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# The Application of the Raman Spectroscopy Method for Evaluating Implants from the Dura Mater

P.E. Timchenko[1], E.V. Timchenko[1], L.T. Volova[2], O.O. Frolov[1], N.K. Kiyko[1], A.Yu. Kulabukhova[1]

[1]Samara National Research University, 34, Moskovskoye shosse, Samara, 443086, Russia
[2]Samara State Medical University, 89, Chapayevskaya street, Samara, 443099, Russia

## Abstract

The results of a comparative spectral evaluation of the component composition of the surfaces of implants from the dura mater manufactured using the Lioplast technology with the use of ultrasound and sterilization are presented. Based on the analysis, coefficients were introduced reflecting the change in the relative concentration of components that determine the quality of the implants. It is established that Raman spectroscopy can be used to assess the change in the composition of implants based on the dura mater during their manufacture.

**Keywords:** Raman spectroscopy, coefficients, spectral features, implants, dura mater.

Corresponding Author:
P.E. Timchenko
laser-optics.timchenko@mail.ru

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## 1. INTRODUCTION

At present, the number of patients with complaints about the increased sensitivity of teeth and roots is increasing. A common cause of this is the recession of the gums, which worsens the appearance of the teeth, gums and smile aesthetics [1, 2]. The prevalence of gingival recession, according to foreign authors, increases with age from 38% in the age group 30-39 years to 90% in the 80-90 age group.

In the clinical practice of a dental surgeon for tissue regeneration using a mucosal-periosteal flap, biological implants of a canned allogeneic dura mater are often used [3].

As a result of experimental studies [4, 5], it was found that the dura mater and the hydrogel layer of the composite mesh, unlike the other materials used, do not lead to the adhesion of the internal organs to the implant, and the mesh with such a coating tightly fuses with the parietal peritoneum, forming durable connective woven frame.

The use of any medical product, especially intended for implantation, is impossible without preclinical evaluation of its biological effect [6].

Due to the prompt and non-invasive type of research, Raman spectroscopy is one of the possible methods for assessing the quality of implants from the dura mater.

Thus, in the article of the authors [7] it was shown that with the help of Raman spectroscopy it is possible to study the process of mineralization of bone tissue. As a result, it was shown that this method can be used to determine the characteristics of the formation, mineralization and maturation of bone tissue.

And in [8], the Raman spectroscopy method is used to study the effect of mechanical stress and the resulting deformation on the bone tissue microstructure. Raman spectra obtained near the deformation zone show an increase in the amide bands of types I and III. These changes indicate a break in the amide bonds. However, in the deformed region, there were no signs of a discontinuity of the transverse bond, which indicates that in this region only the compression of the organic matrix takes place. These results provide a new understanding of the mechanisms and causes of bone marrow failure at the microstructural level.

The paper [9] presents the results of experimental studies of samples of donor bone tissue of rat, rabbit and human with different degree of mineralization, performed with the Raman scattering method. In the course of this work, Raman spectra were obtained for Raman bands 950-962 $cm^{-1}$ $(PO_4)^{3-}$, 1065-1070 cm−1 $(CO_3)^{2-}$ and 1665 $cm^{-1}$ (amide I). In demineralized bone tissue, a sharp (up to 98%) decrease in the intensities of the peaks 950-962 and 1065-1070 $cm^{-1}$ is observed, which is accompanied by the appearance of the band 1079-1090 $cm^{-1}$ corresponding to the hydrated state $(CO_3)^{2-}$.

The aim of this paper is to use the Raman spectroscopy method to evaluate implants.

## 2. MATERIALS AND EXPERIMENTAL INSTALLATION

Twelve samples of dental implants measuring 10 * 10 mm (Fig. 1), manufactured using the "Lioplast" ® technology (TU-9398-001-01963143-2004), were used as the objects of the study.

Samples were divided into four groups: sterile ultrasound treated; not sterile ultrasound treated, sterile without ultrasound treatment and not sterile without ultrasound treatment.

The Raman spectroscopy method was realized using the experimental stand presented in Fig. 2 and included: a Raman spectrum analyzer, which was a high-resolution digital spectrometer Shamrock sr-303i with a built-in cooled camera DV420A-OE

**Figure** 1: Test sample of an implant.

from ANDOR, a Raman probe RPB785 from InPhotonics combined with laser module LuxxMaster Raman Boxx firm PD-LD [10].

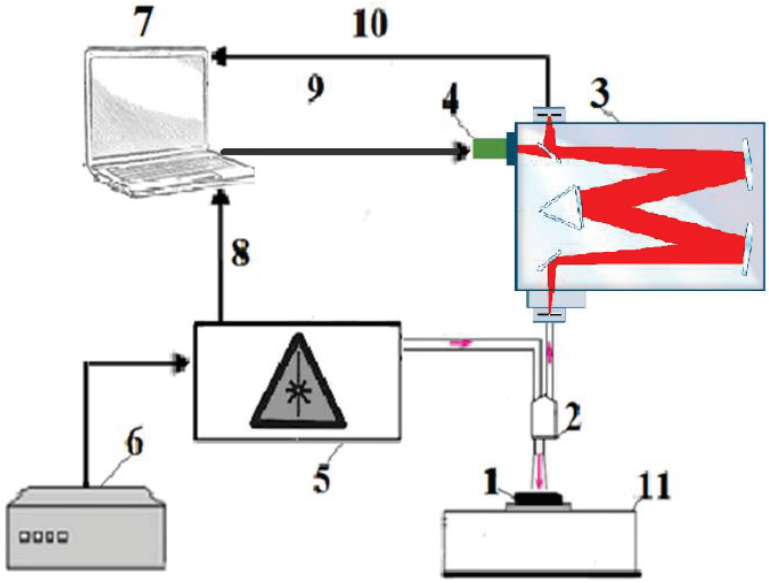


**Figure** 2: Experimental stand for the study of Raman spectral shifts: 1 - the object under study; 2 - Raman probe RPB785; 3 - Shamrock sr-303i spectrometer; 4 - built-in cooled camera DV420A-OE; 5 - laser module LuxxMaster Raman Boxx; 6 - power supply of the laser module; 7 - the computer; 8, 9, 10 - information electrical cables; 11 - coordinate table.

The Raman probe RPB785 in the study performs the functions of focusing the laser radiation at the object, filtering the probing radiation from the light, collecting the radiation scattered by the object and converting it into a parallel beam, suppressing the elastically scattered object and shortwave with respect to the probing radiation.

In the course of the research, a series of test experiments to study the non-invasive effects and optimal plant parameters was first used, the laser power from 50 to 500 mW was used. A change in the height of the probe over the object in the interval 6-8 mm exerted an insignificant influence on the values of the ratio of Raman scattering lines (the error value did not exceed 7%) [11].

## 3. RESULTS OF THE EXPERIMENTS

Figures 3 show the characteristic Raman spectra of implants from the dura mater with different types of treatment.

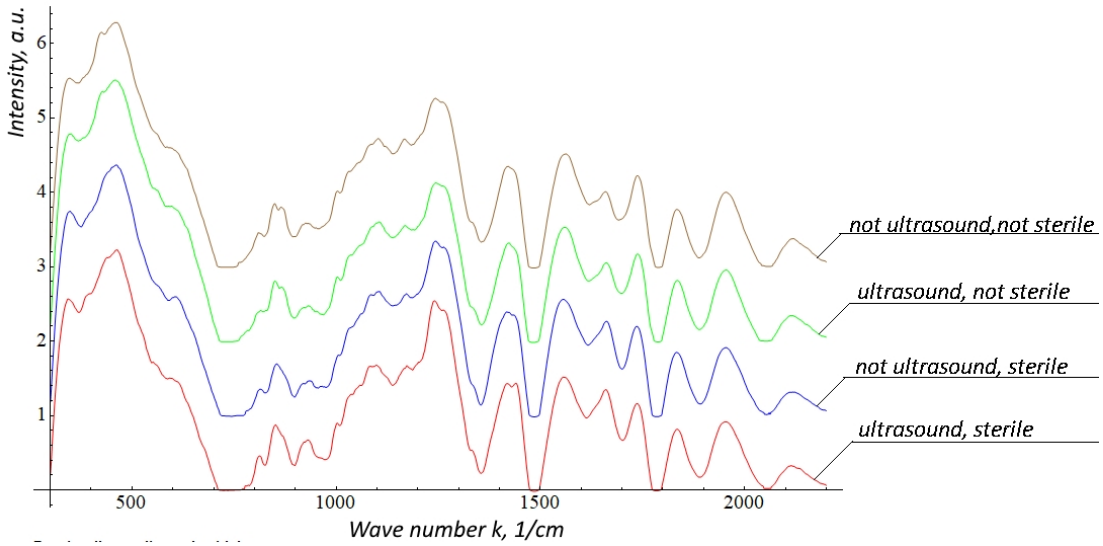


**Figure** 3: Raman spectra of implants with different types of treatment.

The main spectral differences were revealed at wave numbers 835 $cm^{-1}$ (tyrosine), 855 $cm^{-1}$ (proline), 940 and 1167 $cm^{-1}$ (GAGs, CSPGs), 1240 $cm^{-1}$ (amide III), 1560 $cm^{-1}$ (amide II), 1660 $cm^{-1}$ (amide I).

The collagen component, in addition to the CP lines of proline and hydroxyproline, is represented by amide groups III (in the region of 1230-1289 $cm^{-1}$), amide II (in the range of 1555-1565 $cm^{-1}$) and amide I (in the range 1655-1675 $cm^{-1}$), as well as a 1030 $cm^{-1}$ Raman line corresponding to the $CH_2$-$CH_3$ vibrations of phenylalanine.

The degree of processing and quality of implants is determined by the complete removal of cellular components (DNA, RNA) and the preservation of the created extracellular matrix (EM), the main components of which are collagen, glycosaminoglycans, proteoglycans. The quality of the implant directly depends on the content of the components in it.

Of greatest interest in the analysis of Raman spectra are the lines at wave 835 $cm^{-1}$ (Tyrosine), 1240 $cm^{-1}$ (amide III), 1660 $cm^{-1}$ (amide I).

Therefore, to evaluate the implants, the following coefficients were introduced and the two-dimensional dependencies depicted in Figure 4 were constructed:

$$M = \frac{I_{1240}}{I_{1660}} \quad (1)$$

$$L = \frac{I_{835}}{I_{1660}} \quad (2)$$

where Ii is the line intensity at the wave number i;

M is a coefficient characterizing the ratio of amide III to amide I.

L is the coefficient proportional to the change in the relative concentration of tyrosine in implants;

Figure 4 shows the two-dimensional dependence of the coefficients M and L of implants with different types of processing.

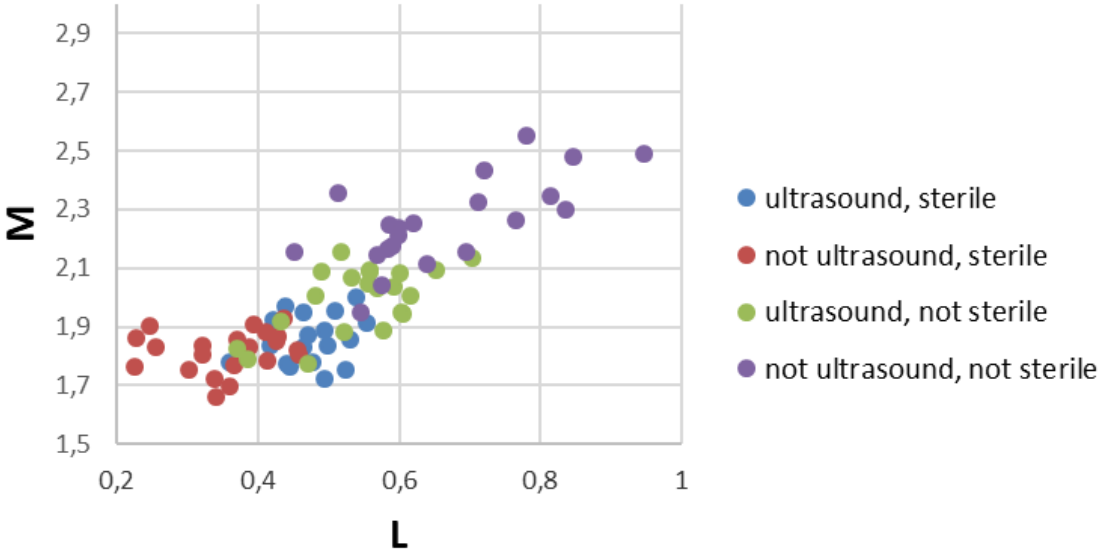


**Figure** 4: Two-dimensional dependence of the coefficients M and L.

It can be seen from Fig. 4 that the values of the parameters M and L have a linear dependence.

It can be seen from the figure that sterile implant samples are characterized by lower values of the coefficients M and L.

Thus, when using spectral analysis of Raman spectra to evaluate implants made on the basis of the dura mater, it is shown that two-dimensional dependencies allow to determine the degree of processing of implants during their processing.

## 4. CONCLUSIONS

Specific features of the Raman spectrum for implant samples with different types of processing are obtained. It was found that the spectral differences between the groups of samples studied were revealed at wave numbers 835 $cm^{-1}$ (tyrosine), 855 $cm^{-1}$ (proline), 940 and 1167 $cm^{-1}$ (GAGs, CSPGs), 1240 $cm^{-1}$ (amide III), 1560 $cm^{-1}$ (amide II), 1660 $cm^{-1}$ (amide I).

A two-dimensional analysis of the introduced optical coefficients M and L has been carried out, which makes it possible to evaluate implants from the dura mater. It was found that sterile samples are characterized by a lower value of the optical coefficients L and M

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