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Color stability of experimental composites containing different photoinitiators

Francisca Daniele Jardimino Silami^a, Fabrício Mariano Mundim^a,
Lucas da Fonseca Roberti Garcia^a, Mário Alexandre Coelho Sinhoreti^b,
Fernanda de Carvalho Panzeri Pires-de-Souza^{a,*}

^a Department of Dental Materials and Prosthodontics, Ribeirão Preto School of Dentistry, University of São Paulo, Ribeirão Preto, SP, Brazil

^b Department of Restorative Dentistry, Area of Dental Materials, Piracicaba School of Dentistry, State University of Campinas, Piracicaba, SP, Brazil

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ABSTRACT

Objectives: To evaluate the color stability (ΔE) of experimental composites containing different photoinitiators when submitted to accelerated artificial ageing (AAA).

Material and methods: Thirty test specimens were made in a Teflon matrix (8 mm × 2 mm), using an experimental composite ($n = 10$) with the same monomer composition and particle size, but varying photoinitiator used: Group CQ (0.4% Camphorquinone), Group PPD (0.4% 1-Phenyl-1,2 Propanodione) and Group CQ + PPD (0.2% CQ + 0.2% PPD). The samples were light activated (QTH – Ultralux – Dabi Atlante – 40s) and polished before performing the initial color readouts (EasyShade – Vita). Next, they were submitted to AAA for 300 h, after which final color readouts were made.

Results: The results (1-way ANOVA – Tukey – $p < 0.05$) demonstrated that all the groups presented color alteration above the clinically acceptable level ($\Delta E \geq 3.3$), however, with no statistically significant difference among them ($p > 0.05$). Analysis of Δb demonstrated increase in the values of this coordinate, indicating yellowing in all groups.

Conclusions: It was concluded that the type of photoinitiator, which presented a tendency towards yellowing, did not interfere in the color stability of composites submitted to AAA. **Clinical significance:** Alternative photoinitiators have been extensively studied since Camphorquinone presents a yellowish color, which compromises the aesthetic performance of composites, especially the lighter-shade ones.

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1. Introduction

Aesthetic demands by patients have led to dentists increasingly using composites of light shade for the fabrication of restorations¹; however, various studies have demonstrated that these composites present greater color alteration over the course of time than those of darker hue.^{2–4} This alteration is mainly due

to their greater translucence, which allows more absorption and transmission of light, and less scattering when the light is reflected.⁵ Therefore, the natural degradation of chemical additives present in composite formulations, such as ultraviolet filters, initiators, co-initiators and inhibitors⁶ promotes more evident intrinsic staining in this class of materials.⁷

Contemporary composites are light activated by light within the blue band of the spectrum (400–500 nm), using a

* Corresponding author at: Faculdade de Odontologia de Ribeirão Preto – USP, Departamento de Materiais Dentários e Prótese, Avenida do Café, s/n, Bairro Monte Alegre, CEP: 14040-904, Ribeirão Preto, São Paulo, Brazil. Tel.: +55 016 3602 3973; fax: +55 016 3633 0999.

E-mail address: ferpanzeri@usp.br (F. de C.P. Pires-de-Souza).

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diketone as photoinitiator, Camphorquinone (CQ).⁸ On absorbing this light, CQ is excited, and combines with a reducing agent present in the monomer matrix, generating free radicals that initiate the polymerization process.⁹ However, some composites with a lighter shade use alternative photoinitiators, as CQ presents a yellowed hue,⁸ compromising its aesthetic performance, since photoinitiators degrade over the course of time.^{7,8,10} This fact has led to researchers testing different types of photoinitiators, such as PPD (Phenyl Propanodione), BAPO (Bis-alkyl Phosphine Oxide) and Mono-alkyl Phosphine Oxide, with the intention of replacing CQ, or acting in conjunction with it, diminishing its concentration in the monomer matrix even further.^{11,12}

The spectrum emitted by the light source and the capacity of absorption by the photoinitiator have an effect on the polymerization process of composites,^{8,9,13–15} which in turn influence properties, particularly mechanical strength, water sorption and color stability.^{6,16} Recent studies have demonstrated that the use of PPD increases the efficiency of polymerization of composites, and diminishes the “yellowing” effect of CQ, making it a feasible alternative as a photoinitiator system.^{17,18} Therefore, it is necessary to analyse the color stability of experimental composites containing alternative photoinitiators in their formulations.

Thus, the aim of this study was to evaluate the color stability of experimental composites containing different photoinitiators when submitted to accelerated artificial ageing (AAA). The null hypothesis tested was that there would be no difference in the color stability of the different composites, irrespective of the photoinitiator used.

2. Materials and methods

2.1. Preparation of experimental composites

To conduct the study, 3 experimental composites were formulated, with the same monomer composition and type of filler particles, but varying the photoinitiators used. In the organic matrix, the following dimethacrylate monomers were used, similar to Z250 composite (3M ESPE, Sumaré, SP, Brazil) formulation: Bisphenol A-glycidyl dimethacrylate – 30 wt% (Bis-GMA – Sigma-Aldrich Inc., St. Louis, MO, USA), Urethane Dimethacrylate – 29 wt% (UDMA – Sigma-Aldrich Inc.), Bisphenol-A dimethacrylate ethoxylate – 29 wt% (Bis-EMA – Sigma-Aldrich Inc.), Triethyleneglycol dimethacrylate – 8 wt% (TEGDMA – Sigma-Aldrich Inc.) and Dimethylamino ethyl methacrylate – 0.8 wt% (DMAEMA – Sigma-Aldrich Inc.). The inorganic filler particles used were barium aluminosilicate (BaAlSiO – 0.05 μm) and colloidal silica (SiO₂ – 0.04 μm) (Biodinâmica, Iporã, PR, Brazil), which were added in the proportion of 80 wt% and 20 wt% respectively. As photoinitiators of the organic matrix, Camphorquinone (CQ – 0.04%) or 1-Phenyl-1,2 Propanodione (PPD – 0.04%) were added (Sigma-Aldrich Inc.).

2.2. Test specimen fabrication

A Teflon matrix (8 mm in diameter \times 2 mm thickness), was used to fabricate 30 test specimens ($n = 10$), according to the

type of photoinitiator used: Group CQ (0.4% Camphorquinone), Group PPD (0.4% 1-Phenyl-1,2 Propanodione) and Group CQ + PPD (0.2% CQ and 0.2% PPD).

The composite was inserted into the matrix in 1 mm-thick increments, and the last increment was pressed with a glass slide to allow excess material to flow out. After insertion into the matrix, each increment was light activated using a Halogen light appliance (Ultralux, Dabi Atlante, Ribeirão Preto, SP, Brazil) for 40 s. After this, the test specimens were polished using water abrasive paper (Norton, São Paulo, SP, Brazil) in a decreasing sequence of grits (320, 600, and 1200). After polishing, the test specimen thicknesses were measured with a digital caliper (Digimess, Shinko Precision, Gaging, China), since any alteration in test specimen thickness could influence the spectrophotometric results. All the test specimens were coded and stored in isolated receptacles at 37 °C and kept in the absence of light until they were submitted to color analysis.

2.3. Color stability

After obtaining the test specimens, initial color readouts (baseline) were taken (Spectrophotometer Easyshade, VITA Zahnfabrik, BadSäckingen, Germany), according to the CIE L*a*b* System (Commission Internationale de l'Éclairage).

Next, the samples were submitted to AAA (Accelerated Ageing System for non-metallic materials C-UV, Comexim Matérias Primas Ltda, São Paulo, SP, Brazil), for 300 h, which corresponded to six months of clinical use.¹⁹ The fixed working programme was 4 h of exposure to UV-B at 50 °C and 4 h of exposure to water steam at 50 °C.

After AAA, final color readout was performed and color stability (ΔE) was determined by the difference between the coordinates obtained before and after the ageing process of the samples, by the following formula:²⁰

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

where ΔE is the color alteration, $\Delta L = L_F^* - L_I^*$, $\Delta a = a_F^* - a_I^*$, and $\Delta b = b_F^* - b_I^*$.

The subscript letter “F” corresponded to the final readout, taken after AAA, and “I” to the initial readout.²⁰ ΔL represents the difference in luminosity, Δa the difference in the red–green parameter ($-a^*$ = green and $+a^*$ = red) and Δb the difference in the yellow–blue parameter ($-b^*$ = blue and $+b^*$ = yellow).²¹

Values of ΔE equal to or higher than 3.3 were considered clinically unacceptable.²² After obtaining the data, they were submitted to a statistical test for one factor – color alteration (1-way ANOVA, Tukey – $p < 0.05$).

3. Results

Table 1 shows the original values for all the coordinates (L^* , a^* and b^*) before and after AAA. Means values for color stability (ΔE) and variation in the blue–yellow parameter (Δb) are shown in Table 2.

All the groups presented color alteration above the clinically accepted level ($\Delta E \geq 3.3$), however, without statistically significant difference among them ($p > 0.05$). As regards

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