Color and Surface Temperature Variation During Bleaching in Human Devitalized Primary Teeth: An In Vitro Study

Isa T. Gontijo, DDS, MSc Ricardo S. Navarro, DDS, MSc, PhD
Ana Lídia Ciamponi, PhD Walter Miyakawa, PhD
Denise Maria Zezell, PhD

ABSTRACT

This study's purpose was to make an in vitro assessment of 2 whitening techniques in primary teeth, regarding color and temperature surface variation, during dental bleaching using different catalytic sources. Twenty-one extracted human upper central deciduous incisors were used in this in vitro study. The teeth were darkened with human blood for a period of 21 days. After preparing the teeth, they were randomly distributed into 2 groups, according to bleaching source of activation: (1) a diode laser (DL) group; and (2) a halogen lamp (HL) group. The bleaching process was performed, according to the manufacturer's guidelines, using Whiteness HP (FGM, Joinville, Brazil). The color was assessed by spectrophotometer (CIELab) and the VITA scale (3M) before and immediately after tooth whitening. The temperature increase in the radicular surface during the bleaching was registered with a thermographic camera ThermaCAM SC 3000 (Flir Systems, Danderyd, Sweden) at the Nuclear and Energy Research Institute, IPEN-CNEN (São Paulo, Brazil). There was no significant difference between the groups in terms of color changes, but there was a statistically significant difference for temperature variation. The use of a diode laser and halogen lamp both promoted whitening in devitalized primary teeth in vitro. As a catalytic source of energy, the diode laser—with the applied parameters—promoted a smaller temperature increase compared to the halogen lamp during the bleaching procedure on nonvital primary teeth.

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Many studies have confirmed that a great number of children in the primary dentition stage suffer traumatic lesions in the orofacial area mainly affecting the maxillary anterior teeth due to their position. Traumatic injuries promote pulpal hemorrhages, leading to blood penetration into dentinal tubules, and sometimes cause an irreversible darkening of the teeth. The pulp vitality can be irreversibly affected, leading to pulp necrosis and requiring the endodontic treatment of primary teeth.[1]

Dr. Gontijo is a graduate student, Dr. Navarro is a postgraduate student, and Dr. Ciamponi is associate professor, all in the Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of São Paulo, São Paulo, Brazil; Dr. Miyakawa is a graduate student and Dr. Zezell is senior researcher, both at the Laboratory of Biophotonics, Nuclear and Energy Research Institute, IPEN/CNEN, São Paulo, Brazil. Correspond with Dr. Ciamponi at aciamponi@uol.com.br.

Even after endodontic treatment is completed, tooth discoloration may persist and, in some cases, becomes worse depending on the endodontic material used in treatment. In these situations, for esthetic reasons, parents and young patients desire the whitening of teeth.

Today, the internal bleaching of vital and nonvital stained teeth has been one of the most common procedures used for esthetic purposes. The major advantages of tooth bleaching over other procedures are the preservation of the tooth structure, low cost, effective results, effective results, and safe and fast clinical treatment.[2]

The esthetic concerns in the primary teeth are not different from the permanent teeth in teenagers and adults, even considering that they are temporary. Unfortunately, chemical bleaching in general has been reported for use only in adults, perhaps because of concerns relating to safety and effectiveness.

Although a reduced number of studies have reported tooth whitening in young children, Waterhouse and Nunn (1996)[3] and Wray and Welbury (2001)[4] related the efficacy and security of primary teeth whitening. There is no a rational and safe protocol, however, for bleaching nonvital primary teeth.[5,6]

One of the most common internal bleaching techniques is the termocatalitic approach, where hydrogen peroxide (H_20_2) is applied inside the pulp chamber followed by a heat source that catalyzes and accelerates the reaction. The process for activating whitening by light is called photoxidation and may be done with halogen lamp appliances or lasers.[7,8]

The halogen lamp is an instrument capable of transmitting high intensity blue light, ideally with a wavelength oscillating between 400 and 500 nm. It is considered to be a good option for activating the whitening process. Its ability to use higher temperatures without causing discomfort to the patient makes it possible to increase the whitening efficiency rate.[7]

The great benefit of using lasers as a source of energy in tooth bleaching is its greater catalytic potential compared to light curing and heat spatulas. The principle effect in laser energy is the conversion of light energy into heat. When irradiated on the bleaching agent, the laser may also be absorbed by the cromophores inside the bleaching products, thus activating the molecules and improving the tooth bleaching process.[9] The differentiated characteristics of the cromophores react differently to several wavelengths of the lasers.[10] The FDA approved the use of argon, CO_2, and most recently diode lasers for bleaching procedures. The chief advantage of the diode laser is its small size, portability, and flexible optic fibers.[11] If a bleaching system can be designed to properly use the photoactivation of light sources, improved tooth whitening performance may be achievable.[12,13]

Laser bleaching still raises a number of concerns, including effect of the increase of temperature in tooth tissues. It is crucial to observe the temperature variation in catalytic dental bleaching techniques because an increase of temperature above 10°C may cause necrosis in the periodontal ligament, bone injuries, such as ankylosis of the cementum to the alveolar bone, and extensive radicular resorptions.[14]

This study's purpose was to make an in vitro assessment of 2 whitening techniques in primary teeth, regarding color and temperature surface variation, during dental bleaching using different catalytic sources.

METHODS

Twenty-one extracted human upper central deciduous incisors were used in this in vitro study approved by the ethics committee of the School of Dentistry, University of São Paulo (USP), São Paulo, Brazil (project no. 47/03 and no. 271/02). The lingual access was used in all teeth with a highspeed drill using a spherical diamond burr, according to the size of the pulp chamber. The teeth were darkened with human blood (previously taken from the first author) for a period of 21 days. To isolate the root dentin, a layer of resin modified glass ionomer cement (Vitremer, 3M ESPE, São Paulo, Brazil) was manipulated, applied according to the manufacturer's instructions, and placed over the root filling. The bleaching process was performed, according to the manufacturer's guidelines, using Whiteness HP (FGM, Joinville, Brazil). This is a strong bleaching agent product with 35% H_20_2 that can be used for vital and nonvital teeth. It has a neutral pH ranging from 6.0 to 7.0. Applying a 1-mm thick layer, the bleaching agent was placed in the tooth, pulp chamber, and buccal surface. After preparing the teeth, they were randomly distributed into 2 groups: (1) a diode laser (DL) group; and (2) a halogen lamp (HL) group.

In the DL group (N=10), the bleaching agent was activated via the infrared diode laser (GaAlAs; Softlase, ZAP Lasers, Pleasant Hill, CA) using a wavelength of 808±5 nm, 1.0 W power, a quartz optic fiber of 400 µm, in continuous emission mode, with a pulse width of 50 µm/second. The fiber was cleaved before its initial use to ensure its efficiency. The energy meter was used to check for what emerged from the equipment, resulting in a calculated intensity of 0.85W/cm^2 to 0.89W/cm^2. The fiber was applied perpendicularly at a distance of 1 mm from the buccal surface and covered by the bleaching agent for 10 seconds. With a scanning movement, the optic fiber run on mesial to distal direction, from cervical to incisal direction and on alleatory movements, per 30 seconds, to distribute the laser irradiation through the whole buccal surface.

In the HL group (N=11), the bleaching agent was activated by a halogen lamp (Demetron Research Corp, USA). It was applied perpendicularly at a distance of 1 mm from buccal surface and covered by the bleaching agent for 40 seconds. The radiometer was previously used to check for electromagnetic radiation intensity, with diameters ranging from 8 to 13 mm and intensity variations ranging from 0 to 1,000 mW/cm^2, using model no. 100 P/N 105003 (Demetron Research Corp, Orange, Calif). The intensity was higher than 380 mW/cm^2.

The color was assessed by spectrophotometer and the VITA scale (3M) before and immediately after tooth whitening. Computerized spectrophotometer or colorimetry systems (Comission International L'Eclairage CIELab, Vienna) assessed the colors 3-dimensionally by calculating the values for L* (luminosity), a*and b* (values related to the matrix and the chroma) and C*.

From the reflectance, the x, y, and z coordinates of chromaticity were obtained, as recommended by CIE. VITA-3D scale was assessed by 3 examiners. The initial tooth color was denominated as RS-1 (spectrophotometer) and RV-1 (VITA scale). Immediately after tooth whitening the reading was denominated as RS-2 and RV-2 for the spectophotometer and VITA scale, respectively.

The temperature increase caused by the irradiation of both the laser and halogen lamp in the radicular surface during the bleaching was registered with a thermographic camera ThermaCAM SC 3000 (Flir Systems, Danderyd, Sweden) at the Nuclear and Energy Research Institute, IPEN-CNEN (São Paulo, Brazil). The infrared thermographic camera measures and captures images of the emitted infrared radiation from an object. The fact that the radiation is a function of an object's surface temperature makes it possible for the camera to calculate and display its temperature. The radiation measured by the camera, however, depends on object temperature and a function of its emission.

Therefore, to measure the temperature accurately, it is necessary to compensate for the effects of a number of different energy sources; this is done automatically by ThermaCAM SC3000. The following object parameters must be supplied: (1) emission; (2) ambient temperature; (3) atmospheric temperature; (4) distance; (5) relative humidity of the air; (6) external optics transmission; and (7) temperature. The emission is the most important parameter to set correctly to measure how much radiation is emitted from the object compared to that emitted by a perfect black body. Usually, object materials and surface treatments exhibit emissions ranging from approximately 1 to 9.5 µm. A polished and reflective surface falls below 1 µm, while an oxidized or painted surface has a much higher emission. The emission from an object can be calculated through its area when the object presents a different atmospheric temperature. The atmospheric temperature is the parameter used to compensate for the radiation reflected in the object and the radiation emitted from the atmosphere between the camera and the object. The parameters used in this study were:

1. Object: Emission capacity=9 µm; distance=0.1m; and atmospheric temperature=23.3°C.
2. Atmosphere: Atmospheric temperature=21°C; and relative humidity=66%.
3. External optical effects: Temperature=21°C; and transmission=10 µm.

The evaluation of temperature variation starts after the necessary adjustments. The features of the thermographic camera include a system of lenses, remote control, cables and connectors to hardware, and software systems. These systems provide excellent and uniform image quality, and allow detailed and dynamic thermal analyses with computerized graphs of the analyzed objects. The camera was maintained in a fixed tripod in the same position during the entire analysis period. The temperature variation was registered in 3 different moments of irradiation: initial (beginning of the irradiation), peak (maximum temperature), and final temperature (ending of the irradiation). The temperature mean values were registered on those 3 moments in the same region/point. The variations obtained were compared. The student *t* test for mean values and the Kruskal-Wallis were used to verify the possible differences between groups.

RESULTS

A total of 21 primary teeth were studied, but it was decided to withdraw one of them from the analysis because it presented with extremely different results from the others, but with very close values. Table 1 shows the means and standard deviations for L*. Table 2 describes the means and standard deviations for C. It was observed that the DL group apparently was the one that caused the greater variation both in L* and in C*, but it should be remembered that teeth variations were great and the variation in C* was very small (0.01 of difference between the groups). To check whether there was any significant difference between the 2 groups, the t test for means was performed. For ΔL* and ΔC*, the descriptive levels of 0.828 and 0.988, respectively, were obtained, which suggested that there was no significant difference between the 2 groups.

Table 1. Means and Standard Deviations for L*

Group	Initial (DP)±(SD)	Final (DP)±(SD)	Variation (ΔL)±(SD)
HL	95.77±2.17	97.77±1.52	2.00±2.01
DL	94.16±2.67	96.36±2.99	2.20±2.19

Table 2. Means and Standard Deviations for C*

Group	Initial (DP)±(SD)	Final (DP)±(SD)	Variation (ΔC)±(SD)
HL	1.466±0.577	1.593±1.274	0.127±1.300
DL	2.068±1.172	2.204±1.774	0.137±1.574

Table 3. Means and Standard Deviations for the VITA Scale Scores

Group	RV 1 (DP)±(SD)	RV 2 (DP)±(SD)	Variation ±(SD)
HL	17.55±5.61	5.09±3.24	12.45±4.57
DL	20.56±5.43	11.33±7.38	9.22±5.29

The variation in color resulting from the whitening treatment was also checked by means of visual analysis by the VITA 3D color scale. To obtain the VITA–3D scale analysis, scores were determined in an ascending scale for each value. The variation of these scores before and after treatment was analyzed. The scores attributed to the teeth before and after whitening were compared, making it possible to analyze the variation in the colors of the specimens. Table 3 shows the means and standard deviations for the VITA Scale Scores. There was a slightly greater variation in the HL group score than for the DL group score. To check whether there was a significant difference between the 2 groups, Kruskal-Wallis test was used. A descriptive level of p=0.170 was obtained, thus suggesting that there was no significant difference between the 2 groups.

Tables 4 and 5 shows the variation of average temperatures (°C) between the initial and final temperatures (ΔT) and the initial and peak temperatures (ΔT max) among the DL and HL groups. (Figures 1 and 2)

Table 4. The Variation of Average Temperature (°C) Between Initial and Final (ΔT) and Initial and Peak (ΔT max) Temperatures of the Irradiation by Diode Laser (DL) in the Same Region/Point

Teeth	ΔT	ΔT max
1	0.8	2.2
2	0.6	0.8
3	0.4	1.2
4	0.3	0.9
5	0.4	0.8
6	0.3	1.3
7	1.2	2.3
8	0.1	0.9
9	0.3	1.4

Table 5. The Variation of Average Temperature (°C) Between Initial and Final (ΔT) and Initial and Peak (ΔT max) Temperatures of the Irradiation by Halogen Lamp (HL) in the Same Region/Point

Teeth	ΔT	ΔT max
1	2.5	4.2
2	1.2	3.2
3	4.2	4.2
4	3.0	5.2
5	3.4	4.8
6	1.7	2.5
7	3.2	4.3
8	2.6	4.6
9	0.5	5.0

Table 6. Mean Values and Standard Deviations for the Temperature Variation ΔT and ΔT max of Different Groups

Groups	ΔT±(SD)	ΔT max±(SD)
Halogen lamp	2.61±0.99	4.13±0.94
Diode laser	0.46±0.37	1.31±0.58

The mean values and standard deviation for the ΔT and ΔT max of the different groups are described in Table 6. The student *t* test for mean values was used to verify the possible existence of differences between the 2 groups. For ΔT and ΔT max, a descriptive level less than 0.0001 was obtained, suggesting that a statistically significant difference existed between the 2 groups.

DISCUSSION

Today, dentistry has been focusing on developing techniques to provide minimal invasive procedures. The development of bleaching techniques has a crucial significance in solving esthetic problems caused by the darkening of traumatic teeth, mainly in children who frequently suffer traumatic injuries in anterior teeth. The bleaching treatment visits are comparatively short, making the technique useful and quickly acceptable to young patients.[5,15]

Bleaching discolored and nonvital primary teeth can be an option, considering the psychological aspect, since children are improving their self-esteem and sociability, and preservation of tooth structure.

The bleaching process still remains partially unclear. The mechanism basically consists in an oxidation and reduction reactions. H_20_2 is used as a whitening agent and has the ability to penetrate tooth structure and produce free radicals that promote a cleavage of stain molecules, transforming them into carbon dioxide and water, which are released with nascent oxygen.[2,16] At present, H_20_2 is commonly used at concentrations of 30% to 35%.[18]

Laser bleaching should be exhaustively studied so that its true value can be evaluated. There is no consensus on the laser's true efficiency compared to other energy sources in esthetics results. Some studies show superior esthetic results with laser bleaching,[12] while other studies not.[8,13]

It is crucial to know the exact wavelength and energy of the laser irradiation, as the main effect of laser energy is the photothermal effect that converts light energy into heat. Additionally, the secondary effect is the photochemical effect that absorbs photons by specific cromophores present inside the bleaching agents, thus producing reactive and unstable molecules of single ($O2^{-1}$) and triple ($O2^{-3}$) oxygen to improve the potential of the tooth bleaching process.[2,10]

The difficulty of defining the color scale to assess whitening must be considered. All the color scales present with a single color, not considering the polychromacity in the different thirds of natural teeth. Some authors use scores for color assessment,[16] while others consider it better to assess whitening via photographs. Ho and Goerig,[17] Rotstein,[18] Lorenzo et al,[19] Horn et al,[20] and Vachon et al,[21] showed that the spectrophotometer is able to more precisely assess tooth color than direct visual assessment. Therefore, the authors of this study opted to assess the color of whitened teeth by means of spectrophotometer. The color was also assessed by the VITA scale, however, since, in clinical studies, this is one of the most frequently used scales and has been shown to be effective compared with spectrophotometry.[3,22,23] There was a trend towards similarity between the analysis of color by spectrophotometer and the VITA 3D scale.

The source of activation of the whitening agent did not influence the whitening, as there was no statistically significant difference between the 2 groups analyzed. In both techniques primary tooth whitening was observed.

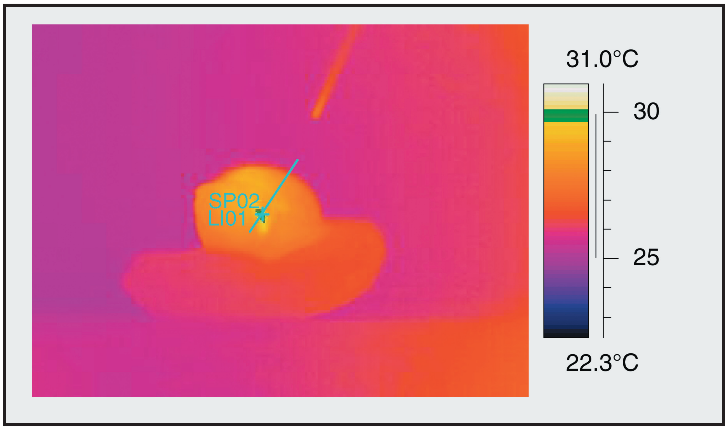

Figure 1. Thermographic image using the diode laser; the spot (SP02) indicates that the high temperature was monitored in the line (L101) during the entire procedure.

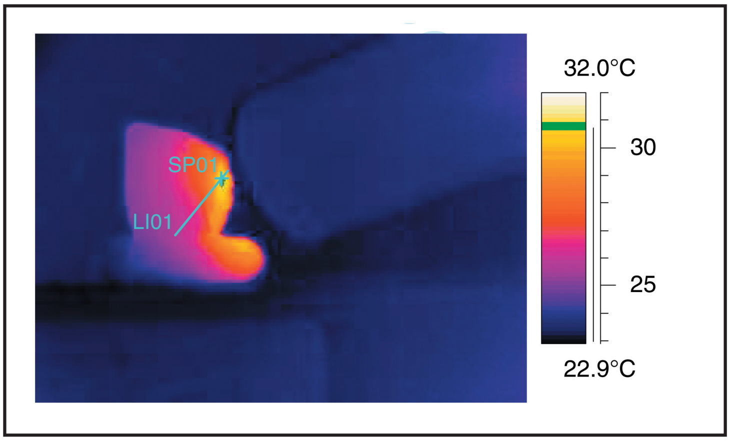

Figure 2. Thermographic image using the halogen lamp; the spot (SP01) indicates that the high temperature was monitored in the line (L101) during the entire procedure.

From the esthetic point of view, when comparing primary with permanent dentition, the fact that primary teeth have an accentuated, opaque, white shade perhaps explains why any type of stain—whether it is yellowish or grayish—is more noticeable. Hence, even after whitening treatment, if this darkening has not been completely eliminated, it will be more evident. These considerations are perhaps a reason why pediatric dentists quite frequently consider whitening treatment to be unsatisfactory for primary teeth.

Besides considering the color alteration, researchers tend to focus the adverse effect on pulpal tissue caused by an increase of intrapulpal temperature. Buchalla et al[24] found, in a systematic review, that application of activated bleaching procedures should be critically assessed considering the physical, psysiological, and pathophysiological implication. For devitalized teeth, intrapulpal temperature is not a significant matter, but the increased temperature of periodontal ligaments has to be considered.

Some methods are suggested in the literature to measure the temperature reached during the bleaching treatment. The thermocouple is usually used to measure the intrapulpal temperature, while the superficial temperature can be measured with a thermographic camera.[8,13,25] Since this study's purpose was to evaluate the temperature in the cervical area (enamel dentin junction), the thermographic camera was used, especially for its capacity to measure the surface temperature of specimens.

Regarding the analyzed parameters, the temperature variation was smaller when the laser was used (mean=0.46°C), as opposed to the halogen lamp (mean=2.61°C). After the statistical t test application, when the temperature reached the maximum peak and the total variation of the temperature was determined, a significant difference was verified between the 2 groups (1.31oC and 4.13ºC for laser and halogen lamp, respectively).

Wetter et al[13] demonstrated similar brighter results comparing the diode laser and xenon arc lamp in the bleaching of nonvital permanent incisors. The diode laser, however, promoted higher temperatures values using 0.9 W and 2W when comparing the xenon energy source. According to Friedman et al,[26] and White et al,[8] the increase of the temperature concentrated on the tooth structure's surface, using the halogen lamp and the diode laser, cannot be considered an etiological factor affecting the external cervical reabsorption, as it did not reach 10°C in the cervical region (enamel dentin junction), which is the temperature considered to be harmful to the periodontal ligament and the alveolar bone, according to Ericksson and Albrektsson.[14]

It is important to emphasize, however, that when the temperature increases, the H_20_2 can diffuse through dentinal tubules as far as the cervical periodontal ligament area. The caustic effect of the H_20_2 on the periodontal ligament may cause an inflammatory reaction, resulting in reabsorption. Alternatively, it may denature dentin and provoke an immunological response, enhancing osteoclastic activity and resulting in the external reabsorption process.[26]

The lack of previous studies related to bleaching using different energy sources in the vitalized and devitalized primary teeth made it difficult to associate and compare the data and discussions with previous studies.

New studies should be done using others irradiations parameters—including intensity, wavelength, and different times of laser and halogen lamp incidence—to establish the most efficient irradiation parameters and the best conditions for bleaching treatment in infant patients.

CONCLUSIONS

The use of a diode laser and halogen lamp both promoted whitening in devitalized primary teeth in vitro. Tooth whitening obtained with the use of a diode laser—at the parameters 808 nm±5 nm, 1.0 W, 10Hz, using a fiber of 400 µm, and in continuous mode—was statistically similar to whitening performed using the halogen lamp. There was a trend of similarity between the analysis of color by spectrophotometer and the VITA 3D scale. The use of the VITA 3D scale in a daily clinic would seem to be efficient.

As a catalytic source of energy, the diode laser—with the applied parameters—promoted a smaller temperature increase compared to the halogen lamp during the bleaching procedure on nonvital primary teeth. The laser and halogen lamp were both considered useful and safe methods, especially considering the temperature variation and the fact that no harmful temperatures were reached in the cervical region during the bleaching procedure.

REFERENCES

1. Holan G. Development of clinical and radiographic signs associated with dark discolored primary incisors following traumatic injuries: A prospective study. Dent Traumatol 2004;20:276-87.
2. Luk K, Tam L, Hubert M. Effect of light energy on peroxide tooth bleaching. J Am Dent Assoc 1999;135:194-201.
3. Waterhouse PJ, Nunn JH. Intracoronal bleaching of nonvital teeth in children and adolescents: Interim results. Quintessence Int 1996;27:447-53
4. Wray A, Welbury R. UK National clinical guidelines in pediatric dentistry: Treatment of intrinsic discoloration in permanent anterior teeth in children and adolescents. Int J Paed Dent 2001;11:309-15.
5. Donly KJ, Gerlach, RW. Clinical trials on the use of whitening strips in children and adolescents. Gen Den 2002;50:242-50.
6. Lee SS, Zhang W, Lee H, Li Y. Tooth whitening in children and adolescents: A literature review. Pediatr Dent 2005;27:362-8.
7. Goldstein RE, Garber DA. *Complete Dental Bleaching*. 3rd ed. Chicago, Ill: Quintessence; 1995.
8. White JM, Pelino JEP, Rodrigues RO, Zwhalen BJ, Nguyen MH, Wu EH. Surface and pulpal temperature comparison of tooth whitening using lasers and lights. Prog Biomed Opt 2000;1:95-101.
9. Feinman RA, Madray G, Yarborough D. Chemical, optical, and physiologic mechanisms of bleaching products: A review. Pract Period Aesthet Dent 1991; 3:32-6.
10. Garber DA. Dentist-monitored bleaching: A discussion of combination and laser bleaching. J Am Dent Assoc 1997;128(suppl):26S-30S.
11. Coluzzi DJ. Fundamentals of dental lasers: Science and instruments. Dent Clin North Am 2004;48:751-70.
12. Lizarelli RFZ, Moriyama LY, Bagnato VS. A nonvital tooth bleaching technique with laser and LED. J Oral Laser Appl 2002;2:45-7.
13. Wetter NU, Walverde DA, Kato IT, Eduardo CP. Bleaching efficacy of whitening agents activated by xenon lamp and 960 nm diode radiation. Photomed Laser Surg 2004;22:489-93.
14. Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: A vital-microscopy study in the rabbit. J Prosthet Dent 1983;50:101-7.
15. Kotlow LA. Lasers in pediatric dentistry. Dent Clin North Am 2004;48:889-922.
16. Baik JW, Rueggeberg FA, Liewehr FR. Effect of light-enhanced bleaching on in vitro surface and intrapulpal temperature rise. J Esthet Restor Dent 2001;13:370-8.
17. Ho S, Goering AC. An in vitro comparison of different bleaching agents in a discolored tooth. J Endod 1989; 15:106-11.
18. Rostein I. Role of catalase in the elimination of residual hydrogen peroxide following tooth bleaching. J Endod 1993;19:567-9.
19. Lorenzo JA, Gumbau GC, Sanchez CC, Navarro LF. Clinical study of a halogen light-activated bleaching agent in nonvital teeth: Case reports. Quintessence Int 1996;27:383-8.
20. Horn DJ, Lamar A, Hick M, Bulan-Brady J. Effect of smear layer removal on the bleaching of human teeth in vitro. J Endod 1998;24:791-5.
21. Vachon C, Vanek P, Friedman S. Internal bleaching with 10% carbamide peroxide in vitro. Pract Periodontics Aesthet Dent 1998;10:1145-52.
22. Viscio D, Gaffar A, Fakhry-Smith S, Xu T. Present and future technologies of tooth whitening. Compend Contin Educ Dent 2000;21(suppl):36-43.
23. Üngor HAM. In vitro comparison of different types of sodium perborate used for intracoronal bleaching of discolored teeth. Int Endod J 2002;35:433-6.
24. Buchalla W, Attin T. External bleaching therapy with activation by heat, light, or laser: A systematic review. Dent Mater 2007;23:586-96.
25. Launay Y, Mordon S, Cornil A, Brunetaud JM, Moschetto Y. Thermal effects of lasers on dental tissues. Lasers Surg Med 1987;7:473-7.
26. Friedman S, Rotstein I, Libfeld H, Stabholz A, Heling I. Incidence of external root resorption and esthetic results in 58 bleached, pulpless teeth. Endod Dent Traumatol 1988;4:23-6.