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PHYSICAL PROPERTIES OF THIN FILMS ON IMPLANT-MATERIALS

ABSTRACT: In this paper, we present the analysis of thin films in implant materials. Based on preliminary results, it can be concluded that thin polymer films between bone and implant achieve biocompatibility. In addition, analysis will be conducted for other characteristics, such as bioinertia, and biofunctionality.

KEY WORDS: Thin Films, Implant Materials, Bio-compatibility, Physical properties

INTRODUCTION

The development of civilization has followed the development of new implantology ideas and new materials which have been used for that purpose and a large number of discovered archaeological finds can testify to that, as well as an immense number of written documents.

During the 1970’s, with the appearance of Bränemark and his implants, a new era of implantology began. This period is characterized by the appearance of new, as well as the modification of the old designs, and the occurrence of new surgical techniques. The aim of modern implantology is to establish the normal function of mastication, speech, aesthetic appearance, health and comfort, regardless of the type of dental system injury, where the implant will have a central place in all of these rehabilitations. The base of this new philosophy is osteo-integration and a range of prerequisite conditions, so it could be fully realized. Osteo-integration or biointegrity of implants is founded on the hypothesis that, after implantation, a process of remodulation of the bone and osteo-genesis, the implant will integrate into the bone tissue and take over the functional load of prosthetic substitute.
By establishing this term, Bronemark is introducing new principles or factors that can influence attaining this morphological and functional relation between the bone and surface of the dental implant.

Adoption of these principles in everyday work includes implicitly expertise in basic principles of the central injury, inflammation, bone cicatrization, successive addition and remodeling of the bone, as well as physical characteristics of the implant and its surface. Implantation materials regardless of type and nature of the implantation, in the first place should be biologically acceptable.

Closer characteristics that implantation materials should have are:
— That it is compatible with tissues which it is being implanted with
— That it is not toxic to the tissue and human body
— That it does not cause immunological reactions
— That it is not potentially carcinogenic
— That it is resistant to the corrosive influence of the living environment
— That it has acceptable physical and mechanical properties
— That it can be manufactured in to acceptable geometrical shapes
— That it can be sterilized and
— That they must be good thermic and electric insulators

All the above-mentioned conditions are incorporated into the following terms: biocompatible, bioinert, and biofunctional. These properties fill up the ultra thin coating (ultra thin films or nanofilms) as it is expected that ultra thin coatings represent a biophysical system with few free electrons and then the mechanic oscillations of atoms must be smothered.

Biomaterials and biomechanical properties are of fundamental importance for the success or failure of dental implants. Biomaterials are „biological substituents” from which „biological spare parts” can be produced. Biomaterials must not act as an antigen but should successfully induce osteogenesis. Over the past sixty years, research has been carried out on the biomaterials and biomechanical design for surgical implants. The result of this research was the discovery that a wide spectrum of materials can replace living tissues, and among those dental implants take one of the more important places on a scale.

In proportion to biochemical electro-chemical interaction of vital tissue and non-vital material, all biomaterials, according to Osborne (Osborn, 1985) or according to the level of biocompatibility, can be divided to:
— Biotolerant materials (Co, Cr, Mo-alloys, Fe, Cr, Ni-alloys, PMMA)
— Bioinert materials (titan CP, tantalum, bioceramics)
— Bioactive materials (hydroxapatite, Ca-phosphates)

Regarding their origin, biomaterials are divided into antalog, bimolog, hetherolog and alluplastic.

In most cases, dental implants are classified by their division to metal and non-metal. In essence, they are alluplastic materials.

The following come under classification of metals and alloys: titanium CP (Ti), titanium-aluminum-vanadium (Ti-6Al-4V), cobalt-chromium-molybdenum (Co-Cr-Mo), tantalum (Ta), ferrous-chromium-nickel (Fe-Cr-Ni) 316L, and non-metals are classified as: ceramics, hydroxapatite (Ha), carbon, polymers (PMMA).
METALS FOR IMPLANTS — TITANIUM

For its electro-chemical properties, titanium is considered as the most compatible metal, and is often used in modern stomatology, implantology and prosthetics (Fraker, 1988; Lenz, 1998).

Martinović and his associates have researched the corrosion resistance of titanium alloys, used for orthopedic implants, in body liquids. Spectrum-electro-chemical research on titanium alloys in vitro has confirmed the creation of protective oxidation film on the alloy surface. Comparing the stability of titanium in different corrosive baths with results on other alloys, the authors conclude that titan is the most stable. Although titanium is corrosive stable, combined with various metals it can create strong galvanic segments, therefore it is necessary to be cautious while combining titan with other alloys. Some authors consider that precious metals (Au, Ag, Pd) combined with titanium make very small galvanic currents. Combined with the Ni-Cr-Be alloys those currents are more considerable so such combination should be avoided. There has also been research on the influence of amino acids on the corrosiveness of titanium alloys and it is concluded that the existence of tryptophan in the alloy does not affect the corrosive stability of titanium, unlike cysteine, which increases it.

Titanium is a non-precious, extremely reactive material. For that reason, after the titanium is processed, oxide (TiO₂) is formed on its surface (Stamenović, 2003). The thickness of the oxide layer is 15—50 μm. This oxide is resistant to corrosion and is bioinert. Biocompatibility is affected by the high dielectric constant of titanium oxide too. Consequently, biocompatibility derives from titan oxide, and not from the pure metal. Mechanical properties of titanium satisfy all criteria which metal should possess to be used in implantology. It has extremely high tightening strength, which enables it to endure great loads. In addition, it has the property of being forged that makes it resistant to impact. Under a strong force, it plastically deforms but it does not break. On the titanium surface, bone formation is implantopetal. That means the bone is being formed from the bony-bed of implant towards the implant. Firstly the connective tissue callus is formed, then osteoid tissue and on the end lamellar bone. Electronic-electro microscopic researches show that there is a zone (20—40 μm) in which there is noncalcified coat of base substance and collagen filaments belonging to the zone. It means that there is no direct contact between the implant and alveolar bone.

Coating titanium with plasma has the aim of increasing the titan and alveolar bone contact surface. It is obtained by putting particles of melted metal by means of a plasma spout. The thickness of the plasma coat is 30—40 μm. On the surface of implant, there are pores that are interlinked. By the process of spouting plasma, the implant surface is increased by 5 to 10 times. That way the contact surface of the implant and bone tissue is increased too. Presence of pores also stimulates formation of bone tissue and has positive effect on implant integration.

The most recent research show that parts of metal in plasma tissue could be discovered in pre-implant bone tissue. The appearance of such particles is followed by signs of metalosis. To overcome this problem it is necessary to
make an additional enlargement of the implant surface. That can be achieved by sanding, acid erosion, special laser techniques and, in the more recent times, by enlargement of titanium-oxide coat.

NONMETALS FOR IMPLANTS — CERAMIC MATERIALS

A number of ceramic materials are used in implantology and nowadays mostly calcium-phosphate materials in form of hydroxapatite (H, A) and tricalcium phosphate (T, C, P). These materials stimulate the direct apposition of bone tissue on its surface. This means that the process of bone formation is a combination of implantopetal and implantofugal methods of bone forming.

Electronic-microscopic researches show that in the area of these materials there is a direct connection with bone tissue. There is no layer of connecting tissue like in case of pure titan. Titan implants, which have their surface coated with calcium phosphate ceramics, should combine mechanical characteristics of metal and osteo filling abilities of ceramics. Research results show that implants with calcium phosphate show much greater apposition of bone. In clinical practice calciumphosphate ceramic (CFK) materials are used, and coating techniques differ too.

For applying CFK to a metal surface a plasma „spray” technique is mostly used. Synthetic hydroxapatite is warmed up to 1200—1500°C. The way this is done is with an electric arch in a presence of argon gas. This technique is similar to that used for coating plasma over titan. HA particles of 40 μm are coated over the previously prepared metal surface. The metal surface is uneven and porous, as it has been previously treated by sanding and acid erosion. HA particles penetrate into the pores and uneven the surface of metal; after cooling the mechanical relation of HA and metal surface is established. Although the perfected technique of coating metal with CFK, research has shown, the possibility that partial absorption of material can occur because reabsorbed particles have been discovered in pre-implant tissue.

ULTRA THIN COATINGS

At this stage we shall propose the nanocoating model and analyze their thermic and electric properties. The nanocoat model is shown in Fig. 1.
The nano coat should prevent the direct contact between implant and bone for the above mentioned requests, particularly in the sphere of chemical — physical properties. It is known that (Tošić, 1987) structures with markedly diminished dimension can have considerably changed properties regarding the relation to spatially limited structures (balk). That way we can see that electronic nanofilms have a considerably better thermical and electrical insulation properties comparing to corresponding balk structures.

Theoretical analysis of an electronic system in very (extremely) limited and structures with disturbed translational symmetry has found the spectrum of electrons and inner energy (Šetrajčić, 1990; Šetrajčić, 2007). Thermodynamic analysis is specified by the electronic portion (share) in the specific heat of ultra thin film coatings. That is shown in Fig. 2. As we can see, the thinner the coating, the more expressive the insulating properties of the coating are, or specific heat is lower.

Analog analysis has shown the phonon portion in specific heat as in Fig. 3, where we can see that the insulating properties are even more pronounced than in the electronic share.

Complete and complex analysis of the transportation properties of nano-coatings from a physics point of view can be acquired only if the system of electrons and phonons, in extremely limited spatial and structures with disturbed translational symmetry are considered.

This means that the electronic and phonon influences (Tošić, 2006) on the insulating properties must be added up. Dependence of electro-phonon share in specific heat is shown in Fig 4.

Ultra thin coatings have all of the good insulating properties and can satisfy all of the required thermical and electric coating properties needed in implantology.
CONCLUSIONS

Here we have analyzed biomaterials and their biomechanical properties in dental implantology with special retrospection to coatings — thin films that must be ultra thin, or nanofilms. Considering their good insulating properties, it is necessary to change drastically the technology of their coating. Only in that way the characteristics of material used in implantology can be satisfactory.

REFERENCES


ФИЗИЧКЕ ОСОБИНЕ ТАНКИХ ФИЛМОВА НА ИМПЛАНТ-МАТЕРИЈАЛИМА

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Резиме

У овом раду смо презентовали анализу танких филмова на имплантним материјалима. На основу пределинарних резултата, може се закључити да танки полимерни филмови између кости и импланта задовољавају био-компатибилност. Ове анализе су корисне и за друге карактеристике, као што су био-инерција и био-функционалност.

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