STUDY OF SURFACE PHENOMENA IN MATERIALS OF PROSTHETIC RESTORATION

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Abstract

As a direct consequence of their application domain – the oral cavity – dental materials are subjected to the corrosive action of saliva, being surrounded by microorganisms, fluids and alimentary rests, which modify their surface characteristics. Concerns on the quality of the dental materials explain the numerous interdisciplinary studies, characterized by a close relation among various scientific domains (physics, chemistry, biology, science of biomaterials), techniques also applied in clinical stomatology. Analysis of the saliva–dental materials interface made use of ceramic surfaces, composites and artificial saliva, permitting to determine the main surface parameters of the materials of prosthetic restoration, calculated with some physical models, starting from measurements of the contact angle: surface energy, its polar and dispersive components, surface rugosity, adhesion mechanic work. All composites showed low values of the adhesion mechanic work, the conclusion being that they are much more hydrophobic than the ceramic materials. Such a property is especially important from an aesthetic perspective, as the hydrophobic materials have a better colour stability in time.

Keywords: ceramics, composites, contact angle, saliva, surface energy, rugosity.

INTRODUCTION

Knowledge on the surface energetic characteristics of biomaterials influences the adherence of cells, bacteria, the adsorption of surface plasmatic proteins, as well as the capacity of such surfaces of immobilizing certain biological species of special interest in medicine.

If considering the processes developed at the dental materials–biological fluid (oral medium) interface, a double effect may be observed: diseases generated by the materials used in stomatology and the failure of their utilization [1-4].

Nowadays, specialists’ concerns are mainly oriented towards the improvement of the quality of implants and of the minimum-invasive devices for human organism’s analysis, a higher biocompatibility and resistance to corrosion of the materials expected to have a direct contact with the biological tissues.

Oral fluids may generate degradation in the surface layers of the dental materials, causing the release of some free components, or they may cause the introduction of some fluids in the structure of the dental materials.

Such an absorption/adsorption process may also affect the mechanical properties of the materials, such as hardness, elasticity and dynamic stability [5-7].

Each dental material has its own characteristics and management capacities, which recommend it for various applications. The stress caused by masticatory forces and the salivary pH imposes specific requirements for these materials.

MATERIALS AND METHOD

Analysis of the saliva–dental material interface was performed on ceramic (Duceram – Dentsply Ceramco, Burlington, USA; InLine – Ivoclar Vivadent AG, Schaan, Liechtenstein; HeraCeram – Heraeus Kulzer GmbH, Wehrheim, Germany) and composite (Adoro – Ivoclar Vivadent AG, Schaan, Liechtenstein; Signum Ceramis – Heraeus Kulzer GmbH, Wehrheim, Germany; Ceramage – Shofu Dental Corporation, Kyoto, Japan;
Gradia indirect – GC America, Illinois, USA; Sculpture® Plus™ – Pentron) surfaces, applied on glass plates and fixed with double adhesive bands. The surfaces of the materials included in the study were around 2 cm² (figs. 1,2).

The working solution employed was artificial saliva, prepared according to the AFNOR S90 – 701 formula, with components of analytical purity, with pH 8.01.

The main parameters characterizing the surface properties of the materials are:
- surface energy,
- its polar and dispersive components,
- surface rugosity,
- adhesion mechanic work.

These parameters may be calculated by means of some physical models, starting from measurements of the contact angle (fig. 3) between saliva and the materials under investigation.

The requirements of the dental materials, influenced by the value of surface energy are: a good moistening of tooth’s surfaces or of the prosthetic restorations, for obtaining a good adhesion of the saliva and, implicitly, the ability of the materials introduced in the oral cavity of avoiding adhesion of the bacterial plaque.

10 measurements of the contact angle (θ) were performed for each type of material, the given value representing the mean of the calculated measurements made (maximum error: ±1º).

The contact angle was measured with an optic device equipped with a camera, which also permits measurement of its time evolution. The thermodynamic equilibrium was attained 10 sec after placement of the surface drops. Measurements made use of 1 microliter drops, at ambiental temperature and pressure, for assuring equilibrium of the contact angle.

The images of the drop on the solid surface were determined with an optic device, equipped with a camera, then processed and analyzed with a program of contour recognition – ImageJ.

RESULTS

Selection of distilled water as a reference sample in the estimation of contact angle for the materials under investigation is based on the fact that water represents 70% of the human organism and 99.4% of the saliva. One of the most important parts played by saliva is its ability of wetting the mucous membrane and the dental structures, which explains the measurement of the contact angle for checking the surface characteristics of the prosthetic materials.

Following the determinations made for each material, their arithmetic mean was calculated, thus obtaining a series of values which evidence the wettability of a liquid (artificial saliva, distilled water) on the surface of dental materials. Preservation of the liquid on the surface in an almost spherical form increases the value of the contact angle and reduces moistening. If the contact angle has a low value, the solid’s surface is
covered by liquid, moistening increases and adhesion occurs.

When the surface energy of a solid is higher, one may say that this is a hydrophillic material, namely liquid’s molecules will be attracted by solid’s molecules, thus achieving an optimum moistening of the surface. If surface energy is lower, the solid materials will become hydrophobic, namely the liquid will no longer wet the solid surface (fig. 4).

Fig. 4. Water drop wetting or not a surface

A low moistening value of the natural dental surfaces and of the dental biomaterials, obtained by the action of saliva, may be sometimes advantageous: more hydrophobic materials have a better colour stability and higher resistance to colourations, while restoration materials with low surface energy will much better resist to the formation of the bacterial plaque.

Out of the materials considered for the study, the most hydrophobic ones were Ceramage, from the composite ones, and respectively, InLine, from the ceramic masses.

Hydrophillic materials with a higher surface energy are Gradia, among the composites considered in the study and, respectively, Duceram, among the ceramic ones. Thus, the assertion may be made that Gradia and Duceram are dental materials which can most easily avoid the formation of bacterial plaque. This property is also advantageous from an aesthetic perspective, as the hydrophobic dental materials have a better colour stability and longer resistance in time.

Another observation was that all composites show lower $W_a$ values, comparatively with the ceramic materials, which means that they are more hydrophobic. As $W_a$ is a measure of the interatomic and intermolecular forces, at the level of the saliva-dental materials interface, a possible conclusion is that the adhesivity forces are lower in the case of composites.

For a better understanding of the results listed in the above table, surface energy (surface tension) and the polar and dispersive components of the dental materials here under study were calculated, as graphically plotted in figs. 5 a and b.

A comparison of the energetic characteristics of the two phases, saliva and solid surface, provides information on the processes developed at interface level.

Fig. 5. Graphic representation of surface energy ($\gamma_{SV}$) and the polar ($\gamma_{PV}^p$) and dispersive ($\gamma_{PV}^d$) components of: a) composite materials; b) ceramic materials

Surface morphology and chemical composition influence the surface adhesion and moistening properties. In this respect, a comparative study of the materials under analysis was performed by means of AFM images, which permitted to determine the rugosity ($R_{rms}$) of these surfaces.

All the above data show that the lowest rugosity value registered at the level of ceramic
surfaces is obtained for glazed HeraCeram, the lowest one being recorded for InLine (fig. 6). For composite surfaces, the highest rugosity is attained with Adoro, and the lowest one – with glazed Sculpture (fig. 7).

Mention was made of the fact that application of glaze at the level of the ceramic and composite masses considerably diminishes rugosity, improving their biocompatibility by reducing microorganisms’ adhesion degree to their surface.

Having this in view, it is especially important to strictly obey the technological phases of the conjunct gnathoprotetic devices made of composite and ceramic materials.

The lowest value of rugosity recorded confirms that these materials are best suited for dental applications. One should not forget that a higher rugosity involves a possible high absorption (as due to the larger specific surface) and more intense physico–chemical interactions of the elements from the biological liquid (artificial saliva) with the surface of the material (as a result of a higher number of non-covalent, physical-type bonds).

CONCLUSIONS

The biocompatibility of the materials for dental prosthetics depends on the volume and, equally, on their surface properties, such as, for example, surface energy, polarity, interfacial tension, which influence the adherence of bacteria, fungi, cells, proteic substances onto their surface.

The energetic parameters of dental materials’ surfaces, their morphology and rugosity, as well as their chemical composition have a considerable influence in the initial phases of the adsorption of biological liquids, mineral deposits and biofilm formation, and also in the chronic phases of the saliva–surface interface.

References