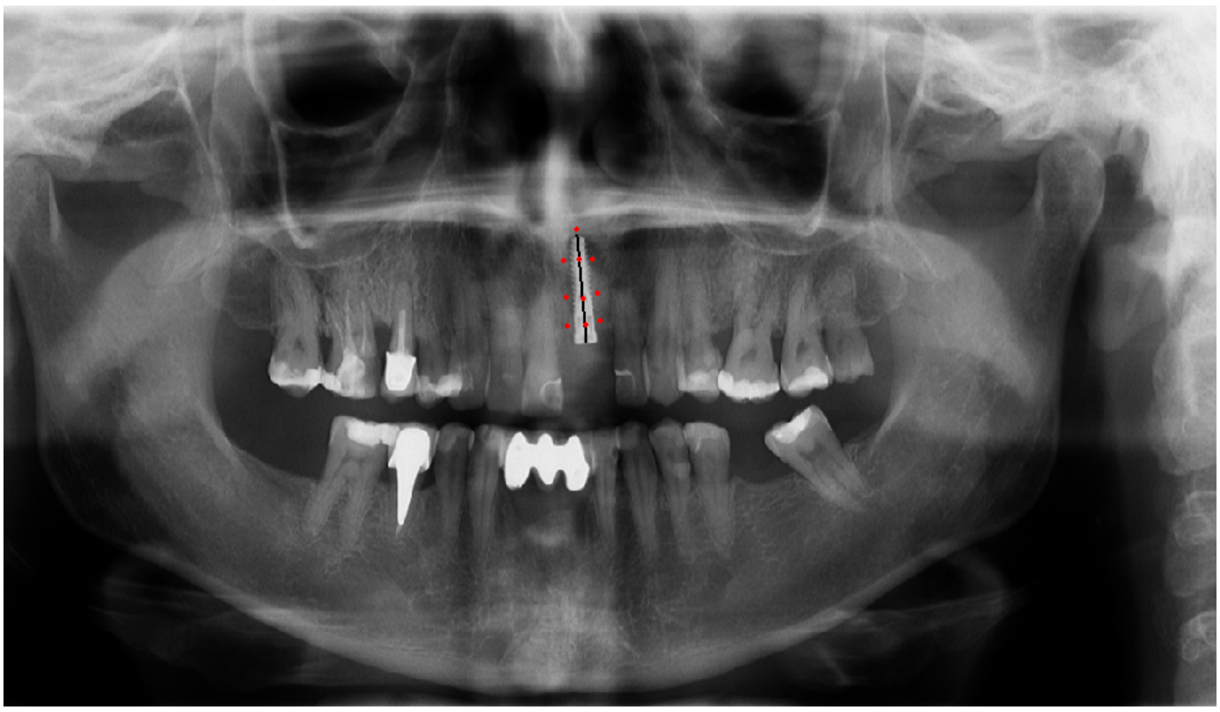

Fig. 16. Densitometric measurement of augmented bone around dental implant after spreading technique, 6 months after surgical procedure

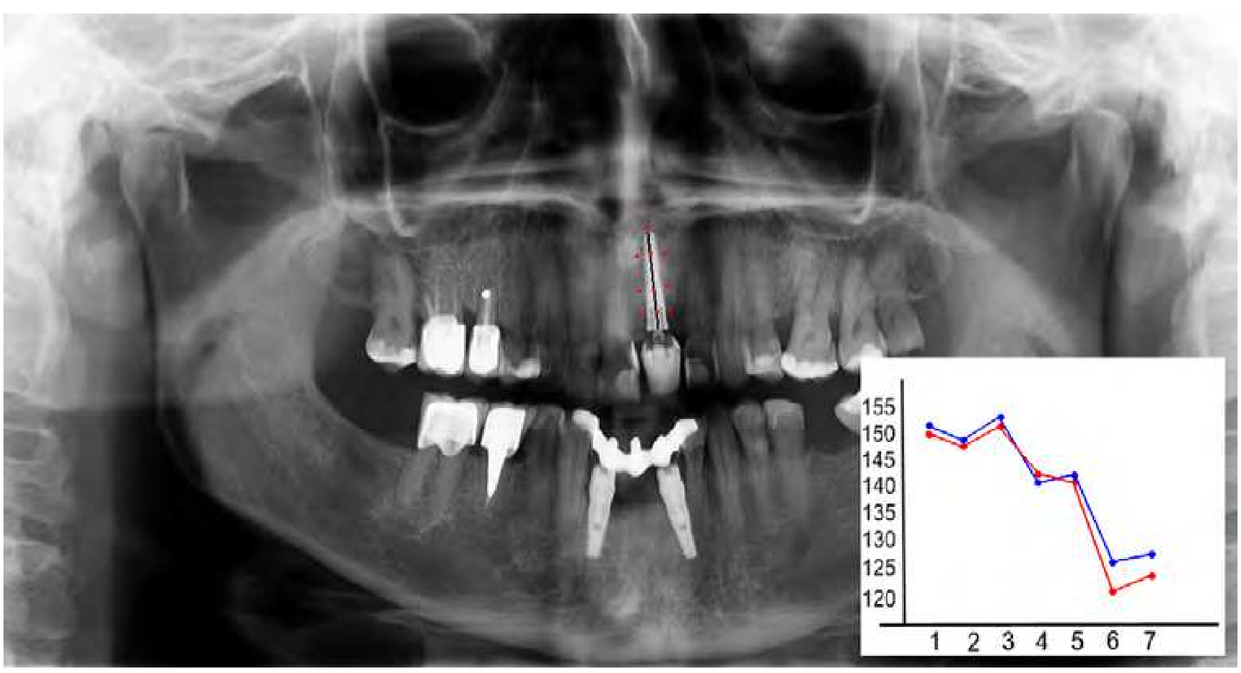

Fig. 17. Densitometric measurement of augmented bone around dental implant after spreading technique, 12 months after surgical procedure

Fig. 18. Radiograph taken after placement od rhBMP-2

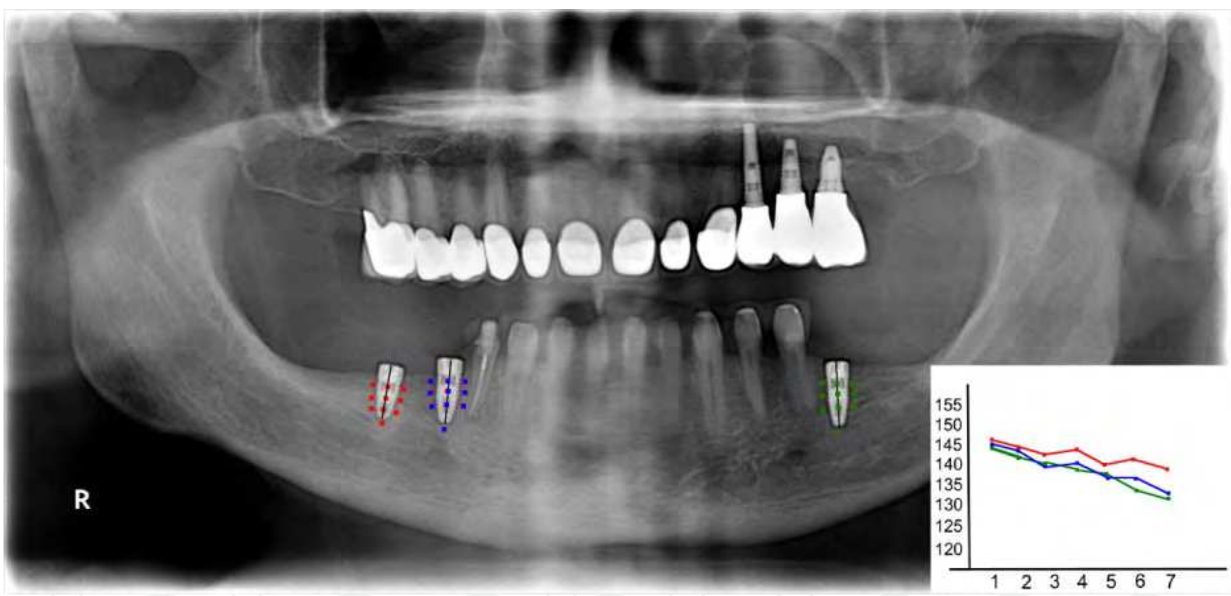

Fig. 19. Densitometric measurement of augmented bone around 3 implants using rhBMP-2

3.7 Importance of bone density in implant dentistry

Currently the use of osseointegrated implants to treat partially or completely the endentulous arch is considered realible and predictable, with a success rate of 98% or higher. The success of dental implant treatment is associated with good primary implant stability. Primary stability corresponds with bone density and it has been determining factor in treatment planing, implant design, surgical approach, healing time and initial progressive bone loading during prostetic reconstruction. Secondary implant stability results after formation of secondary bone contact of woven and lamellar bone. Bone density is related directly to the strenght of the bone and it seems to be a vital factor in the achievement of osseointegration. For assessing bone quality several classification systems and method were introduced. The most popular method was introduced by Lekholm and Zarb

Quality 1	Homogenous compact bone
Quality 2	Thick layer of cortical bone surrounding dense trabecular bone
Quality 3	Thin layer of cortical bone surrounded by dense trabecular bone of favorable strenght
Quality 4	Thin layer of cortical bone surrounding a core of low-density trabecular bone

Table 3. Classification of bone density by Lekholm and Zarb

who listed four bone qualities found in the anterior regions of the jawbone (Table 3). Their scale of bone quality ranges from 1 where is composed of homogeneuous compact bone to 4 where is a thin layer of cortical bone surrounding a core of low density trabecular bone. Their classification has recently been questioned due to poor objectivity and reproductibility because it provides only a rought mean value of the entire jaw. Misch proposed five bone density groups independet of the regions of the jaws based on macroscopic cortical and trabecular bone characteristic, their tactile sence during implant placement, location and CT values. (Table 4). The percentage of bone contact is significantly greater in cortical bone than in trabecular bone. An antherior mandible (D1, D2) provides the highest percentage of bone in contact with implant compared with posterior maxilla (D4) which offer less areas of bone contact with implant. Its reasonable to say that the period of osseointegration is longer in maxilla (4-6 months) than in mandible (3-4 months) and it coresponds with implant success. The male patients had higher average bone density value than that in female patients. That constatation could be explained with the hormonal pecullliarities in females and generally higher bone mass in males.

Bone density	Description	Tactile analog	Typical Anatomical Location	CT values
D1	Dens cortical	Oak or maple wood	Anterior mandible	>1250 HU
D2	Porous cortical and coarse trabecular	White pine or spruce wood	Anterior mandible posterior mandible Anterior maxilla	850-1250 HU
D3	Porous cortical and fine trabecular	Balsa wood	Anterior maxilla Posterior maxilla Posterior mandible	350-850 HU
D4	Fine trabecular	Styrofoam	Posterior maxilla	150-350 HU
D5	Soft bone with incomplete mineralisation	Styrofoam		<150 HU

Table 4. Classification of bone density by Misch

Another bone classification by Tomaso and Vercellotti has universal application and can be used in all fields of bone surgery expecially in implantology. The classification outlines the quantitative characteristics of the cortical crest and separately the density of spongy bone mineralization (Table 5).

Quantitative cortical thickness classification	
0 mm	Thickness of cortical crest at the site of recent tooth extraction after few months
1 mm	Thickness of cortical crest at the site of tooth extraction after several months
2 mm	Thickness of cortical crest at the site of tooth extraction after a few years
3 mm or more	Thickness of cortical crest at the site of tooth extraction after several years and characterized by a reduction in spongy bone resulting in partial merging oft he buccal cortical and lingual cortical bone
Qualitative spongy bone density classification	
High density	The tomographic image is prevalently radiopaque and grayish-whitish in color
Medium density	The tomographic image is rather radiopaque and grayish in color
Low density	The tomographic image is radiolucent and grayish-blackish in color

Table 5. Classification of bone density by Tomaso and Vercellotti

Implant stability can be measured by non-invasive clinical test methods (i.e. insertion torque, the periotest, resonance frequency anaysis). Insertion torque is a method that records the torque required to place the implant. The Periotest M (Figure 20) is a measuring device for use in dental practises and is designed for the following range of applications:

1. Assessment oft he osseointegration of dental implants
2. Diagnosis and assessment of periodontopathies (the Periotest Mmeasuers the damping characteristics oft he periodontium and, indirectly, tooth mobility, which it outputs In the form of a Periotest value)
3. Assessment oft he occlusal load
4. Control of the treatment's progress

The unit scale ranges from -08 to +50. The measuring procedure is electromechanical. An electrically driven and electrically monitored tapping head percusses the test object (tooth or implant) 16 times. The entire measuring procedure requires approximatelly 4 seconds. The tapping head is pressure sensitive and records the duration of contact with the test object. Loose teeth or implants display a longer contact time and the Periotest values are correspondingly higher, while sturdy teeth and implants have a short contact time and result in low Periotest values. The Periotest M should not be applied in the following cases:

all types of acute apical periodontitis and acute trauma (dislocation, root fracture, alveolar process fracture).
Another method, resonance frequency anaysis (RFA) and their instrument called Osstell mentor are commonly used in clinical studies (Figure 20). The technique is contactless, non-invasive, patients experience no pain sensation from the measurement and the measurement takes 1-2 seconds.The unit of Osstell measurement is the implant stability quotient (ISQ) that is calculated from the resonance frequency and ranges from 0 to 100 units.

Fig. 20. Osstell mentor (left) and Periotest M (right)

Turkyilmaz et al found strong correlations between mean bone density scaned by CT, insertion torque and resonance frequency analsysis for the early loading protocols of dental implants. Autors suggested that primary stability is achived for early loading of dental implants when CT value is over 528 HU, insertion torque value is 32 Ncm or 45 Ncm and RF values higher than 65 ISQ.

In the end of this chapter there is a need for discusion of implant success criteria which were proposed by Albrektsson et al. Implant treatment, to be regarded as successful, need to meet the following criteria:

1. No radiolucent zone around the implant
2. The implant is acting as an anchor for the functional prosthesis
3. Confirmed individual implant stability
4. No suppuration, pain or ongoing pathologic processes

4. Conclusion

In this chapter CADIA measurement were described and its values were in strong correlation with CT values. Described CADIA modification is designed to monitor changes in bone density around implants and to compare it with other images. If there is a need to precisely determine a densitometric value, original stepwedge is inevitable, CADIA measurement were follow-up with Osstell device witch was helpful tool for determination of primary stability. Primary implant stability is in strong correlation with implant success.

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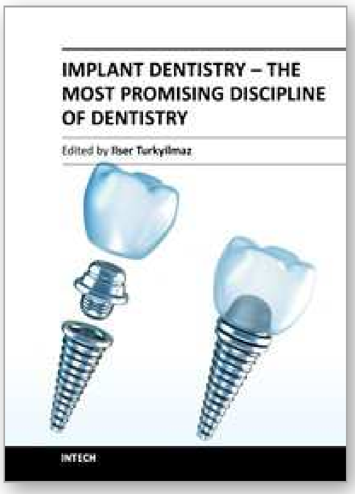

Implant Dentistry - The Most Promising Discipline of Dentistry
Edited by Prof. Ilser Turkyilmaz

ISBN 978-953-307-481-8
Hard cover, 476 pages
Publisher InTech
Published online 30, September, 2011
Published in print edition September, 2011

Since Dr. Branemark presented the osseointegration concept with dental implants, implant dentistry has changed and improved dramatically. The use of dental implants has skyrocketed in the past thirty years. As the benefits of therapy became apparent, implant treatment earned a widespread acceptance. The need for dental implants has resulted in a rapid expansion of the market worldwide. To date, general dentists and a variety of specialists offer implants as a solution to partial and complete edentulism. Implant dentistry continues to advance with the development of new surgical and prosthodontic techniques. The purpose of Implant Dentistry - The Most Promising Discipline of Dentistry is to present a comtemporary resource for dentists who want to replace missing teeth with dental implants. It is a text that integrates common threads among basic science, clinical experience and future concepts. This book consists of twenty-one chapters divided into four sections.