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Relevant optical properties for direct restorative materials

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ABSTRACT

Objectives. To evaluate relevant optical properties of esthetic direct restorative materials focusing on whitened and translucent shades.

Methods. Enamel (E), body (B), dentin (D), translucent (T) and whitened (Wh) shades for E (WhE) and B (WhB) from a restorative system (Filtek Supreme XTE, 3M ESPE) were evaluated. Samples (1 mm thick) were prepared. Spectral reflectance (*R*%) and color coordinates (L^*, a^*, b^*, C^* and $h°$) were measured against black and white backgrounds, using a spectroradiometer, in a viewing booth, with CIE D65 illuminant and *d*/0° geometry. Scattering (*S*) and absorption (*K*) coefficients and transmittance (*T*%) were calculated using Kubelka–Munk's equations. Translucency (TP) and opalescence (OP) parameters and whiteness index (W^*) were obtained from differences of CIELAB color coordinates. *R*%, *S*, *K* and *T*% curves from all shades were compared using VAF (Variance Accounting For) coefficient with Cauchy–Schwarz inequality. Color coordinates and optical parameters were statistically analyzed using one-way ANOVA, Tukey's test with Bonferroni correction ($\alpha = 0.0007$).

Results. Spectral behavior of *R*% and *S* were different for T shades. In addition, T shades showed the lowest *R*%, *S* and *K* values, as well as the highest *T*%, TP an OP values. In most cases, WhB shades showed different color and optical properties (including TP and W^*) than their corresponding B shades. WhE shades showed similar mean W^* values and higher mean *T*% and TP values than *E* shades.

Significance. When using whitened or translucent composites, the final color is influenced not only by the intraoral background but also by the color and optical properties of multilayers used in the esthetic restoration.

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1. Introduction

Traditionally, composites are designed to support masticatory load (posterior teeth) or to produce esthetically beautiful (anterior teeth) restorations [1]. Manufacturers of restorative resin-based composites may manipulate the resin matrix and, mainly, the particle size and shape to improve material properties [1–6].

With the development of nanotechnology, dental nanocomposites have become available, allowing for significant improvements [2]. Nanofillers range from 1 to 100 nm^2, which is below the wavelength of visible light (380–780 nm). This characteristic allows the fabrication of materials unable to scatter or absorb the visible light, named highly translucent materials [2,7]. To obtain these nanocomposites, two types of nanofillers have been synthesized: nanometric particles (nanomers) and nanoclusters. The former are mainly monodisperse, non-aggregated and non-agglomerated zirconia (2–20 nm) or silica particles (2–75 nm) [2,7]. Due to reduced particle size, dental nanocomposites exhibit very good resistance to wear and fracture, along with good sculptability [2]. Nanofillers also offer advantages in optical properties. They can provide low opacity in low staining dental composites, allowing for a wide range of shades and opacities [2].

When light strikes a semi-translucent object, four phenomena can result from this interaction: (1) specular light reflection and (2) diffuse light reflection at the object surface, (3) absorption and scattering of light within the object structure, and (4) transmission of the light flux through object structure [6,8,9]. The light resulting from the interaction of these phenomena will reach the observer eyes with the object color information [6].

Previous studies reported that background color affects the perceived color of dental composites [10,11], suggesting that translucency should not be ignore in esthetic dentistry. Highly translucent and low staining composites, which usually have nanoparticles, allow the perception of the background color through the material [2].

Scattering changes with the wavelength of incident light and it is mostly determined by particle size. Absorption and reflectance also vary with the wavelength of incident light and the nature of colorant pigments [8]. Different esthetic restorative resin systems work with different color and translucency effects and these characteristics should be considered when selecting the restorative material.

Actually, most direct restorative materials offer whitened shades, suggesting they are brighter and more opaque than the classic dental shades [11]. Opalescent materials, such as dental enamel, are able to scatter shorter wavelengths of light. Under reflected light, they appear blue, whereas under transmitted light, they appear brown/yellow [2,12,13].

CIELAB color space is mostly used in dental color research. This space consists of three axes: L^* (lightness), a^* (red-green axis) and b^* (yellow-blue axis). Chromatic attributes related to visual perception, such as chroma (C^*) and hue (h°), are obtained from a^* and b^* coordinates [14]. Therefore, managing the optical properties of esthetic restorative materials is essential to fabricate natural-looking esthetic restorations. Thus, the purpose of this study was to evaluate the color and optical properties of translucent and whitened shades in relation to their original E and B shades. The study tested the hypotheses that (1) direct restorative composite shades present the optical properties suggested by the manufacturer, and (2) there is a significant difference in color and optical properties between the whitened shades and the corresponding original (E and B) shades from a direct restorative composite system.

2. Material and methods

2.1. Samples

An esthetic resin composite restorative system (FS-Filtek™ Supreme XTE, 3M ESPE, St. Paul, MN, USA), based on layering technique [15,16], was evaluated (Table 1).

Specimens (10 mm in diameter and 1 mm in thickness) were fabricated ($n = 3$) with all composite shades. Composite material was packed into an adaptable micrometer metal mold (Smile Line, St-Imier, Switzerland) pressed with a mylar strip and a glass slide. All samples were light activated (Bluephase®, Ivoclar Vivadent, Schaan, Liechtenstein; 1100 mW/cm^2 for 40 s) through the glass slide and after removing the specimens from mold. Specimens were carefully checked to avoid surfaces with impurities, scratches, porosities or any defects that could affect the optical behavior. All samples were lightly polished with Astrobrush® (Ivoclar Vivadent, Schaan, Liechtenstein). The thickness was measured with a digital caliper (Digimatic caliper, Mitutoyo Corp., Tokyo, Japan). Accepted thickness values were 1.00 ± 0.01 mm.

2.2. Reflectance and color measurements

The relative spectral radiance of each sample was measured against white ($L^* = 94.2$, $a^* = 1.3$ and $b^* = 1.7$) and black ($L^* = 3.1$, $a^* = 0.7$ and $b^* = 2.4$) ceramic tile backgrounds (Ceram, Staffordshire, United Kingdom), using a non-contact spectroradiometer (SpectraScan PR-704, Photo Research, Chatsworth CA, USA). A saturated sucrose solution (refractive index $n = 1.5$, approximately) was used as a coupling agent [17–19].

Specimens were measured inside of a color-assessment cabinet (CAC 60, Verivide Limited, Leicester, United Kingdom) under constant illumination (light source simulating the spectral relative irradiance of D65 CIE standard illuminant). Illuminating/measuring configuration corresponded to CIE d/0° [14]. A triangular stand was built to support the specimens and avoid specular reflection from the glossy surface [18,20,21]. Spectroradiometer was placed at 35 cm from the samples, since the field of measurement of the spectroradiometer was 1°. Short-term repeated measurements were performed and each specimen was measured three times.

The relative spectral radiance measured for all specimens at each wavelength was converted into absolute reflectance (R), based on measurements of a white reflectance standard (OPST3-C, Optopolymer, Germany) [18].

Subsequently, color coordinates in CIELAB color space: L^* (lightness), a^* coordinate ($-a^*$: green, $+a^*$: red), b^* coordinate ($-b^*$: blue, $+b^*$: yellow) and the attributes of the color C^*