Evaluation of Fluorescence of Dental Composites Using Contrast Ratios to Adjacent Tooth Structure: A Pilot Study

RODRIGO SANT'ANNA AGUIAR DOS REIS, DDS, MSc, PhD*
LUCIANA ASSIRATI CASEMIRO, DDS, MSc, PhD†
GISELA VÂNIA CARLINO, DDS‡
EMERY CLEYTON CABRAL CORREIA LINS, DDS, MSc, PhD§
CRISTINA KURACHI, DDS, MSc, PhD¶
VANDERLEI SALVADOR BAGNATO, DDS, MSc, PhD**
FERNANDA DE CARVALHO PANZERI PIRES-DE-SOUZA, DDS, MSc, PhD††
HEITOR PANZERI, DDS, MSc, PhD‡‡

ABSTRACT

Statement of the Problem: Fluorescence is an optical signal that is present in natural teeth and some dental restorative materials as a consequence of its molecules energetic decrease. Restorative materials need to match the fluorescence properties of surrounding tooth structure to achieve the best esthetics and appear undetectable.

Purpose: The fluorescence of 10 commercial composites (shade A2 or equivalent) was tested against that of tooth structure using contrast differences.

Materials and Methods: Thirty-three standard preparations (3.0-mm wide and 2.00-mm depth) were done on mean maxillaries incisors and divided into 10 groups containing three test samples each. High-definition images of the restored areas and adjacent tooth structure were obtained both under white light of the visible spectrum (control) and ultraviolet light (UV-A = 300/400 nm). The contrast between composites and tooth structure, expressed in absolute values, was analyzed through digital processing Matlab and Origin softwares and by one-way analysis of variance and Tukey's test ($p \leq 0.05$; statistical differences between groups*).

Results: Based on mean values, the composites were ranked in four groups, according to least fluorescence contrast with tooth structure: (Esthet-X [YE] = Esthet-X [A2] = TPH Spectrum [A2]) < (TPH Spectrum [A2] ≤ Esthet × [A20] = Fill Magic [A2]) < (Charisma [A2] = Filtek Supreme [A2B]) < (Filtek Supreme [A2E] = Z250 [A2] = Z100 [A2]).

Conclusion: There is a considerable variation of fluorescence between the composites and the natural tooth structure.

CLINICAL SIGNIFICANCE

Ideal restorative materials should have fluorescence similar to that of natural teeth. Therefore, it is important to select a composite that possesses adequate fluorescence.

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*Professor, School of Dentistry, UNIGRANRIO, Rio de Janeiro, RJ, Brazil
†Professor, School of Dentistry, UNIFRAN, Franca, SP, Brazil
‡Graduate student, School of Dentistry, UNIFRAN, Franca, SP, Brazil
§Post-graduate student, Post-graduate Institute of Physics of Sao Carlos, USP, SP, Brazil
¶Post-graduate student, Post-graduate Institute of Physics of Sao Carlos, USP, SP, Brazil
**Full professor, Post-graduate Institute of Physics of Sao Carlos, USP, SP, Brazil
††Associate Professor, School of Dentistry of Ribeirão Preto, USP, SP, Brazil
‡‡Full Professor, School of Dentistry of Ribeirão Preto, USP, SP, Brazil

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INTRODUCTION

The achievement of esthetic excellence with composite direct restorations constitutes a permanent challenge for dental practitioners. Masking of restorations is dependent on several factors such as environmental light conditions.[1–3] The predominance of ultraviolet (UV) light in the environment can reveal esthetic restorations made with composites with different fluorescence to that presented by the tooth structure. In these conditions, the composite restorations may present themselves as either lighter or darker than the adjacent tooth structure.[4,5]

The fluorescence contributes to the brightness and provides an appearance almost similar to the natural.[4] The fluorescence of tooth and dental materials is dependent on the duration of the UV light exposure[6] that can happen under natural daylight or artificial light such as fluorescent lamps, photographic flashes, or "dark light" from nightclubs.

The basic components of dental composites alone do not promote its fluorescence. This property is achieved through the incorporation of luminescent elements[2] such as europium,[7] cerium, and ytterbium[8,9] (rare earths). According to researchers,[10] the transfer energy of several rare earths mixed together is not equivalent to the sum of its individual fluorescence. Fluorescence very similar to the one of tooth structure was obtained with the elements belonging to groups III, IV, and V in the periodic table. This fluorescence, however, presented as highly dependent to the type of the material to which they are incorporated.[11] Used as a fluorescent illuminant for many years, uranium oxide had its use abandoned because it released radiation. Besides that, its usage resulted in an emission of a yellow-greenish color when the material was under UV light.[10]

To use UV radiation as a source for fluorescence stimulation is interesting because energy dissipation would happen in the visible region of the light spectrum and can present similarities or differences between restorative materials and tooth structure.[2,3,12] The spectral band of fluorescence of natural teeth eventually varies between 410 and 500 nm[8,10] and provides a characteristic whitish blue color when compared to natural teeth.

Recently, manufacturers have claimed that their composites present fluorescence similar to tooth structure. This property would favor the masking of restorations and, consequently, the achievement of unnoticed restorations under UV illumination.

Research hypothesis was that there was no difference in fluorescence between natural teeth and resin composites. The fluorescence of 10 commercial composites (Table 1) was tested against that of normal tooth structure using contrast differences.

MATERIALS AND METHODS

This research project was not supported by a grant or contract. It was reviewed and approved by the Research Ethics Committee of Franca University (199/2005).

Thirty-three intact mean maxillaries incisor with the same clinical shade and that were recently extracted were selected from Franca University's tooth bank. All shade assessments were made under color equal light conditions (5,500°K, working distance—15 inches) by one calibrated examiner using a standard ceramic shade tab A2 (Vita Classic Shade Guide, Vita Zahnfabrik, Bad Säckingen, Germany). The examiner was calibrated to assess the tooth color by performing comparisons between two Vita Shade Guides (one without color identification).

In order to facilitate sample positioning during image acquisition, palatal surfaces were straightened and roots were removed with a double-faced diamond-coated steel

TABLE 1. EVALUATED MATERIALS.

Code	Composite	Manufacturer	Shade	Lot
A	Filtek Supreme	3M ESPE, Sumaré, SP, Brazil	A2E	4AW
B	Filtek Supreme	3M ESPE	A2B	4EA
C	Z100	3M ESPE	A2	1FT
D	Z250	3M ESPE	A2	9BE
E	Charisma	Heraeus-Kulzer, São Paulo, SP, Brazil	A2	010080
F	Fill Magic	Vigodent SA Indústria e Comércio, Rio de Janeiro, RJ, Brazil	A2	20500
G	Esthet X	Dentsply Indústria e Comércio Ltda., Petrópolis, RJ, Brazil	A2	041026
H	Esthet X	Dentsply Indústria e Comércio Ltda.	A20	0311042
I	TPH Spectrum	Dentsply Indústria e Comércio Ltda.	A2	306477
J	Esthet-X	Dentsply Indústria e Comércio Ltda.	YE	040627

disk (KG Sorensen, Sao Paulo, SP, Brazil) under slow speed (N270, Dabi Atlante, Ribeirão Preto, SP, Brazil). The teeth were cleansed by mechanical debridment with periodontal scalers (Duflex, SSWhite, Rio de Janeiro, Brazil), polished for 60 seconds with a dental prophylaxis paste (Odahcam Prophylaxis Paste, Dentsply Ind. E Co. Ltda., Petrópolis, Brazil) and a rubber cup under slow speed (N270, 10,000 rpm), and washed with water. The teeth were stored in a saline solution with 0.1% thymol until the beginning of the experiment. The remaining pulp tissue was not removed from the teeth.

Prior to the cavity preparations, the teeth were sterilized in an autoclave (Sercon Indústria e Comércio de Aparelhos Médico-Hospitalares Ltda., Mogi das Cruzes, SP, Brazil), under a pressure of +2.20 kg/cm^2 and at 134°C for 8 minutes, in order to prevent cross-contamination. Nowadays, when natural teeth are used for "in vitro" research and in the absence of a defined protocol, chemical (disinfecting solutions or ethylene oxide) and physical (UV and gamma radiation, dry heat, and autoclave) methods are employed to avoid cross-contamination. In this study, an autoclave was used instead of chemical solutions because chemical deposits could accumulate over the tooth surface and alter its light transmission[5,13–16] and, consequently, fluorescent behavior. The autoclaving sterilization does not alter the fluorescence of the teeth.

Standard cavity preparations (3.0-mm width × 2.0-mm depth) were done on the labial surfaces of teeth with a round diamond 1016 (KG Sorensen) on a high-speed handpiece (Dabi Atlante) with an air-water coolant. In order to obtain standard preparations, a ring metal matrix (3.0 mm in internal diameter and 2.0 mm in height) was positioned on the labial surfaces of the teeth. A notch mark was made at each diamond bur, 4.0 mm away from its tip, which served as a depth guide (2.0 mm in bur height and 2.0 mm in matrix height) during cavity preparations.

The acid-etching (Dental Gel Conditioner, 37% phosphoric acid, batch 26951237, Dentsply Indústria e Comércio Ltda.) was applied on the enamel (30 seconds) and dentin (15 seconds). Afterward, the preparations were rinsed (15 seconds) and gently dried by air in order to avoid dehydration. A

single-bottle adhesive system (Prime & Bond 2.1, batch 373894, Dentsply) was applied in accordance to manufacturer's instructions and light-cured by an LED unit (light-emitting diode, Dabi Atlante, 530 mW/cm^2). The intensity of the light source (mW/cm^2) was measured periodically by a radiometer (Curing Radiometer Model 100, Demetron Research Corp., Danbury, CT, USA). The restorative composites were applied in three increments (1.0-mm-thick) and light-cured for 20 seconds. Finishing was done with fine-grit diamonds (KG Sorensen). Specimens were dry-polished by the same operator using a micro diamond-coated polymer disk (PoGo, Dentsply Indústria e Comércio, Petrópolis) and a low-speed handpiece (Dabi Atlante) at 4,000 to 5,000 rpm and mild hand pressure for 30 seconds. PoGo produces a surface finish of <1 µm. All specimens were stored in distilled water at 37°C for 24 hours.

Image Acquisition

The process of image acquisition is shown in Figure 1. The teeth were positioned in a dark plastic putty mass (RGB code: R = 23.9, G = 18.75, B = 21.36) in order to assure a black background and a perpendicular angle between the sample and the camera. Two images of restored teeth were done with a charge-coupled device camera (CyberShot DSC S-90, 4.1MP, Sony, New York, NY, USA), using a fluorescent lamp (Dulux S, Osram, Osasco, SP, Brasil) and a UV-A light source (dark lamp, NEL-3U-25W, LC Light, Rio de Janeiro, RJ, Brazil). One optical filter blocked out the UV radiation reflected by the restored tooth so that the formed image contained only the information about both the tooth's and the composite's fluorescence.

Data Analysis

Digital processing (Figure 1) was applied only to the fluorescent image. Once the captured images revealed information on the contrast of the composite with its surrounding environment (tooth), the characteristic of the image histogram (Figure 2) revealed at least two regions of intensities, one being relative to the resin and another relative to the tooth. By this, it was possible to select an intensity threshold in the histogram that separates the two regions.[17]

The mediation of the contrast of two different colors occurs by converting the colored image to the format of intensities (gray scale) and calculating the difference

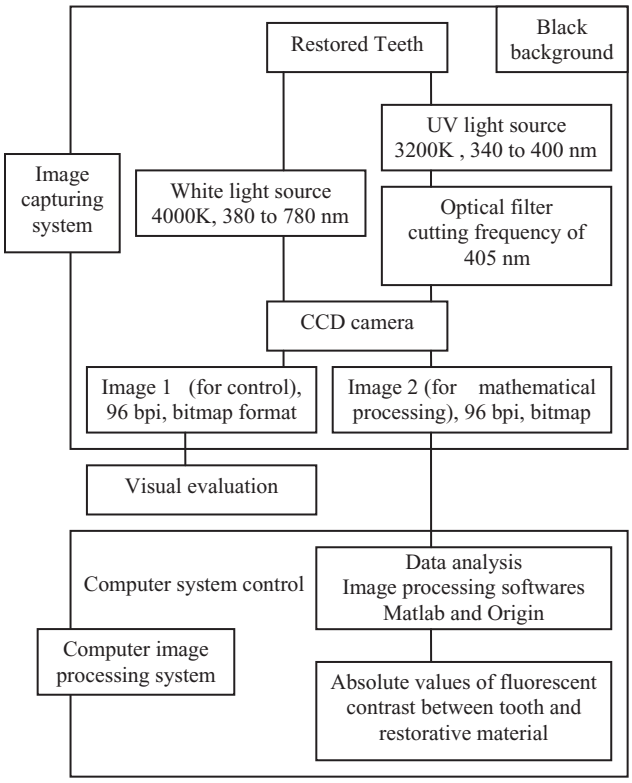


Figure 1. Schematic setup of image acquisition and data analysis.

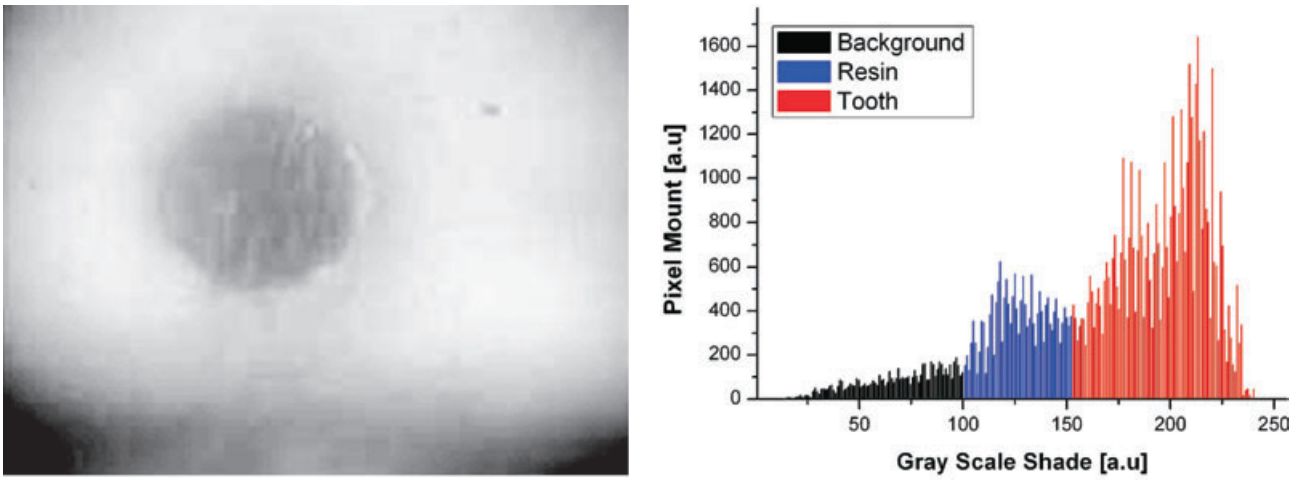


Figure 2. Digital image of a restored tooth in grayscale and its respective histogram.

between the two selected regions. The intensity of a pixel of the colored image was calculated through the following equation:

$$I = 0.299 \cdot V_R + 0.587 \cdot V_G + 0.114 \cdot V_B$$

where V_R, V_G, and V_B are the digital values of the primary colors red, green, and blue that compose the color of the pixel in question.[18]

With the aid of image processing softwares (Matlab, The MathWorks, Natick, MA, USA; Origin, OriginLab, Northampton, MA, USA), the intensities relative to the tooth and to the background were excluded from the image, thus remaining only the composite region. The histogram of this final image showed the intensities that served as the border between the regions.

The average intensity of the composite and tooth region was calculated through the weighted average of each region (number of pixels on each intensity). The contrast was obtained by subtracting the average intensities of the tooth and the composite.

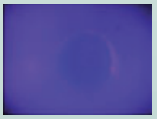
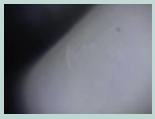
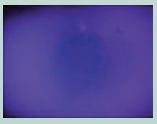
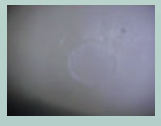
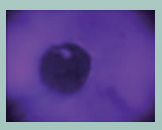
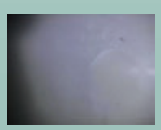
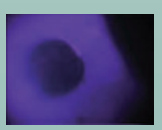
By definition, the contrast between two given colors is the difference of the intensity of the colors. The color identification depends both on the one physical system for color detection (such as a camera or the human visual system) and on the individual physiological sense to understand the color. Therefore, we conclude that the colors and their contrast are dimensionless. Nevertheless, one color can be more or less intense; so the color intensity can be represented by an absolute number in a predefinite scale.

However, the contrast is determined by the difference between the color intensity, it will be an absolute value. Thus, the results obtained were expressed in absolute values. Data were analyzed by one-way analysis of variance and Tukey's test ($p \leq 0.05$).

RESULTS

Mean values and standard deviations of fluorescent contrast, images under white light (control), and images under UV-A light are expressed on Table 2. They are presented in the decreasing order of fluorescence similarity with the tooth structure such as: Esthet-X YE, Esthet X A2, TPH Spectrum A2, Esthet X A20, Fill Magic A2, Charisma A2, Filtek Supreme A2B, Filtek Supreme A2E, Z250 A2, and Z100 A2.

TABLE 2. COMPOSITES, IMAGES OF RESTORED TOOTH UNDER WHITE LIGHT AND FLUORESCENT LIGHT, AND OBTAINED MEAN VALUES AND STANDARD DEVIATIONS FOR FLUORESCENT CONTRAST BETWEEN COMPOSITE AND TOOTH STRUCTURE.

Composite	Light		Contrast
	White	Fluorescent	
Esteth-X YE			0.03 (±0.01) A
Esteth-X A2			0.04 (±0.01) A
TPH Spectrum A2			0.05 (±0.03) A,B
Esteth-X A20			0.06 (±0.01) B
Fill Magic A2			0.07 (±0.01) B
Charisma A2			0.1 (±0.01) C
Filtek Supreme A2B			0.1 (±0.02) C
Filtek Supreme A2E			1.1 (±0.27) D
Z250 A2			1.2 (±0.11) D
Z100 A2			1.5 (±0.11) D

Means with same letters do not differ statistically ($p \leq 0.05$).

DISCUSSION

The evaluation of fluorescence of esthetic dental materials has been the goal of some researchers.[5,8,9,12,15,17] Based on current knowledge about color and its components, and assuming the fact that spectral distribution of either reflected or transmitted light is dependent on the light source, it is necessary to study the behavior of these materials under several sources of illumination, such as UV light. In order to do that, a methodology using a mathematical tool to evaluate the fluorescent contrast between composites and tooth structure was developed and evaluated in this work. In this preliminary research, it analyzed one lot of each material and only the shade A2 or similar; however, it is possible that there could be lot-to-lot and shade variations in terms of fluorescence of composites. Therefore, the investigation of these variable factors is necessary to complement and confirm the results obtained.

According to the methodology employed, which is based on the quantification of the fluorescent difference between restorative composite and tooth structure, it was observed that composites J (0.03 ± 0.01), G (0.04 ± 0.01), I (0.05 ± 0.03), H (0.06 ± 0.01), and F (0.07 ± 0.01) presented similar behavior to the tooth structure when submitted to UV light. Composites

E (0.1 ± 0.01) and B (0.1 ± 0.02) presented an intermediate fluorescent difference when compared to the other materials. The largest differences were observed for materials A (1.1 ± 0.27), D (1.2 ± 0.11), and C (1.5 ± 0.11) (Table 2).

Visually analyzing the images obtained under UV light, if the light emission as function of UV stimulation was not sufficient or not present at all, the restorations presented themselves extremely dark. This was evident for materials A, D, and C, where their fluorescent contrast with natural tooth structure was more pronounced. This condition is undesirable for all esthetic restorative materials.[4,5]

The results obtained allow us to point out that there is a considerable variation of fluorescence between the selected materials and the natural tooth structure. For some, light transmission was remarkably less than that of the tooth structure, resulting in a clear mismatch of the restoration under UV light. One should consider that situations where patients find themselves in places where natural or artificial UV lights are present are not uncommon. In these conditions, the fluorescence property could determine the esthetic success or failure of the dental treatment.

The comparison of the results obtained with that observed in other studies is not possible because the methodologies employed are different. For example, Lee and colleagues[12] determined the fluorescence of the composites by comparing spectral reflectance values based on the inclusion or exclusion of the UV component. In this research, it developed a new methodology based on measuring the contrast between composites and tooth structure through digital processing (Matlab and Origin softwares). Thus, the results cannot be compared directly.

The clinical interpretation of results obtained can be made by associating the results of mathematical analysis (absolute values) and the images obtained under UV light. Thus, we conclude that values lesser than 0.06 are clinically acceptable (the material matches the fluorescence of the surrounding tooth structure) and those higher than 0.06 are unacceptable (the material mismatches the fluorescence of the tooth).

In this work, variable factors such as the application of surface sealants[15] and the accumulation of pigments over the restorations[14–16,19,20] were not considered. However, it is accepted that they can alter the fluorescence of composite resins because they either interfere with the light transmission of the material's surface or absorb the emitted fluorescence.[8] The aging of the material in vitro (150 kJ/m^2) also interferes with this property.[12] On the other hand, the prediction of fluorescence duration through in vitro studies is difficult because oral conditions and hygiene, as well as dietary habits, can vary significantly. Also, fluorescent pigments are dispersed through the entire material and it is very possible that a recontour or repolish procedure may boost fluorescence again. This could be a topic for further studies, as well as the evaluation of variations of fluorescence between the lots and shades, which were not considered in this work.

CONCLUSIONS

Within the limits of the current study design, the order of increasing fluorescence contrast between composites and tooth structure could be clustered into four groups: (Esthet-X [YE] = Esthet-X [A2] = TPH Spectrum [A2]) < (TPH Spectrum [A2] ≤ Esthet × [A20] = Fill Magic [A2]) < (Charisma [A2] = Filtek Supreme [A2B]) < (Filtek Supreme [A2E] = Z250 [A2] = Z100 [A2]) ($p \leq 0.05$)*.

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are included in this article.

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Reprint requests: Luciana Assirati Casemiro, Av Caramuru, 2100 ap.901, Ribeirão Preto, SP, Brasil, CEP 14030-000. Tel.: 55-16-36206716; Fax: 55-16-39173384; e-mail: lucianacasemiro@hotmail.com