ASPECTS OF THE BIOACTIVE IMPLANTS INVOLVED IN PERIOINTEGRATION CONCEPT

NORINA CONSUELA FORNA

University of Medicine and Pharmacy Iasi, Faculty of Dental Medicine,
Removable Prosthesis Department, Str. Kogalniceanu 9, Iasi, Romania. E-mail norina_forna@yahoo.com

Received December 15, 2009

INTRODUCTION: The change of the implants' surface becomes a sine-qua-non condition for the realisation of the perio-integration concept, essential aspect for the viability of the implant-prosthetic therapeutic solutions.
METHODS: The experiments were conducted on dental implants manufactured from titanium Ti6Al4V and Periotype implants from the Kavo Company, with a micro RBM (Resorbable Blasting Media) surface. The process of total bio-mimic covering made use of two solutions which can deposit calcium phosphate from watery solution, at the body's temperature the synthetic biological fluid – FBS and the oversaturated solution in ions of SCS-calcium.
RESULTS: From the study of the microscopic structures obtained and researched it resulted that the micro bio-mimic ceramic layer is continuous, porous and adherent to the metal surface.Through AFM electronic microscope studies it was highlighted, within 3D coordinates, the relief of the ceramic layer deposited. This phenomenon confirms itself also through *in vivo* experiments conducted on animals.The determining of the chemical nature for the ceramic layer was conducted through a difractometric study with X-XRD ray. The evolution in time of the reconstruction process of the bone tissue and of bone integration was measured through micro-X-raying of the implanted areas at a 30-days interval; [3] In the case of the experiments done on animals, these determinations.
DISCUSSION and CONCLUSIONS: Following the specific operating times specific to such type of therapeutic manual labour, after the finalization of the implant's application it was radio-physiologically ascertain at four months after the very good intervention of the implant, that the bone structure presented an evident condensation, a fact which pleads in favour of the correct integration in full harmony with the sustaining structures.
The bio-active apatite's layer led to considerable results regarding the surface's state. It is remarkable the highly degree of bio-compatibility, facilitating a very good osseous-integration of implants with the surface's state thus modified.

Key words: Periointegration; Implant; Bioactive Hydroxyapatite; Biocompatibility.

INTRODUCTION

Edentation, along with its distinct clinical forms: unilateral, partial, subtotal or total is a complex clinical phenomenon with deep impact on the appearance of the stomatognat system (Forna, 2007), also influencing the patient's social insertion in an age governed by aesthetic demands. In the past few years the progress achieved in the precision techniques, biology, biomaterial sciences, masticatory function analysis as well as in research focused on both basic and applied sciences have allowed a significant increase in the number of patients who recover the functions affected by edentation due to implanto-prothetic rehabilitation (Forna, 2001).

In 1981, Albrektsson established the classical requirements that should be met in order to attain long term osteointegration:

1. implant biocompatibility
2. implant design
3. implant surface treatment

4. osseous bed treatment PAT
5. insertion surgical technique
6. occlusive loading conditions attained by means of rehabilitation.

The complex aspects of tissue conditioning induced by the implant shape and surface in order to have a firm attachment, a real bareer against bacterial colonization, pleads in favour of periointegration as opposed to osteointegration associated with unidirectional bond implant-osseous capital (Eger, 2000).

A complex of factors contribute to this aspect starting with the implantory surface, the implant type, the augmentation biomaterials associated with the prothetic field preparation in the view of implant insertion (Sethi, 2000).

This study has in view the practical use of the periointegration concept by forming an active bioceramics layer on the implant surface as well as the analysis of its biocompatibility and higher quality compared with the untreated surface implants (Buchter, 2005).

METHODS

The experiments were conducted on dental implants manufactured from titanium Ti6A14 V and Periotype implants from the Cavo Company with a micro RBM (resorbable blasting media) surface.

The process of biomimetic coverage confirmed and completed the working parameters for the three covering stages:

1. The controlled oxidation of the implant surface in diluted solution of NAOH with Sodium Titanate formation according to the given reaction:

$$Ti + 2NaOH = Na_2O \cdot TiO_2$$

2. The thermal treatment of the implant surface at 60°C so that the Sodium Titanate layer may bond to the metal.

3. The formation and fixation on the implant oxidated surface of the micronic ceramic layer of Calcium Phosphates in calcic biologic solutions at the normal human body temperature of 36–37°C according to the basic reactions.

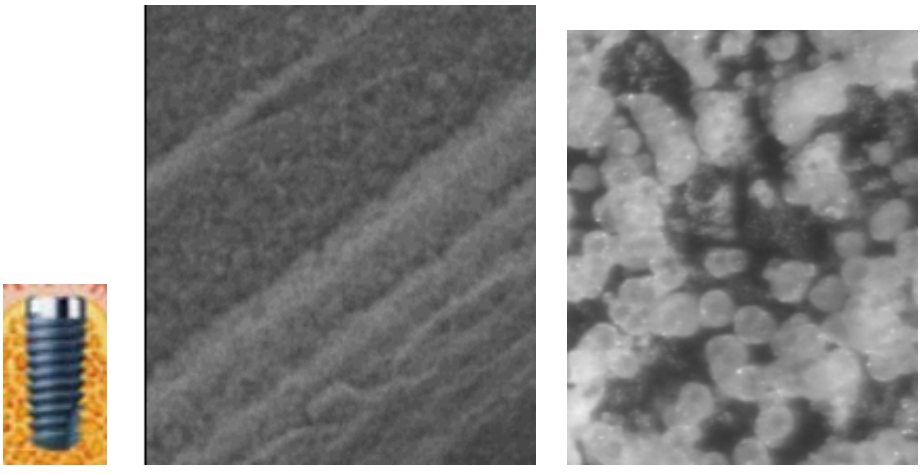
A highly important aspect was the clinical application of the periotype implant at a patient diagnosed with partial reduced edentation where the implanto-prosthetics solution was best fitted. The clinical experiments were conducted following two steps: on animals, namely rabbits, using titanium metal thighbone implants under the form of screw samples either covered or not by an apatite-like bone layer and on human patients under the form of actual dental implants covered by bioactive ceramic film.

RESULTS

The micronic layer of apatite formed on the implant surface was studied as follows:

1. The physical properties of the layer thickness, consistence, continuity and roughness were obtained by means of optical microscopy, electronic microscopy SEM (in collaboration with the Technical Physics Institute, Iasi), and by means of electronic microscopy AFM (in collaboration with the "A. I. Cuza" University, Iasi), confirming the proper form of a continuous and consistent layer of ceramic material on the implant surface.

Figure 1 shows the physical aspect of the ceramic layer formed on the studied implants starting from the geometric shape of the dental implant.



a b c

Fig 1. Physical aspect of the studied implants:
a. the geometric form of the covered implant;
b. the optical microscopy aspect (×50) of the applied ceramic layer;
c. the electronic microscopy SEM of the formed ceramic layer.

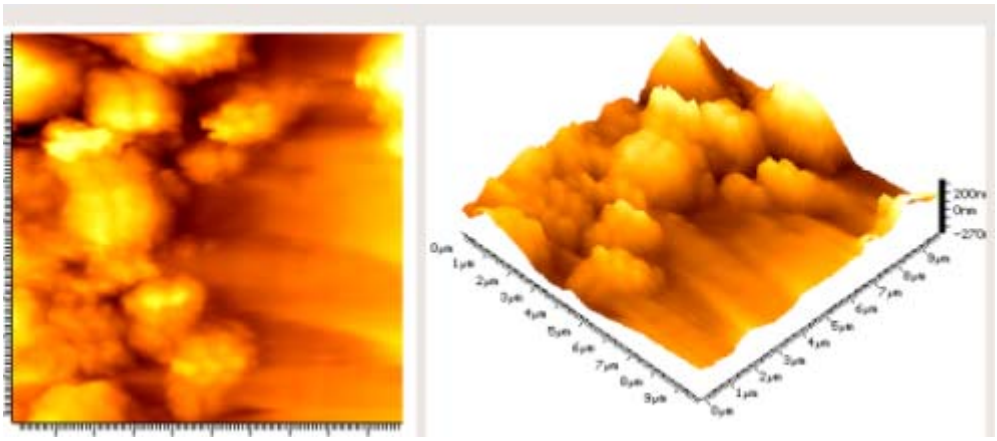


Fig 2. The aspect of electronic microscopy AFM for the ceramic layer applied on dental implants.

From the study of the obtained and analyzed microscopic structures resulted that the applied biomimetic microceramic layer was continuous, rough, porous and adherent to the metallic surface.

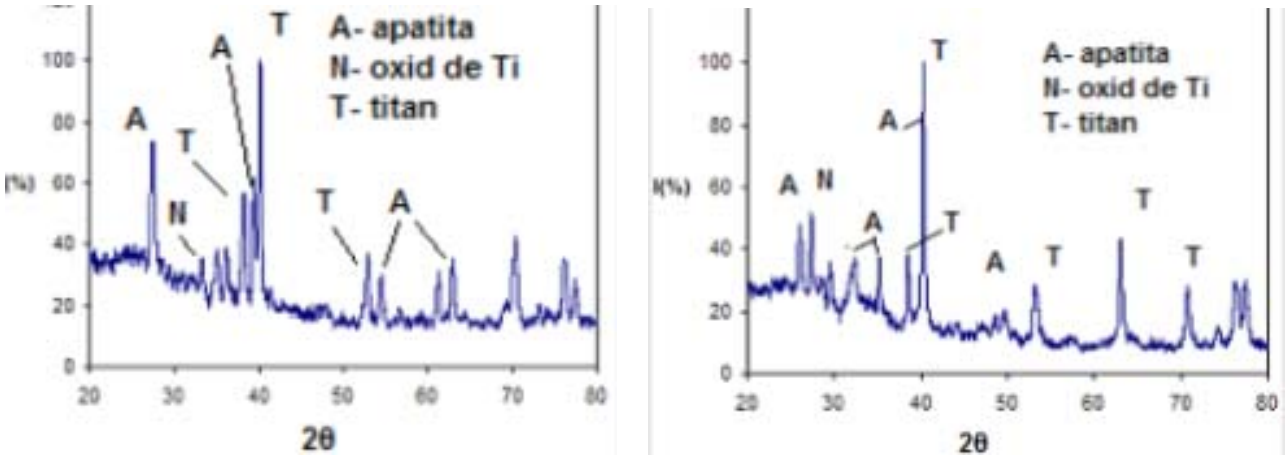
2. The electronic microscopy studies AFM presented in 3D the relief of the applied ceramic layer (Fig. 2), with an uneven rough aspect necessary for the growth and development of the biologic tissue at the living tissue-implant interface, a phenomenon confirmed by the *in vivo* experiments on animals.

3. Qualitative Determinations By Means of XRay Difractiometry

The chemical nature of the ceramic layer was determined by means of X-XRD ray difracto-metric study (in collaboration with the Institute of Technical Study, Iasi), as shown in Figure 3. The modern method of analysis used in research highlighted the formation and presence of a superficial ceramic layer of apatite on the implant surface.

These determinations brought into evidence the difference in calcium phosphate components formed in synthetic fluid solution in the two different procedures. The ceramic layer immersed in SBF solutions is richer in hidroxyapatite than the layer introduced in SCS that presents a higher concentration of calcium phosphates of the Ca_3PO_4 type. The influence of the organic phosphatic compounds on the ceramics bioactivity was shown during the *in vivo* experiments on animals, in collaboration with the Faculty of Veterinary Medicine of the Agronomic Institute Iasi.

4. The Study of Initial Biocompatibility of the Bioceramic Implant *in vitro*



a. Difractogram of the biomimetic apatite layer deposited in SBF

b. Difractogram of the biomimetic apatite layer deposited in SCS

Fig. 3. Difractogrammes obtained by means of XRD analysis showing the presence of hydroxyapatite and calcium phosphates in the ceramic layer.

The laboratory experiments conducted to verify if, in accordance with the techniques presented above, the covered dental implants are completely biocompatible in salivary fluids having a composition similar with the human oral cavity. The tested implants were immersed in a prepared salivary solution of the Fusayama Neyer type and kept at 37°C in a thermostatic bath for 7 days. No chemical interaction between implants and solution were reported.

Phenomena indicating poor biocompatibility with the salivary medium are:

– a change of the salivary solution colour;

– a change of colour in the surface of the implant covered by a white layer of hidroxyapatite;

– electrochemical corrosion at the sample surface.

There was concluded that the dental implant samples covered with a bioactive apatite layer immersed in artificial salivary solution showed no reaction between fluid and samples. The secondary stage of the biocompatibility test consisted in implants on rabbits.

5. The Study of Biocompatibility and Bioactivity *in vivo* for the Bioactive Metallo- Ceramic Implants.

This test is the decisive stage of research in the field of bioactive implants and focuses simultaneously on the bioactive and the biocompatible behaviour of the implants in contact with living tissue. Preliminary biologic tests were conducted in collaboration with the Faculty of Veterinary Medicine of the Agronomic Institute, Iasi.

The implant samples were made of titanium in the form of rectangular plates of 2 by 10 mm, biomimetically covered with a micro film of bioactive apatite by means of SBF and SCS procedures in accordance with the technique presented at ch1.

After visual and microscopic evaluation the samples were handed to the specialists from the Faculty of Dental Medicine and the Faculty of Veterinary Medicine who conducted the *in vivo* experiments.

During this secondary stage of implant biocompatibility and bioactivity experiments (the 1st stage being done in salivary synthetic fluid medium), the samples were implanted subcutaneously in the thoracic area on a 2 month female rabbit. Two symmetrically positioned incisions were made.

There were taken samples by means of circular cutaneous and adjacent conjunctive tissue incision after 14 days. The tissue fragments along with the extracted samples were immersed in formol 10% for fixation, then taken out from the seal. The histologic fragments were subsequently introduced in parafine, sectioned by microtome up to 5 micrometres each. The fragments were displayed on lamellas and HEA coloured. After the fixation and consolidation of Canada balm the resulting histologic fragments (6 for each sample) were interpreted at the optical microscope.

The samples SCS-3 and SBF presented reduced lymphohistiocitary and fibroblastic proliferation with a tendency of foreign body incapsulation into thin fibrous conjunctive tissue. The implanted samples did not affect the animal's general health condition, were well tolerated and, histopathologically, they did not induce major inflammatory tissue reactions suggesting a good tissue compatibility as shown in Figures 4a, b.

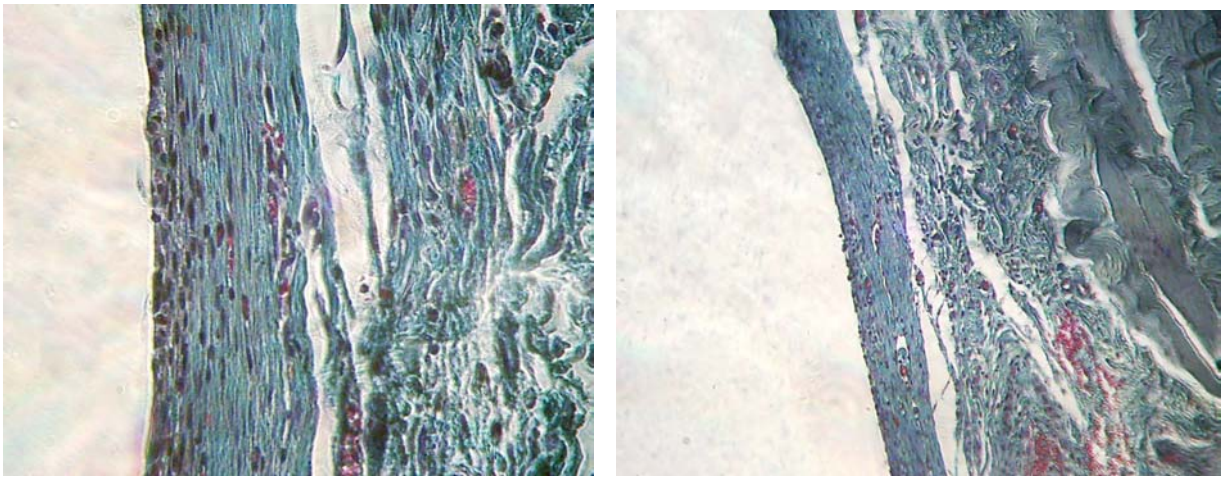


Fig. 4a. The histologic aspect, sample SCS-3: reduced lymphohistiocitary proliferation with a tendency of foreign body incapsulation into thin fibrous conjunctive tissue.

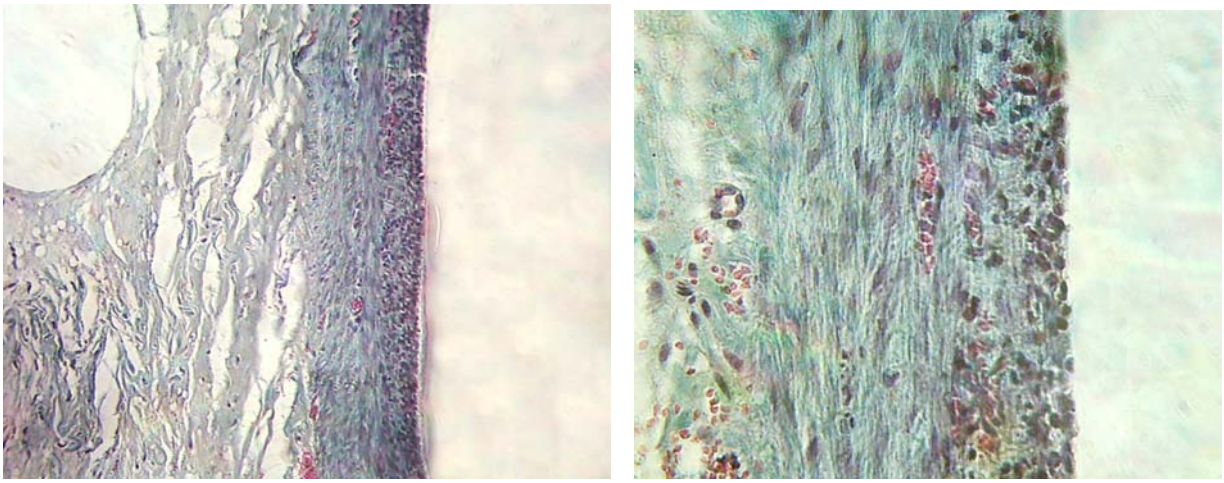


Fig. 4b. Histologic aspect, SBF sample: reduced lymphohistiocitary proliferation with a tendency of foreign body incapsulation into thin fibrous conjunctive tissue.

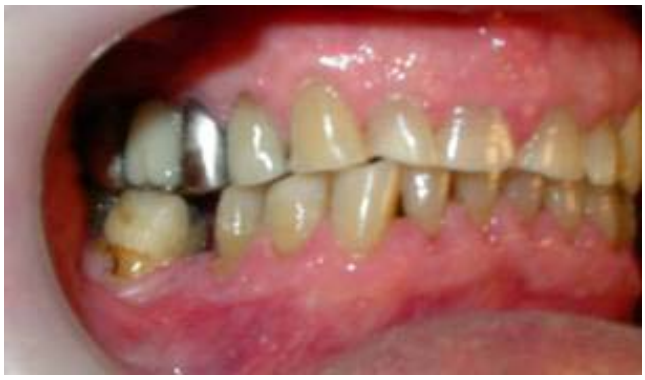


Fig. 5a. The initial clinical situation of the patient which will receive the optimized implant.

Fig. 5b. Aspects of the hydroxyapatite-covered implants; the adjacent kit.

From a group of 5 patients diagnosed with partial edentation presenting a favourable general condition who gave their accord to the experiment with periotype implants covered in active hydroxyapatite there was selected a clinical case of 3rd class Kennedy partial edentation where the therapeutic solution was implanto-prothetic (Fig. 5a, b).

The periotype implant surface was treated as described above. The general algorhythm followed the classical steps of implanto-prothetic rehabilitation. The post-implantory and subsequent 4-weeks radiovisiographic images showed uniform trabeculation, a marker of osteo- and periointegration with no negative symptomatology, preserving an osseous capital favourable to successful implantoprothetic rehabilitation (Fig. 6).

There was evidenced both better osseous capital recovery and higher biological integration as compared to the cases where this new type of optimization was not implemented.

There was also noted a good cellular integration and 70–90% adaptation to the implant surface. The tissue integration in the context of local growth factors allowed for the development and maturation of blood vessels between bone and implant.

In the first stage an extracellular matrix layer with precollagen fibres was inserted in the implant rough surface covered with active hidroxiapatite leading to local conjunctive transformation.

The tissue integration took place at the osseous, conjunctive and epithelial tissue levels. Fibroblastes, differentiated into osteoblastes with osseous matrix mineralization, favoured the implant stabilization.

In the first osteointegration stage of the spongeous tissue incorporation there is formed a 150–400 micrometre gap between the preexistent osseous tissue and the implant surface, subsequently filled in by the newly formed spongeous tissue.

The next stage consists of remodellation of the spongious tissue formed from the lamellary tissue, which is rendered radiographically.

CONCLUSIONS

1. The technology of the biomimetic filming of titanium dental implants was conducted by means of two procedures namely immersion in SBF and SCS solutions.

2. The physico-chemical properties of the apatite ceramic layer were studied by means of modern techniques in authorized laboratories and confirmed the quality, adherence and chemical composition of the micro film.

3. The biocompatibility properties of the implant samples were tested in salivary synthetic fluid and *in vivo*, *i.e.* in living biologic tissue, by means of both technologies of biomimetic filming.

4. The essential aspects of active bioceramics layer application are tied to the periointegration concept materialization – a sine-qua-non condition for the therapeutic solution viability.

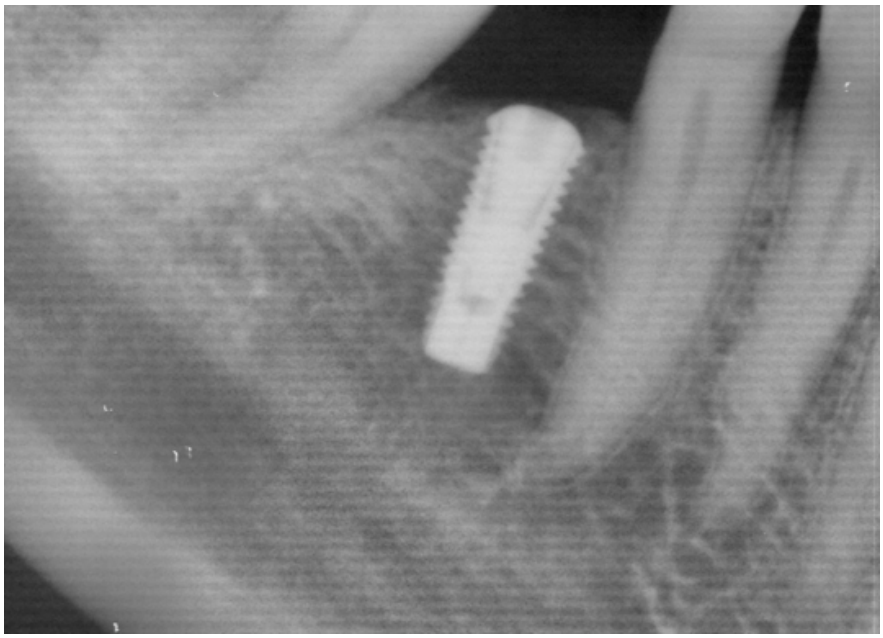


Fig. 6. Radiovisiographic image after 4 weeks.

REFERENCES

1. Forna N., Burlui V. *Clinical Guidelines and Principles in the Therapy of Partial Extended Edentation.* Iaşi: Ed. Apollonia, 2001, 470–477.
2. Norina Forna**,** *Evaluarea Starii De Sanatate Afectate Prin Edentatie***,** Editura Demiurg, 2007 ISBN 978-973-152-017-9, Carte editata cu sprijinul Autoritatii Nationale pentru Cercetare Stiintifica, 25–26
3. Norina Forna, Magda Antohe**,** *Reabilitarea Pierderilor De Substanta* **Editura Demiurg, 2007, ISBN 978-973-152-035-3,** Carte edtitata cu sprijinul Autoritatii Nationale pentru Cercetare Stiintifica, 180–186
4. Büchter A., Kleinheinz J., Wiesmann H.P., Jayaranan M., Joos U., Meyer U., Interface reaction at dental implants inserted in condensed bone. *Clin Oral Implan Res* 2005; 16: 509–517.
5. *** www.clinical-house.com
6. Sethi A., Kaus T., Sochor P., The use of angulated abutments in implant dentistry: five-year clinical results of an ongoing prospective study. *Int J Oral Max Implan* 2000; 15: 801–810.
7. Eger D.E., Gunsolley J.C., Feldman S., Comparison of angled and standard abutments and their effect on clinical outcomes: a preliminary report. *Int J Oral Max Implan* 2000; 15: 819–823.