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ORIGINAL PAPER

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Microspectral laser analysis of selected dental implants

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ABSTRACT

Aim. In the paper the microspectral analysis of selected dental implants was presented.
Material and methods. The following implants were analysed: Osteoplant, Keystone Dental, Mozo Grau, Alpha Bio, Sky, and Implant Direct. The probes of each implant were analysed in the laser spectrophotometer.
Results. The result of the study was: Keystone Dental, Mozo Grau, Alpha Bio and Implant Direct titanium implants were shown to include aluminium and vanadium components while the Osteoplant and Sky implants to be made of pure titanium.

Key words: dental implants, microspectral laser analysis, titanium purity.

Introduction

Dental implants made of titanium are used to treat missing teeth in more and more difficult bony conditions. Therefore, it is required to improve their mechanical strength during their manufacture. It is achieved by modifying titanium alloys composition through the application of admixtures or additions.

Because of its properties titanium and its alloys have been used in medicine for many years. This metal was discovered by William Gregor in 1791 and, independently, by Martin Heinrich Klaproth in 1795 [5]. However, it was only in the 1950s that it started to be used commercially. Titanium is obtained from titanium ores: rutile, ilmenite, titanomagnetite, or a mixture of these ores. Main titanium alloy additions are: Al, Sn, Mo, V, Mn, Fe, Cr. Alloy elements, being dissolved in titanium, increase its strength with Fe, Cr and Al producing the greatest hardening effect. The additions affect the temperature of allotropic transformation, too. Some of them, like Cr, Mn, Fe, Al show limited solubility and form intermetalic compounds enabling alloy precipitation hardening. Still, this effect is slight. Depending on their chemical composition titanium alloys may be of a monophase α, monophase β, or diphase $\alpha + \beta$ structure [8]. Monophase α alloys show very good resistance to corrosion and oxidation, good weldability, resistance to brittle cracking, and creep strength, better than presented by the β alloys. Still, the α alloys are characterised by worse strength and deformability than the β alloys. The diphase $\alpha + \beta$ structure alloys combine the advantages of the α and β alloys. The most commonly used alloy addition in the α and β alloys to stabilise and enhance the α phase is Al, which also increases its thermal stability together with decreasing the alloy density. The β-isometric elements (V, Mo, Nb, Ta) cause an increase in the plasticity of the β phase. In general, the $\alpha + \beta$ alloys show good strenght, plasticity and corrosion resistance. With an increase of the β-phase component mechanical properties of the $\alpha + \beta$ alloy improve, reaching its maximum in a structure composed of 50% of the α phase and 50% of the β phase. The most commonly used Ti6A14V alloy belongs to this group. It displays an effective combination of strength, resistance to brittle cracking and fatigue strength [2]. This alloy is applied in the production of numerous elements in aviation and cosmic industry as well as in the production of surgical implants. In the construction of machines and devices there is already a wide spectrum of the application of this alloy, especially in the parts exposed to a dynamic load. Titanium alloys such as Titanium Grade 5ELI, which are used to manufacture surgical implants, are resistant to corrosion, bio-compatible and bio-connective. These features result in the alloys to be practically adopted by the human body what enables the cells to connect to an implant [1, 6]. There are reports in literature showing aluminium and vanadium, the Ti6A14V alloy components, to be toxic. Therefore there are attempts to substitute vanadium with niobium (Ti6A17Nb) [3, 9].

One of the features likely to produce a negative effect on the tissues adjacent to an implant, and the whole body too, is release of trace amounts of metals which are the implants components. Therefore, the authors have undertaken an effort to independently and objectively determine the presence of impurities and additions of metals in dental implants.

Aim

The aim of the paper is to test the presence of metalic impurities found in selected titanium implants, using microspectral laser analysis.

Material and methods

Six different titanium implants were examined: Osteoplant, Keystone Dental, Mozo-Grau, Alpha Bio, Sky, Implant Direct (Figure 1).

A laser microprobe was used in the study. A laser microprobe includes a neodymium laser with a supply system, an optic microscope for work in a reflected light, an impulse excitation source, and a spectrograph. A laser impulse is to evaporate a microscopic volume of the studied sample, which is later excited with an impulse of a spark discharge. Evaporation and excitation is a one-stage process.

Both the observation of the studied sample field and focusing of a laser beam is done with the use of a special microscope objective lens. The lens and mirror assembly allows a marked distance between the focus and the objective lens surface, maintaining a very short focal length. Such a construction of an optical system ensures a big magnification of the microscope (500x) and its protection against possible damage done by the evaporated material from the studied sample. Laser head is equipped in another objective lens of a bigger focal length designed to fix additional electrodes in the laser beam axis, to control a distance between them, and to observe bigger fragments of the studied sample (50x magnification). The microscope optical system is secured against premature triggering of the laser impulse during the observation of sample surface. The profile and dimensions of the crater created on the examined material depend of the laser working conditions, its output and power density as well as on the thermal properties of a sample material [4, 7] (Figure 2).

Figure 1. An Osteoplant implant prepared for the examination

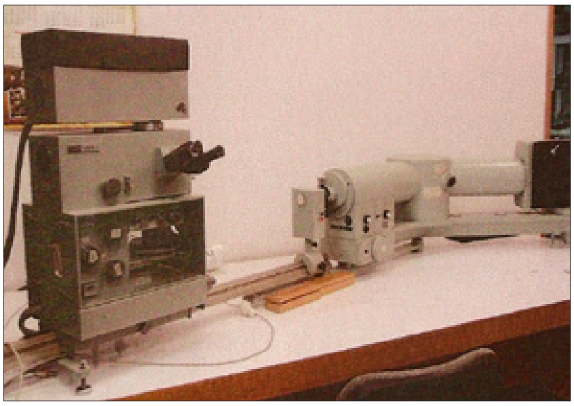

Figure 2. A laser microprobe. On the left – a laser microanalyser head, on the right – a Q-24 spectrograph for spectrum registration

Result and discussion

The results of the microspectral laser analysis of the selected dental implants are presented on figures (Figures 3–6). On some pictures aluminium and vanadium lines are visible indicating the presence of these metals. On some others, there are no metalic traces except for titanium. Figure 4 shows a fragment of the examined Keystone Dental implant spectrum where the lines corresponding with the range of aluminium can be seen (indicated with the blue arrows).

To sum up, laser analysis showed that the titanium implants by Keystone Dental, Mozo Grau, Alpha Bio and Implant Direct include aluminium and vanadium

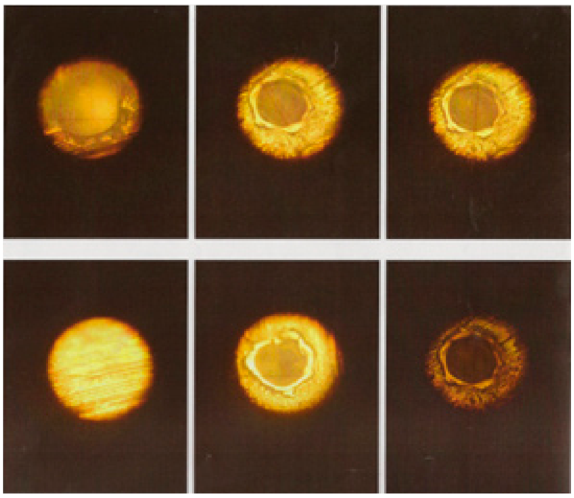

Figure 3. Pictures of the analysed sample surface following the laser impulse. Crater diameters range from 50 to 70 µm

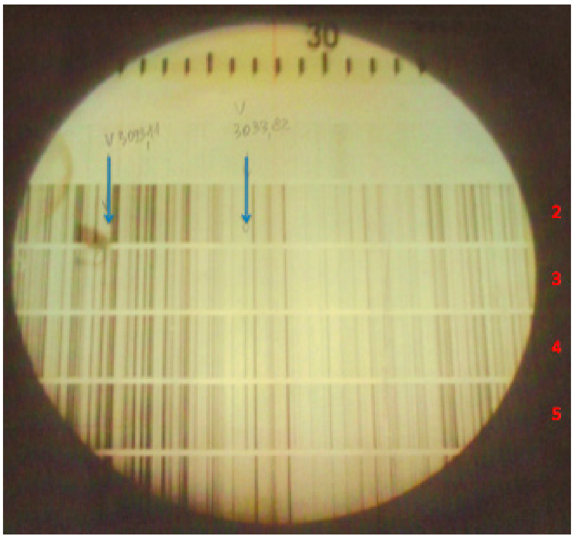

Figure 5. A spectrum of the studied Keystone Dental implant (fragments 3, 4 and 5) showing the lines characteristic of vanadium. Fragment 2 corresponds with the standard

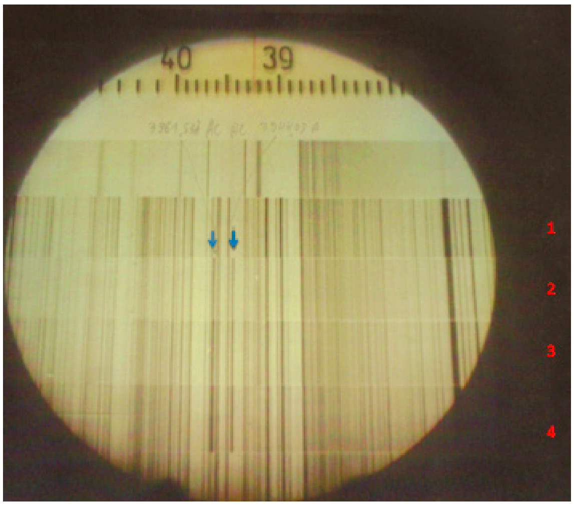

Figure 4. A plate with a fragment of a Keystone Dental implant spectrum (fragment 2, 3, and 4). The blue arrows pointing to the lines indicate the presence of aluminium in the studied material. Fragment 1 shows no line as it corresponds with the titanium standard. Fragments 2, 3 and 4 include aluminium found in various places in the studied implant

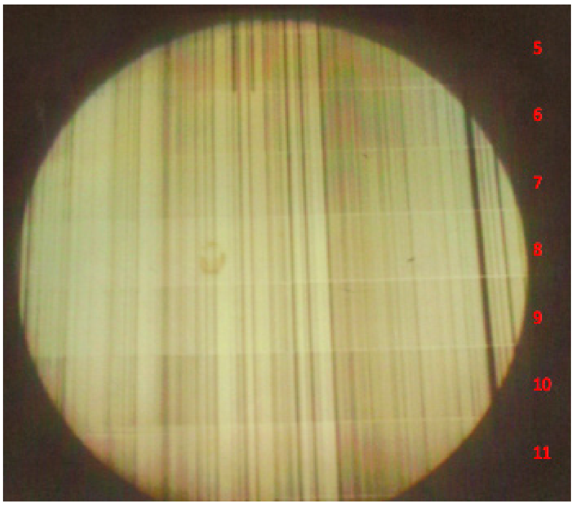

Figure 6. A fragment of a plate presenting the studied Osteoplant implant with no lines indicating the presence of aluminium (fragments 6, 7, 8, 9, 10 and 11). Fragment 5 corresponds with the Keystone Dental implant and a line indicating aluminium is visible on it

additions and therefore they are titanium-aluminium-vanadium alloys while the implants by Osteoplant and Sky do not include additions of other metals are are pure titanium products.

The basic aim of spectral analysis is determination of the qualitative and quantitative composition of the examined materials basing on their emissions spectra. In the qualitative studies the appearance of special lines in the spectrum indicates the presence of a given element in the source of excitation. The qualitative laser spectral microanalysis does not pose many difficulties. Still, it is essential to observe procedure rules to ensure that the obtained spectrum comes from the studied sample and not from the electrode material on which some evaporated material from the previous sample is likely to deposit.

On the other hand, the quantitative study may cause bigger problems. Here, it is essential to maintain identical parameters of a laser impulse when photographing the spectra of the studied sample and the standards. An additional difficulty is a choice of appropriate internal standards which must have homogeneous composition as the laser micoanalysis is of a local character. If it is only possible, the whole analytic process should be done basing on one impulse of a laser because numerous experiments displayed poor correlation between the line intensity and mass of the evaporated sample. The lack of correlation may be also due to composition nature of the sample (its heterogeneity) as well as to explosive character of evaporation during which, apart from volatile elements, liquid and solid elements may be expelled.

Laser microanalysis shows an advantage over other methods of analysis with regard to:

– performing the analysis without possible damage to the structure of the studied object. The crater diameter formed in a studied material by one laser impulse is about 100 μm, the loss in its mass is 10^{-6}–10^{-7} g. It allows to detect the components as small as some parts per million (ppm)
– performing local analysis, i.e. determining the chemical composition of a studied heterogeneous sample in its concrete place. The advantage of this method is that it does not require special preparation of a sample. Laser microanalysis allows specification of the type of inclusions, defects of materials and impurities in various substances.

Metals harmfulness and their influence on the human body cannot be ignored. Studies which consist of laser microspectral analysis ensure precise determination of trace amounts of metals in the studied samples. Such detailed analysis makes a starting point for further research on real release of trace elements from these implants since their presence does not imply their release. Still, confirmation of their presence is indispensable for precise evaluation of a potential risk their release may pose on the environment. Dental implants manufacturers are constantly improving the composition and structure of implants surface. However, they do not reveal the implants structure and composition and the reason they give is to keep it secret from their competitors on the market.

Conclusions

1. Titanium implants by Keystone Dental, Mozo Grau, Alpha Bio and Implant Direct are titanium-aluminium-vanadium alloys.
2. Implants by Osteoplant and Sky are made of pure titanium.

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