The Effectiveness of Low-Intensity Red Laser for Activating a Bleaching Gel and Its Effect in Temperature of the Bleaching Gel and the Dental Pulp

PATRÍCIA RONDON PLEFFKEN, DDS*, **ALESSANDRA BÜHLER BORGES,** DDS, PhD†, **SÉRGIO EDUARDO DE PAIVA GONÇALVES,** DDS, PhD†, **CARLOS ROCHA GOMES TORRES,** DDS, PhD†

ABSTRACT

Statement of the Problem: The effectiveness of low-intensity red laser for activating a bleaching gel and its effect in pulp temperature was not investigated in dental literature.

Purpose: The objective of this study was to assess the effectiveness of low-intensity red laser for activating a bleaching gel, as well as its effect in temperature of the bleaching gel and the dental pulp.

Materials and Methods: Forty extracted bovine teeth were immersed in a solution of coffee 14 days for darkening. The initial colors were recorded by spectrophotometric analysis. The specimens were randomly distributed into two groups ($N = 20$): the control, which did not receive light and the experimental group that received light from an appliance fitted with three red light-emitting laser diodes ($\lambda = 660$ nm). A green-colored, 35% H_2O_2–based bleaching gel was applied for 30 minutes, and changed three times. After bleaching, the colors were again measured to obtain the *L* a* b** values. Color variation was calculated (ΔE) and the data submitted to the non-paired *t*-test (5%). To assess temperature, 10 human incisors were prepared, in which one thermocouple was placed on the bleaching gel applied on the surface of the teeth and another inside the pulp chamber.

Results: There was a significant difference between the groups ($p = 0.016$), and the experimental group presented a significantly higher mean variation (7.21 ± 2.76) in comparison with the control group (5.37 ± 1.76). There was an increase in pulp temperature, but it was not sufficient to cause damage to the pulp.

Conclusion: Bleaching gel activation with low-intensity red laser was capable of increasing the effectiveness of bleaching treatment and did not increase pulp temperature to levels deleterious to the pulp.

CLINICAL SIGNIFICANCE

The application of a low-intensity red laser was effective for activating a bleaching gel with green dye, without any deleterious increases in pulpal temperature.

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INTRODUCTION

Tooth whitening has become one of the most popular esthetic dental procedures. Bleaching treatment has been used for over a century,[1] with substances capable of releasing highly reactive free radicals that cause bleaching by oxidation of the pigments.[2] The bleaching procedures have been shown to be reasonably, relatively safe and effective.[2–4]

*Postgraduate student, São José dos Campos School of Dentistry, São Paulo State University, SP, Brazil

†Assistant Professor of the Department of Restorative Dentistry, São José dos Campos School of Dentistry, São Paulo State University—UNESP, SP, Brazil

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Over the last few years, there has been an improvement of the "in-office" technique. The bleaching agents at high concentrations can be associated with physical and/or chemical dye catalyzers that can be activated by halogen, plasma arc, laser, and light-emitting diode (LED) light sources, substituting the old hot lamp and spatula techniques.[5–9] The activation of a bleaching agent by thermocatalytic technique has been questioned, its thermal effects may result in an excessive heating of pulpal tissue, increasing the incidence of postoperative sensitivity and deleterious effects on tooth structure.[10–13]

Although studies have proved the efficiency of bleaching agents that use hydrogen peroxide at high concentrations, the adverse effects on dental tissues must be carefully assessed for their safe use.[11–15]

Clinically, the more usual adverse effect of vital tooth whitening is sensitivity that may occur during and after the procedure done by the professional,[16] which can be attributed to the hydrogen peroxide penetrating into the dental tissue,[17] due to its low molecular weight, resulting in pulp irritation and in reversible pulpitis.[18,19]

Besides, bleaching agents with light-activated, heat-enhancing colorant influences temperature rise of bleaching gel and also may increase intrapulpal temperature values. Use of intense lights does elevate bleach temperature and also results in increased intrapulpal temperature that may further impact on patient sensitivity.[20]

The advent of dental laser has provided one possible treatment option for dentinal sensitivity.[21] Effects, such as anti-inflammatory, vascular, myorelaxant, and healing activity have been attributed to the application of low-intensity laser.[22,23] It is believed that in the same way as with the non-opiate analgesics, low-intensity laser therapy (LILT) can lead to diminishment of pain intensity and even analgesia, acting at a low wavelength.[23] The LILT stimuli promote the inflammatory process modulation by stabilizing cell membrane, altering the transmembrane electric potential, activating Na+ and K+ ATPase pump, and increasing the synthesis of adenosine triphosphate (ATP).[24] This way, the application of low-intensity laser in hypersensitive teeth has led to favorable results in diminishing pain[25,26] and acceleration on the pulp repair process after pulp exposition.[27]

Nevertheless, the use of LILT during or after bleaching procedure was not investigated in dental literature. As it occurs with dentinal sensitivity, it would be expected that the LILT could minimize the discomfort that occurs during and after the bleaching treatment, which can be associated with other light sources in hybrid appliances or applied after bleaching treatment.

Hybrid LED/laser hybrid appliances usually have only one laser diode located in the center of the active tip. The use of an appliance fitted with more sources of low-intensity laser diodes to activate bleaching gel would, in principle, be desirable because there would be optimization of the bleaching procedure in conjunction with a supposed analgesic, anti-inflammatory, and tissue regeneration action. Thus, it is opportune to assess the degree of dental bleaching obtained by activating the bleaching gel with the low-intensity laser.

The objective of this study was to assess the effectiveness of low-intensity diode laser in activating the 35% hydrogen peroxide-based bleaching gel used in the dental bleaching procedure, as well as its effect in bleaching gel and dental pulp temperatures. The null hypotheses tested were that LILT does not improve efficiency of dental bleaching and it does not increase pulp temperature in deleterious levels.

MATERIALS AND METHODS

Specimen Preparation

Forty healthy bovine incisors were obtained from animals with a mean age of 3 years, and remained stored in distilled water at 4°C until they were used, not longer than 28 days.[28]

The teeth were sectioned mesio-distally through their long axes with a carborundum disk and a high-speed lathe, and only the vestibular halves were used. Kerr type

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endodontic files were used to remove the pulp tissue. The incisor and root were worn in order to obtain a specimen with 7 mm of crown and 4 mm of root.

After the teeth were prepared, they were submitted to the darkening process. The specimens were immersed in a solution of 25% instant coffee (Nescafé, Nestlé, Araras, SP, Brazil) dissolved in distilled water, for 14 days and the coffee solution was changed after 1 week (Figure 1A).

The specimens were maintained at 37°C in a bacteriologic oven during this period, then were subjected to prophylaxis with a bicarbonate jet and immersed in distilled water in an ultrasound appliance to obtain a residue-free surface. To delimit the color reading area, a circular adhesive label 9 mm in diameter (Pimaco, Rio de Janeiro, RJ, Brazil) was adhered to the center of the buccal surface (Figure 1B). The entire buccal and other surfaces were coated with colorless nail varnish (Colorama, São Paulo, SP, Brazil). After the nail varnish was dried, the label was removed, exposing a dental enamel "window" 9 mm in diameter (Figure 1C).

Color Measurements

The baseline color values (L^*, a^*, b^*) of each specimen were measured with a spectrophotometer (Easyshade, Vita, Bad Säckingeni, Germany). The spectrophotometer was calibrated with a standard white card before each group of specimens was measured, and measurements were repeated three times for each specimen before the mean values were calculated.

Bleaching Procedure

The specimens were randomly distributed into two groups ($N = 20$): the control, which did not receive light

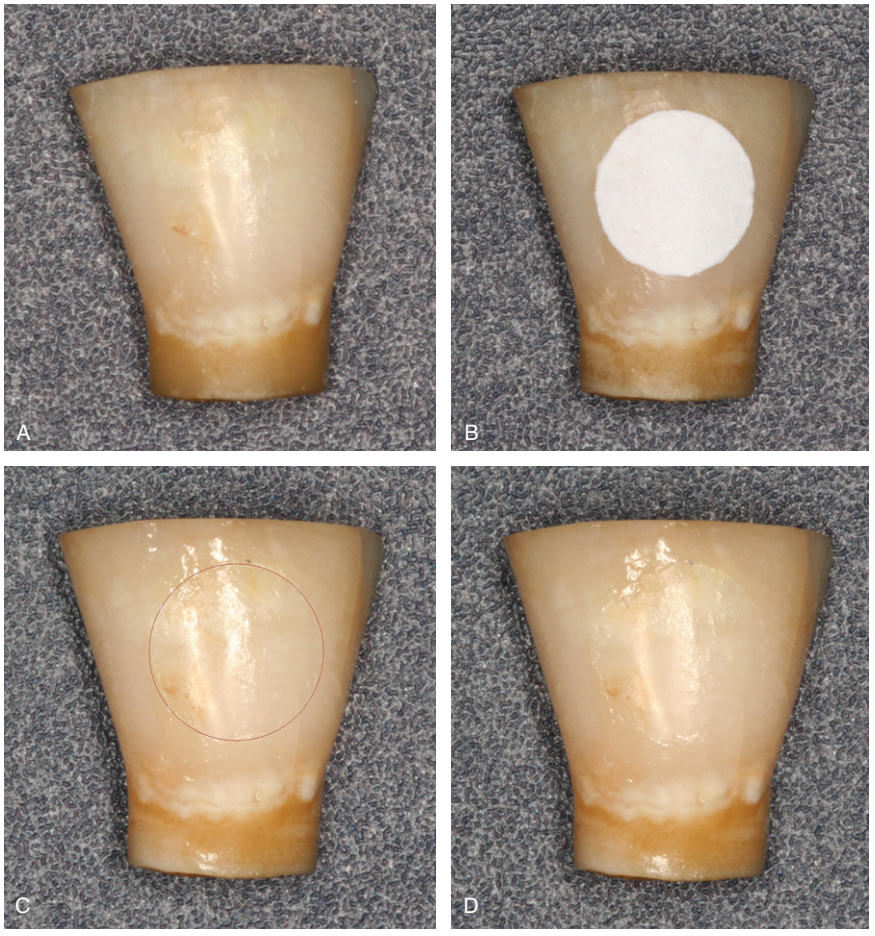

FIGURE 1. Specimens preparation: A, Tooth after darkening. B, Delimitation of the bleaching area with an adhesive tape. C, Tooth after nail varnish coating. D, Bleached specimen.

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and experimental group, which was light activated. A 35% hydrogen peroxide-based experimental bleaching gel was used, resulting from the mixture of components from two bottles with neutral pH. The gel had a green dye with the aim of absorbing red light with greater intensity.

The gel was manipulated in a plastic vat by adding nine drops of bleaching agent and three drops of thickener. A uniform layer of gel approximately 2 mm thick was deposited on the enamel platform at a distance of 1 cm from surface and was immediately activated by the light source from an appliance with three red light-emitting laser diodes ($\lambda = 660$ nm, 50 mW—CleanLine—Taubaté, São Paulo, Brazil), for 2 minutes and 40 seconds. Then, the gel on the enamel surface was stirred with a spatula to displace oxygen bubbles formed and 1 minute was waited to avoid possible overheating of the dental structure, which could be deleterious to the pulp tissue under a clinical condition. Procedures were repeated three times, totaling 10 minutes. Next, the gel was removed with a suction cannula and washed with distilled water. All the procedures described above were repeated twice more, totaling 30 minutes of the bleaching gel action (Figure 1D).

Statistical Analysis

After bleaching, the specimens were stored in distilled water at 37°C for 1 week and colors were measured again in the spectrophotometer to obtain the values of L^* a^* b^*. Color variation was calculated (ΔE) and data were submitted to the non-paired *t*-test (5%).

Temperature of the Dental Pulp

To assess temperature alteration, 10 human incisors were prepared, whose dental pulps were removed and the pulp chambers were filled with a zinc oxide-based thermal paste (Implastec, Votorantim, São Paulo, Brazil) to enable heat conduction, similar to what would occur with the pulp tissue. The bleaching agent was applied, the same as previously, on the entire vestibular surface of the teeth, with an approximate thickness of 2 mm. Type K thermocouples were placed inside the pulp chamber, immersed in the paste, touching the dentin in the region at the center of the vestibular face of the tooth crowns and another in the bleaching gel. These thermocouples were connected to a digital thermometer (MT-507, Minipa, São Paulo, São Paulo, Brazil), which enabled the temperature to be read in °C. All the tests were performed in a room with a constant temperature of 26°C. After this, the teeth were irradiated with the light sources described above, for 3 minutes without interruptions and the temperature was recorded every 30 seconds. The temperature variation values for each specimen were calculated, subtracting the value recorded after each interval of activation from the value of the initial temperature. Each tooth received irradiation with a light source of a red light-emitting laser appliance, as described above.

The mean temperature values of the bleaching gel (dental surface) and inside the pulp chamber were obtained from the data.

RESULTS

Table 1 shows the results of the non-paired *t*-test for the action of light on dental bleaching, in which a significant difference is noted between the groups, and the laser group presented a significantly higher mean variation in comparison with the control group.

Figure 2 presents the mean temperature values of the bleaching gel (dental surface) and inside the pulp chamber, in which a discrete increase in temperature can be observed. The difference between the final and the initial temperature was 2.29°C for the bleaching gel (26.94°–24.65°), and 1.18°C for the dental pulp (25.62°–24.44°).

TABLE 1. Results of the non-paired *t*-test (5%)

Groups	Means (± standard deviation)
Laser	7.21 (±2.76)
Control	5.37 (±1.76)

*$p = 0.016$.

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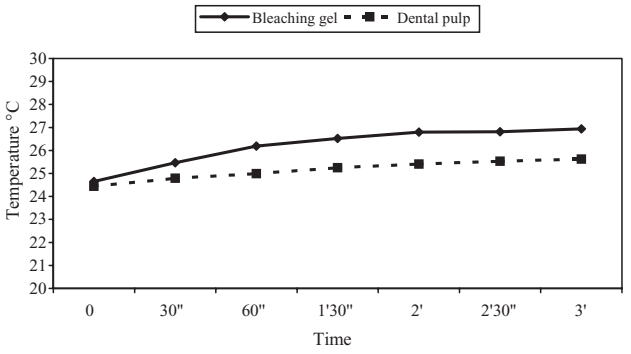

FIGURE 2. Graph of temperature increase for the bleaching gel and dental pulp according to time.

DISCUSSION

The aim of associating dyes with bleaching gels used in dental offices is to increase the effectiveness of dental bleaching by means of greater light absorption by the gel. Nevertheless, it is necessary for the color of the pigment to be complementary to the color of the light from the emitting appliance,[13] to provide greater bleaching effectiveness and low temperature increase.[29] Therefore, a 35% H_2O_2–based experimental bleaching gel associated with a green dye was developed for use with the diode laser appliance, which emits light in a red spectrum ($\lambda = 660$ nm), with the view of intensifying its absorption.

However, light absorption by the bleaching gel with dye leads to its heating, which is reflected in the dental structures.[20] Eldeniz and colleagues 2005,[12] compared the pulpal temperature of teeth submitted to bleaching associated with halogen or LED/laser light sources and found the highest temperature values in the halogen lamp appliances.

Zach and Cohen reported irreversible pulpal damage in 15% of rhesus monkeys for temperature elevations of 5.6°C, 60% for temperature elevations of 11°C, and 100% for temperature elevations of 16.6°C.[30] In the present study, it was found that low-intensity laser, in accordance with the protocol used, did not raise the temperature in the pulp and on the tooth surface to a level that would be sufficient to cause pulp damage, the maximum variation obtained being 2.29°C in the bleaching gel and 1.18°C in the dental pulp. These results have shown that the use of a bleaching gel should be able to offer a protective insulating layer against the surface and pulpal temperature increases.[31]

However, tooth sensitivity is a common side effect of external tooth bleaching, mainly with in-office technique.[32] The mechanisms that would account for the tooth sensitivity after external tooth bleaching have not yet been fully established. In vitro experiments have shown that peroxide penetrated enamel and dentin and entered the pulp chamber.[33] The amount of peroxide detected in the pulp chamber was related to the concentration of hydrogen peroxide in the preparations applied.[34] An in vivo study in dogs indicated that hydrogen peroxide alone or in combination with heat caused alterations in odontoblasts and deposition of dentin,[35] these factors can cause hemorrhage and inflammation in pulp and consequently, tooth sensitivity. Low-intensity lasers have shown anti-inflammatory, analgesic, and tissue regeneration effects in pulp hyperemia processes, and it is an important therapeutic auxiliary in cases of dentinal hypersensitivity,[26,36,37] nevertheless, its use as a desensitizing agent during bleaching procedures needs to be further investigated.

The principle of using LILT is to supply direct biostimulative light energy to the body's cells. Cellular photoreceptors can absorb low-level laser light and pass it on to mitochondria, which promptly produce the cell's fuel, ATP.[38]

These wavelengths stimulate circulation and cell activity, acting in biostimulation due to the increase of mitochondria ATP production and lead to an increase in the excitability of free nerve endings, which results in an analgesic effect. There is evidence suggesting that LILT may have neuropharmacologic effects on the synthesis, release, and metabolism of a wide range of neurochemicals, including serotonin and acetylcholine at the central level, and histamine and prostaglandin at the peripheral level.[39] The therapeutic effect on pain also can be explained by the increase in the release of β-endorphins, which are physiological analgesic

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substances produced by the body at the level of nerve ending synapses.[39,40]

Thus, it would be speculated that the use of a low-power laser appliance as an auxiliary in the bleaching procedure could minimize the frequent sensitivity that occurs during and after bleaching. This way, it would be desirable that this possible therapeutic effect could be associated to the use of the red light as a bleaching activating agent, without harm to the pulp.

The first null hypothesis tested was rejected because there was improvement in bleaching treatment effectiveness when associated to gel containing green pigment exposed to red light from the low-intensity diode laser. The second hypothesis was accepted since there was no temperature increase in the bleaching gel and pulp that could irreversibly affect the pulp tissue.

The obtainment of favorable results with regard to the action of the laser in the bleaching gel tested encourages future studies in order to observe the clinical effects on the bleaching result, which can be obtained with this association, as well as assessing the possible reduction in sensitivity resulting from the bleaching procedure.

CONCLUSION

Within the limitations of this study, it can be stated that activation of the green-colored bleaching gel with the red low-intensity laser was capable of increasing bleaching treatment effectiveness without producing harmful heating of dental structures.

DISCLOSURE

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

REFERENCES

1. Goldstein RE, Garber DA, Goldstein CE, et al. Esthetic update: the changing esthetic dental practice. J Am Dent Assoc 1994;125(11):1447–56.
2. Haywood VB. History, safety, and effectiveness of current bleaching techniques and applications of the nightguard vital bleaching technique. Quintessence Int 1992;23(7):471–88.
3. Papathanasiou A, Bardwell D, Kugel G. A clinical study evaluating a new chairside and take-home whitening system. Compend Contin Educ Dent 2001;22(4):289–94, 96, 98; quiz 300.
4. Heymann HO. Tooth whitening: facts and fallacies. Br Dent J 2005;198(8):514.
5. Torres CRG, Borges AB, Kubo CH, et al. Bleaching teeth with hybrid LED/laser devices. São Paulo: Editora Santos; 2007, p. 140. (In Portuguese.)
6. Kwon YH, Huo MS, Kim KH, et al. Effects of hydrogen peroxide on the light reflectance and morphology of bovine enamel. J Oral Rehabil 2002;29(5):473–7.
7. Sulieman M, Addy M, Macdonald E, Rees JS. A safety study in vitro for the effects of an in-office bleaching system on the integrity of enamel and dentine. J Dent 2004;32(7):581–90.
8. Sulieman M, Addy M, Macdonald E, Rees JS. The bleaching depth of a 35% hydrogen peroxide based in-office product: a study in vitro. J Dent 2005;33(1):33–40.
9. Lima DA, Aguiar FH, Liporoni PC, et al. In vitro evaluation of the effectiveness of bleaching agents activated by different light sources. J Prosthodont 2009;18(3):249–54.
10. Carrasco TG, Carrasco-Guerisoli LD, Froner IC. In vitro study of the pulp chamber temperature rise during light-activated bleaching. J Appl Oral Sci 2008;16(5):355–9.
11. Papathanasiou A, Kastali S, Perry RD, Kugel G. Clinical evaluation of a 35% hydrogen peroxide in-office whitening system. Compend Contin Educ Dent 2002;23(4):335–8, 40, 43–4 passim; quiz 48.
12. Eldeniz AU, Usumez A, Usumez S, Ozturk N. Pulpal temperature rise during light-activated bleaching. J Biomed Mater Res B Appl Biomater 2005;72(2):254–9.
13. Buchalla W, Attin T. External bleaching therapy with activation by heat, light or laser—a systematic review. Dent Mater 2007;23(5):586–96.
14. Sulieman M, Addy M, MacDonald E, Rees JS. The effect of hydrogen peroxide concentration on the outcome of tooth whitening: an in vitro study. J Dent 2004;32(4):295–9.
15. de Silva Gottardi M, Brackett MG, Haywood VB. Number of in-office light-activated bleaching treatments needed to achieve patient satisfaction. Quintessence Int 2006;37(2):115–20.
16. Nathanson D. Vital tooth bleaching: sensitivity and pulpal considerations. J Am Dent Assoc 1997; 128(Suppl):41S–4S.

 DOI 10.1111/j.1708-8240.2011.00444.x

17. Haywood VB, Leech T, Heymann HO, et al. Nightguard vital bleaching: effects on enamel surface texture and diffusion. Quintessence Int 1990;21(10):801–4.
18. Bowles WH, Thompson LR. Vital bleaching: the effects of heat and hydrogen peroxide on pulpal enzymes. J Endod 1986;12(3):108–12.
19. Dahl JE, Pallesen U. Tooth bleaching—a critical review of the biological aspects. Crit Rev Oral Biol Med 2003;14(4):292–304.
20. Baik JW, Rueggeberg FA, Liewehr FR. Effect of light-enhanced bleaching on in vitro surface and intrapulpal temperature rise. J Esthet Restor Dent 2001;13(6):370–8.
21. Gerschman JA, Ruben J, Gebart-Eaglemont J. Low level laser therapy for dentinal tooth hypersensitivity. Aust Dent J 1994;39(6):353–7.
22. Takeda Y. Irradiation effect of low-energy laser on alveolar bone after tooth extraction. Experimental study in rats. Int J Oral Maxillofac Surg 1988;17(6):388–91.
23. Midda M, Renton-Harper P. Lasers in dentistry. Br Dent J 1991;170(9):343–6.
24. Tafur J, Van Wijk EP, Van Wijk R, Mills PJ. Biophoton detection and low-intensity light therapy: a potential clinical partnership. Photomed Laser Surg 2010;28(1):23–30.
25. Marsilio AL, Rodrigues JR, Borges AB. Effect of the clinical application of the GaAlAs laser in the treatment of dentine hypersensitivity. J Clin Laser Med Surg 2003;21(5):291–6.
26. Lan WH, Lee BS, Liu HC, Lin CP. Morphologic study of Nd : YAG laser usage in treatment of dentinal hypersensitivity. J Endod 2004;30(3):131–4.
27. Pretel H, Oliveira J, Lizarelli R, Ramalho L. Evaluation of dental pulp repair using low level laser therapy (688 nm and 785 nm) morphologic study in capuchin monkeys. Laser Phys Lett 2008;6(2):85–92.
28. Tonami K, Takahashi H, Nishimura F. Effect of frozen storage and boiling on tensile strength of bovine dentin. Dent Mater J 1996;15(2):205–11.
29. Luk K, Tam L, Hubert M. Effect of light energy on peroxide tooth bleaching. J Am Dent Assoc 2004;135(2):194–201; quiz 28–9.
30. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19:515–30.
31. Sulieman M, Rees JS, Addy M. Surface and pulp chamber temperature rises during tooth bleaching using a diode laser: a study in vitro. Br Dent J 2006;200(11):631–4; discussion 19.
32. Bernardon JK, Sartori N, Ballarin A, et al. Clinical performance of vital bleaching techniques. Oper Dent 2010;35(1):3–10.
33. Thitinanthapan W, Satamanont P, Vongsavan N. In vitro penetration of the pulp chamber by three brands of carbamide peroxide. J Esthet Dent 1999;11(5):259–64.
34. Gokay O, Yilmaz F, Akin S, et al. Penetration of the pulp chamber by bleaching agents in teeth restored with various restorative materials. J Endod 2000;26(2):92–4.
35. Seale NS, McIntosh JE, Taylor AN. Pulpal reaction to bleaching of teeth in dogs. J Dent Res 1981;60(5):948–53.
36. Kimura Y, Wilder-Smith P, Yonaga K, Matsumoto K. Treatment of dentine hypersensitivity by lasers: a review. J Clin Periodontol 2000;27(10):751–21.
37. Clavijo EMA, Clavijo VRG, Bandéca MC, et al. Clinical efficiency of low-level diode laser in reducing dentin hypersensitivity. Laser Phys Lett 2009;19(10):2041–4.
38. Passarella S, Casamassima E, Molinari S, et al. Increase of proton electrochemical potential and ATP synthesis in rat liver mitochondria irradiated in vitro by helium-neon laser. FEBS Lett 1984;175(1):95–9.
39. Montesinos M. Experimental effects of low power laser in encephalin and endorphin synthesis. J Eur Med Laser Ass 1998;1:2.
40. Honmura A, Yanase M, Obata J, Haruki E. Therapeutic effect of Ga-Al-As diode laser irradiation on experimentally induced inflammation in rats. Lasers Surg Med 1992;12(4):441–9.

Reprint requests: Patrícia Rondon Pleffken, DDS, São José dos Campos School of Dentistry, São Paulo State University, SP 12245-000, Brazil; email: pattypleffken@gmail.com

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