The use of materials for dental applications

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THE USE OF MATERIALS FOR DENTAL APPLICATIONS

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Abstract

Nowadays in our society modern science uses a wide range of materials to perform multiple functions. One of the fields in which biological, synthetic and hybrid materials have found various applications is related to the medical one. The variety of materials used in medicine adapts to specific requirements and applications, due to the wide range of physical, chemical and biological properties that these materials can guarantee. The present review paper offers a short review, based on the data available in the scientific literature, on the possibility of using materials for dental application.

Key words: material science, biomaterials, properties, dental application

1. Introduction

Materials are essential and they are in a particular position in our life. Materials become more and more important with the speedy evolution of our modern society and the need of a continuous development is essential. In particular, the tendency to create new materials, starting from traditional ones and modifying or transforming them with different procedures, or creating innovative materials using different scientific approach to do this are continuously increasing.

Medical implants are very important. Materials and the techniques involved to obtain these implants have acquired an intensive growth. Medical implants are devices or tissues positioned inside or on the surface of the body without affecting the quality of the life and with no any adverse consequences. Their function is mostly related to substitute missing body parts and/or to provide support to the organs and to the tissues.

Peoples with different health problems create a high request for useful treatments, where biomaterials become more and more important.

The present review paper presents shortly some important aspects related to materials used in medical application, based on the current scientific literature. It will include natural and synthetic materials used in key area of dentistry or orthopedic field. The authors would like to point out, that the paper does not exhaustively report any development and result about the performed actions in such direction, but it shows some significant features, which, according to their knowledge, are appropriate to such a widespread area.

Generally, the materials for such purpose have been chosen due to their physical, chemical, mechanical properties, excellent biocompatibility and their specific behavior to maintain these features over the time, since during their function they are in contact with many internal environmental factors and thus can expose the body to multiple complications, if inaccurately exploited. Different kind of materials can be used for medical purpose, starting from stainless steel till to the most innovative metallic alloys, ceramic, composite and polymeric materials. For all of them there are some advantages and disadvantages.

According to some studies, a minimal bone damage is a universal phenomenon that occurs in the patients suffering metallic implant failure [1]. The above mentioned problem is prevalently caused by the stress shielding effect, meaning that the load transmitted from the inserted implant to alveolar bone is unsatisfactory caused by the important difference of the elastic modulus among Ti alloys (about 130 GPa) and the adjacent bone tissues (about 30-35 GPa) [2]. However, in this wide-ranging background, there is a growing inclination to explore and to obtain new material compositions and to employ them in medicine. To reduce the above mentioned difficulties, regarding the stress shielding effect, β-type Ti alloys development is proposed in [3]. The results acquired reveal an excellent opportunity to use such alloys for medical purpose, focalizing the application on bone replacement or even if in dentistry.

As innovation concerns, Zr, Zr-Nb, Zr-Ta and Zr-Mo based materials are interesting solutions, too. Zr goes to the similar group as Ti and reveals comparable behaviours [3]. The possibility to use Ta in TiNi shape memory alloy increase the biocompatibility of the bio-alloy. Anyway, also with these materials the problem coming from the stress shielding effect is present. Nowadays, other solution represents Mg and its biodegradable alloys that can be proposed as excellent materials for the elaboration of short-term implants providing temporary support.

Regarding dental implant, the durable employment of such elements is moreover linked to the condition of alveolar bone. According to [4], the density of mandible bone differs with a range of less than ±10 % of the regular value, in particular in case of people who suffer of osteoporosis. Toughness of the dental implant can be balanced for example using porous materials (spongy Ti) or using composite material, like polyether-ether-ketone (PEEK) reinforced with some fibers. In the commercial dental implants in the patients of different age and physical condition, problem of fixed stiffness arises due to different alveolar bone conditions in the patients. In [5], metal-polymer structure made up of two biocompatible materials that are titanium and PEEK, have been proposed to solve this problem of fixed stiffness. The stiffness of titanium and softness of PEEK have been used purposely in three configurations to achieve the desired implant fitting in various conditions as shown in Fig.1.

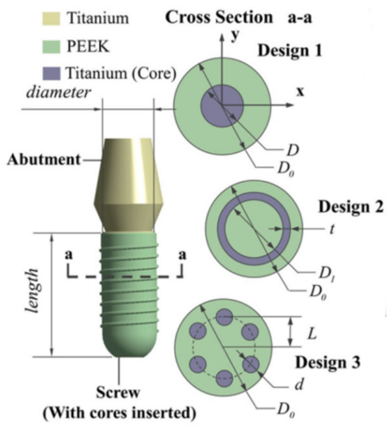

Fig. 1: Schemes of implants in composite material with Ti as central part [5]

During the high evolution of materials and technologies, the beneficial impact of nanotechnologies applied to polymeric structures used in dental restorations was observed. Thus, new materials have emerged, such as phosphine oxide and methacrylate diluents [6], nanowires and nanomaterials [7-9] crosslinking agents and calcium and phosphorus ion release agents by imitating the process of natural mineralization of dentin [10, 11] have led to the production of dental composites with improved properties. A significant beneficial impact of nanotechnologies is also highlighted for the control of the microbiota and the prevention of dental plaque formation and the occurrence of inflammatory and infectious processes, by improving the mineralization process of used enamel or dentinal hypersensitivity. To this end, the therapeutic advantages of nano-hydroxyapatite and other compounds with a protective role, which have calcium ions in their structure [12, 13] are highlighted. Nanomaterials also have an impact on endodontic therapeutic processes by delivering bioactive, antibacterial and anti-inflammatory molecules. Recent studies have demonstrated the efficacy of bone morphogenetic proteins for tooth pulp regeneration and dentin formation [14]. Using 3D printing technology, prevascularized pulp-type hydrogels have been used in root canals [15]. Research in the field of reconstructive dental therapies has known both the stem cell approach and the formation of a viable tooth germ that would later be transplanted into the alveolar bone and later develop into a functional tooth [16–19]. Another approach, based on tooth-shaped polymeric biodegradable skeletons, which are filled with polymeric additives and implanted in the alveolar bone is reported in [20]. Nanotechnologies have been applied to modify and improve conventional glass ionomers and composite materials, because nanoparticles (e.g. quartz, colloidal Si, Zr, ZnO, etc.), due to their small size (between 1 and 100 nm) have the ability to delay and translocate inside the tooth contributing to its regeneration and consolidation.

2. Evolution of value-added product in dentistry - combined use of different materials

Caries is considered one of the recognized oral diseases. Composite resins (CRs) are commonly employed as dental curative constituents for the treatment of caries. The depositions of the plaque on their teeth are encouraged by the adsorption of protein on its surface and for this reason one of the practicable way is to suppress this adsorption: CRs can be important for impeding the creation of plaque and after that the development of secondary caries. In [21], there is a presentation of the possibility to provide a modification of the surface through a chemical reaction using specific polymers in the course of the curative process, contributing to avoiding further development of caries. In [22], the authors studied how some polymer materials when dispersed in water have an important effect on some mechanical properties of the teeth structure. Vat-polymerization additive manufacturing (AM) methods for the development of dental parts, containing different resins based on acrylic esters as main component have gained popularity in present times. In [23], the authors described a valid procedure for the production of occlusal device by joining two diverse photosensitive resins with a vat-polymerization 3-dimensional printer, consenting the development of a particular device which contain on the external part a durable resin as shown in Fig. 2.

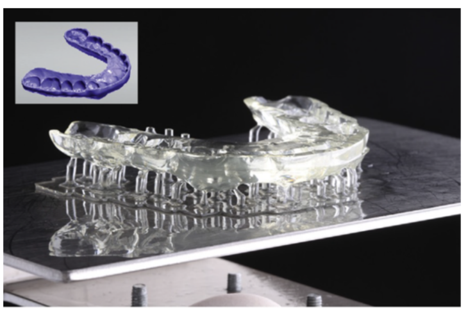

Fig. 2: Occlusal device from layer 1 to 116 obtained by additive manufacturing technique using hard resin, Virtual view (inset) [23].

The mechanical performance of polymer-infiltrated Si_3N_4 composites (PISNCs) with the aim to employ such materials for dental restoration have considered and investigated in [24]. PISNC reveal outstanding flexural strength combine with reasonable hardness and modulus of elasticity, which can be attributed to its unusual configurations including a porous structure, made by elongated ceramic particles and highly interconnected continuous organic-inorganic microstructure. Additionally, PISNCs demonstrated brilliant biocompatibility. The effect of the photo-initiator on the polymerization mechanism of methacrylamide-based monomers, used as substitutes instead of methacrylates in dental adhesives is presented in [25, 26]. In this study, some simple molecules have been combined with functional monomers containing the same polymerizing elements as the monofunctional counterparts to develop more complex molecules for adhesive monomers. The study concluded that the methacrylamide-based monomers would have the same polymerization kinetics behavior as the methacrylate-based monomers, and the polymerization kinetics would not be influenced by the type of initiator used.

The aqueous solubility of lipophilic drugs can be achieved, according to the study reported in [27], by employing an oligosaccharide able to generate a drug distribution system, offering constant release of the developed molecules, amplifying the mineralization of the stem cells from human-extracted deciduous teeth. This cytocompatible system has high potential in vital dental pulp rehabilitation. According to [28], the effect of the sensitive polymeric units, as reinforcement materials, on the mechanical properties of photo-curable dental resin is important. Crosslinked polymeric nanoparticles can be produced by emulsion polymerization of mono- (methyl methacrylate) and trifunctional (trimethylol propane trimethacrylate) units, where the nanoparticles are distributed in polymeric based dental resin matrix in order to develop photo-curable nanocomposites. The cross-linked nanoparticles considerably affect the mechanical properties of the reinforced dental resin nanocomposites and have a positive influence on the mechanical behavior of their nanocomposites.

Bioactive adhesive structures could determine a superior prediction of restorative actions. In [29], the authors proposed therapeutic polymer approaches for dental adhesives. High attention has been attributed to the use of antibacterial resin structures constructed on quaternary ammonium compounds. Human dental destruction initiated by materials with acid pH can be considered as the most important cause for tooth decline. In [30], the authors investigated the properties in terms of configuration and chemical composition of polymer films made on in vitro dental enamel.

Coating containing hydroxyapatite determine a good passivation leading to lower erosive effects that usually can be observed when citric acid solutions came into a contact with a dental glaze surfaces. Promotion of healing of surrounding tissues is proposed by the authors [31, 32], through fibroblast growth factor loaded with different polymeric particles into a bioactive dental adhesive resin. The material employed is helpful to stimulate tissue renewal and its use would be helpful for root-end filling or the restoration of parts. In [33], the authors shows the effect of addition of hydroxylapatite in the therapeutic mixture which determine significant natural polymerization of self-etch adhesives. For dental restorative purpose there is possible to prepare new samples of polymer-infiltrated-ceramic composites, through infiltration of polymers into partially sintered sodium aluminum silicate ceramic blocks followed by curing techniques, obtaining higher mechanical properties [34]. In [35], the authors report a study on the consequence of surface graft polymerization of hydroxyapatite on the physical and mechanical behavior of dental composite resin, highlighting the possibility of the development of encouraging modification processes for the creation of successful dental materials.

The mixture of different class of materials consents an important step in the expansion and development of a high variety of biomaterials and their uses for dental purpose.

5. Conclusions

Research has led to important advances in the application of materials and nanotechnologies for medical purpose. During the time, the researchers have considered different approaches and different kind of materials investigating various sustainable and effective solutions in order to attain fully functional materials to be employed for medical applications with minimally invasive diagnosis and personalized treatments, which further have the capability to improve public health and be free of side effects. The aim of the present review paper was to present and to provide some information, based on a wide range of scientific literature data, on the evolution of materials in such applications. A continuous progress was observed and it comes out that in such scenario medical engineering and nanotechnology have key role to find innovative materials with enhanced properties. Analyzing the literature data it comes out that polymers show improved performance and biocompatibility, able to reduce the risks, and to increase the spectrum of real applications where these materials can be successfully used. Also, the involvement of nanotechnology, through the unique properties of interference and durable repair of nanoparticles, low toxicity and long life cycle of these particles, offers useful and effective alternatives for diagnosis and treatment in medicine.

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