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The effects of different opacifiers on the translucency of experimental dental composite resins

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ABSTRACT

Objective. The aim of this study was to evaluate the effects of different opacifiers on the translucency of experimental dental composite-resins.

Methods. Three metal oxides that are used as opacifiers were tested in this study: titanium oxide (TiO_2), aluminium oxide (Al_2O_3) and zirconium oxide (ZrO_2). Experimental composite-resins were fabricated containing 25 wt.% urethane dimethacrylate (UDMA)-based resin matrix and 75% total filler including different concentrations of metal oxides (0, 0.25, 0.5, 0.75 and 1 wt.%) blended into silane treated barium-silicate filler. The specimens (15.5 mm diameter and 1 mm thickness) were light-cured and tested in the transmittance mode using a UV/VIS spectrophotometer at wavelengths from 380 to 700 nm under a standard illuminant D65. The color differences (ΔE^* ab) between different concentrations of opacifiers were also measured in transmittance mode based on their Lab values.

Results. Statistical analysis by ANOVA and Tukey's test showed a significant decrease ($p < 0.05$) in light transmittance with the addition of opacifiers to the experimental composite-resins. There was a linear correlation between different concentrations of TiO_2 and Al_2O_3 and total transmittance. Total transmittance was also found to be wavelength dependent. The color differences for the concentrations of 0–1 wt.% of the opacifiers were above 1 ΔE^* unit, with Al_2O_3 showing the smallest color shift.

Significance. The type and the amount of the opacifiers used in this study had a significant effect on the translucency of the experimental UDMA-based dental composite resins. The most effective opacifier was TiO_2, followed by ZrO_2 and Al_2O_3 in decreasing order, respectively.

1. Introduction

It has been shown that the appearance of a restoration is influenced by many factors including color, translucency and opacity, light reflectance and transmittance, and surface texture [1]. The inherent translucency of tooth structure and different morphology across the surface contributes to the complexity of achieving a natural looking restoration. Furthermore, it is often challenging for the clinician to mask the

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dark visual effect of the oral cavity on a class III or class IV restoration, or when trying to mask intense discolorations on the tooth structure. In order to overcome these problems, the opaque shades and dentin shades of dental composite resins have been manufactured. These new shades have higher opacity compared to the standard monochromatic dental composite shades [1–5].

According to Ragain and Johnston [6], a translucent material or a tooth undergoes four optical phenomena when light reaches it: (I) specular transmission of the light flux through the tooth; (II) specular reflection at the surface; (III) diffuse light reflection at the surface; and (IV) absorption and scattering of the light flux within the dental tissues.

The color and translucency of the composite resin are influenced by its shade, thickness and background color [7]; matrix composition [8]; filler particle size and content [9], pigment additions [10] and potentially the initiation component and filler coupling agent [11]. It has been also reported that translucency and color of resin composites are affected by depth of cure [12], light transmittance [13], and two wavelength-dependent elements such as absorption coefficient and scattering coefficient [14].

Scattering of light is an effect of refraction and reflection at the interface between the resin matrix and particles or voids [13]. It has been reported that opacifiers in composite resins can act as scattering centers and therefore, affect their translucency.

Metal oxides such as titanium oxide (TiO_2), aluminium oxide (Al_2O_3) and zirconium oxide (ZrO_2) are known opacifying agents which are added in minute amounts to the resin mixture. These opacifiers have refractive indices substantially different from the matrix. In addition to the refractive index, it has been shown that the shape and the size of filler particles, also have a significant effect on the light transmittance characteristics and the color of experimental composite resins. Materials that contain smaller size opacifiers with irregular shapes demonstrate higher light transmittance and diffusion angle distribution, in comparison to composites containing spherical-shaped and larger fillers [13–15].

An ideal opacifier is the one that is able to mask the unwanted discoloration or background darkness efficiently in minute concentration. Studies on the effects of different pigments and opacifiers at different concentrations on the translucency of dental composite resins are rare. Therefore, the aim of this study was to evaluate the effects of different opacifiers on the translucency of the experimental dental composites. The null hypothesis was that the addition of different opacifiers does not have any significant effect on the translucency of experimental dental composite resins.

2. Materials and methods

2.1. Specimen composition

All the materials used in this study for fabrication of the experimental composites, except for the opacifiers (metal oxides), were supplied by Dentsply (Konstanz, Germany).

Resin matrix was prepared by mixing the following ingredients: UDMA (99.22%), camphorquinone (CQ) (0.3%), dimethylaminobenzoic acid ethyl ester (DMABE) (0.3%), 3,5-di-*tert*-butyl-4-hydroxytoluene (BHT) (0.12%) and 2-hydroxy-4-methoxybenzophenone (HMBP) (0.06%).

The experimental composite resins were produced by mixing 25 wt.% of resin matrix with 75 wt.% of filler.

The filler used was silane treated barium silicate glass filler (particle size 1.5 μm). Three metal oxides were used as opacifiers: titanium oxide (TiO_2), aluminum oxide (Al_2O_3) and zirconium oxide (ZrO_2)—particle size of all <5 μm, according to manufacturer (Sigma-Aldrich, Dorset, UK).

2.2. Specimen groups

13 groups (Table 1) of experimental composite resins were made containing different concentrations of the opacifiers: 0.25, 0.5, 0.75 and 1 wt.%. The metal oxides were blended in the filler mixture, giving the same total filler content of 75 wt.% for all four groups. A control group with no opacifier was also prepared.

As the silica filler varied in minute amounts for the four groups to give the same total content of 75 wt.% of filler, an additional group was tested in a pilot study containing no opacifier and 1 wt.% reduction of glass filler and compared with the control group to evaluate whether varying only these minute concentrations of silica filler would significantly affect the translucency. No significant differences in optical proper-

Table 1 – Composition of the filler and opacifiers in different experimental composite resins.

	Silica filler (wt.%)	TiO_2 (wt.%)	Al_2O_3 (wt.%)	ZrO_2 (wt.%)
Composition 1	74.75	0.25	0	0
Composition 2	74.50	0.5	0	0
Composition 3	74.25	0.75	0	0
Composition 4	74	1	0	0
Composition 5	74.75	0	0.25	0
Composition 6	74.50	0	0.5	0
Composition 7	74.25	0	0.75	0
Composition 8	74	0	1	0
Composition 9	74.75	0	0	0.25
Composition 10	74.50	0	0	0.5
Composition 11	74.25	0	0	0.75
Composition 12	74	0	0	1
Composition 13	75	0	0	0