

Bleaching Efficacy of Whitening Agents Activated by Xenon Lamp and 960-nm Diode Radiation

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ABSTRACT

Objective: This *in vitro* study examines the efficacy of two different dental whitening agents, Opalescence X-tra and Opus White, by analyzing the change in color achieved by the treatment and the temperature increase induced in the pulpal chamber. **Background Data:** Bleaching techniques achieved significant advances with the use of coherent or incoherent radiation sources to activate the bleaching chemicals. **Methods:** The bleaching agents, containing 35% of hydrogen peroxide, were stimulated with 0.9 W of xenon arc lamp and 0.9 W or 2 W of a 960-nm diode laser during 60 sec (0.9 W) and 30 sec (2 W) on 33 extracted human teeth. During irradiation, the temperature in the pulpal cavity was monitored. The color change was evaluated using the CIE L*a*b* color space measurement system. **Results:** The treated groups showed an increase in color saturation (ΔC^*) of 3–32% and a change in whiteness (ΔL^*) of 0–8%. This study found that only some of the irradiated groups show statistically significant difference ($p < 0.05$) in the effectiveness of their treatment when compared to the control, whereas no significant statistical difference was obtained in between the irradiated groups. Temperature increase was 2–4°C when using the xenon arc lamp, 2–8°C and 4–12°C when using the diode laser at 0.9 W and 2 W, respectively. **Conclusions:** The results of this study suggest that Opalescence Extra and Opus White are both effective to provide brighter teeth. However, according to the conditions used in this study, only the xenon arc lamp induced a safer temperature increase.

INTRODUCTION

SINCE THE LATE 1800s, dentists have been bleaching teeth by using various forms of peroxide. Early work on dental bleaching techniques discovered that peroxide releases oxygen, which eliminates the stains on the enamel.¹ This discovery eventually led to the introduction in 1895 of the first commercial product called Pyrozone—a mixture of five parts of hydrogen peroxide at 25% and one part of ether.² The early peroxides were very concentrated and had a water-like consistency so they could only be applied in the dental office. This had a change with the introduction of whitening gel, which could be used at home.³

Significant advances in cosmetic dentistry have been made with the introduction of bleaching systems that use the conjunction of whitening gel and some sort of incoherent irradiation font.⁴ The use of coherent light to improve the bleaching effect is quite new, it was first described by D. Yarborough⁵

and Smigel⁶ in 1996. Both techniques, using coherent or incoherent light, have the advantage of being quick and convenient when compared to the techniques in the previous paragraph. In addition, there can be some beneficial effect on the sensitivity.⁷ Depending upon the emission spectra of the light source the interaction with the whitening gel is mainly photochemical for short wavelength light and photothermal for infrared light.

Since the early 1920s, a significant goal of color vision research has been the specification of human color response in a way that can be implemented as electronic color measurement devices. A recent milestone in this effort is the CIE L*a*b* color system⁸ (CIE LAB for short), first used in 1976. The three last letters in the CIE LAB name refer to the three opponent process dimensions: a* is the red-green contrast (a+ is a carmine red and a– is its opposite, blue green); b* is the yellow-blue contrast (b+ is light yellow and b– is deep blue). L* is the luminosity dimension or whiteness, ranging from 0 (pure black) to 100 (reference white) and it is proportional to the

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power of the light reflected from the object's surface. The distance between any two similar colors within the color solid approximately equals the apparent dissimilarity between them. The chroma C^* or color saturation, which means the distance from the grey axis (L^*) in CIE LAB space, represents the change from unsaturated (dull) to saturated (bright) colors. The larger C^* , the more intense (saturated) is the color. To the human eye, color intensity (chroma) seems like light intensity (whiteness). This is especially true for the yellow color, which reaches its strongest saturation at high whiteness values.⁹ Therefore, the two attributes that define the perceived increase in brightness achieved by the bleaching procedure, are the change in whiteness (ΔL^*) and the change in chroma (ΔC^*).

The aim of this study was to analyze the efficacy of different whitening systems, by means of spectrophotometric measurements and temperature analysis inside the pulpal cavity.

MATERIALS AND METHODS

Color analyses

The 33 extracted incisors (approved by the ethics committee of the Brazilian Ministry of Health; project no. 041/CEP-IPEN/SP) had their buccal surface cleaned with Robinson's brush (8040 Viking model, KG Sorensen, São Paulo, Brazil) and pumice (SS White Artigos Odontológicos Ltda., Brazil). The roots were separated from their crowns, using a diamond saw (model 15 HC, Bühler, USA), and the pulpal dentin was sealed off with UV-curing epoxy-resin. The crowns were then stored in a staining liquid made of tobacco, tea and red wine and maintained for seven days at constant 37°C. This mixture was carefully agitated (twice a day) so that the heaviest staining products would not decant and remain at the bottom of the recipient. After this staining period, the crowns were washed off with water, dried and measured for the first time with the spectrophotometer (model Cintra 10, GBC Scientific Equipment Inc., USA). The 33 samples were randomly divided into seven groups as shown in Table 1.

As incoherent light source, a commercial Xenon arc lamp (model Apollo 95E, Elite Medical Diagnostic Systems Inc., California, USA) with a 9 mm diameter light guide was used according to the manufacturer instructions, whereas the coher-

ent source, a diode-laser, was developed at the Centro de Lasers e Aplicações of the University of São Paulo. The lamp emitted 430 nm to 500 nm and the diode laser emitted up to 15 watt coherent radiation at a wavelength of 960 nm from a 600 micron diameter fiber with a numerical aperture of 0.22. Groups G3 and G4 were irradiated with the diode laser using the same power and exposure time as the groups G5 and G6, irradiated by the xenon lamp, to obtain an effective comparison.

Two different whitening agents containing 35% of hydrogen peroxide were used. Opalescence X-tra (Ultradent, South Indian, UT) contains Carotene (red color) and has its main absorption at 400–500 nm. Opus White (Opus Dent, London, UK) contains silica (light blue colored) and its use is indicated by the manufacturer with near infrared (NIR) diode lasers.

Prior to irradiation the bleaching agents were applied on the buccal surfaces covering completely the area. The tip of the xenon arc lamps light guide was put at a 2 mm distance from the bleaching agent and perpendicular to the tooth surface. The tip of the diode laser optical fiber was also held at a distance of 2 mm from the bleaching agents and the whole surface was covered with a uniform sweeping motion in order to guarantee deposition of equal values of radiation energy upon the whole tooth surface. After the irradiation, the tooth samples were immediately rinsed with water, dried and a^* , b^* and L^* were measured with the spectrophotometer. The chroma (C^*) or color saturation was calculated through the following formula: $(C^*)^2 = (a^*)^2 + (b^*)^2$.

The results were analyzed using multifactorial ANOVA inferential analysis. A value of $p < 0.05$ was considered significant.

Temperature analysis

For the temperature analysis two molars, one pre-molar and one incisor were prepared and treated in the same way as for the color analysis except for the fact that they were not sealed with epoxy-resin, exposing the pulpal chamber for posterior insertion of the temperature sensor.

To register the temperature, a thermocouple type K (Omega Engineering Inc., USA, 0.005 inch diameter) was used with a temperature converter (model TC-253, BeckmanInc., CA) coupled to a digital oscilloscope (model TDS360, Tektronix Inc., OR). The thermocouple was placed inside the pulpal chamber

TABLE 1. IRRADIATION PARAMETERS

Group	Sample number (n)	Bleaching agent	Radiation type (light source)	Power (W)	Radiation time (cw) (sec)
G1	5	Opalescence Extra	Diode laser	2	30
G2	4	Opus White	Diode laser	2	30
G3	5	Opalescence Extra	Diode laser	0.9	60
G4	4	Opus White	Diode laser	0.9	60
G5	5	Opalescence Extra	Xenon arc lamp	0.9	60
G6	5	Opus White	Xenon arc lamp	0.9	60
G7	5	Control group	—	—	—

directly underneath the area to be irradiated. Good thermal contact of the thermocouple to the dentine layer was guaranteed using thermal conducting paste. The dental samples were fixed on the top of a thermo-electric plate, with its temperature control adjusted to 37°C (model CP2-12706L, Melcor, NY). For better thermal contact and to simulate the oral environment, the teeth were embedded in a modeling mass, with exception of the area to be irradiated.¹⁰

The only measurements shown are the ones with OE that generated marginally higher temperature increase when compared with OW. After applying the bleaching gel, the teeth were irradiated with the same parameters used for color analysis and the temperature data were collected with a digital oscilloscope.

RESULTS

Color analysis

Most of the irradiated groups showed an increase in whiteness (L*) on the color sphere (Fig. 1), and all of them moved from a grayish color towards a saturated light yellow (b*+). The ANOVA repeated measurements of the L* values resulted in statistically equivalent whitening of the teeth by the different techniques with exception of G1 versus G6.

The mean value of the chroma change, ΔC*, together with the mean whiteness change ΔL* of each group is shown in Figure 2. No statistical difference of ΔC* existed between the treated groups, but G1 and G5 groups are statistically different when compared with G7—the control group.

All groups had positive sums of ΔC* and ΔL* and therefore increased in brightness, the largest changes occurring for G1 and G2 groups, both irradiated by the diode laser at 2 watts. G1, G2 and G5 groups are statistically different when compared with the control group but all irradiated groups are statistically equivalent amongst them.

Temperature analysis

For G5 and G6 groups a maximum temperature increase inside the pulpal chamber of 4 +/-0.5 degrees was measured as shown in Figure 3a. The only measurements shown are the ones with Opalescence Extra that generated marginally higher temperature increase than with Opus White. When using the diode laser at 0.9 W, some teeth heated up to 8 ± 0.5°C (Fig. 3b), and at 2 W, the temperature increase amounted to 12 ± 0.5°C (Fig. 3c). The temperature increase measurements for molar teeth were safer in all cases. And for the diode laser and the xenon arc lamp at 0.9 watts they were approximately equal.

DISCUSSION

The methodology for the temperature measurement was chosen in order to reproduce closely the clinical conditions. The thermal paste used in the experiment has a thermal conductivity similar to soft tissue.¹¹ It has been shown that the pulp tissue contributes to heat dissipation whereas the pulpal blood flow has only negligible dissipating effect upon the heat flow.^{12,13} The teeth were inserted in a modeling clay at 37°C in

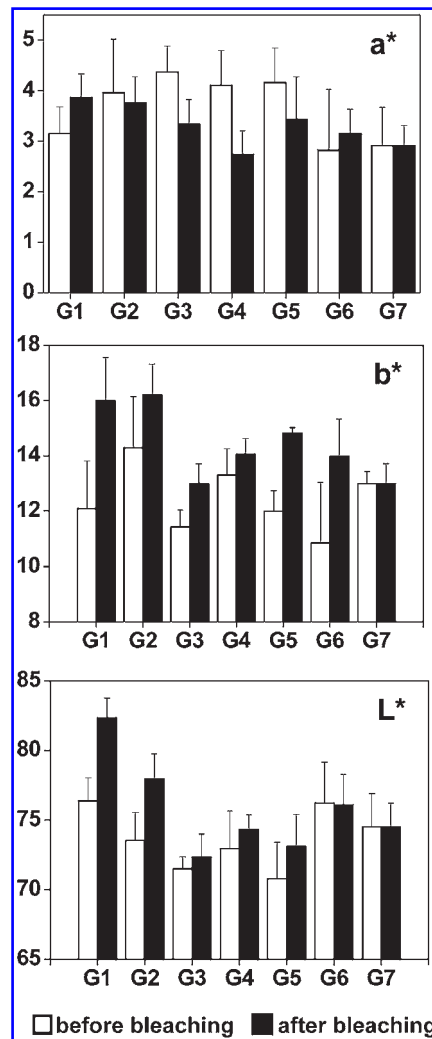


FIG. 1. Mean CIELAB values and standard error of the a* (carmine red), b* (light yellow) and L* (whiteness) dimensions as measured for the groups G1–G7.

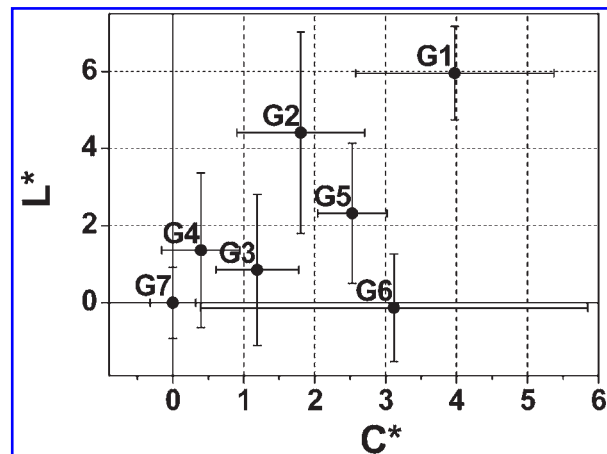


FIG. 2. Change in chroma (ΔC*) and whiteness (ΔL*) of groups G1–G6 and control G7.

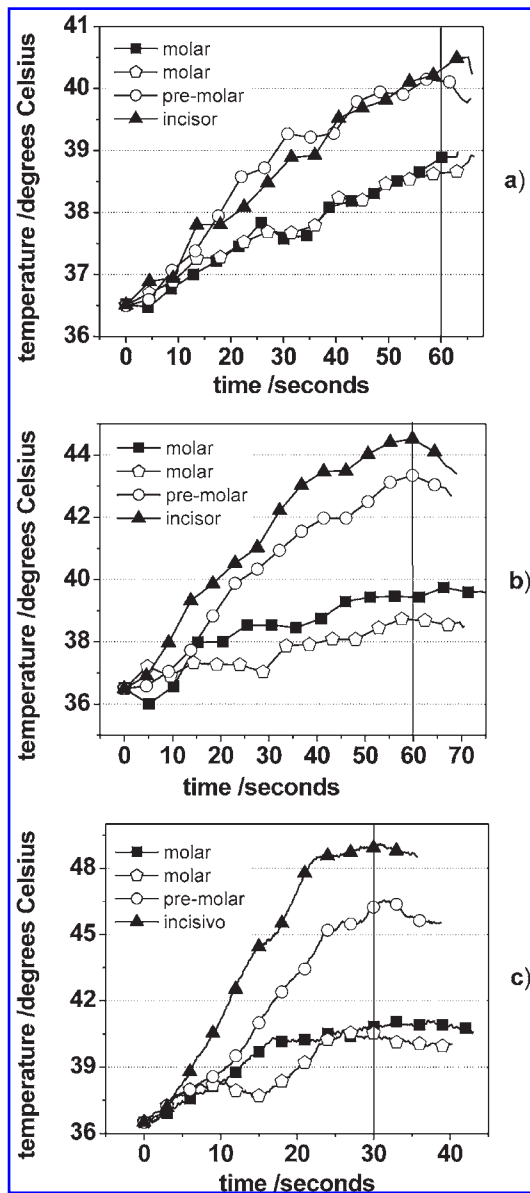


FIG. 3. Temperature change induced with the arc lamp at 0.9 W (a), the laser at 0.9 W (b), and at 2 W (c) as a function of tooth type.

order to simulate body temperature for thermal conductivity is a function of temperature.

According to Zach and Cohen,¹⁴ the temperature rise inside the pulpar chamber may not exceed 5.6°C, otherwise irreversible damage to the pulpar tissue is produced. As can be seen from our measurements, independently of the irradiation source, the molars always remained at a lower temperature than the incisor or pre-molar and showed safer temperature increase measurements. It is possible to state that tooth size does matter: a very different temperature increase could be achieved as a function of tooth size.

The temperature rise in Figure 3a, applying the xenon lamp to the incisor or pre-molar, is smaller than when using the diode at the same output power (Fig. 3b) in part due to the fact that

the xenon's light guide is larger than the tooth width and therefore not all of its light can be collected onto the tooth surface. Therefore, when using bare fibers for irradiation, the radiation time or power should be normalized by the tooth area. Smaller teeth must be irradiated for less time or receive less power in order not to exceed the safe activation temperature of the bleaching agent. This clearly shows that mouthpieces or fiber tip probes should be used for irradiation emitting beam diameters that are larger than the teeth and therefore deliver automatically the correct energy which corresponds to the tooth area.

The mean temperature increase measured for the xenon arc lamp is in excellent agreement with the data obtained by White et al.¹⁵ which also used a plasma arc lamp for 60 sec on single rooted teeth and found this treatment to be safe. In their article, they found that the diode laser at 2 W is safe at all times, whereas our results suggest that this is valid only for molars being not safe for incisors and pre-molars. Using two irradiation intervals of 15 sec each instead of one with 30 sec could already create safer irradiation conditions while maintaining the good bleaching results.

The color analyses found that all irradiated groups shifted from dull grayish to a light yellow (b*+). Consequently, all groups increased their average color saturation, that is, changed from dull to brighter colors (positive ΔC^*).

Furthermore most groups generated whiter teeth (ΔL^*) and the brightness ($\Delta C^* + \Delta L^*$) increased considerably for all groups. No statistical difference between the brightness results of the irradiated groups was detected (Fig. 2).

The general results of the brightness are, again, in agreement with White et al.¹⁵ However, it should be pointed out that, different from their results, a large increase occurred for the chroma value that changed from a dull grayish to a light, bright yellow whereas they detected a shift from red to green. On the other side, the average change in whiteness was less in our case.

This research compared the results obtained by a short wavelength (xenon lamp) and an infrared wavelength source (diode laser) applied each to a short (Opalescence X-tra) and long (Opus White) wavelength absorbing whitening agent. The results of Figure 2 show that the mean brightness increase ($\Delta C^* + \Delta L^*$) is always higher for Opalescence X-tra independent of the light source. When comparing the xenon arc lamp with the diode laser at the same irradiation parameters (groups G3–G6), the average brightness increase is higher for the plasma arc lamp. This is probably because the higher energy photon of the plasma lamp excites more effectively the hydrogen peroxide molecules.⁵ Furthermore, only the xenon arc lamp provided safer temperature increase measurement values for all groups and all teeth size. This behavior is in part expected due to its high water content, the dentinal tissue absorbs the wavelength of the xenon light source much less than the diode laser at 960 nm.

CONCLUSION

A comparison of two agents and two different light sources showed that Opalescence Extra and Opus White are both effective to provide brighter teeth. However, according to the conditions used in this study, only the xenon arc lamp induced safer temperature increase measurement values. This clearly suggests

that bare fiber tips are not appropriate and that some sort of hand piece should be used, which generates a larger laser beam diameter when compared with the teeth area. The highest efficacy was achieved using a diode laser at 2 W; however, further investigation is necessary to establish safer exposure times.

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