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ORIGINAL RESEARCH

Staining Beverages and Cigarette Smoke on Composite Resin and Human Tooth Fluorescence by Direct Spectrometry

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ABSTRACT

Introduction: This study evaluated the fluorescence intensity (FI) of different brands of composite resins (CRs) and compare those values with the FI of human tooth, under the action of cigarette smoke (CI), coffee (CA), and soft drink (CO), measured by direct spectrometry.

Materials and methods: A total of 30 specimens of each brand (Filtek Z350, Esthet-X, Amelogen, Durafill) were made. Others 30 tooth specimens (3 mm/diameter) were obtained from human molars using a trephine bur. The specimens were randomly divided into three groups (n = 10), according to substances: CI, CA, CO. The FI was directly measured using an optic fiber associated with a spectrometer and was measured at baseline and after staining. Data were submitted to Kruskal–Wallis, Dunnett, and Dunn tests.

Results: Staining influenced FI mean values among CRs and between those with human tooth. Z showed the closest FI mean values of tooth after staining.

Conclusion: Staining beverages and cigarette smoke negatively influenced on FI of CR and human tooth.

Clinical significance: The study shows darkening treatments influenced on the fluorescent property of the dental tissues and restorative materials according to the direct spectrometry analysis.

Keywords: Composite resins, Dye, Enamel, Fluorescence.

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INTRODUCTION

The high scientific–technological level of dental materials requires that the dentist has a deep knowledge on the technique to achieve the best results. Regarding direct esthetic materials, the knowledge on color, translucence, opacity, opalescence, and fluorescence is mandatory, as well as the knowledge related to the patient's dietary habits that could influence on these properties. Accordingly, the professional technique, materials' properties, and patients' habits admittedly account for the highest indexes of restoration replacements in dental offices and public services. The replacements result in expensive treatments and reduce the time of tooth maintenance in the mouth.[1,2]

Recently, the optical property of fluorescence is advocated by the manufacturers of composite resins (CRs). Ideally, CRs should have fluorescence similar to natural teeth, to mimic the dental properties.[3] Esthetic quality would be poor, mainly under ultraviolet (UV) light (black light), without this ideal fluorescence. Fluorescence is a photophysical process present in dental tissues. The process occurs through the absorption of a photon followed by the spontaneous emission of the second photon of energy equal to or less than the absorbed photon. For dental tissues, the absorption occurs at UV spectrum and the emission at visible light, ranging from 410 to 500 nm, emitting a bluish-white color.[4-6] This property

is responsible for the white and shinning aspect of teeth when exposed to daylight UV or artificial lights. Dental fluorescence intensity (FI) is attributed to the organic components, such as tryptophan and hydroxypyridine that are photosensitive to the UV spectrum.[7]

Although explored as marketing proposal, previous studies show that fluorescence is one of the optical properties affecting only subtly the visual perception and appearance.[8,9] Fluorescence can be influenced by the diet (food, drinks, and smoke) and oral hygiene habits (mouthrinses).

According to the World Health Organization, about one billion people around world smoke, since adolescence in most cases.[10] This is of great concern because tobacco affects the individual's general and oral health.[11] Smoke contains carbon monoxide, ammonia, nickel, arsenic, tar, and heavy metals, such as cadmium and lead.[11,12] In contact with teeth and the restorative material, smoke can yellow or darken the surface, unfavoring the esthetics.[11,13] Furthermore, tooth and CRs surface may be affected by penetration of dye agents from food and drinks, such as coffee, tea, wine, cola-based soft drinks, and mouthrinses.[14-16] The pigments of these substances have affinity to composite polymeric chains favoring the absorption and adsorption to the restorative material surface.[14,15,17] Moreover, coffee is drunk at high temperatures.[15,18,19] Cola-based soft drinks are consumed more by teenagers and children. Studies report that these drinks have both darkening and corrosive potential, compromising CR properties.[16,20,21]

Thus, this study aimed to evaluate the FI of different brands of CR and compare those values with the FI of human tooth, under the action of cigarette smoke, coffee, and soft drink (coke), measured by direct spectrometry. The null hypothesis was the FI of CRs and human tooth would be equal before and after the staining beverages and cigarette smoke action.

MATERIALS AND METHODS

Specimen Preparation

The following CRs brands were used to compare the FI with those of a human tooth: Microfiller (Durafill VS; Heraeus Kulzer, Heraeus GmbH, Hanau, Germany), nanohybrid (Esthet-X; Dentsply International, York, PA, USA), microhybrid (Amelogen Plus; Ultradent, South Jordan, UT, USA), and nanofiller (Filtek Z350; 3M ESPE, St. Paul, MN, USA). For each CR brand (shade A2), 120 specimens were constructed (n = 30) using a nonstick metal matrix and were standardized at 2 mm in thickness and 4 mm in diameter. A polyester matrix strip was placed over a CR and pressed with a glass slide to provide compact, smooth, and standardized specimens. The glass slide was removed and each specimen was light-cured (LED Light Curing System, Demi Plus, Kerr Corporation, Middleton, USA) at power density of 1,200 mW/cm^2 for 40 seconds.

Thirty sound human molars, extracted for therapeutic reasons, were used for comparison of the FI of enamel and fluorescence level of the CRs. The teeth were obtained according to the protocol submitted and approved by the Local Ethics Committee. The teeth were fixed on acrylic holder (2.5 cm/diameter and 2.0 cm/height) and placed in a universal cutting machine (Labcut 1010, Extec Technologies Inc., Enfield, CT, USA) at low speed, under refrigeration. The teeth were cut at mesial–distal direction to obtain the dental specimen from the buccal and lingual surfaces. The enamel sections were placed in the cutting machine with a trephine diamond bur to obtain round enamel specimens measuring 3 mm in diameter and 1.5 mm in thickness. The specimens were polished in polishing machine (DP-10, Panambra, São Paulo, Brazil), with 1,200 and 4,000 grit aluminum oxide sandpaper (Extec Corp., Enfield, CT, USA), under refrigeration, for 30 seconds on each surface.

All specimens were individually stored in microtubes (Eppendorf) containing artificial saliva[22] at 37°C.

Fluorescence Analysis

To measure the fluorescence, an anodized aluminum matrix was constructed to provide the correct position and alignment of the specimens for detection by fluorescence optical signal, connected to the UBS 4000 Spectrometer (Ocean Optics®, Florida, USA). The matrix's windows enabled the excitation using an UV light-emitting diode light irradiated at 2.8 W with a peak centered at approximately 398 nm on each specimen, without external interferences, assuring the quality of the fluorescence measurements. The values obtained were reproduced in graphs using computer software (Origin 8.0; OriginLab Corporation®, Northampton, USA). The FI values were located in the visible light spectrum between 450 and 700 nm.[23] The initial fluorescence of CRs and tooth specimens was recorded directly on the surface at 24 hours after the polishing. The final fluorescence was recorded after the treatment with dye substances (cigarette smoke, coffee solution, and cola-based soft drink).

Cigarette Smoke Exposure

To expose the specimens to the action of cigarette smoke, a hermetically closed box was constructed to mimic the smoking action inside the mouth, adapted from the study of Mathias et al.[10] The box had two chambers separated by a plate with 10 orifices to put the cigarettes. The first chamber had an air entrance pumped by air compressor, providing constant air steam. The cigarettes were placed and lighted in this first chamber and the air steam enabled

Table 1: Mean ± standard deviation of the fluorescence intensity (AU) for all the groups

Treatments	*Tooth*	*Filtek Z350*	*Amelogen plus*	*Durafill VS*	*Esthet-X*
Baseline	4100 ± 2130	3748 ± 395.1	6042 ± 1110	22871 ± 7696	9768 ± 3161
Cigarette smoke	2599 ± 1946	1168 ± 588	2551.9 ± 256.6	5782 ± 2092	3133 ± 391
Coffee	946 ± 604	983.5 ± 97.1	1348 ± 443	5379 ± 847	2721 ± 434
Soft drink	153.4 ± 45.6	1641.7 ± 242.1	2363.3 ± 286.8	9128 ± 3007	4261 ± 427

the cigarette smoke to reach the second chamber, where the specimens were placed. The second chamber had two orifices with a hose refluxing the cigarette smoke, which provided the maximum contact of the cigarette smoke with the specimens. One single operator performed this experiment properly dressed with personal protective equipment. During the daily exposure, the machine was maintained in a chapel with exhauster turned on to protect against smoke.

During 7 days, the specimens were exposed to the cigarette smoke (Derby, Souza-Cruz, São Paulo, Brazil), for 8 minutes, twice a day, resulting in the consumption of 20 cigarettes or one pack per day.[10] After the daily exposures, the specimens were immersed in artificial saliva at 37°C.

Staining Beverages

Daily, the specimens of each CRs (n = 40) and human tooth (n = 10) were immersed into 20 mL of staining beverages (coffee solution and cola-based soft drink).

The coffee solution was prepared with 3.4 gm of coffee powder (Pilão, São Paulo, Brazil) mixed in 300 mL of boiled water, filtered on paper filter inside the coffee machine. The specimens were immersed into coffee solution, at 37°C, for 7 days, which simulated about 7 months of coffee consumption.[15]

Other specimens of each composites (n = 40) and human tooth (n = 10) were immersed in 20 mL of cola-based soft drink (Coke, Atlanta, GA, USA) at 37°C for 7 days. The cola-based soft drink was changed daily.

Statistical Analysis

Kruskal–Wallis (KW), Dunnett, and Dunn tests were performed at a level of significance of 5%.

RESULTS

Table 1 presents FI mean and standard deviation values of CRs and human tooth. The highest mean occurs at baseline for tooth and CRs. Mainly after immersion in coffee solution, FI means reduced after treatments, which had the smallest FI means.

According to KW test, FI means of all CRs were statistically different for coffee solution (KW = 34.2162; p = 0.00001, <0.05), cola-based soft drink (KW = 27.3569; p = 0.00001, <0.05), and cigarette smoke (KW = 26.0885; p = 0.00001, <0.05).

According to Dunnett test (Table 2) that compared the FI means between tooth and CR, the CR Filtek Z350 did not show statistically significant differences (p > 0.05). The means of FI in the composite Amelogen Plus exhibited significant differences compared to tooth only for cola-based soft drink (p < 0.05). Esthet-X FI means were significant compared to those of tooth after coffee and cola-based drink (p < 0.05). Durafill VS FI means were statistically different compared to those of tooth for all treatments.

The result of Dunn test (5%) showed that all treatments were statistically significant for all CR brands. Filtek Z350 had the smallest FI when compared to those of Durafill VS and Esthet-X. Esthet-X showed intermediate FI mean between that of Durafill VS and Amelogen Plus; Amelogen Plus had intermediate FI mean between that of Esthet-X and Filtek Z350 (Table 3).

DISCUSSION

The fluorescence is an optical property inherent to dental tissues. Aiming for excellence in restorative procedures,

Table 2: Results of Dunnett test (5%) to compare the fluorescence intensity between tooth and CRs

Treatments	*Tooth × Filtek Z350*	*Tooth × Amelogen Plus*	*Tooth × Esthet-X*	*Tooth × Durafill VS*
Cigarette smoke	11.00	−1.533	−10.80	−19.40*
Coffee	−1.178	−9.978	−22.56*	−32.28*
Soft drink	−11.30	−20.70*	−30.50*	−36.10*

*Significant differences (p < 0.05)

Table 3: Results of Dunn test (5%) for the fluorescence intensity of CRs

	Cigarette smoke				*Coffee*				*Soft drink*			
CRs	*Mean*	*Homogeneous groups**			*Mean*	*Homogeneous groups**			*Mean*	*Homogeneous groups**		
Durafill VS	31.70	I			34.50	I			31.60	I		
Esthet-X	24.60	I	II		24.88	I	II		26.00	I	II	
Amelogen Plus	16.30		II	III	14.70		II	III	16.20		II	III
Filtek Z350	7.00			III	6.40			III	6.80			III

*Different letters in row mean significant differences among groups (p < 0.05)

composites' manufacturers have introduced fluorophores agents in composites as a way to give this property to the materials. The closer the FI values are of those of the dental tissues and restorative materials, the greater will be the degree of reproducibility of the tooth esthetic characteristics.[7,8]

Efforts are made toward understanding the fluorescence property by analyzing tooth structure and CRs. It is known that the FI of the dentin is greater than enamel and is linked to the presence of amino acids, such as tryptophan and hydroxypyridine in its composition.[7,24] Still, literature reports the greater the age of the tooth or the heat application on the surface, the greater will be the intensity emitted.[24]

However, little is known about the fluorophore agents present in the CRs, because it is a trade secret.[23,24] There is no fluorescence pattern to be followed, comparatively to which happen with the color scales. Most manufacturers follow the VITA color scale (A, B, C, and D). However, which fluorescence scale do the manufacturers follow? It seems that CRs are more or less fluorescent according to different manufacturers,[7,8] corroborating the results of this study. Moreover, FI seems to be not related to shade or the characteristics of the resin particles.[8]

One reason for the lack of knowledge on fluorescence is the fact that its measure is not as simple as color-making, performed through using standard color scales and visual method. In general, the fluorescence measurements are made in the laboratory by indirect methods, using spectrofluorometers and bench spectrophotometers from different brands,[7,25] making difficult the study results comparison among FI means and clinical conditions. The current study employed the optical fiber spectrometer, which is another manner to record the fluorescence values directly obtained from the specimens, and compatible with the clinical use. The optical fiber spectrometer enables the direct position over the tooth, contributing for the best esthetics results of restorations.[23]

In addition, there are reports in the literature that the surface and subsurface layer of a stratified restoration in different types of CRs would present different FI.[23] To avoid this bias, the fluorescence of the CRs was evaluated in this study using a standard shade – A2, specified as enamel composites to compare with the tooth substrate. The action of cigarette smoke and staining beverages promoted differences of FI among different CRs and that of tooth, rejecting the null hypothesis of this study.

The results showed that the CR Filtek Z350 obtained FI means closest to those of tooth, corroborating previous studies.[8,23] Esthet-X, Amelogen Plus, and Durafill VS showed higher intensity values than those of tooth, as observed by da Silva et al.[23] It may be related to differences in fluorophore within the composition of each CR, trade secret not disclosed by the manufacturers. The differences in fluorescence values could be related to the difference in type of particles as well as resin matrix. These types of CR had the same polymer matrix composition (bisphenol A glycidyl methacrylate), but the amount and type of particles are different. The variability of FI among CR brands certainly compromises the esthetic result and predictability.

Furthermore, it could be seen that daily habits as the use of tobacco, coffee intake, and cola-based drink can directly interfere the FI emitted for restorative materials and dental tissue. Similar as observed by previous study,[26] the fluorescence of CRs was not maintained after aging, reducing significantly the intensity values.

Cigarette smoking has been explored in some studies of optical changes of teeth or restorative materials, despite the large number of smokers worldwide. The tar, the main component responsible for the coloring of dental tissue, is deposited on surface and penetrates into the cracks of interface promoted by hydrolytic degradation and, simultaneously, deposits on the restoration, causing staining. This study proves this change capacity provided by the cigarette, evidenced by the significant FI difference of materials and tooth. The exposure to smoke cigarette promoted the reduction of 36% in FI value of tooth; 68% in FI value of Filtek Z350; 57% in FI value of Amelogen Plus; 74% in FI value of Durafill VS; and 67% in FI value of Esthet-X. As seen in Table 2, Durafill VS microhybrid resin showed the greatest significant differences compared to human tooth after cigarette exposure. Notwithstanding, it is worth noting that this study found some materials that showed the same result of dental structure (Filtek Z350), while other CRs did not (Amelogen Plus, Esthet-X, Durafill VS).

According to previous studies,[11,27] exposure to cigarette decreases the luminosity and increases the composite staining, when tested alone. However, when tested together with another staining substance, e.g., coffee, the tendency toward staining increases. Accordingly, the cigarette smoke showed the smallest FI reduction in this study compared to coffee solution. Considering clinical condition in which smoking is associated with coffee ingestion, probably the FI of CRs would be more altered, regarding the sum of habit effects.

At high temperatures, coffee also leads to significant changes in certain properties of the CR.[28] However, when we analyzed only the temperature, a study showed that FI increased after application of heat (37–50°C), but remained unchanged at 4°C. The authors suggested the increase is partially connected to a physical–chemical mechanism that depends on temperature.[24] In the same way, our study demonstrated the potential of tobacco and coffee adsorption into tooth and CR surfaces, reducing fluorescence intensities.

Similar to observed in color analysis studies, the results of this study showed that coffee also had a negative influence on the FI of different composites and dental tissue. After coffee immersion, FI reduced 77% in average for tooth, 74% for Filtek Z350, 77% for Amelogen Plus, 76.5% for Durafill VS, and 72% for Esthet-X. The regions visibly staining occurred in the surface areas where it may have been a greater loss of resinous matrix. This probably occurred due to substances with high polarity contained into drink that penetrates easily in the organic phase of the material.[29]

Furthermore, this study demonstrated that the effect of cola-based soft drink on the fluorescence was relatively lower than coffee and cigarette smoke. According to previous studies, cola-based drink produces no color change.[16] As the optical property of the color, in this study, no significant change in the fluorescent property of CRs occurred. However, in relation to dental structure, coke reduced 96% of FI, decreasing the initial FI emission from 4100 to 153.4 AU after immersion. Along with color potential, coke had the erosive effect on dental enamel.[21] The pH of the solution could have influenced on degrading the enamel, therefore, affecting the fluorescence emission.

Deep comparisons of the results with those of the literature were limited because the study on fluorescence by direct spectroscopy is innovative and only observed by our group.[23] Many of the studies related to staining evaluated only the color. The direct measuring method of FI on restorative materials and tooth substrate is promising. However, further studies using direct spectrometry are necessary to increase the knowledge on the dental materials and tissues fluorescence similar to color analysis.

CONCLUSION

Within the limitations of this study, it can be concluded that: (1) FI of CRs showed statistically significant difference among themselves and between those with human tooth, except Z350XT that showed the closest FI values to dental enamel; (2) cigarette smoke and staining beverages negatively influenced on FI of CRs and human tooth.

CLINICAL SIGNIFICANCE

The study shows darkening treatments influenced on the fluorescent property of the dental tissues and restorative materials according to the direct spectrometry analysis.

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