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Influence of biofilm formation on the optical properties of novel bioactive glass-containing composites

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ABSTRACT

Objective. Bioactive glass (BAG) has been suggested as a possible additive for dental restorative materials because of its antimicrobial effect and potential for promoting apatite formation in body fluids. The purpose of this study was to investigate the effects of bacterial biofilm on the change of colorimetric value and translucency of novel BAG-containing composites having different initial surface roughness.

Methods. Composites with 72 wt% total filler load were prepared by replacing 15% of the silanized Sr glass with BAG (65 mol % Si; 4% P; 31% Ca), BAG-F (61% Si; 31% Ca; 4% P; 3% F; 1% B), or silanized silica. Light-cured discs of 2-mm thickness ($n = 10$/group) were divided into 4 different surface roughness subgroups produced by wet polishing with 600 and then up to 1200, 2400, or 4000 grit SiC. CIE $L^*a^*b^*$ were measured and the color difference and translucency parameter (TP) were calculated before and after incubating in media with or without a *Streptococcus mutans* (UA 159) biofilm for 2 wks (no agitation). Results were analyzed using ANOVA/Tukey's test ($\alpha = 0.05$).

Results. All the color differences for BAG and BAG-F composite showed significant decreases with bacterial biofilm compared to media-only. The mean TP (SD) of BAG and BAG-F composite before aging [10.0 (2.8) and 8.5 (1.4)] was higher than that of the control composite [4.9 (0.8)], while the change in TP with aging was greater compared to the control with or without bacteria. BAG-F composites with the smoothest surfaces showed a greater decrease in TP under bacterial biofilm compared to the BAG composite.

Significance. Highly polished dental composites containing bioactive glass additives may become slightly rougher and show reduced translucency when exposed to bacterial biofilms, but do not discolor any more than control composites that do not contain the BAG.

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1. Introduction

New dental composites are being developed with bioactive additives having the potential to render them less susceptible to oral bacteria and promoting of tooth remineralization [1,2]. These composites will be used in all areas of the mouth, and will therefore have the same requirement for initial and long term esthetics as current materials.

Bioactive glasses (BAGs) area group of ceramic materials with the ability to bond chemically to both soft and hard tissues [3]. BAGs are considered a potential candidate as filler particles in resin-based dental composites, because they can enhance hard tissue regeneration and show some antimicrobial effect on oral microorganisms by the dissolution of the glass and releasing of ions in body fluids [1,4,5]. A recent study reported that BAG containing composites showed mechanical properties comparable to commercial composites [2]. Also, adding a filler particle based on a fluoride-containing BAG (BAG-F) enabled the composite to release both calcium and fluoride ions in solution, and to be rechargeable with fluoride upon exposure to external fluoride solutions [6]. While these properties provide optimism about the potential use of BAG additives in composites, the potential dissolution of the glass filler may cause concern about the integrity of the resin composite surface, and its overall esthetic appearance during aging.

The color of a resin composite is influenced by various factors including its light scattering and absorption characteristics, light reflectivity and translucency [7]. When light passes through a resin composite, it can be scattered in many different directions, primarily at the surface of the filler particles. Some of the light passes directly through as a more straight-line transmission while other light scatters through diffuse transmission, depending on the thickness of the composite [8–10]. The characteristics of the fillers and other additives used in the materials will therefore play a very significant role in determining their esthetic properties.

The characteristic of translucency allows an underlying background to show through by allowing light to at least partially pass through a material [11]. The inherent translucency of resin composites can be clinically beneficial for shade matching with an adjacent tooth by allowing the underlying and adjacent tooth structure to reflect or show through the restoration [12]. The translucency of tooth-colored restorative material is considered no less important than color, because the material with the same composite shade can look significantly different over different background colors [13]. A study reported that the translucency of resin composite was significantly correlated with diffuse light transmission, but not with the straight-line transmission [10]. It has been shown that the shape, size, and content of filler particles are all capable of affecting the light transmittance characteristics and color of resin composites [14].

Dental composites are susceptible to discoloration after prolonged exposure to the oral environment, and this is a function of their formulation [15]. One of the primary reasons dental composite restorations are replaced is due to unacceptable color change [16]. It is clinically important for these materials to maintain color stability for prolonged periods of time [17]. Therefore, conditions in which changes in color and translucency are produced within or on the surface during aging may cause the restoration to become clinically unacceptable. For example, it has been shown that organic acids and enzymes produced by bacteria within the oral biofilm can soften the resin matrix of dental composites [18], which can increase the susceptibility of the surface to staining [19,20], and may therefore influence the overall esthetics of the restoration. However, little is known about the direct effect of bacterial biofilm formation on the stability of the optical properties of dental composites.

As new dental composite materials are produced with additives, such as BAG and calcium phosphates that may impart bioactive characteristics, it will be important to evaluate the color stability during aging, especially after exposure to clinically relevant oral conditions, such as biofilm formation. The aim of this study was to investigate the effect of bacterial biofilm on the optical properties of composites with different levels of polish, especially those containing potentially bioactive additives such as BAG and BAG-F. The hypothesis to be tested was that all composites would experience a change in color and translucency as a result of surface degradation, but that the BAG and BAG-F-containing composites would experience less change due to the presence of some antimicrobial effect. It was also expected that aging in media with or without bacterial would cause a dissolution of the BAG, creating a slight surface roughening, especially when the composite was highly polished. However, the effect of this roughening on the color change, if any, was not predictable and therefore important to assess.

2. Materials and methods

2.1. Preparation of BAG

BAG fillers were synthesized via sol–gel methods in our lab as previously described [1]. The synthetic glasses were ball milled in ethanol and sieved to a total particle size of less than 38 μm. The particles were then further processed using a Micronizer Jet Mill (Sturtevant Inc., Hanover, MA, USA), determined by laser particle size measurements (Beckman Coulter LS13 320, Brea, CA, USA) to routinely produce a fine particle size range (0.04–3.0 μm).

2.2. Formulation of experimental composites

The three experimental composites all contained 57 wt% of strontium glass filler treated with silane (1–3 μm average size, Bisco, Inc.), further modified as follows: The control group included a silane-treated aerosol-silica (OX-50), while micronized BAG (BAG65) and fluorine-containing micronized BAG (BAG61) replaced the silica in the groups designated as BAG and BAG-F (Table 1). The fillers were mixed with Bis-GMA and TEGDMA monomers in a 50:50 formulation