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Influence of fluorescent whitening agent on the fluorescent emission of resin composites

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ABSTRACT

Objectives. The objective of this study was to determine the fluorescent emission of experimental resin composites after addition of a fluorescent whitening agent in varied concentrations. The effects of thermocycling and composition of resin matrix on the fluorescent emission were also determined.

Methods. An experimental light curing resin matrix was made by mixing Bis-GMA, UDMA and TEGDMA in the ratio of 1:1:1 by weight, and silane coated glass filler was added in the ratio of 50 wt.% of resin composite. A fluorescent whitening agent [FWA, 1,4-double-(benzoxazole-group-2-group)naphthalene] was added with the concentration of 0.01–0.1%. To determine the difference by the resin matrix, two resin composites (60 wt.% Bis-GMA or UDMA with 40 wt.% TEGDMA) with the same filler content were made, and the FWA was added. Five specimens of 2 mm in thickness were made for each group. Spectral reflectance was measured relative to the illuminant D65 on a reflection spectrophotometer. From the spectral reflectance values, the difference in reflectance (fluorescence spectra) by the inclusion or exclusion of UV component was calculated. After the baseline measurement, thermocycling was performed for 500 and 1000 cycles, and the fluorescent emission was measured again.

Results. The concentration of FWA influenced the fluorescent peak heights and areas ($p < 0.05$), but thermocycling up to 1000 cycles did not influence the values. Fluorescence peak wavelength was not changed by the resin matrix, but peak height and area were influenced by the resin matrix ($p < 0.05$).

Significance. FWA added with the concentrations of 0.01 and 0.05% emitted fluorescence, which was higher than those from commercial resin composites.

1. Introduction

Ideal esthetic restorative materials should have similar fluorescence to that of teeth. If it is absent, esthetic qualities of the restorations suffer under UV illumination [1]. Since resin composites are applied by layering to mimic the layering of natural teeth and have become to be used for the restoration of large areas [2], fluorescence of resin composites is important as in dental porcelains [3].

Fluorescence is the absorption of light by a substance and the spontaneous emission of light in a longer wavelength within 10^{-8} s of activation [4]. Natural teeth emit a blue fluorescence under the action of UV light, which makes teeth whiter and brighter in daylight [5]. When human dentin was irradiated with 365 nm UV light, fluorescence was observed with a peak at 440 ± 10 nm [6]. Fluorescence in a material tends to give a bright iridescence effect, and can be used to brighten dark teeth without negatively affecting the translucency [7].

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Fluorescence adds to the vitality of a restoration and minimizes the metameric effect between the teeth and restoration [8].

Several commercial resin composites are claimed by the manufacturers to have tooth-like fluorescence. Some commercial resin composite showed fluorescence and others did not [1]. Fluorescent emission was determined by the difference in spectral reflectance values, which were measured under the UV-included and excluded conditions of the illuminant D65 [1]. And also, the influence of surface sealant and staining on the fluorescent emission of resin composites was determined [9]. If fluorescent emission of a resin composite is increased, higher masking and brightening effect can be obtained [10].

Cerium oxide was added to impart fluorescence to dental porcelain [11]. In case of resin composite, fluorescent glass filler containing rare earth oxides was added into resin composite to enhance fluorescence [12]. However, it has not been reported on the influence of fluorescent agent directly added in the resin matrix.

Fluorescent whitening agents (FWAs) are chemicals added to most fabrics and papers during manufacture to increase color temperature, 'whiteness', and 'brightness'. FWAs accomplish this by absorbing energy in the UV part of the spectrum and emitting it as visible blue light [13]. FWA did not penetrate into the subepithelial layers of the skin after cutaneous application [14], and it was concluded that the possibility of systemic toxic effects in man as a result of percutaneous absorption of FWA was remote [15]. It was also reported that none of the FWAs was phototoxic [16]. Therefore, FWA was considered as a possible fluorescent agent, which can be added into dental resin composite to give fluorescent properties.

The null hypothesis of the present study was that the concentration of FWA added into resin composites did not influence the fluorescent emission. The purpose of this study was to determine the difference in the fluorescent emission of experimental dental resin composites after addition of FWA in varied concentrations. The effects of thermocycling and composition of resin matrix on the fluorescent emission were also determined.

2. Materials and methods

An experimental resin matrix (BUT) was made by mixing Bis-GMA, UDMA and TEGDMA in the ratio of 1:1:1 by weight. Silane coated filler (average size: 1.55 μm, Schott, Germany) was added in the ratio of 50 wt.% of resin composite. Photoinitiator, accelerator and inhibitor [0.7% camphoroquinone, 0.35% 2-(dimethylamino) ethylmethacylate, and 0.05% butylated hydroxytolune] were added. To determine the influence of concentration of FWA, FWA [1,4-double-(benzoxazole-group-2-group)naphthalene, $C_{24}H_{14}O_2N_2$, CAS no. 5089-22-5] was added in the concentrations of 0.01, 0.05 and 0.1% of the resin composite. FWA was not added in the control group.

To determine the influence of resin matrix on fluorescent emission, two resin mixtures composed of 60 wt.% Bis-GMA and 40 wt.% TEGDMA (BT), and 60 wt.% UDMA and 40 wt.% TEGDMA (UT) were made. Into these matrices, 50 wt.% silane coated filler was added. The same amount of photoinitiator, accelerator and inhibitor were added. FWA was added in the concentrations of 0.01 and 0.05%.

Specimens of 10 mm in diameter and 2 mm in thickness were made with a polytetrafluoroethylene mold. Specimen was light polymerized for 40 s in four overlapping areas with a light-polymerizing unit (Spectrum 800, Dentsply-Caulk, Milford, DE, USA). Five specimens were made for each group.

Spectral reflectance was measured according to the CIELAB color scale relative to the standard illuminant D65 [17] over a white standard tile (Reference white standard, GretagMacbeth Instruments Corp., New Windsor, NY, USA, CIE $L^* = 94.28$, $a^* = -0.40$, and $b^* = 1.34$) on a reflection spectrophotometer (Color-Eye 7000A, GretagMacbeth Instruments Corp.). A UV filter was positioned to 0% UV or 100% UV condition. The aperture size was 3 mm × 8 mm, and illuminating and viewing configuration was CIE diffuse/8° geometry [18]. Measurements were repeated three times for each specimen.

After the baseline color measurement, thermocycling was performed for 500 and 1000 cycles between 5 and 55 °C distilled water with a dwell time of 15 s.

From the spectral reflectance values, the difference in reflectance by the inclusion or exclusion of UV component was calculated [1,9]. With the following calculations, subtraction spectrum (fluorescent emission spectrum) was obtained. Preliminary subtraction spectrum from 400 to 750 nm was obtained by subtracting the spectral reflectance value obtained with UV component excluded condition at each wavelength from that obtained with UV component included condition. Then to eliminate the influence of composition of resin composite, the difference in spectrum at each wavelength of the control group (no FWA) by the inclusion or exclusion of UV component was subtracted from the preliminary subtraction spectrum at each wavelength. Peak wavelength, height and peak area (from 400 to 500 nm) were calculated. The wavelength range for the area calculation was chosen because the subtraction values were higher than 0 in this range for all the specimens.

The influence of the concentration of FWA and thermocycling on the fluorescent peak and area was analyzed using a two-way analysis of variance (ANOVA) at the significance level of 0.05. Two-way ANOVA by the type of resin matrix and concentration of FWA was performed for the fluorescent peak height and peak area at the significance level of 0.05. Means were compared with a Fisher's protected least significant difference (PLSD) interval at the significance level of 0.05.

3. Results

Subtraction spectra (differences in the reflectance by the UV-component of the illumination: fluorescence in the reflectance mode) of BUT based resin composite are presented in Fig. 1, and those after thermocycling are presented in Fig. 2. The values for the fluorescent peak height and fluorescent area of BUT based resin composites before and after thermocycling are listed in Table 1. In the control group (no FWA), fluorescent peak was not detected. The concentration of FWA influenced the fluorescent peak height significantly ($p < 0.05$), but thermocycling up to 1000 cycles did not influence the value ($p = 0.902$), and there was no significant interaction between two inde-