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STRUCTURAL CHARACTERIZATION AND CORROSION BEHAVIOR OF TITANIUM DENTAL IMPLANT

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The paper presents research on materials used on dental implants. In this paper, a conical screw and abutment were used for investigation. The samples were analysed by SEM analysis, EDS, optical microscopy and corrosion test. The compositional analysis confirms that the dental implant is made by Ti–6Al–4V for the screw and the abutment is made by NiCr dental alloy. They were subjected to the process of electrochemical corrosion in artificial saliva medium. The corrosion rates were calculated, resulting that the experimental sample has an adequate corrosion and electrochemical behavior in terms of its possible use as dental implant material.

Keywords: Titanium alloy, Implant, Corrosion, Microstructure

1. Introduction

The dental implant is the best possible replica of a natural, healthy tooth and represents the most modern and efficient solution for replacing lost teeth. Dental implants allow having a normal life - to eat, to smile, to laugh, to talk without being worried about missing teeth.

With the new implants, patients no longer have to sacrifice natural teeth to anchor types of dental crowns, no longer use removable dentures, which create permanent discomfort, but can instead benefit from fixed, implant-anchored dentures that look and feel just like natural teeth.

Tooth loss is a real problem and unfortunately sometimes ignored or frequently postponed.

A dental implant is a piece of pure (99.95%) titanium, generally in the form of a screw. It aims to create an artificial root in the jawbone, where a single natural tooth or several teeth are missing [1].

The reconstruction consists of two segments – one intraosseous (implant) and one supraosseous called the prosthetic abutment.

Crowns, bridges, or dentures can be anchored over the prosthetic abutment. The implant is protective compared to traditional bridges that require the sacrifice

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of adjacent teeth. (nerves are extracted, root canals are filled, and healthy teeth will be excessively polished) [2].

Dental restoration based on implants brings both functional and extraordinary aesthetic benefits, the patient does not perceive the "artificial" sensation and he forgets that he has lost a tooth in that area. An effective treatment with dental implants restores teeth aesthetically and functionally for at least 30-40 years, i.e. for life. To achieve this goal, careful investigation, a correct diagnosis and impeccable execution are necessary on the part of the doctor, and on the part of the patient, rigorous oral hygiene, two annual check-ups and the avoidance or cessation of smoking [3].

Ni-Cr alloys are used due to their superior mechanical properties and reasonable price.

Titanium implants have an excellent success rate (over 95%) and have been used for over 30 years in implantology. Titanium alloys have a special mechanical resistance, are non-toxic, resist corrosion and are extremely well tolerated by the body, thus favoring the process of osseointegration (the process by which bone tissue is formed around the dental implant, resulting in increased stability) [4].

The long-term use of titanium implants means that they are supported by numerous long-term studies. Recently, a new option is presented - zirconium implants, which, however, need extensive studies as they appeared relatively recently [5].

Another important aspect that has to be considered in dental applications is the aggressive oral environment, which can initiate corrosive processes followed by the release of ions and corrosion products, eventually inducing in several cases the hypersensitivity for the patients.[6]

2. Materials and methods

2.1. Materials used in the study

For the study, a titan dental implant was investigated. The implant consists of two components: screw and abutment, which were then, subjected to Energy-dispersive X-ray spectroscopy, scanning electron microscope, optical microscopy and corrosion tests.

Fig. 1. The implant consists by two elements: the screw and the abutment

2.2. EDS (Energy-dispersive X-ray spectroscopy)

Energy-dispersive X-ray spectroscopy (EDS, EDX, EDXS or XEDS), sometimes-called energy dispersive X-ray analysis (EDXA or EDAX) or energy dispersive X-ray microanalysis (EDXMA), is an analytical technique used for the elemental analysis or chemical characterization of a sample. It relies on an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing a unique set of peaks on its electromagnetic emission spectrum[7] (which is the main principle of spectroscopy). The peak positions are predicted by the Moseley's law with accuracy much better than experimental resolution of a typical EDX instrument.

2.3. SEM

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the intensity of the detected signal to produce an image. In the most common SEM mode, secondary electrons emitted by atoms excited by the electron beam are detected using a secondary electron detector (Everhart-Thornley detector). The number of secondary electrons that can be detected, and thus the signal intensity, depends, among other things, on specimen topography. Some SEMs can achieve resolutions better than 1 nanometer [8].

Surface morphology is observed using SEM scanning electron microscopy images [9].

2.4. Optical microscopy

The optical investigations, made on three polished samples, were performed on a Reichert UnivaR microscope; viewing can be done in bright field (BF), dark field (DF) and in simply reflected polarized light. It was used a compact Hitachi KPF1 digital camcorder, lightweight CCD camera, color, integrated type, using the latest 2/3 inch CCD image size type, with CCIR signal type; The actual 782x582 pixel count in combination with a high-density montage. The Analysis Program is Omnimet Express, which includes a powerful database and report generator that allows you to store images and their associated data to generate a report.

2.5. Corrosion tests

Corrosion is the process of degradation of metallic materials under the influence of the environment around them. When a metallic material is found in a biological environment, an oxide layer forms on its surface as a result of the reaction of the material with that environment. Through the oxide layer on the surface of the material diffuses metal ions. Corrosion is one of the parameters that determine the biocompatibility of dental alloys [10].

In this paper, a study was conducted on the influence of the corrosion resistance, in artificial saliva type Fusayama Meyer on the screw[11].

3. Results and discussions

3.1. EDS results

In the first phase of the experimental research, the screw was analysed.

Determination of the chemical composition of screw was carried out by EDS analysis.

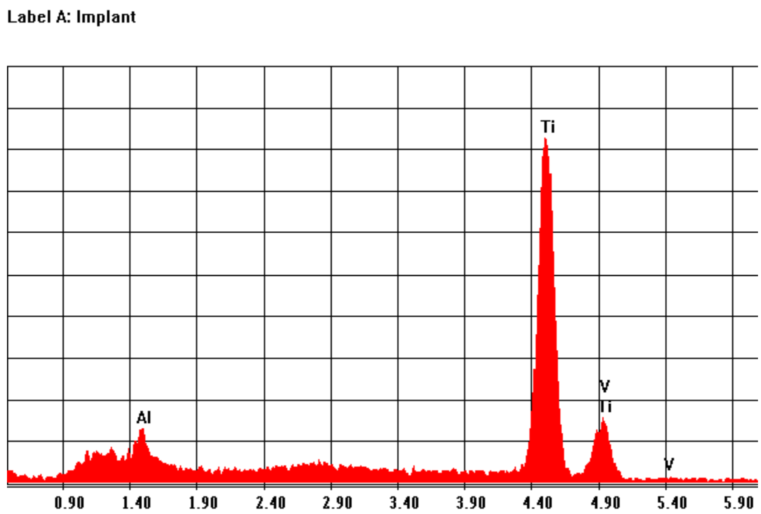

Fig. 2. Chemical composition (EDS) corresponding to the screw

Table 1

The chemical composition of the screw

Element Symbol	Weight concentration, (Wt%)
Ti	91.12%
Al	6.56%
V	2.32%

This determination shows that the screw is made of a Ti6Al4V alloy.

In the second stage, the abutment was analysed.

Determination of the chemical composition of abutment was carried out by EDS analysis.

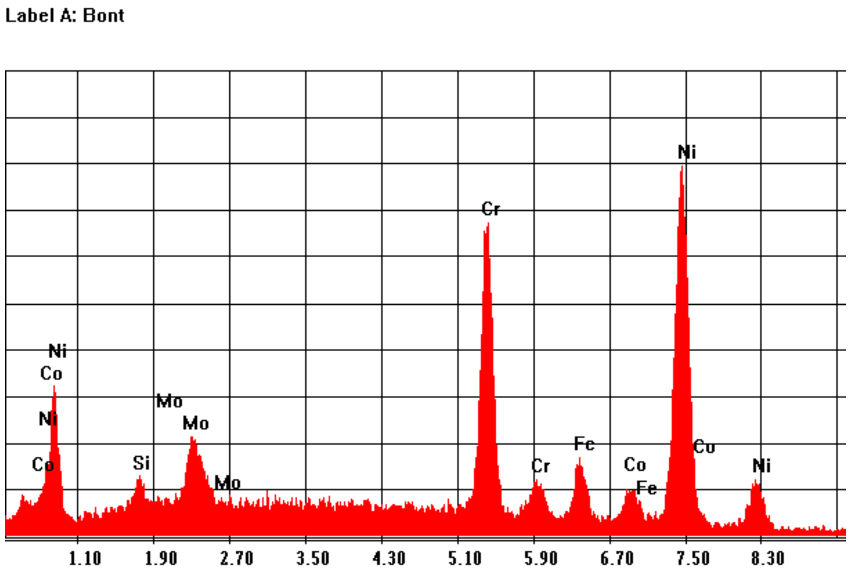

Fig. 3. Chemical composition (EDS) corresponding to the abutment

Tabel 2

The chemical composition of the abutment

Element Symbol	Weight concentration, (Wt%)
Ni	56.14%
Cr	22.73%
Mo	7.52%
Fe	6.67%
Co	5.04%
Si	1.9%

This determination shows that the abutment is made of a NiCr alloy, which is an alloy used in dental technique.

3.2 SEM

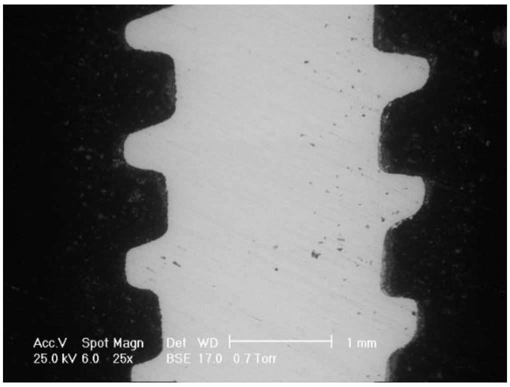

Fig. 4. SEM images of the titanium screw

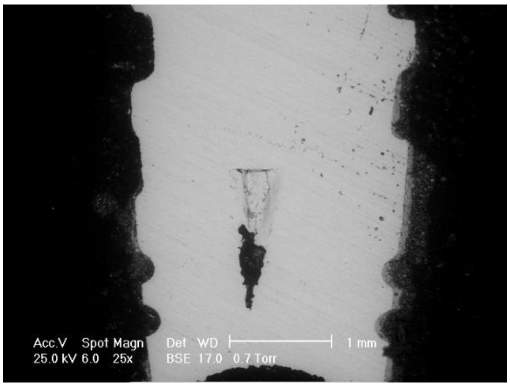

Fig. 5. SEM image with closed shrinkage defect

In Fig. 5, can be observed the closed shrinkage defect, which represents a discontinuity of material.

3.3 Optical microscopy

Below are the results obtained in the investigation by optical microscopy.

Following the optical microscopy, the biphasic structure α + β in the screw is highlighted (Fig. 6).

Can be observed α- light grains, and β dark grains, but the bright ones predominate.

Fig. 6. Optical microscopy image of the screw

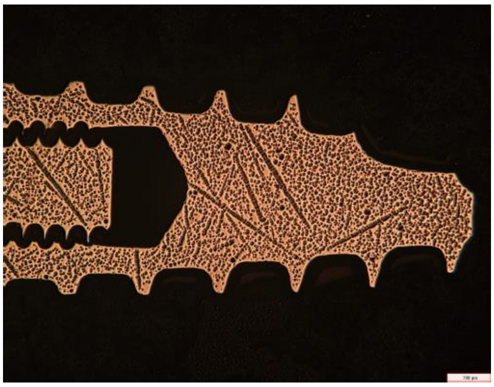

Fig. 7. Optical microscopy image of the screw and abutment

In the threading area, the abutment has a part removed by breaking. It occurred as a result of a strong rupture (Fig. 8).

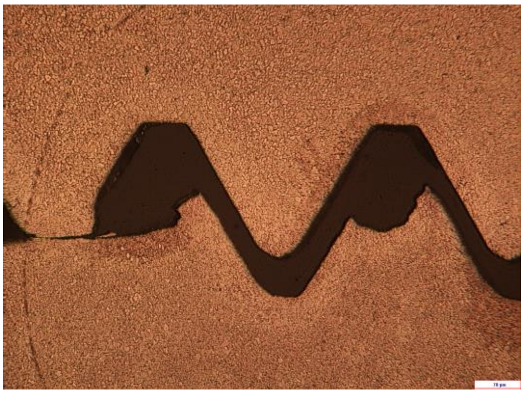

Fig. 8. Optical microscopy image of the screw and abutment, chemically attacked

3.4. Corrosion resistance

Corrosion resistance was determined by the linear polarization technique. This technique consists of tracing polarization curves involving the following steps:

• measuring the open circuit potential (EOC), for a period of 12 hours;

• plotting potentiodynamic curves from -1V (vs OCP) to + 1V (vs SCE) - with a scanning rate of 0.1 mV / s.

Corrosion resistance tests were performed using a Potentiostat / Galvanostat (model PARSTAT 4000, manufacturer Princeton Applied Research, USA) to which a low current module (VersaSTAT LC, manufacturer Princeton Applied Research) was coupled (Fig. 9), and the potentiodynamic curves (Tafel) were purchased using VersaStudio software.

Fig. 9. Potentiostat / Galvanostat PARSTAT 4000, Low Current Module VersaSTAT LC

For the tests, a corrosion cell was used, which consists of a saturated calomel electrode (SCE) - reference electrode, a platinum electrode - auxiliary electrode and the working electrode which consisted of the implant made of Ti6Al4V alloy.

The tests were performed at the temperature of the human body (37 ± 0.5 ° C) with the help of a bath with heating and recirculation model CW-05G produced by Jeio Tech.

The tests were performed in Fusayama-Meyer artificial saliva at pH = 5. The variation of the open circuit potential (E_{oc}) and the potentiodynamic curve corresponding to the material tested in SA, are presented in Fig. 10 and Fig. 11.

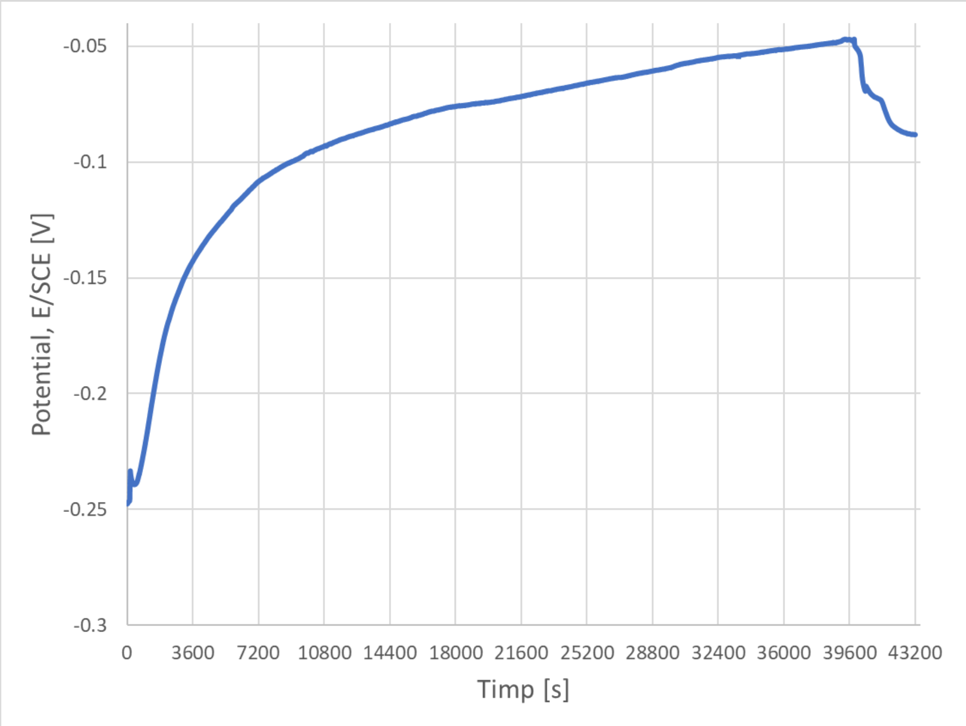

Fig. 10. Variation of the open circuit potential

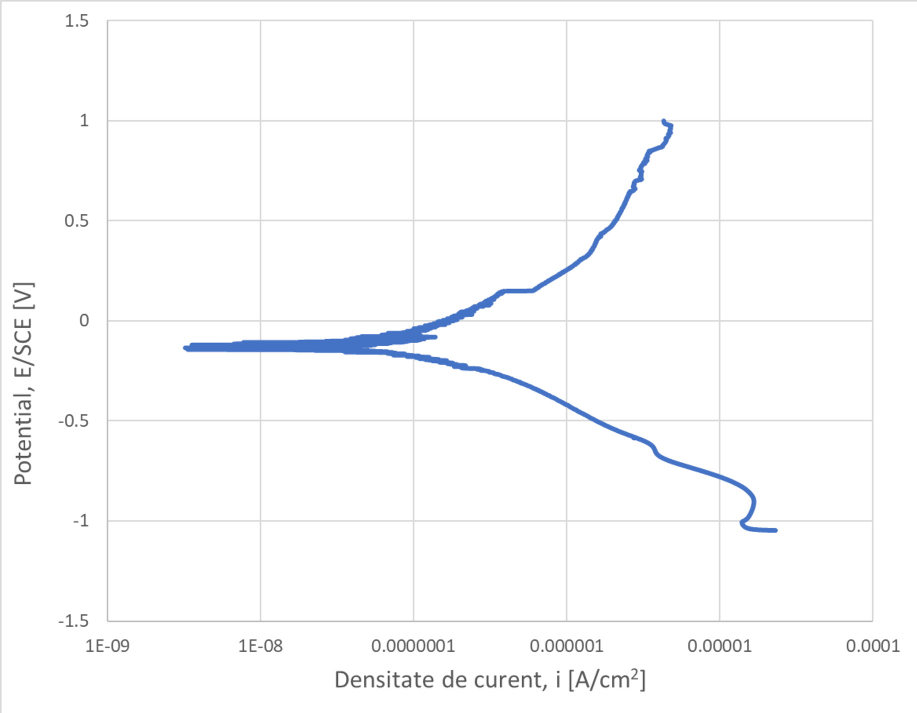

Fig. 11. Potentiodynamic curve of the tested material

From the corrosion tests performed in SBF and with the help of Tafel extrapolation, the following parameters were determined that characterize the corrosion resistance of the investigated material:

- open circuit potential (E_{oc}),
- corrosion potential (E_{cor}),
- corrosion current density (i_{cor}),
- slope of the cathodic curve (β_c),
- slope of the anodic curve (β_a).

Table 3 presents the main parameters of the electrochemical corrosion process obtained in the tests performed in SBF.

Table 3

The main parameters of the corrosion process in SA

Nr. crt.	Proba	E_{oc} (mV)	E_{cor} (mV)	i_{cor} (nA/cm^2)	β_c (mV)	β_a (mV)
1	Ti6Al4V	-88,10	-125,43	109,59	264,685	454,443

4. Conclusions

Following the EDS analysis determinations, it was determined that the screw is a Ti6Al4V alloy, and the abutment is made of a Ni-Cr alloy, which is frequently used for the manufacture of these types of implants.

Using the parameters identified from the potential-dynamic curves, as well as the characteristics of the material used in the development of implants, the corrosion rates corresponding to the artificial saliva were calculated, resulting in the experimental sample having good corrosion resistance.

In conclusion, the screw made of Ti6Al4V alloy is indicated in the manufacture of implants that are used for a longer period in the oral cavity.

R E F E R E N C E S

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