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Translucency thresholds for dental materials

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ABSTRACT

Objective. To determine the translucency acceptability and perceptibility thresholds for dental resin composites using CIEDE2000 and CIELAB color difference formulas.
Methods. A 30-observer panel performed perceptibility and acceptability judgments on 50 pairs of resin composites discs (diameter: 10 mm; thickness: 1 mm). Disc pair differences for the Translucency Parameter (ΔTP) were calculated using both color difference formulas (ΔTP_{00} ranged from 0.11 to 7.98, and ΔTP_{ab} ranged from 0.01 to 12.79). A Takagi–Sugeno–Kang (TSK) Fuzzy Approximation was used as fitting procedure. From the resultant fitting curves, the 95% confidence intervals were estimated and the 50:50% translucency perceptibility and acceptability thresholds (TPT and TAT) were calculated. Differences between thresholds were statistically analyzed using Student t tests ($\alpha = 0.05$).
Results. CIEDE2000 50:50% TPT was 0.62 and TAT was 2.62. Corresponding CIELAB values were 1.33 and 4.43, respectively. Translucency perceptibility and acceptability thresholds were significantly different using both color difference formulas ($p = 0.01$ for TPT and $p = 0.005$ for TAT). CIEDE2000 color difference formula provided a better data fit than CIELAB formula.
Significance. The visual translucency difference thresholds determined with CIEDE2000 color difference formula can serve as reference values in the selection of resin composites and evaluation of its clinical performance.

1. Introduction

The increased demand of patients for highly esthetic restorations has driven the development of dental materials with suitable optical properties. Translucency is an important property of dental tissues and materials. Thus, an appropriate determination and communication of optical properties should include translucency, in addition to more popular parameters such as: lightness (L^*), a^* and b^* (CIELAB coordinates), hue angle (h°) and chroma (C^*).

Translucency describes the ability of a material to transmit light [1]. The translucency parameter [2] (TP) has been used to assess the translucency of dental materials [3–7]. TP is defined

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as the CIELAB color difference (ΔE^*_{ab}) for a material, at a particular thickness, on optical contact with ideal black and white backings [2]. Aiming to improve correction between perceived and computed color differences of CIELAB formula, the Commission Internationale de l'Éclairage (CIE) [8] recommended the use of CIEDE2000 color difference formula. However, at the moment in the majority of translucency studies in dental literature, the TP is still quantified using the CIELAB color space and its associated color formula (ΔE^*_{ab}).

Thus, determination of TP has shown differences in translucency of different composite resins depending of its shade [9], thickness [10]; matrix composition [11]; filler particle size and content [12,13] and type and amount of the opacifiers used [14].

Perceptibility difference threshold represents the lower perceptual limit, and it is widely applicable, mainly, to develop new color notation systems and their color difference metrics, to study discernible colors by the human visual system [15] and to understand the mechanisms of color vision [16]. However, in many practical situations, differences above the threshold (supra-threshold) are used, passing from perceptibility thresholds or "just noticeable differences" to higher differences, named "acceptable differences" or "tolerances." The industrial interest on these differences is justified, on one hand, by the high cost required to maintain the industrial production below the limits of the visual threshold (perceptible threshold) and, on the other hand, by the need of maintaining the differences under an admissible limit. The complete absence of control (monitoring) should involves a lack of similarity in the production outcome, with negative implications on the overall quality of the product.

In dentistry, there were few attempts [17,18] to reach a translucency perceptibility threshold. A study [17] used the contrast ratio (CR) parameter to evaluate dental porcelains, reporting an overall mean translucency perceptibility threshold of 0.07 and 50% of this population perceived a 0.06 CR (6%) difference in translucency. Another study [18] applied regression equations between TP and CR [19] reporting visual perceptibility thresholds for translucency difference in TP of 2.

Nevertheless, there is no study on the translucency thresholds for restorative dental materials using TP and controlled illumination, recommended viewing geometry and a suitable fitting procedure. Therefore, the purpose of this study is to determine 50:50% acceptability and perceptibility translucency thresholds using the CIEDE2000 (TAT_{00} and TPT_{00}) and CIELAB (TAT_{ab} and TPT_{ab}) color difference formulas and the Takagi–Sugeno–Kang (TSK) fuzzy model, testing the null hypothesis that there is no difference between the acceptability translucency thresholds (TAT_{00} and TAT_{ab}) and between the perceptibility translucency thresholds (TPT_{00} and TPT_{ab}).

2. Materials and methods

2.1. *Samples and translucency parameter measurements*

Thirty resin composites discs (diameter: 10 mm and thickness: 1 mm) of shade A3 from different commercial brands (Table 1) were fabricated using a 10-mm diameter mold (Smile Line, Switzerland) with adjusted height to 1 mm. The resin composite was inserted into the mold, pressed with a glass slide and light activated (Bluephase Style, Ivoclar-Vivadent, 1100 mW/cm^2) for a total of 40 s (2 × 20 s). Clinically, class III resin-based composite restorations are light activated through a translucent Mylar strip. Therefore, several *in vitro* studies [19–22] use similar procedure, i.e. light activation of resin-based composite specimens through translucent Mylar strip or glass slide to produce a clinically relevant surface finish. It was necessary to overlap two areas of light activation to cover the 10-mm diameter surface of the specimens. All specimens were examined for surface defects under magnification (10×). Specimen thickness was verified using a digital caliper to measure different areas of the specimen.

The spectral reflectance of all specimens was measured against white ($L^* = 94.2$, $a^* = 1.3$ and $b^* = 1.7$) and black ($L^* = 3.1$, $a^* = 0.7$ and $b^* = 2.4$) 50 mm × 50 mm ceramic tile backgrounds (Ceram, Staffordshire, United Kingdom), using a spectroradiometer (SpectraScan PR-670, Photo Research, Chatsworth CA). Specimens were positioned 30 cm away from the spectroradiometer and measured at 45°. A viewing cabinet (Color Viewing Light 4 BASIC, Just Normlicht) with light source simulating the spectral relative irradiance of CIE D65 standard illuminant was employed to provide consistent viewing conditions. Specimens were placed in the center of the viewing cabinet on a 45° tilted base, which corresponds to diffuse/0° illuminating/measuring geometry (Fig. 1). A saturated sucrose solution (refractive index n = 1.5 approximately) was used as coupling media between the specimen and the background [4]. The CIE 1931 2° Standard Colorimetric Observer was used to calculate color coordinates from CIE L*a*b* color system.

Short-term repeated measurements (3/specimen) without replacement were performed on each specimen. Similar to other studies [4,6], a triangular stand was used to support the specimens and avoid specular reflection from the glossy surface.

TP values were determined by calculating the color difference between readings over the black and white background for the same specimen, according to the following CIELAB color difference formula (TP_{ab}) [2].

$$TP_{ab} = [(L*_B - L*_W)^2 + (a*_B - a*_W)^2 + (b*_B - b*_W)^2]^{1/2} \quad (1)$$

where the subscripts "B" and "W" refer to color coordinates over the black and the white backgrounds, respectively.

In addition, CIEDE2000 (1:1:1) color difference formula was also used to calculate the translucency parameter (TP_{00}):

$$TP_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L}\right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C}\right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H}\right)^2 + R_T\left(\frac{C'_B - C'_W}{K_C S_C}\right)\left(\frac{H'_B - H'_W}{K_H S_H}\right)\right]^{1/2} \quad (2)$$

where the subscripts "B" and "W" refer to lightness (L′), chroma (C′) and hue (H′) of the specimens over the black and the white backgrounds, respectively. R_T is the rotation function that accounts for the interaction between chroma and hue