Dental implants of Innovative Design: Experimental Characterization of Mechanical Properties and Bone-Implant Surface Interaction

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Introduction:

A dental implant is a surgical device designed to be placed in the upper or lower jaw: its clinical success depends on effective bone-implant connection.

Implant systems are generally composed by two elements: the abutment toward the crown and the fixture, surgically inserted and integrated with the bone.

They are made of titanium grade 5 according to ASTM classification; their surface is treated to increase the contact area between bone and implant and to improve osseointegration, i.e. enhancing the bone-implant contact without interposition of soft tissue.

This study is conducted on a new type of endosseous dental implant shaped blade patent-pending, to resolve the problems arising from the use of traditional tapered systems where the bone thickness is reduced.

Materials and Methods:

A dental implant is mechanically reliable if its tensile strength exceeds 800 N [1]; in the absence of normative references, the experimental tests are conducted the tests on innovative installations follow the guidelines of ISO 14801:2007 (fig.1), using the machine with servo-hydraulic Instron 8501 actuator speed of 2 mm / min.

Fig. 1. implementing rules of tensile strength tests

The technical assessment of the implant is extended to in vitro testing [2], performing tests of insertion and extraction of dental implants in animal bone, after a specific implant site preparation done by the piezoelectric device developed by Mectron® [3].

In order to fully assess the degree of interaction between the new implant and the bone site of insertion, I analyzed the bone directly in contact with the implant surface by FT-IR spectroscopy and scanning electron microscopy with EDS probe [4], to detect traces of the bone after extraction.

The application of these techniques of investigation, with the objective laid out, had not yet been made on bone tissue.

In order to characterize the state of the surface, comparing a system never put in place and one that has been incorporated in animal bone, I made an assessment on different sites of the surface by atomic force microscopy in contact, to assess the homogeneity coating and the average surface roughness.

Results and Discussions:

The tensile strength tests carried out are 9: 3 are performed on implants with abutment and fixture of different brands, and 6 on systems with innovative components.

By experimental tests, it has been found that both systems with compatible components and with original members are able to withstand static load over 800 N.

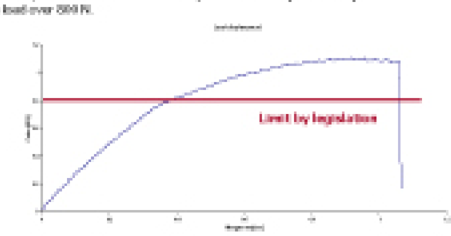

Fig. 2. ultimate strength of a new implant

The tensile strength, in fig.2, shows that the system has an elastic trend exceeding the levels described in the legislation.

The instability between the components of an implant could cause loosening of the screw fixture-abutment connection, causing an unfavorable soft tissue response and the failure of osseointegration [2].

The insertion tests of the new implant type, carried out in vitro, represent a preliminary analysis on the surgical procedure and the surface and geometry characteristics of the device.

The primary stability of the implant, defined as the first mechanical anchorage of the device into the bone, depends strongly on the geometry of the same: should not occur micro-movements, capable of destroying the cells that form in the interstitium and causing bone resorption.

INSERTION		
Sample	Maximum Load [KN]	Depth [mm]
1	0,123?5	7,4[illegible]
2	0,23?16	7,?9629
3	0,23405	8,00050
4	0,29237	7,90204
5	0,26992	7,68017
6	0,27549	7,99681
Average	**0,23546**	**7,8348**

Tab. 1. values of insertion of 6 new implant

Excluding the maximum and minimum value obtained experimentally (tab.1), the average magnitude of the applied load is equal to 0,2492 KN; the amount of insertion force depends on the mechanical properties of bone in which the surgery is performed.

The bone surrounding the implant is evolving according to the tissue response to stress-induced device.

The osseointegration of implants is linked to early interactions between osteoblastic cells and the surface of titanium.

The challenge in designing implant surfaces is to attract mainly osteoblasts that produce bone extracellular matrix, ensuring a high degree of contact between bone and implant [2].

The analysis of surface of the bone area, which hosted the facility, could be a method of investigation of the first interaction that occurs between implant and bone during surgery.

The spectroscopic analysis is performed on a bone reference sample treated in the same way as samples of animal bones that have hosted the innovative devices.

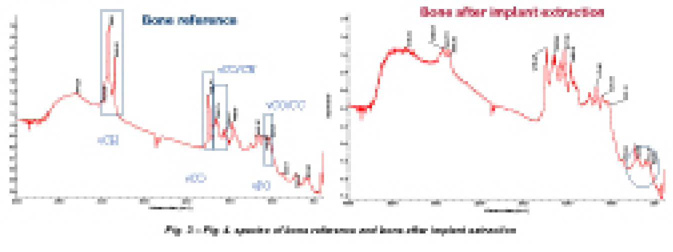

Fig. 3 – Fig. 4. spectra of bone reference and bone after implant extraction

Examining the spectra in Figure 3 and 4, between 3069 and 2800 cm^{-1}, we can see the peaks typical of CH stretching, belonging to the alkyl chain, aliphatic and aromatic ring. In the region 1750-1604 cm^{-1}, the peaks are associated with primary amide and stretching of the primary CO. In the region 1029-870 cm^{-1}, the absorptions indicate the presence of carbohydrate and phosphorus.

In fig. 4, we can observe a broad absorption in the region between 700 and 450 cm^{-1}.

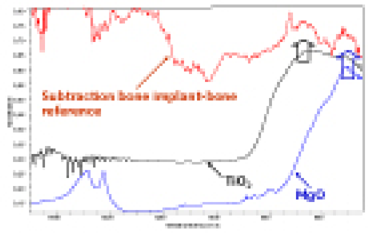

Fig. 5. spectra of subtraction bone implant-reference, TiO_2 and MgO

The spectra of Ti oxide ang Mg oxide in KBr are performed to detect the presence of metals ions in the spectra of the bone fragments, that have been in contact with the implant.

Through the spectrum of subtraction highlighted in red in fig.5, we note the presence of two absorption bands, corresponding to the stretching vibrational modes of the bulk of inorganic oxides.

The contact between implant and bone has been likely to release traces of surface treatment of the device at the site of action: the surgical procedure used has pierced the bone preserving the integrity.

The bone sample analysis, which has been in contact with the implant, is conducted making global and local scans of the most interesting areas of the sample by SEM-EDS.

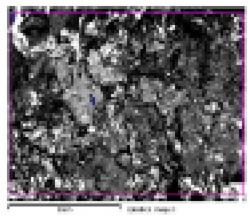

Fig. 6. SEM-EDS image of bone after implant extraction

In fig. 6, the trabecular component predominates: in fact, we can distinguish aggregates of trabeculae leaning against each other. Items such as oxygen, calcium, potassium, sodium and sulfur are typical of the organic: the purpose of the analysis is found in the sample traces of titanium and magnesium.

Experimental tests show that there isn't a detectable amount of Ti, while there are traces of magnesium; the result is in agreement with the electrochemical oxidation treatment which incorporates magnesium cations.

The surface treatments, performed on dental implants, are extremely important to promote osseointegration: each device produces a bone-implant primary stability through mechanical retention of bone with the implant surface structures [2].

The homogeneity of the coating surface is characterized by atomic force microscopy: in order to evaluate the specific interaction between implant and location of installation, a comparison is made between a system never put in place and one incorporated into a bone [4].

Fig. 7 – Fig. 8. AFM images of implant never put in place and one that has been incorporated in bone

The surface treatments and machining operations performed on the devices are high-level. Observing figures 7 and 8, we can see the homogeneity of the surfaces, indicating the effectiveness of the coating process undergone by the implants.

Conclusions:

Experimental results show that new implants are mechanically reliable in 83% of cases; they may adopted where the traditional tapered implants fail.

The type of stress due to the inclusion of the new implant is much lower than the stress normally used for standard implants. The insertion values obtained represent a starting point for the resolution of side effects present when the planting site conditions are unfavorable, because of low bone density or a thin bone.

The characterization of the bone-implant interaction through the spectroscopy has been very interesting: the exploration of ways of stretching vibration of organic components, together with the absorption bands of the oxides of Ti and Mg, has allowed the identification of bands characteristics of the oxides in the region of low frequencies in the spectra of components of bone.

The detection of traces of oxides by SEM-EDS is less effective when compared to infrared spectroscopy: a very small traces of Mg oxide is present, the amount of oxide of Ti is small enough to be within the range of error tool.

The uniformity of the coating in the presence of jaggies has been verified by atomic force microscopy: the surfaces are homogeneous even in the presence of discontinuities.

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