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Bleaching and enamel surface interactions resulting from the use of highly-concentrated bleaching gels

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ABSTRACT

Tooth bleaching is considered a non-invasive treatment, although the use of highly-concentrated products may provoke increased surface roughness and enamel demineralization, as well as postoperative sensitivity. Thus, the aim of this study was to investigate whether hydrogen peroxide (H_2O_2) concentration would affect tooth bleaching effectiveness and the enamel surface properties. Enamel/dentin bovine specimens (6 × 4 mm) were immersed in coffee solution for 7 days and evaluated with a spectrophotometer (Easyshade; baseline), using the CIE$L^*a^*b^*$ color parameters. Hardness was measured using a hardness tester. The specimens were randomly assigned into four groups: one negative control, in which the specimens were not bleached, but they were irradiated with a laser-light source (Whitening Lase II, DMC Equipments); and three groups using distinct H_2O_2 concentration, namely LP15% (15% Lase Peroxide Lite), LP25% (25% Lase Peroxide Sensy), and LP35% (35% Lase Peroxide Sensy), all products from DMC. The bleached specimens were also irradiated with the laser-light source. After bleaching, all specimens were evaluated using scanning electron microscopy (SEM). pH kinetics and rate was monitored during bleaching. The data were analyzed using ANOVA and Tukey's test ($p < 0.05$). All bleaching gels produced similar color change ($p > 0.05$). Concerning hardness, only the LP25% and LP35% significantly reduced hardness after bleaching; also, there was a progressive tendency for a greater percentage reduction in hardness with increased H_2O_2 concentration of the gel ($R^2 = 0.9973$, $p < 0.001$). SEM showed that LP25% and LP35% produced an etching pattern on enamel with prism rods exposure. In conclusion, H_2O_2 concentration above the 15% level does not increase bleaching effectiveness, and may increase the possibility for alteration of enamel hardness, surface morphology, and acidity of the medium. When using H_2O_2-based bleaching agents, dental practitioners should choose for less concentrated gels, e.g., around the 15% level.

1. Introduction

Dental bleaching is a worldwide treatment with predictive aesthetic results. There are several products available for use, which may be applied in-office by the professional (i.e., the more concentrated products) or at home by the patient itself (i.e., the less concentrated products) with or without professional' supervision (Demarco, Meireles, & Masotti, 2009). Concerning the in-office products, they are commonly comprised of different peroxide concentration that varies from 5 to 40% of hydrogen peroxide (H_2O_2) or carbamide peroxide. The foregoing materials have demonstrated efficacy and patient acceptability overtime (Buchalla & Attin, 2007; Meireles, Fontes, Coimbra, Della Bona, & Demarco, 2012).

Even though tooth bleaching is considered a non-invasive treatment, peroxide molecules act by changing chemical structure of organic substances adhered to the enamel surface or those found within the bulk of dental substrates, thereby compromising tooth morphology and structure (Kwon & Wertz, 2015). Indeed, this assumption was revealed to be dependent on peroxide concentration (Azrak, Callaway, Kurth, & Willershausen, 2010; Goldberg, Grootveld, & Lynch, 2010). Worth mentioning, negative side-effects have been demonstrated elsewhere, such as enamel surface alteration (Azrak et al., 2010), surface roughness increase and tooth demineralization (Bolay, Cakir, & Gurgan, 2012), and reduction of fatigue resistance and flexural strength of dentin (Tam, Cho, Wang, & De Souza, 2015). Furthermore, postoperative sensitivity is a frequent adverse effect that occurs post-

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bleaching (Almeida, Riehl, Santos, Sundfeld, & Briso, 2012; He, Shao, Tan, Xu, & Li, 2012; Reis, Dalanhol, Cunha, Kossatz, & Loguercio, 2011), probably in response to the penetration of hydrogen peroxide molecules through enamel and dentin, which may lead to hypersensitivity and/or pulp inflammatory reactions (Benetti et al., 2017). The greater the H_2O_2 concentration, the greater the probability of hydrogen molecules penetrating through enamel and dentin (D'Arce et al., 2013).

Despite all of the aforementioned, bleaching agents may also vary with the pH of the product, which would produce different surface damage to enamel during bleaching treatment (Azrak et al., 2010). There are controversial findings about the effect of peroxide concentration on bleaching effectiveness (D'Arce et al., 2013; Dey et al., 2016; Kwon & Wertz, 2015; Sun et al., 2011). Notwithstanding, most of studies have compared different products and from different manufacturers among each other, so that it may be difficult to confirm about the true effect that bleaching agents with varying peroxide concentration and pH may produce on dental substrates. Hence, the aim of this study was to investigate whether peroxide concentration would affect tooth bleaching effectiveness and the enamel surface properties. Here, bleaching agents with similar composition and from the same manufacturer were used, differing only regarding to their peroxide concentration. Three null-hypotheses were tested: (i) the bleaching effect does not increase with concentration of H_2O_2; (ii) H_2O_2 concentration does not influence the pH of the bleaching agent; and (iii) H_2O_2 concentration does not affect the enamel surface properties.

2. Materials and methods

2.1. Sample preparation

Bovine incisors were obtained, cleaned and stored in a 0.5% aqueous solution of Chloramine T for one week. From their buccal surface, enamel/dentin disc-shaped specimens (6 mm in diameter × 4 mm in thickness) were obtained using a table drilling machine (FB13 Somar, Schulz S/A, Joinville, SC, Brazil) and polished using SiC abrasive papers (#600-, #1200-, and #1500-grit) in order to standardize the enamel surface. All specimens were immersed in a standardized coffee solution [12 g of coffee (Melitta, Avaré, SP, Brazil) boiled in 200 mL of distilled water for 5 min followed by filtering in a coffee maker (Melitta)], which was renewed daily during 7 days (Meireles et al., 2012); next, specimens were washed and stored in distilled water at room temperature.

2.2. Initial color and hardness measurements

For color analysis, all specimens were measured with a digital spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen, Germany) and using the CIE$L^*a^*b^*$ color system (International Commission on Illumination) (L'Eclairage, 1978), where the L^* axis indicates the value (lightness or darkness), the a^* axis represents the redness ($+a^*$) or the greenness ($-a^*$), and the b^* axis demonstrates the yellowness ($+b^*$) or the blueness ($-b^*$).

For hardness evaluation, each specimen was measured using a microhardness tester (FM 700, Future Tech, Chung Ho, Taipei Hsien, Taiwan) in an attempt to determine its initial surface Knoop Hardness Number (KHN_0). A load of 50 g was applied during 10 s (Ren, Amin, & Malmstrom, 2009), and three indentations were made across the center of each specimen. The KHN is the ratio of the load applied to the indenter to the unrecovered projected area.

2.3. Bleaching procedure and group's allocation

The specimens were randomly allocated into four groups (n = 8): one negative control, in which the specimens were not bleached, but they were irradiated with a laser-light source (Whitening Lase II; DMC Equipments, São Carlos, SP, Brazil); and three bleached groups using distinct H_2O_2 concentration, namely LP15% (15% Lase Peroxide Lite), LP25% (25% Lase Peroxide Sensy), and LP35% (35% Lase Peroxide Sensy). All bleaching products were purchased from DMC and applied according to the manufacturer directions of use (Table 1).

Table 1
Manufacturer information, lot number, and directions of application of the hydrogen peroxide agents used in the study.

Material	LP15%	LP25%	LP35%
Manufacturer	DMC Equipments, São Carlos, SP, Brazil		
Lot number	10155	10428	40113
Directions of application	*Gel preparation*	Mix 3 drops of peroxide (phase 1) for every drop of thickener (phase 2) with the aid of a spatula.	
	Gel application	Apply the gel from 1 mm to 2 mm of thickness using a spatula or syringe.	
	Gel irradiation	Irradiate with Whitening Lase II for 1 min; let the gel to rest for 3 min, repeating the irradiation and resting procedures twice more.	
	Gel removal	After 10–15 min of application, remove the gel with the aspirator tip and clean the surface with some gauze.	
	Repeat the previous procedures for up to twice more, depending on the result obtained.		

LP: Lase Peroxide.

2.4. pH kinetic of bleaching gels

Each bleaching agent was prepared according to the manufacturer directions (Table 1) and applied over enamel/dentin specimens (n = 3), which were prepared as aforementioned. Next, the electrode of a pHmeter (PM608, Analion, Ribeirão Preto, SP, Brazil) was placed in contact with the surface of the gel-covered specimen and the pH of each gel was monitored, minute-by-minute, during 15 min since its mixture. The same irradiation protocol used during the bleaching procedure was also performed, corresponding to 1 min of light application at the 4th, 8th, and 12th minutes of application. Data were plotted using a Data Analysis and Graphing Software (OriginPro 8 SRO, OriginLab Corporation, Northampton, MA, USA) and curve fitting was performed by Hill 1 parameter non-linear regression. Using these data, the rate of pH alteration (per minute) was calculated as the pH value at time t subtracted of pH value at time $t + 1$ (according to a similar previous kinetic study) (Munchow et al., 2013).

2.5. Final color and hardness measurements

After bleaching, all specimens were measured with the Easyshade as previously described. The alteration of color (ΔE^*) was calculated as: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ (L'Eclairage, 1978), where ΔL^*, Δa^*, and Δb^* are the difference between the final and initial L^*, a^*, and b^* color parameters, respectively. After color measurement, the final Knoop Hardness Number (KHN_1) of each specimen was measured as aforementioned. The alteration of hardness (ΔKHN) was calculated as follows: $\Delta KHN = KHN_0 – KHN_1$.

2.6. Scanning electron microscopy (SEM) analysis

For enamel morphology analysis, four specimens were selected for SEM evaluation: three bleached specimens (i.e., one per each gel used – LP15%, LP25%, and LP35%), and one as control, where no bleaching gel was applied. Immediately after gel application (for 45 min, in total), the specimens were dried for 15 s with air-stream and blotted dry for 30 min at 37 °C. They were then sputter-coated with gold/palladium and morphologically evaluated using a scanning electron microscope (SSX-550, Shimadzu, Tokyo, Japan).

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