# Periimplantitis as the Cause of Separation the Prosthetic Bridge Based on Implant

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**Abstract.** The paper discusses the basic problems of the possible complications after implant-prosthetic treatment, with particular emphasis on periimplantitis. Presented are the results of materials science expertise for prosthetic bridge based on the implant, lost by sixty year old female patient as a result of perigraft tissue inflammation. The results allowed to assess whether the separation of the prosthetic system – in addition to biological factors – was influenced by mechanical factors, such as damage to restoration structures.

**Keywords:** Computational geometry · Graph theory · Hamilton cycles

## 1 Introduction

The development of implant prosthetics over the past few decades has made that, starting from the experimental field of dentistry, it has become almost routine solution for the reconstruction of partial or complete lack of teeth. Evolution comprised here both the procedures applied, instrumentation, and implants themselves in – terms of design and material solutions. While the said method of treatment has gained great popularity, there are still some failures (around 10 %), leading to loss of stability of the implant-bone system, and in effect the implant separation. Scheme of the course of implant-prosthetic therapy is shown below – Fig. 1 [3,6].

Complications arising after the implant surgery are twofold: mechanical and biological (Fig. 2). The main causes of complications of a mechanical nature can include improper implant construction, structural defects of materials of which individual components are made, as well as unfavourable loading of the implant with occlusion forces. As regards the biological causes complications: they have their origin in a variety of factors, some of which being only cited


M. Gzik et al. (eds.), *Innovations in Biomedical Engineering*, Advances in Intelligent Systems and Computing 526, DOI 10.1007/978-3-319-47154-9_8


**Fig. 1.** Diagram of the course of the implant-prosthetic treatment [5]

below because of their plurality. Among others these include: systemic diseases (osteoporosis, diabetes), abnormal occlusion, inadequate design of the implant, poor oral hygiene, impaired wound healing after surgery, stimulants [1].

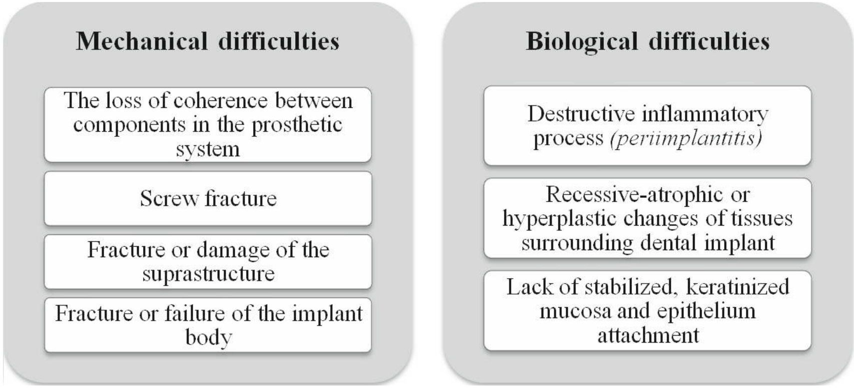


**Fig. 2.** Categorizing of difficulties occurring after implant-prosthetic treatment [4]

One of the most common causes of stability loss, and then separating the implant is an inflammation of the perigraft tissues (periimplantitis). The direct consequences of this phenomenon is the soft tissues atrophy of the gingiva and resorption of bone tissue. Periimplantitis reasons lie in imbalance of the equilibrium between the resident flora surrounding the implant and the immune system of the body, often intensified by the presence of occlusal disorders, systemic diseases, genetic and/or social conditions, such as poor oral hygiene, tobacco smoking, and even stress [1,2].

## 2 Materials and Methods

Materials science expertise has been applied to elements of the three-point prosthetic bridge fixed in the mouth of sixty years old female patient for a period of six years, lost in the course of periimplantitis. The bridge was anchored to the conical, self-drilling implant Alpha Bio SPI of nominal diameter 3.75 mm and a length of 10 mm, made of the alloy Ti6Al4V. The implant system consisted of an angle joint, screw and implant. Abutment of prosthetic crown was made of Ni–Cr–Mo alloy, whereas as a veneering layer was feldspathic ceramics GC Initial

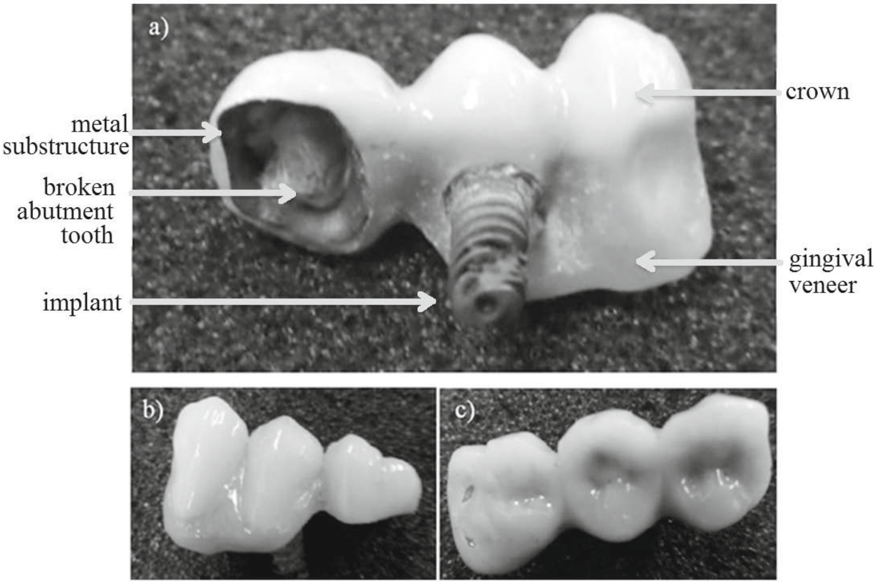


**Fig. 3.** Dental bridge after removal from the oral cavity of the female patient: (a) bottom view; (b) buccal view; (c) occlusal view

MC, determined by the manufacturer as being compatible with metal alloys having a coefficient of thermal linear expansion in the range of $13.8 \div 14.9\,\mu\text{m/m}\cdot\text{K}$. Part imitating gum (Fig. 3) is made of acrylic. Based on an interview conducted by a dentist, it was determined that due to smoking tobacco patient is at risk group of biological complications.

In order to prepare the prosthetic restoration to carry out testing separated were the system components by using precision cutting device Struers Secotom–15. In the following steps performed were:

- microscopic observations using a stereoscopic microscope (Zeiss Discovery V8), scanning electron microscope, a light microscope (Zeiss Observer),
- electrochemical impedance spectroscopy,
- study of resistance to pitting and galvanic corrosion.

Electrochemical impedance spectroscopy was performed by the measuring system AutoLab PGSTAT 302N in the frequency range $10^{-3} \div 10^{4}$ Hz. Measuring system was equipped with a module FRA2. The experiment was performed in Ringer's solution, which was to simulate the environment of perigraft tissues. Obtained results provided information on the electrochemical properties of the implant and enabled the assessment of the phenomena taking place on its surface.

The examinations of corrosion resistance have been carried out using a potentiostat PGP–201 of Radiometer Analytical SAS company. The evaluation of pitting corrosion resistance was carried out – as in the case of the EIS – for the titanium implant in an Ringer's solution. For the abutment and metal substructure, the evaluation of resistance to galvanic corrosion (Evans method) was performed, and as a study environment the solution of artificial saliva was selected.

## 3 Results

Based on preliminary observations using a stereoscopic microscope, it was found that the prosthetic system revealed signs of wear in the form of small cracks, and abrasions of the surface of ceramic crown. As a result of damages the exposure of the substructure material has occurred (Fig. 4a). There was also damage to the thread observed (Fig. 4c), probably caused by the destabilization of the implant and its movement in regard to the bone. On the abutment surface, the areas covered by corrosive changes were observed (Fig. 4d). It was also found that within the substructure of the crown based on the patient's own tooth the remnants of that pillar have retained (Fig. 4b).

After cleaning the implant surface, observations were made by using a scanning electron microscope. Despite carefully conducted process of removing impurities from the implant surface it failed to remove all biological residues (Fig. 5a). It was also noticed that the porous surface structure of the implant has deformed (Fig. 5b).

After preparation of metallographic specimens in accordance with obligatory methodology, observations were made of the constituent materials structures of

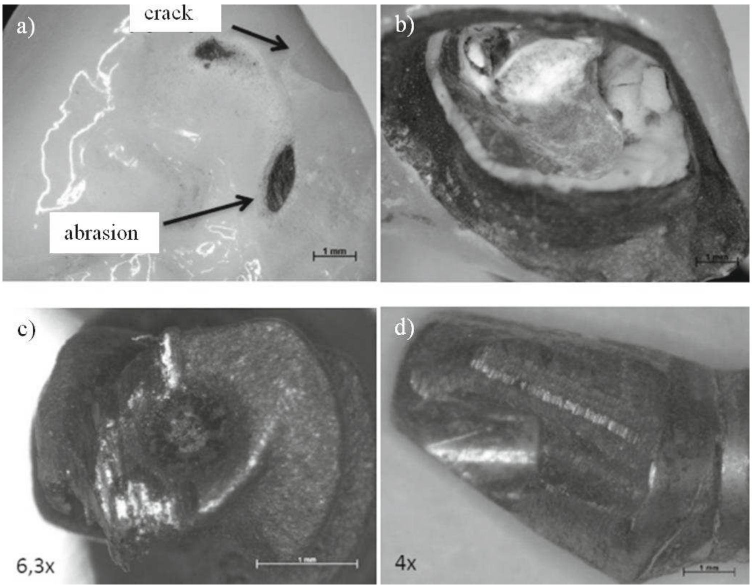


**Fig. 4.** Images from the stereomicroscope: (a) prosthetic crown; (b) tooth retained in substructure; (c) thread abrasion; (d) abutment with corrosive changes of the surface

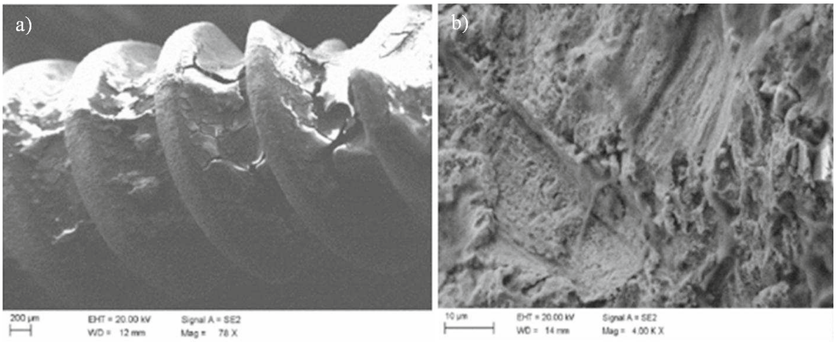


**Fig. 5.** SEM image of the surface of the implant in magnification: (a) 78x; (b) 4000x

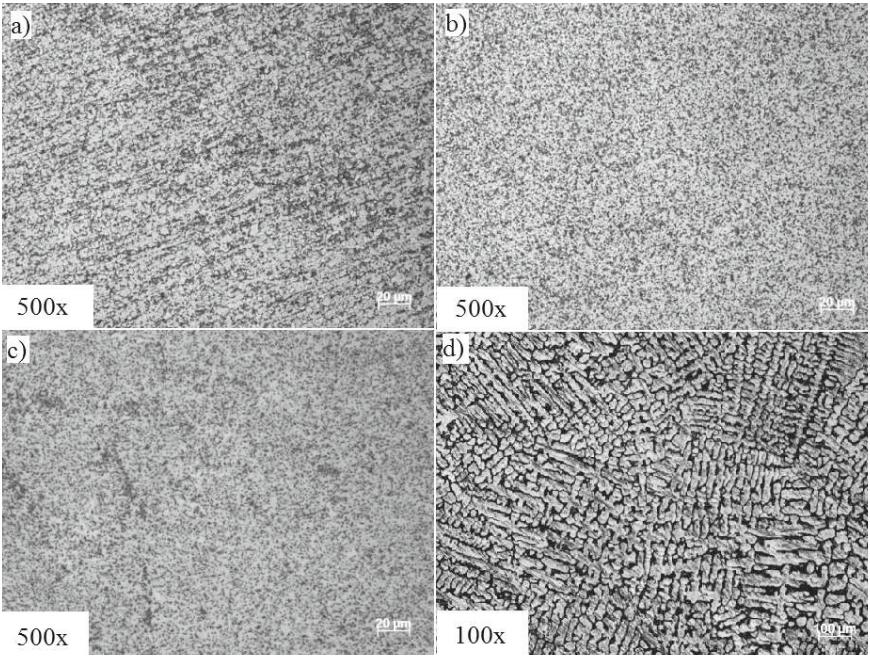


**Fig. 6.** The structures revealed in observations made by light microscope: (a) longitudinal section of the implant; (b) cross-sectional view of the implant; (c) longitudinal section of the abutment; (d) cross-sectional view of the substructure

the prosthetic system being examined. For this purpose a light microscope was used. The disclosed structures are depicted (Fig. 6) and described below.

On the basis of obtained images, it was found that the material of both the implant and abutment was characterized by fine-grained two-phase structure $\alpha+\beta$ (Fig. 6a–c), typical for the alloys Ti6Al4V. In the case of the substructure material, observed was the existence of dendritic structure being characteristic

**Table 1.** The results of impedance examinations

| Material | $R_s$ [$\Omega cm^2$] | $C_{dl}$ | | $R_{ct}[k\Omega cm^2]$ |
|---|---|---|---|---|
| | | $Y_{dl}[\Omega^{-1}cm^{-2}s^{-n}]$ | $n_{dl}$ | |
| Ti6Al4V | 40.1 | $2.535 \cdot 10^{-4}$ | 0.7568 | 14.25 |

for the components made by casting, not subjected to metal forming. On the basis of observations and their comparison with the literature, revealed was the presence of intermetallic phase $\gamma$ with increased content of Ni–Cr and molybdenum enriched interdendritic areas [7]. In addition, during the observations of microscopic cross-section of a prosthetic crown (Fig. 7) confirmed was the existence of a layered construction of veneering layer – on the surface of the substructure, it was clearly visible layer of opaquer (not translucent) with a thickness of approx. 150 $\mu$m.

Literature sources also show the presence of the porous oxide layer on the surface of the metal substructure, however, used magnifications do not create the possibility of separating it from remaining structures of prosthetic crown. The presence of this layer, produced by oxidation process (after streamed abrasive treatment of substructure surface), aims to increase the strength of the connection between the ceramic veneering and substructure materialy [8].

As a result of impedance examinations EIS the spectra of Bode (Fig. 8a) and Nyquist (Fig. 8b), were recorded, as well as characteristic parameters that describe the properties of the surface structure of the implant (Table 1).

Nyquist diagram indicates the occurrence of characteristic impedance response of thin oxide layers, which means that the implant surface has been

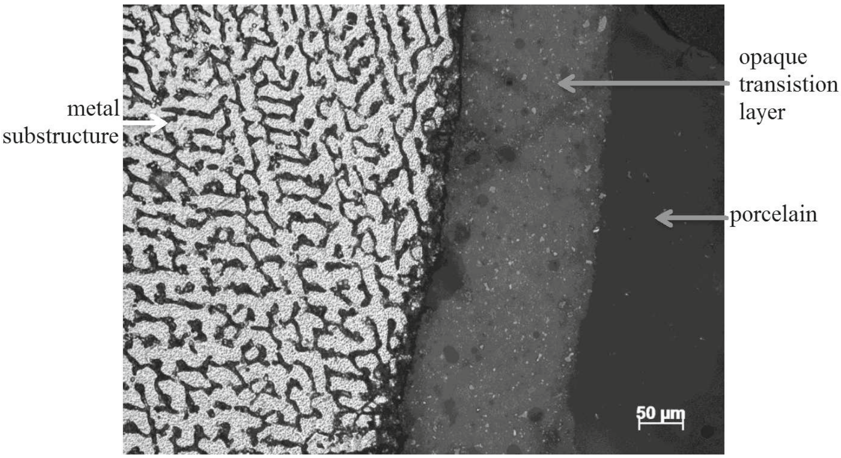


**Fig. 7.** Section through a prosthetic crown in 200x magnification (image from a light microscope)

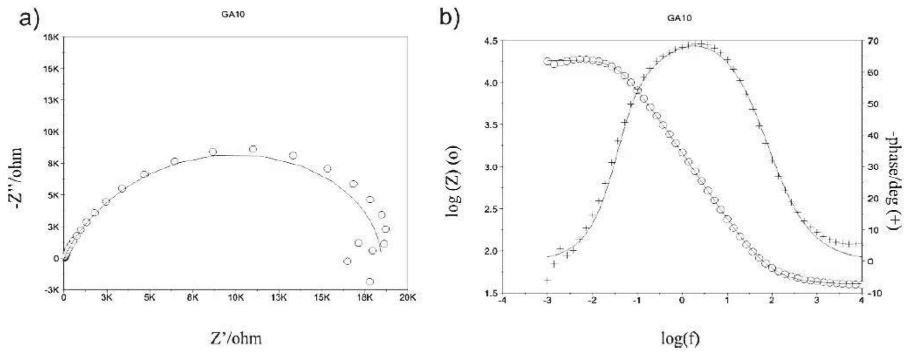


**Fig. 8.** Impedance spectra (a) Nyquist diagram (b) Bode diagram

passivated. On their basis, it was stated that the phase shift angle is approximately 70°, whereas the slope of the log|Z| in the applied frequency range is close to value −1.

Before testing the resistance to pitting corrosion of the implant the opening potential was established, which amounted to $E_{ocp} = -91\,\text{mV}$. Then, starting from the value $E_{start} = E_{ocp} - 100$, using the rate of potential change of 1 mV/s, recorded was the anodic polarization curve (Fig. 9). Then the specific parameters were appointed: $E_{cor} = -148.9\,\text{mV}$, $R_p = 456.5\ \Omega\text{cm}^2$, $I_{cor} = 11.85\,\text{A/cm}^2$.

Resistance to galvanic corrosion of the abutment and crown started from the identification of opening potential. The values of these potentials are −192 mV for the abutment and −378 mV for the substructure. On the basis of this measurement, it was found that an electrode with a higher electronegativity (substructure) in the main study is to act as the anode while the abutment having smaller electronegativity – the role of the cathode. The area ratio of anode to

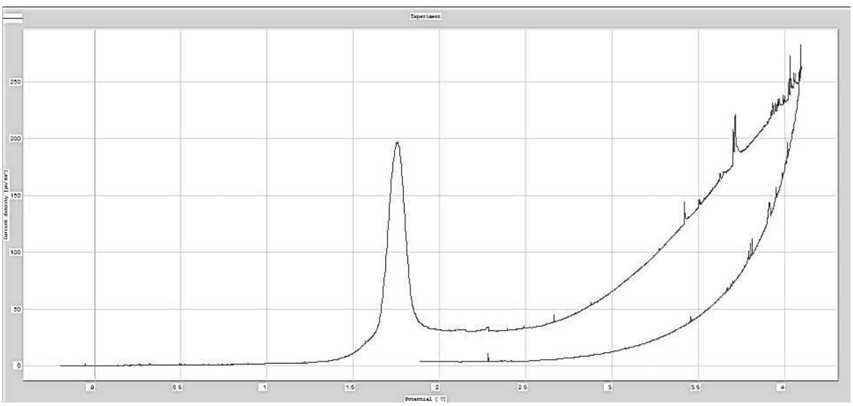

**Fig. 9.** Anodic polarization curve for implant of Ti6Al4V

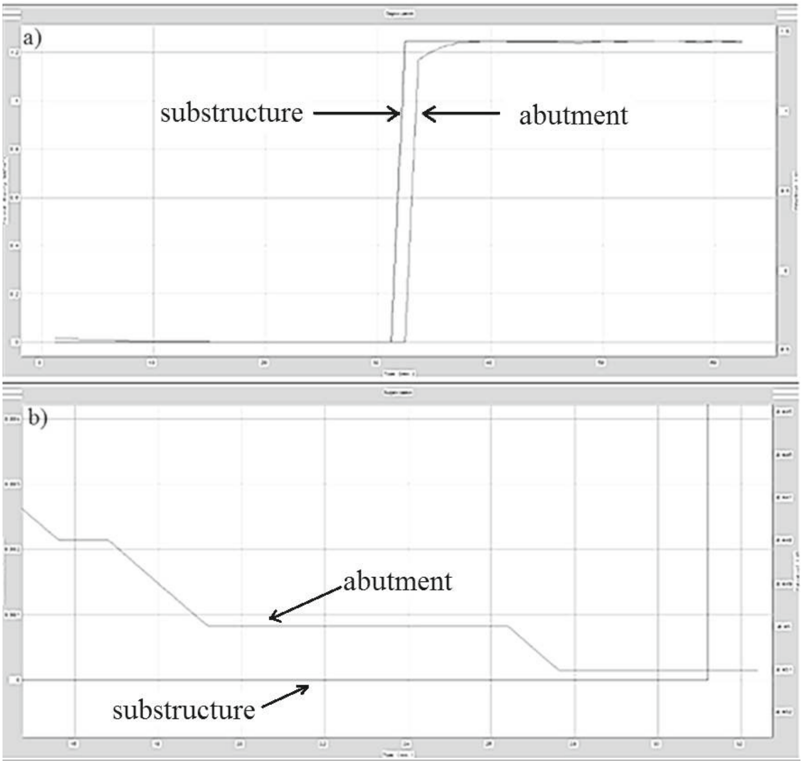


**Fig. 10.** Graphs of changes of the potential and current density in time (a) curves of polarization; (b) the point of intersection of the curves

cathode was set at 1:1. As a result of measurements recorded were the graphs (Fig. 10a) of changes course of the current density and potential in time for the abutment and substructure. On this basis, the values $i = 0.13\,\mu\text{A/cm}^2$ oraz $E = -450\,\text{mV}$ at the curves intersection has been established (Fig. 10b).

## 4 Conclusions

Microscopic observations allowed a preliminary assessment of exploitative damages within the prosthetic crown, which could be caused by abnormal occlusion, and therefore the occurrence of occlusal parafunctions and adverse overloading of the implant. The reason for the appearance of defects could also be in mismatched shape of prosthetic crown to the antagonistic teeth. As a result, it could lead to the emergence of micro-cracks and loss of integration of the implant with the bone.

It was also noted the presence of adverse corrosive changes on the surface of the substructure and abutment, which could – by penetration of metal ions into the surrounding tissues – to have an effect of perigraft structures irritation. This in turn could induce inflammation or exacerbate the adverse influence of other potential factors responsible for the occurrence of periimplantitis.

Observations with methods of light microscopy confirm that the materials used, despite the many years of being in the female patient's body, were characterized by structures typical for these specific material groups. It was also established that as a result of the periimplantitis course and loss of stability of the implant there has distorted the porous structure of the implant surface.

Characteristic of impedance spectra EIS and the results of assessment of resistance to pitting corrosion provide a basis to conclude that the Ti6Al4V implant has good corrosion resistance in assumed conditions. The basis of this reasoning is the phenomenon of transpassivation that occurred on the implant surface.

Evaluation of resistance to galvanic corrosion for the substructure-abutment system showed that despite the conditions conducive to the formation of a galvanic cell, the examined elements exhibit invulnerability to this type of corrosion. This is due to the low current density value. The environment of tissues and body fluids in the course of inflammation, however, changes its characteristics and becomes more aggressive (higher temperature, lower pH). Corrosion changes on the surface of the substructure and the abutment observed through a stereoscopic microscope can therefore be the result of the implant stay just in the inflammatory environment. However, relevant experience has not been performed in conditions simulating the tissue reaction changed by inflammation, so it is impossible to formulate a clear opinion about the cause of corrosion changes referred to above.

From the information obtained in dental interview it was determined that the female patient was at risk of biological complications due to habitual smoking resulting in increase of the number of anaerobic bacteria in the oral cavity and increase of the bacteria activity that cause inflammation of the periodontal tissues. Therefore, it was concluded that nicotine addiction could be a major causative factor initiating the periimplantitis. However, the attention should also be paid to information on the patient's age (60 years) which may indicate a reduced bone density or osteoporotic lesions of bone tissue.

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