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EDITORIAL

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Materials and manufacturing techniques trends in prosthetic dentistry.

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Introduction

Nowadays, the new and accessible technologies have made possible the development of new materials and methods for obtaining medical devices that are currently being used in the clinical practice of dental restorations.

In the past decade, prosthetic dentistry, along with the rehabilitation of edentulous patients, has been seriously impacted by the progress made in computer-driven technologies. According to literature reports [1,2], the fabrication of prosthetics devices using computer-aided design and manufacturing (CAD/CAM) or additive manufacturing (AM) technologies has proven to be feasible and reliable. Most materials used (metallic - Ti, Co-Cr, and Ti alloys; ceramics - ZrO_2; fiber-reinforced composite) in prosthetics dentistry devices manufacturing are also suitable to be obtained with the new technologies.

The help of the new technologies used in dental restorations that can support a more accurate fabrication of complex anatomical shapes, along with the new types of materials available, indicates that special attention must be given in accordance with the patient's needs and/or restrictions. For this purpose, many researchers are considering different ways of testing these new medical devices and the materials from which they are made to more accurately identify their usefulness. Moreover, new methods of increasing the biofunctionality through surface treatments of dental devices are being studied.

Corrosion behavior at various pH of Co-Cr alloys

Cobalt-chromium (Co-Cr) alloys are one of the most frequently encountered biomaterials in dentistry, being a good alternative to other dental alloys, and are used to obtain fixed dental prosthetic restorations. In terms of biocompatibility and feasibility of the dental prosthetic restorations fabricated from metallic dental alloys, it can be stated that the corrosion resistance of these biomaterials in the oral cavity, which is known to be a harsh environment that is characterized by pH and temperature variation, but also by the bacterial load [3,4], is of significant importance and should be addressed accordingly.

Thus, F. Bechir et al. [5] analyzed the corrosion behavior in Carter Brugirard artificial saliva with different pH values, of 3, 5.7, and 7.6, respectively, at human body temperature (37 ±1 °C) of two Co-Cr dental alloys commercially available, in order to establish the influence of gastroesophageal reflux disease (GERD) on the investigated alloys. The investigated samples of Co-Cr dental alloy were manufactured by casting and milling (CAM). GERD pathology is characterized by the pH variation of the oral fluid toward more acidic values, which can dramatically influence the characteristics, properties, and behavior of dental materials, including that of metallic dental alloys [5]. The corrosion tests highlighted that both Co-Cr dental alloys, which were cast and milled, have a better corrosion behavior at higher pH values of artificial saliva. Additionally, the authors have also observed that the milled Co-Cr alloy presented the lowest corrosion rates in acidic medium, suggesting that Co-Cr alloy manufactured by CAM technique could be a proper option for the prosthetic treatment of patients suffering from GERD. The chemical composition analysis of the surfaces of the alloy immersed in artificial saliva after the corrosion tests revealed that the increment of the pH value of saliva leads to a higher quantity of oxygen, suggesting that the pH value influences the formation of oxides on the surface of the material and that by increasing the pH also the thicknesses of oxides increase, thus functioning as a kinetic barrier on metal ions.

In conclusion, F. Bechir et al. [5] showed that in an acidic oral environment, the Co-Cr dental alloys fabricated by milled technology showed the lowest corrosion rate, indicating this type of alloy, coupled with CAM technology, may be a suitable option for the prosthetic treatment of patients suffering from GERD.

Mechanical properties of zirconia-based ceramics

The fabrication of fixed dental prostheses using esthetic materials has become a routine in today's dentistry and the CAD-CAM technology is extensively used for full zirconia fixed prosthetic restoration manufacturing. The main reasons for using new types of zirconia-based materials are driven by aspects such as enhancing the appearance of restorations without altering the biomaterial strength and withstanding mechanical stress, while preserving the internal and marginal fit, the chemical stability, and biocompatibility in the oral medium which is known for its complexity [6,7].

Manufacturers have succeeded in enhancing the optical characteristics by introducing multilayer zirconia discs (for CAD-CAM manufacturing) with higher translucency, which, to a certain extent, has led to a reduction of the flexural strength [8], offering at the same time an acceptable fracture load compared to the maximum occlusal bite force [7]. Compared to other bioceramic materials such as conventional zirconia and lithium disilicate, the multilayered zirconia exhibits esthetic and mechanical properties in between, being recommended for individual anterior teeth restorations and full-mouth prosthetic rehabilitation [9,10].

To study the bending fracture of three-unit full zirconia fixed prosthetic restorations obtained by CAD-CAM technology, P. Fischer et al. [11] performed bending tests on different types of zirconia bioceramic (KatanaTM Zirconia HTML and KatanaTM Zirconia STML/Kuraray Noritake Dental Inc.; NOVAZir® Fusion float® ml/NOVADENT/Dentaltechnik; and 3D PRO Zirconia/Bloomden Bioceramics). The three-unit full zirconia fixed prosthetics obtained were codified by K-H, N, B, and K-S respectively. To establish if there are any correlations between the material structure and bending resistance, the authors have also investigated the morphology, grain size area distribution, and elemental composition of the zirconia-based materials in three different areas, namely the upper, middle, and lower areas. Following the mentioned investigations the study revealed the presence of defects, microcracks, and pores, as well as the fact that the grain size area and its distribution vary with respect to the manufacturer. The authors have shown that even though in terms of grain size distribution, all investigated zirconia-based materials followed the same trend when passing from the upper to the lower area, with no notable differences, in terms of defects, the B zirconia samples stand out as having only minor defects, irrespective of the examined area, compared to the other investigated materials, whose specimens presented noticeable defects.

After the mechanical tests were performed, P. Fischer et al. [11] emphasized that the bending strength of all three-unit dental prostheses tested is in correlation with the size, shape, and distribution of particles along with the presence of material defects. Nevertheless, the bending tests indicated that the highest forces at the failure values were registered for the B zirconia samples, followed by K-H and N samples, while the lowest values were obtained for the K-S specimens. The study proved that the bending test is in correlation with the particle size and distribution, but also with the presence of certain defects in the zirconia-based material. Nevertheless, all investigated materials have exhibited higher fracture toughness values than the ones clinically accepted.

Fiber reinforced composite dental materials

Among the materials used in prosthetic oral rehabilitation are the fiber-reinforced composites (FRCs). This new class of dental reinforced composites was developed with the aim to design materials with enhanced mechanical strength, longer usage, and to acquire other important characteristics, such as specific weight and low cost. Even though they are still the most used materials in medicine due to their exceptional characteristics, metallic materials also present disadvantages such as allergic hypersensitivity, improper weight and/or density, long processing time and perhaps one of the most important factor, the possibility to release metallic ions due to metal corrosion in the oral cavity, an aspect that can alter the normal function of the prosthetic restoration. Dental reinforced composites can be thought of as a suitable substitute of the metallic one, especially since certain diseases can cause fluctuation of the pH of saliva (GERD) between values that can negatively impact the corrosion behavior of the latter one.

Taking these things into account, F. Bechir et al. [12] evaluated the behavior of two high-performance CAD/CAM milled FRC dental materials, namely Trinia and TriLor, in simulated saliva at pH values specific for patients affected by GERD, through immersion tests, in order to determine if there are any changes in terms of weight or surface morphology. The pH values of the Carter Brugirard synthetic saliva used for testing the materials were 5.7, 7.6, and a varied pH (two days immersion in pH 5.7 and one day in pH 3). The tests were performed for 21 days at a temperature of 37 ±1 °C, and at 3, 7, 14, and 21 days, the weight loss/ gain of the samples was assessed. The surface morphology of the samples at 3 and 21 days after immersion was evaluated with a scanning electron microscope.

According to the results obtained, it can be said that irrespective of the pH level, the two CAD/CAM milled FRC materials present a similar evolution of the weight after 21 days, highlighting proper stability when in contact with the synthetic saliva, as following. During the first 7 days of immersion, the weight of the samples decreases, while from day 14th the weight begins to increase, reaching a maximum after 21 days. Moreover, the surface morphology investigations have indicated that FRC biomaterials do not present notable differences and that the immersion tests did not alter the surface morphology regardless of the immersion time and/ or pH value of the medium.

The authors, who also refer to the limits of their study [12], concluded that FRC biomaterials can be seen as a suitable alternative to the metallic ones used for prosthetic frameworks, and represent a feasible alternative for the oral rehabilitation of patients suffering from GERD.

Techniques used to increase apatite formation

The need to enhance the behavior and performance of implantable biomaterials during their interaction and staying in the human body without affecting their properties, biocompatibility, and biomechanical characteristic has given rise to smart tunable surfaces [13]. Biological fixation is considered a pre-request for long-term success of any implant. The quality, efficiency, and healing period associated with the osseointegration process are intercorrelated with the surface properties of the implant, among which the surface chemical composition and roughness are key players in implant-tissue interaction and behavior [14].

Researchers around the world have focused on developing various surface engineering tools to obtain tunable surface properties of the implants. Of the methods used for this purpose, the following can be found machining/ micromachining, airborne-particle abrasion, acid etching, electropolishing, anodic oxidation, electrochemical deposition, pulsed laser deposition, chemical and physical vapor deposition, and plasma spraying [15–17].

To increase the apatite formation ability of titanium (cp-Ti), well-known for its superior biocompatibility and excellent corrosion resistance, C. M. Cotrut et al. [18] evaluated the influence of different surface morphologies obtained by mechanical (grinding and polishing prepared (M) and airborne-particle abrasion also known as sandblasting (S)) and chemical (anodic oxidation (A)) surface modification techniques, on the biomineralization capacity and corrosion behavior. The obtained surface morphologies were as follows: (i) the grinded and polished materials present a smooth surface with some minor scratches; (ii) the surfaces prepared by airborne-particle abrasion reveal an irregular morphology with signs of plastic deformations; (iii) the surface that suffers the anodic oxidation treatment reveal a morphology consisting in aligned TiO_2 nanotubes (NT), vertically oriented, hollow, that can also be described as parallel tubular structures, uniformly distributed on the surface. The surface roughness investigation on the obtained morphologies showed that the sandblasted surfaces registered the highest roughness (approx. 3 μm) followed by the anodized one (180 nm) and the metallographically (80 nm) prepared ones. On the other hand, the contact angle revealed a hydrophilic character of M and A samples and a hydrophobic character of S samples.

The apatite formation ability (biomineralization) of the obtained surfaces was investigated through immersion in synthetic body fluid (SBF) at 37 ±1 °C for 14 days. The weight gain of the samples was monitored at 1, 3, 7, and 14 days along with the surface morphology and Ca/P ratio of the apatite deposited on the developed surfaces.

The study has shown that all three surface modification techniques can improve the bioactive character of cp-Ti through simple and cost-effective methods that can be successfully implemented to obtain medical devices with enhanced features. As a general remark of the study, it can be said that a contact angle lower than 90°, which indicates a hydrophilic surface coupled with a roughness in the nanometric scale (under 200 nm) favors the nucleation and growth of a newly apatite layer, thus indicating an enhanced bioactive character and higher osseointegration. Thus, the highest weight gain of apatite was found for the surfaces modified with TiO_2-NT. All the aforementioned were observed for the anodized surfaces, with poorer results being noted for the group which was exposed to airborne particle abrasion [18].

The authors conclude that the presented modification techniques are very friendly and they can be used, adjusted, adopted or coupled with respect to the implantable device design, which can either present a more or less complex geometry in order to obtain biomaterials with advanced and tunable surface properties that can be easily implemented in the medical device market.

Conclusions

This editorial has barely managed to bring into question a small part of the numerous current directions of interest in dental prosthetics regarding the usage of new materials and manufacturing processes. However, it can be said with certainty that the new materials developed along with the advances in the obtaining and processing techniques of dental prosthetic devices are the subject of many ongoing research studies which aim to identify their precise role as accurately as possible in order to improve the life quality and to increase patient satisfaction.

Conflict of interest: None to declare.

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