Effect of Light Irradiation on Tooth Whitening: Enamel Microhardness and Color Change

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ABSTRACT

The aim of this study was to evaluate the influence of light exposure associated with 35% hydrogen peroxide (Pola Office, SDI, Melbourne, Vic., Australia) or 15% hydrogen peroxide (BriteSmile, Discus, Culver City, CA, USA) on the microhardness and color changes of bovine enamel. Experimental groups were Britesmile + Light (BL) (15% hydrogen peroxide + plasm arc; 4 × 20 minutes), Britesmile + No Light (BN) (BL, no light), Pola office + Light (PL) (35% hydrogen peroxide + LED; 4 × 8 minutes), and Pola office + No light (PN) (PL, no light). Color changes (ΔE) and the CIELAB (Commission Internationale de l' Eclairage, L^* a^* b^* color system) parameters (L^*, a^*, and b^*) were assessed with a spectrophotometer before (B), immediately (A), 1 day and 7 days after bleaching. The microhardness was measured before (B) and after (A), the obtained data were submitted to a two-way analysis of variance, and ΔE were submitted to *t*-test for each period. Only Pola Office, in which the peroxide is associated with the light, improved ΔE when evaluated immediately after bleaching ($p < 0.001$). Light exposure did not influence ΔE after 1 day or 7 days for either bleaching system. The enamel microhardness was not altered after bleaching for BriteSmile. However, enamel microhardness was reduced after bleaching for Pola Office, 283 MPa (±21) and 265 MPa (±27), respectively. It was concluded that these two bleaching systems were efficient regardless of the light systems used. However, the 35% hydrogen peroxide altered the enamel microhardness.

CLINICAL SIGNIFICANCE

Enamel microhardness was affected by a 35% hydrogen peroxide in-office bleaching therapy. Moreover, the in-office bleaching outcome was not improved by using the light associated with systems tested in this study.

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INTRODUCTION

Bleaching techniques have been widely used and modified to satisfy patient expectations of less time with minimal damage to dental structures. The tooth discoloration can be classified in two major groups: extrinsic (tea, coffee, cigarette smoking, and foods with artificial pigments) and intrinsic caused by staining (fluorosis, tetracycline, tooth development malformations, hematologic disorders).[1,2] Intrinsic staining is self-made or incorporated by the organism, such as hemosiderin, iron, bilirubin, and some tetracycline salts.[2] Overall, extrinsic staining from the environment is related to high molecular weight organic compounds, structured by complex carbon chains with double bonds, most with heteroatoms and so-called carbonyl and phenyl rings (chromophores).[2] The breakdown of chromophore bonds occurs as one or more double bonds into the conjugated chain are destroyed by cleavage of the conjugated chain or oxidation of other chemical moieties in this chain using the hydrogen peroxide,[3] which macroscopically results in tooth bleaching.

On the other hand, bleaching agents are composed by hydrogen peroxide and its precursor, the carbamide peroxide, in which the final degradation products on tooth surface are oxidizing radicals (HO_2^-, H* + *OOH, 2 *OH, etc.) that act in chromophore breakdown. The efficacy of bleaching treatment depends on the product concentration, contact time with the exposed substrate, the nature of its oxygenlike free radicals, the releasing rate, its diffusion through the dental hard tissues, and the capacity to react with the chromophore molecule as well as how much time they contact these staining substances.[4]

The bleaching efficacy is commonly evaluated by the comparison with a tooth shade guide. Because of drawbacks on color evaluation experienced, even by the most trained individuals, an alternative method represents the spectrophotometer. The use of this equipment can reduce the subjective nature and environmental influence on the color perception.[5] Some devices use the CIELAB system (Commission Internationale de l' Eclairage, L^* a^* b^* color system). Color values in this system are graphically depicted by three spatial coordinates, where L^*, b^*, and a^* positive values indicate an increase on lightness, yellowness, and redness, respectively. For bleached teeth, there is an increase on L^* values, with a subsequent reduction on b^* values, whereas a^* values have a minimal influence in this process.[6]

Effects of bleaching agents on microhardness and dental morphology have been studied by several authors.[7–10] After bleaching, slight micromorphological alterations of the enamel composition can be observed by using scanning electron microscope analysis.[8,10] Although those alterations are not clinically observed, several laboratory studies have highlighted this issue, particularly when high peroxide concentrations and longer exposure times are used.[8,10–13] On the other hand, some studies indicate that mineral surface loss because of bleaching agents that could probably reduce microhardness is similar to that seen during common habits.[14,15] Grobler, Senekal, and Laubscher evidenced that consumption of soft drinks and fruit juices for few minutes can rapidly dissolve minerals on the enamel substrate as much as an immersion of teeth on bleaching agents for several hours.[16]

Since the beginning of the 20th century, the light is used to promote a sudden temperature rising on the hydrogen peroxide, accelerating the chemical bleaching process.[11,17] The use of a hot spatula or an extraoral heated bleaching was common in the past. Nowadays, to reduce the treatment time, clinicians have been trying to catalyze or accelerate the peroxide decomposition velocity by means of different light source associations (halogen lamps, plasma arc, light emitting diode [LED], laser or

the so-called hybrid sources) with several irradiances and emission spectra.[18] This has been speculated that the light source can energize the tooth stain to aid the overall acceleration of the bleaching process.[19,20] Concerns on the intrapulpal temperature rising because of the association between the light and bleaching agents are of utmost importance because excessive heating can cause irreversible damage to this tissue.[17,20]

Several controversies exist on the effectiveness of bleaching agents associated with available light sources. In this way, the purpose of this in vitro study was to evaluate the influence of different light sources on in-office bleaching agents regarding color changes (ΔE) and the microhardness of the bovine enamel tissue through defined time periods. The null hypothesis was that the bleaching material and the light source have no influence on ΔE after 7 days and cannot reduce the enamel microhardness.

MATERIALS AND METHODS

Specimen Preparation

A total of 36 intact bovine teeth were stored in distilled water at room temperature prior to the testing. All teeth were cut at the cemento–enamel junction, and the roots were discarded. Two parallel and two perpendicular sections were made with a diamond saw (Labcut 101, Extec Corp, Enfield, CT, USA) at a distance of 7 mm to remove the central portion of each tooth. Buccal surfaces were ground by using SiC grinding papers of 600-, 800-, 1,200-, 1,500-, 2,000-, and 4,000-grits (Buehler, Lake Bluff, IL, USA) for 60 seconds each disk with water irrigation. Teeth were randomly divided in four groups, according to the technique and the proposed materials listed on Table 1.

For the BL group (Britesmile + Light), specimens were set in PVC (polyvinyl chloride) rings similar to a dental arch configuration in order to receive the same

TABLE 1. EXPERIMENTAL GROUPS AND BLEACHING TECHNIQUES USED IN THIS STUDY.

Groups	Bleaching agent	Light source	Technique	Manufacturer
BL	15% hydrogen peroxide	Plasm arc, Irradiance: 130–160 mW/cm^2, λ = 380–520 ηm	Apply bleaching agent and change solution every 20 minutes; perform 4 sessions of 20 minutes under light exposure during application intervals as recommended by the manufacturer	(Discus, Culver City, CA, USA)
BN	15% hydrogen peroxide	No light	Similar to BL, no light exposure	
PL	35% hydrogen peroxide	LED Irradiance: 1500 mW/cm^2 λ = 440–480 ηm	Apply bleaching gel in 4 sessions of 8 minutes each; Expose gel to the light source for 3 minutes in each session	(Pola Office, SDI, Melbourne, Australia)
PN	35% hydrogen peroxide	No light	Similar to PL, no light exposure	

BL—Britesmile + Light; BN—Britesmile + No light; PL—Pola office + Light; PN—Pola Office + No light.

TABLE 2. MEANS AND SD OF KNOOP HARDNESS CONSIDERING HYDROGEN PEROXIDE CONCENTRATION, LIGHT EXPOSURE AND EVALUATION PERIOD.

Main factors	KHN mean (SD)	
	BriteSmile (Discus, Culver City, CA, USA)	Pola (SDI, Melbourne, Australia)
Light exposure		
Yes	277 (±39)*	272 (±61)*
No	279 (±6)*	275 (±26)*
Period		
Before	269 (±21)*	283 (±21)[a]
After	288 (±44)*	265 (±27)[b]

Different letters represent statistically different means.
*n.s.
SD = standard deviation.

irradiance. This procedure was not necessary in the PL group (Pola Office + Light), in which the light exposure occurs individually for each tooth.

Knoop Microhardness

Microhardness tests were performed immediately and after bleaching procedures. Five indentations with a 300 µm distance apart were made on the enamel surface with a 200 g load for 15 seconds,[21] by using a microhardness tester (HMV-2T, Shimadzu, Kyoto, Japan). Specimens were stored in distilled water at 37°C prior to testing. Two-way analysis of variance (ANOVA) tests were used to statistically analyze the data ($p < 0.05$) for each bleaching agent. Statistical analysis was performed by using the GMC software, version 7.4 (Ribeirao Preto, SP, Brazil).

Color Changes

Color changes (ΔE) were measured at four time periods: before the bleaching (B), immediately (A), 1 day (1d) after bleaching, and 7 days (7d) after bleaching. Color evaluation was made with a spectrophotometer Vita EasyShade (Vident, Brea, CA, USA). Three measurements were taken at the central portion of each specimen. The CIELAB L^* and b^* parameters were used to compare all data.

An ethylene vinyl acetate mold was fabricated for the present study, with an aperture by using a vacuum-forming device to fit the buccal surface of each specimen. The acetate molds held the probe of the color analyzer perpendicular to the same surface of the tooth so that repeated color measurements could be obtained.

The *t*-test was performed to assess differences in color changes (ΔE) between BL, PL and BN, PN at each evaluation period to identify statistically significant differences at a level of 5%. A two-way ANOVA was performed to detect possible differences between periods.

RESULTS

Knoop Microhardness Test

No significant differences were verified among the main factors light exposure and evaluation periods interactions for BriteSmile (Discus, Culver City, CA, USA). The enamel microhardness was not altered before and after bleaching for BriteSmile. However, enamel microhardness was lower after bleaching for Pola Office (SDI, Melbourne, Vic., Australia), 283 MPa (±21) and 265 MPa (±27), respectively. The means and standard deviations are shown in Table 2.

Color Changes (ΔE)

The two-way ANOVA analysis for each bleaching agent showed no difference for the main factor period. The *t*-test for each period showed that the light exposure did not influence ΔE immediately, 1 day, and 7 days after using both bleaching systems, except immediately for Pola Office ($p < 0.001$).

Figure 1 shows the *t*-test evaluation for each period with and without

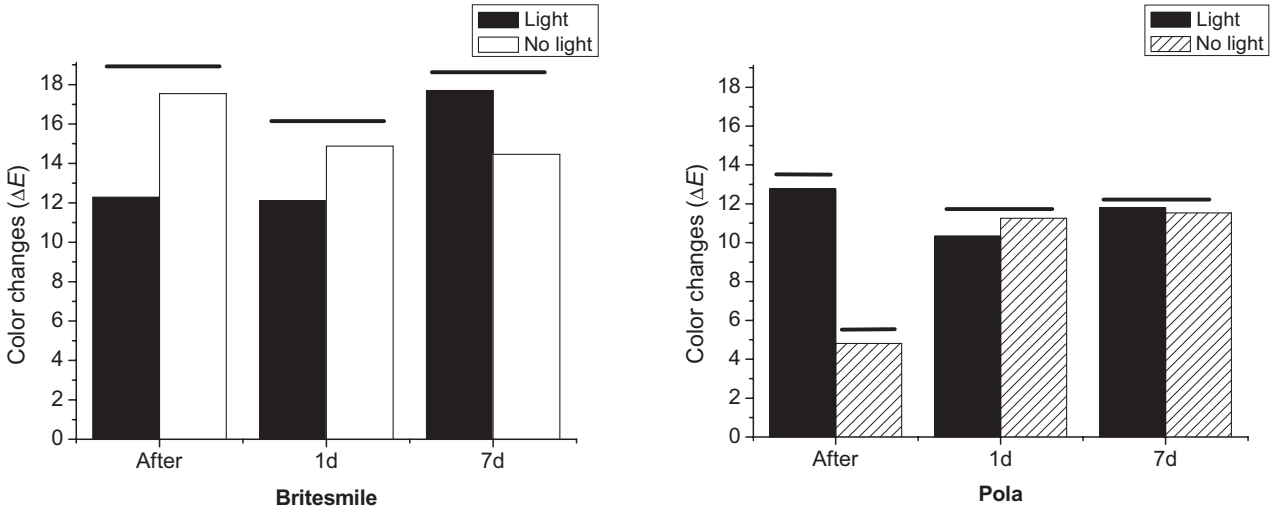

Figure 1. Mean color change (ΔE) through different periods. Different letters represent statistically significant values ($p < 0.05$).

the light exposure for each bleaching system.

DISCUSSION

Results from laboratorial findings cannot be extrapolated to the clinical practice without judicious statement but they are of a great importance to understand the mechanisms behind the clinical process. In this work, although the authors used a bovine enamel and dentin fragments, results were not in agreement with the data from studies that advocated the use of light sources to obtain better results during dental bleaching.[19,22–24]

Human and bovine enamels are very similar.[25] Even thus, the bovine enamel appears to be more susceptible to caries than the human one.[26] This information suggests that the effects of in-office whitening on human enamel would be even more negligible. There is a high ΔE on extracted bovine teeth because of the lack of a dentinal fluid, which provides more permeability to the bleaching agent.[27] Moreover, the bovine enamel was not stored in saliva or any saline solution prior to the microhardness test or after bleaching, which means that no enamel remineralization minimized the effects of bleaching agents.[28–30]

Microhardness Test

The use of 35% hydrogen peroxide bleaching agents modifies the microhardness of the bovine enamel only for the highest concentration regarding the use of the light.

The enamel microhardness is related to its mineral content.[31] There is some controversy on peroxide concentration and the time used to promote substantial alterations on enamel tissue. Some authors related minor changes on the enamel morphology and its composition when they observed it using SEM (scanning electron microscopy), AFM (atomic force microscope), or spectroscopic analysis.[31] The study performed by Ruse et al. with the X-ray photoelectron spectroscopic and the secondary ion-mass spectroscopic did not find any alteration on the enamel composition after 35% peroxide bleaching for 60 minutes.[32] However, the FTIR (Fourier Transform Infrared Spectroscopy) investigation performed by Bistey et al. reported superficial alterations on

the hydroxyapatite and the carbonate apatite of human enamel bleached with 10, 20, and 30% hydrogen peroxide solutions. A possible hypothesis would be the replacement of CO_3 by OH^- ions from the hydrogen peroxide, but its weak interactions would be reversed by a fluoride application. Another explanation is that the hydrogen peroxide can form H_4O_4, a substance that can alter the enamel apatite, replacing the PO_4 molecule, generating a new complex.[33]

In this work, the longest exposure time of the bovine enamel using 15% hydrogen peroxide was 80 minutes under a pH value of 6.5.[6] The long-time exposure and the low concentration of hydrogen peroxide may not have been enough to reduce the microhardness. The hypothesis that the association of the light with the bleaching agent would reduce the microhardness was rejected in this study.

Color Changes

In this study, color changes (ΔE) were verified immediately (A), 1 day, and 7 days after bleaching. Color evaluation immediately after bleaching must be carried out with caution. Some studies have shown considerable effect of the bleaching gel with light exposure linked to the dehydration just after light exposure, which is observed even without a bleaching gel in the process.[22,34] Because of alterations over time, color must be checked when water uptake is completed.[35] These findings support our study results, showing that the greatest ΔE were seen 7 days after bleaching.

A possible disadvantage in this study is related to the short period of time (7 days) to show the stabilization of bleaching treatment. It was not possible to determine when color stabilization occurred because of the lack of a long-term follow-up protocol. There is no consensus about the color stabilization after tooth bleaching procedures. Haywood and Leonard verified the color stabilization after 2 weeks,[36] Zekonis et al. after 6 weeks,[37] and Rosenstiel et al. verified after 6 to 9 weeks.[35] Some authors considered that in-office bleaching cannot be sustained on a longitudinal basis because of the limitations on color stabilization, especially when this was performed in a single session and compared to home-bleaching techniques.[19,38]

Considering color changes (ΔE), the null hypothesis was confirmed. The bleaching procedure is not influenced by light exposure regarding ΔE, which corroborates other findings.[19,23,39]

Overall, investigations showed that there is a higher trend to reduce the b^* parameter than to increase the L^* parameter during bleaching procedures.[6,34] Another study verified that patient satisfaction is more related to changes on b^* than on L^* or a^* parameters using a subjective questionnaire before and after bleaching.[40]

Color alteration values with ΔE lower than 1 cannot be visually detected, whereas values above 3.3 are considered visually moderate. In this way, this study presented no color changes visually observed 7 days after bleaching.[41]

The BriteSmile system uses a plasma arc light source with a 380 to 520 nm wavelength range, which simultaneously irradiates all incisors up to 130 to 160 mW/cm^2, with a distance of 4.45 cm from the light source to the bleaching gel. On the other hand, the Pola Office system uses an LED light (Radii plus, SDI). This device has a 440- to 480-nm wavelength range and irradiance peak of 1,500 mW/cm^2. Even with differences on irradiance and wavelength parameters, these light sources did not produce changes on ΔE values.

Goldstein and Garber reported that light sources increase temperature of bleaching agents on the enamel surface and increase the decomposition rate of hydrogen peroxide.[42] However, the increasing amount of

radicals does not necessarily improve their efficacy on bleaching because such substances have short half-life periods and they are created on enamel surfaces and not in the dentin depth, thus, away from the site that encompasses the greatest number of chromophores, the dentin.[43]

According to Hein et al., there are two mechanisms that can accelerate decomposition rate of the hydrogen peroxide: thermocatalysis and photocatalysis. A significant increase is only seen with 35% hydrogen peroxide heated above 85°C (185°F), which precludes this mechanism in the oral cavity. Thus, the efficacy of the bleaching agent is related to its chemical composition (possibly to pH values) and not to the type of light source used.[19,22] On the other hand, for the photolytic process to decompose hydrogen peroxide in two hydroxyl radicals, a device with a 248 nm wavelength is necessary (Ultraviolet-C radiation), making its use not recommended on the oral cavity.[44]

CONCLUSIONS

The use of a light source did not influence color changes when associated with bleaching products except immediately after bleaching by using 35% peroxide. Moreover, the bleaching process using a 15% office bleaching system did not alter enamel microhardness regardless of the use of a light source.

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