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Model Operation of the Strength Properties of Ventplant Biocompatible Coatings

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A special porous coating is applied on the surface of dental implants to improve it`s biocompatibility. During the maintenance the tensions originate in such coatings, which is added to the residual pressure and significantly reduce the strength of the coatings. It is almost impossible to get the numericalled value of these tensions experimentally, so in this article we solve the problem of mathematical model operation of the tension originating in porous coatings in the process of their forming, and in the course of maintenance.

Keywords: Plasma spraying, The tension in the coatings, A biocompatibility, A model operation, The porosity of the coatings, A dental implant.

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The implants for various purposes are widely used in modern medicine, and so the ventplants are. Using plasma spray technology the special porous composite coating is applied to their surface to improve the biocompatibility (Fig. 1) [1].

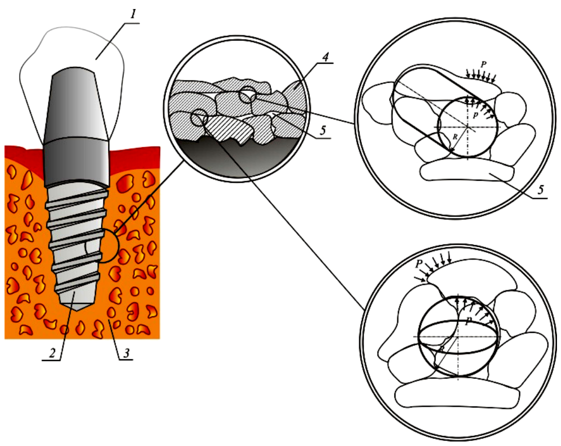

Fig. 1 – Dental implant with a plasma sprayed coating on the intraosseous part and the model introducing of the coating: 1 is the crown; 2 is the intraosseous part of the implant; 3 is the bone cloth; 4 is the sprayed particle; 5 is the macropore

The structure of porous coating comprises a solid framing made of specially selected biocompatible materials and a pore, i.e. a cavity between the powder particles, the coating is shaped of. The coating framing is expedient to shape so that it contains a relatively large pores (macropores) and capillary channels with nanoscale diameter (nanochannels), which are formed in the particles` bulk of the coating (Fig. 1).

The big practical interest is represented with the problem of forming of the porous coating with the predicted structure on the implant surface. The complexity of solving this problem arises from the fact that the increase in the degree of porosity is invariably associated with the reduced strength of the coating. Obviously, the technology of producing porous coatings of implants should provide some optimum ratio between the strength and porosity of the coating.

Formating of plasma sprayed coatings is realized by creating a stream of accelerated and heated to a high temperature particles and placing them on the surface of the substrate. Interacting with the surface of the substrate the particles are deformed and the contact tensions arise in the places of their contact, which, form a so-called residual tensions after cooling the particles [1, 2].

Except for that during functional application of the implant with the coating the tension caused by alternating functional tests (such as chewing or walking) originates in the stuff of the coating.

Thus, the strength of the implant coating will be characterized by the modification of the tension, according to the formula (1).

$$\sigma_n = \sigma_{ost} + \sigma_{dv} \quad (1)$$

where σ_{ost} is the residual tension of the coating; σ_{dv} is the tension caused by percussion motion of the implanted member.

It is obvious, that the direct measurement of the tension in a zone of connection of sprayed particles for an estimation of size of durability of a covering is an unsolvable practically problem. At the same time, the values of these tensions are very important for the prediction of quality exponents of the implant coverings. In this connection in the research the methods of estimating of the tension quantity in the zone of interaction of sprayed particles is offered by a method of statistical model operation.

A method of model operation is as follows. Some geometrical configuration including a number of sprayed particles is evolved from the porous structure of a covering. On the basis of this geometrical configuration an individual abstract porous formation is created in a form of a hollow cylinder or a hollow sphere (Fig. 2).

In the model operation geometrical parameters of abstract geometrical figures set in a way that their vol-

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umes of the hollow formations would correspond to the average volume of a real modelling porous configuration

$$V_p \sim V_c \sim V_s \qquad (2)$$

The coatings of a cylindrical and spherical configuration, with the edges incorporated with each other, are observed as a model [3].

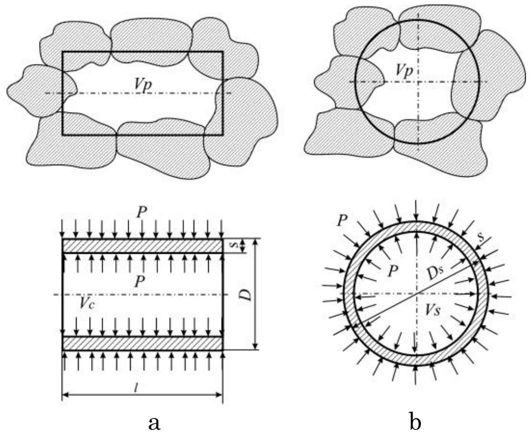

Fig. 2 – The circuit of transformation of a geometrical configuration of particles in an abstract geometrical figure: a is a hollow cylinder, b is a hollow sphere; l is the length of the cylinder; V_p is the pore volume; V_c is the volume of a cylinder, V_s is the volume of a hollow sphere, D is the ring diameter; D_s is the diameter of the spherical coating

The regular force U (meridional) and T (ring), the traversal forces Q, as well as bending moments M_m (meridional) and M_t (ring) originates in the material of the coatings under the acting of external loadings.

The external force p, the stretched force Q are applied to the coatings, as well as the boundary load Q_0 and M_0 which are the result of the response of termination of the coating edge to external or internal forces and moments.

The tension on an external and internal surface of the coating is defined under the following formulas (3) [4].

$$\begin{cases} \sigma_{m_0} = \sigma^{p}_{m_0} + \sigma^{(Q_0-Q)}_{m_0} + \sigma^{M_0}_{m_0} \\ \sigma_{t_0} = \sigma^{p}_{t_0} + \sigma^{(Q_0-Q)}_{t_0} + \sigma^{M_0}_{t_0} \\ \sigma_{\max} = \max\left\{\sigma_{m_0};\sigma_{t_0}\right\} \end{cases} \qquad (3)$$

where σ_{m_0} is the meridional stress; σ_{t_0} is the ring tension; $\sigma^{p}_{m_0}, \sigma^{(Q_0-Q)}_{m_0}, \sigma^{M_0}_{m_0}$ is the meridional tension originating at the edge of the shell under the action of loads of p, $(Q - Q_0)$, M_0; $\sigma^{p}_{t_0}, \sigma^{(Q_0-Q)}_{t_0}, \sigma^{M_0}_{t_0}$ is the horizontal tension originating at the edge of the shell, under the action of loads of p, $(Q - Q_0)$, M_0, respectively.

In the researches presented in the paper [4] the boundary load Q_0 and M_0 is calculated according to the formulas (4).

$$\begin{cases} \Delta^{u}_{p} - \Delta^{u}_{Q_0} + \Delta^{u}_{M_0} = \Delta^{c}_{p} + \Delta^{c}_{(Q_0-Q)} + \Delta^{c}_{M_0} \\ \Theta^{u}_{p} - \Theta^{u}_{Q_0} + \Theta^{u}_{M_0} = -\Theta^{c}_{p} - \Theta^{c}_{(Q_0-Q)} - \Theta^{c}_{M_0} \end{cases} \qquad (4)$$

where $\Delta^{u}_{p} - \Delta^{u}_{Q_0} + \Delta^{u}_{M_0}$, $\Theta^{u}_{p}, \Theta^{u}_{Q_0}, \Theta^{u}_{M_0}$ is respectively, radial and angular deformations of edge of the cylindrical shell under the action of loads of p, Q_0, M_0; $\Delta^{c}_{p}, \Delta^{c}_{(Q_0-Q)}, \Delta^{c}_{M_0}$, $\Theta^{c}_{p}, \Theta^{c}_{(Q_0-Q)}, \Theta^{c}_{M_0}$ is respectively, radial and angular deformations of the spherical shell under the action of loads of p, Q_0, M_0.

Radial and angular deformation is calculated by the formula (5) [4].

$$\begin{cases} \Delta^{u}_{p} = \dfrac{(2-\mu)R^2}{2ES}p; \Delta^{c}_{p} = \dfrac{pa^2}{2ES}(2-\mu-\dfrac{a^2}{b^2}) \\ \Delta^{u}_{Q_0} = \dfrac{2\beta R^2}{SE}Q_0; \Delta^{c}_{Q_0} = \dfrac{2\beta a^2}{SE}Q_0 \\ \Delta^{u}_{M_0} = \dfrac{2\beta^2 R^2}{SE}M_0; \Delta^{c}_{M_0} = \dfrac{2\beta^2 a^2}{SE}M_0 \\ \Theta^{u}_{Q_0} = \dfrac{2\beta^2 R^2}{SE}Q_0; \Theta^{c}_{Q_0} = \dfrac{2\beta_s^2 R^2}{S_s E}Q_0 \\ \Theta^{u}_{M_0} = \dfrac{4\beta^3 R^2}{SE}M_0; \Theta^{c}_{M_0} = \dfrac{4\beta_s^3 R^2}{S_s E}M_0 \\ \beta = \sqrt[4]{3(1-\mu^2)}\sqrt{RS}; \beta_{э} = \sqrt[4]{3(1-\mu^2)}\sqrt{aS_s} \\ R = \dfrac{D}{2}; a = \dfrac{D_s}{2}; b = \dfrac{D_s}{4} \end{cases} \qquad (5)$$

where μ is the Poisson's ratio; D is the diameter of the shell; D_s is the diameter of the spherical coating; S_s, b, a is the width, breadth and radius of the spherical coating.

The tension at the edge of the shells may be calculated by the following formulas (6) [4].

$$\begin{cases} \sigma^{p}_{m_0} = \dfrac{pR}{2S}; \sigma^{p}_{t_0} = \dfrac{pR}{S} \\ \sigma^{M_0}_{m_0} = \dfrac{6M_0}{S^2}; \sigma^{M_0}_{t_0} = \dfrac{2M_0\beta^2 R}{S} \\ \sigma^{Q_0}_{m_0} = 0; \sigma^{Q_0}_{t_0} = \dfrac{2Q_0\beta R}{S} \end{cases} \qquad (6)$$

The quantity of the residual tension is estimated under Hertz formula [4].

$$\sigma = 0{,}418\sqrt{q\frac{E}{\rho}} \qquad (7)$$

where q is the regular load per unit length of contact lines; E is the module of elasticity of the material; ρ is the reduced radius of the skewness of the particles ($\rho = \dfrac{R_1 R_2}{R_1 - R_2}$); R_1, R_2 is the radiuses of interreacted particles.

The presented mathematical model can also be used for calculation of the tension in the porous plasma sprayed coatings of various applications and provides an opportunity to estimate the hardness of porous coatings without the use of experimental methods.

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