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Effect of Light Activation on Tooth Sensitivity After In-Office Bleaching

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Clinical Relevance

The use of a light activation source does not affect the outcome of in-office bleaching and increases the duration of tooth sensitivity.

SUMMARY

This clinical study evaluated the effects of light-emitting diode (LED)/laser activation on bleaching effectiveness (BE) and tooth sensitivity (TS) during in-office bleaching. Thirty caries-free patients were divided into two groups: light-activated (LA) and non-activated (NA) groups. A 35% hydrogen peroxide gel (Whiteness HP Maxx, FGM Dental Products, Joinville SC, Brazil) was used in three 15-minute applications for both groups. For the LA group, LED/laser energy (Whitening Lase Light Plus, DMC Odontológica, São Carlos SP, Brazil) was used, in accordance with the manufacturer's directions. Two sessions of bleaching were performed at one-week intervals. Color was registered at baseline and after the first and second bleaching sessions using a Vita shade guide. Patients recorded TS on a 0 to 4 scale during bleaching and within the next 24 and 48 hours of each session. BE at recall each week and intensity of TS were evaluated by repeated measures analysis of variance (ANOVA) and Tukey tests (α=0.05). Tooth sensitivity was compared using the Friedman repeated measures analysis of variance by rank and the Wilcoxon sign-ranked test. Faster bleaching was observed for the LA group than for the NA group after the first session (4.8 and 3.8 shade guide units [SGUs]; p=0.0001). However, both techniques were capable of bleaching the same number of SGUs after the second bleaching session (p=0.52). Most of the LA group (53.3%) had sensitivity even 24 hours after each bleaching session, but only 26.6%

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from the NA group reported TS. The intensity of TS was similar for both groups immediately after bleaching but significantly higher for the LA group 24 hours after each bleaching session (p=0.001). After two bleaching sessions, the use of LED/laser light activation did not improve bleaching speed. Persistent tooth sensitivity and higher tooth sensitivity after 24 hours of bleaching were observed when light activation was used.

INTRODUCTION

Tooth whitening nowadays is one of the most frequently requested cosmetic dental procedures by patients who want a "perfect white smile."[1] Usually, vital tooth bleaching can be categorized generally as in-office (professionally administered), at-home (professionally dispensed) or over-the-counter (self-administered).

Advantages of in-office dental bleaching over at-home or over-the-counter bleaching techniques include professional control, avoidance of soft tissue exposure and material ingestion, reduced total treatment time, and the possibility of immediate results.[2,3] Most bleaching solutions contain hydrogen peroxide or carbamide peroxide as the active ingredient delivered through various carrier designs[4] that are applied with or without light activation.

Proponents of light-activated bleaching claim that this procedure reduces total in-office bleaching time by energizing hydrogen peroxide through the use of various light sources.[1,2,5] The theoretical advantage is the ability of the light source to heat the hydrogen peroxide, thereby increasing the rate of decomposition of oxygen and accelerating the release of free radicals with higher kinetic energy, thus enhancing the rupture of stain-containing molecules.[6,7]

Despite the fact that many curing lights have been introduced onto the dental market for the purpose of accelerating the bleaching process, the effectiveness of such an approach has been controversial.[1,8-16]

One of the most common side effects associated with vital tooth bleaching is tooth sensitivity. Reports and estimates of bleaching-induced tooth sensitivity incidence range from 55% to 100%,[1,3,13,17,18] and the degree of tooth sensitivity in these reports ranges from very mild to intolerable. Existing literature reveals that activation of bleaching agents by heat or light (halogen, light-emitting diode [LED], or laser) may have an adverse effect on pulpal tissue.[19,20] It was already reported that the use of intense lights does elevate bleach temperature, but it results in increased intrapulpal temperatures,[21] which may further impact patient sensitivity and pulpal health.

As dental professionals, we have an obligation to pursue scientific knowledge about what is available to treat our patients' teeth, so that we can differentiate between effective and safe bleaching methods and those that are marketed on the basis of promotional speculation.[22] Therefore, the aim of this clinical study was to evaluate the effects of LED/laser activation on bleaching effectiveness and tooth sensitivity during in-office bleaching.

MATERIALS AND METHODS

This clinical investigation was approved (protocol number 05531/09) by the Scientific Review Committee and by the Committee for the Protection of Human Subjects at the local university. On the basis of pre-established criteria, 30 students from the same university were selected for inclusion in this study. All patients had anterior teeth with initial shade C2 or darker, as judged by comparison with a value-oriented shade guide (Vita Lumin, Vita Zahnfabrik, Bad Säckingen, Germany). Two weeks before the bleaching procedures were performed, all subjects received a dental screening and dental prophylaxis and signed an informed consent form.

Inclusion and Exclusion Criteria

Patients included in this clinical trial were at least 18 years old and had good general and oral health. Participants were required to have eight caries-free maxillary anterior teeth without restorations on the labial surfaces and central incisors shade C2 or darker. They were asked to sign a consent form. Patients who had undergone tooth-whitening procedures and those presenting with anterior restorations, were pregnant/lactating, had severe internal tooth discoloration (tetracycline stains, fluorosis, pulpless teeth), or bruxism habits, or without general good oral health, were excluded from the study. Patients were asked about previous sensitivity the week before bleaching therapy was begun, using the criteria described in the tooth sensitivity evaluation section. Patients with sensitivity equal to or greater than mild were excluded from the study.

Study Design

Subjects were randomly divided into light-activated (LA) and non-activated (NA) groups by means of a coin toss. This was a single-blind study in that only

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the evaluator who measured the color after the bleaching protocol was blinded to the experimental condition. After prophylaxis procedures were performed, the gingival tissue of the teeth to be bleached was isolated using a light-cured resin dam (Top Dam, FGM Dental Products, Joinville SC, Brazil). The 35% hydrogen peroxide gel (Whiteness HP Maxx, FGM Dental Products) was used in three 15-minute applications for both groups. For the LA group, LED/laser energy (Whitening Lase Light Plus, DMC Odontológica, São Carlos SP, Brazil) was used according to the manufacturer's directions. This light source is made of a matrix of LEDs with wavelength of 470 nm and three infrared laser diodes with 830 nm and light intensity of 200 mW/cm^2. The tooth surfaces were activated for 1 minute, and then the device was turned off for 2 minutes. This procedure was repeated three times. The in-office bleaching agent was refreshed every 15 minutes during the 45-minute application period. Two sessions of bleaching at one-week intervals were performed. All participants were instructed to brush their teeth regularly using fluoridated toothpaste (Sorriso Fresh, Colgate-Palmolive, São Paulo, Brazil). The NA group had the same protocol of gel application but without light activation.

Shade Evaluation

The color was registered at baseline and after the first and second bleaching sessions using a Vita shade guide. The 16 tabs of the shade guide were arranged from highest (B1) to lowest (C4) value, making the shade C2 as number 7. Although this scale is not linear in the truest sense, we treated the changes as representing a continuous and approximately linear ranking for the purpose of analysis. Shade changes from the start of the active phase to the individual recall times were calculated by calculating the change in the number of shade guide units (Δ SGUs) that occurred toward the lighter end of the value-oriented list of shade tabs. Two calibrated evaluators recorded the shade of each subject's teeth at baseline and weekly. The measurement area of interest for shade matching was the middle one-third of the facial surface of the anterior (central) incisors, according to American Dental Association[23] guidelines. Five patients whom we did not include in the sample because they were used in the pilot study participated in the training phase of this study. The two examiners scheduled these patients for bleaching and evaluated their teeth weekly against the shade guide. The two examiners were required to have agreement of at least 85% (kappa statistic) before beginning the study evaluation.

Tooth Sensitivity Evaluation

Patients recorded their perception of TS on a 0 to 4 scale during bleaching and within the next 24 and 48 hours of each session. We asked subjects to use the following scale to record daily whether they experienced sensitivity: 0 = none, 1 = mild, 2 = moderate, 3 = considerable, and 4 = severe.[3,24] We averaged these values for statistical purposes and arranged them into two categories: overall percentage of patients with tooth sensitivity and overall tooth sensitivity intensity.

Statistical Analysis

Agreement between examiners was evaluated using the kappa statistic. Means and standard deviations for changes in Δ SGUs after each of the two bleaching sessions for each group were calculated. To evaluate whether or not bleaching therapies were effective, the Δ SGU of each group was submitted to a one-way repeated measures analysis of variance (ANOVA). Post-hoc analysis (Tukey test, α=0.05) was used to make pairwise comparisons. The different percentages of patients with sensitivity at different periods of time for each group were compared using the Friedman repeated measures analysis of variance by rank. The percentage of patients with tooth sensitivity at each period of time between groups was compared using the Wilcoxon sign-ranked test (α=0.05).

RESULTS

All participants completed the study. The kappa statistic agreement between the two evaluators was 89%. Means and standard deviations of Δ SGU are depicted in Table 1. Both bleaching therapies were effective in terms of bleaching, as statistically similar changes in the total number of SGUs were observed after two sessions of in-office bleaching. However, comparison of bleaching speed after just the first clinical appointment showed that the LED/laser-activated group bleached more SGUs than the non-activated group ($p<0.05$), and was therefore faster.

With regard to prevalence of tooth sensitivity, 86.6% of participants from the non-activated group and 100% of participants from the LED/laser-activated group experienced tooth sensitivity immediately after bleaching (p=0.48; Table 2). The percentage of patients with tooth sensitivity de-

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Table 1: *Tooth Shade at Assessment Points for the Two Treatment Groups*[a]

	Treatment	
	With LED/Laser	**Without LED/Laser**
Baseline	7.61 ± 0.9 aA	8.12 ± 1.1 aA
After first session	2.82 ± 1.0 bB	4.32 ± 0.9 cC
After second session	1.11 ± 0.6 dD	1.34 ± 0.7 dD

[a] *Similar lower case letters indicate statistically similar means within columns. Similar upper case letter indicate statistically similar means within rows (p<0.05).*

creased significantly after 48 hours for both groups ($p<0.05$). Approximately 53.3% and 26.6% of participants from the LED/laser-activated and non-activated groups, respectively, showed tooth sensitivity after 24 hours. Around 33% of participants from the LED/laser-activated group reported tooth sensitivity after this period; no participants from the non-activated group presented sensitivity (Table 2). The percentage of patients with sensitivity was similar for the two groups immediately and after 24 hours ($p>0.05$). However, a significant difference between groups was detected after 48 hours. The percentage of patients with sensitivity was significantly higher in the LED/laser-activated group (33.3%) than in the non-activated group (0%) after 48 hours ($p=0.04$) (Table 2).

Figure 1 depicts percentages of participants according to the level of reported tooth sensitivity

Table 2: *Comparison of Numbers and Percentages (%) of Patients Who Experienced Tooth Sensitivity During the Bleaching Regimen*[a]

	With LED/Laser		Without LED/Laser	
	Number (%)	**Statistical Analysis**	**Number (%)**	**Statistical Analysis**
Immediate	15 (100)	aA	13 (86.6)	cA
24 hours	8 (53.3)	bB	4 (26.6)	dB
48 hours	5 (33.3)	bC	0 (0.0)	dD

[a] *Similar lower case letters indicate groups with similar medians (Friedman repeated analysis of variance) within columns. Similar upper case letters indicate groups with similar medians within rows (Wilcoxon sign-rank test) (p<0.05).*

for both groups immediately after bleaching. One can observe that severe sensitivity was reported by only two participants from the LED/laser-activated group, and two participants from the non-activated group did not present sensitivity. The sensitivity levels of both groups were similar immediately and after 48 hours (median, 2 and 0, respectively) ($p>0.05$). However, a significant difference between groups was detected after 24 hours. The intensity of sensitivity was significantly higher in the LED/laser-activated group (median, 1) than in the non-activated group (median, 0) after 24 hours ($p=0.01$) (Table 3).

DISCUSSION

Comparison of color change after in-office bleaching as described in the existing literature is difficult because of the different methods of measurement (shade guides and spectrophotometers) and the different units of measurement (CIELAB system, shade guide units, etc.) used. However, studies that used 35% hydrogen peroxide (with and without light activation) and reported their results in shade guide units (SGUs) usually observed an overall color change of 5 to 8 SGUs after two bleaching sessions,[1,9,25] which is consistent with results of the present investigation. This wide range of color change is probably the result of different materials employed and the length of time after which color was assessed.

In the current study, faster bleaching was observed for the LA group than for the NA group after the first session of bleaching. The rationale behind the benefits of light activation is that a small fraction of light is absorbed by the bleaching product, and its energy is converted to heat. Most likely, this is the main mechanism of action of all light-activated bleaching procedures, and it leads to increased release of hydroxyl radicals through a rise in temperature (thermocatalysis),[5,26] which may favor the initial whitening effect observed for the LA group after the first bleaching session. It is also reported that release of hydroxyl radicals from H_2O_2 is possible through direct excitation by light (photolysis).

Different light sources have been used to activate bleaching agents, including halogen curing lights, ultraviolet and infrared lamps, plasma arcs, light-emitting diodes (LEDs), and lasers (CO_2, argon, and diode lasers). The light source used in this study is made of a matrix of LEDs and three diode lasers. Although the temperature rise was not measured, one can suppose based on previous studies that the

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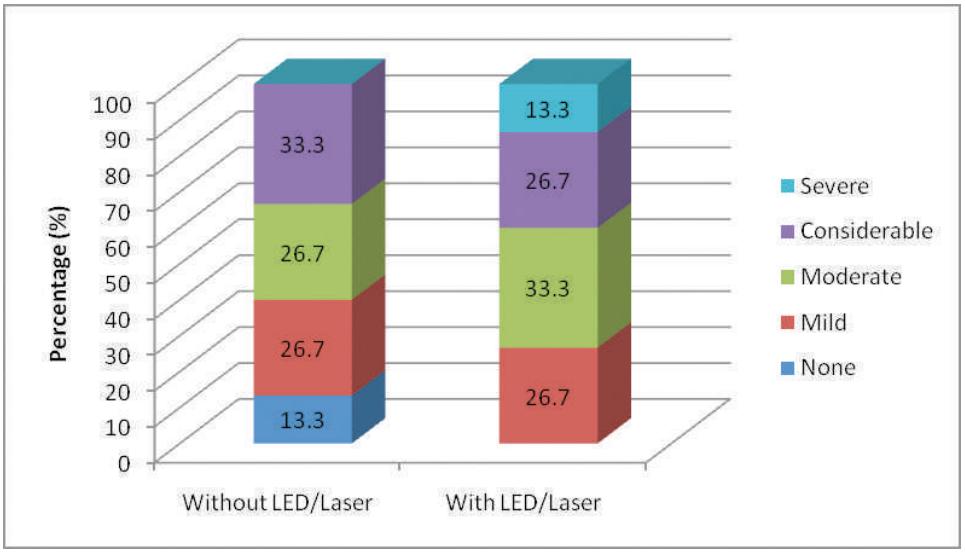

Figure 1. *Levels of sensitivity (%) perceived by participants in both groups immediately after the bleaching protocol.*

LED source produces the least thermal insult during the light activation process[27-29]; this light source was employed in the present investigation for this reason. The use of high-intensity light to raise the temperature of the hydrogen peroxide and to accelerate the rate of bleaching was reported in 1918.[5] Other approaches for heating peroxide, such as heated dental instruments, have historically been described to accelerate tooth whitening. However, these techniques could excessively heat the pulpal tissues, causing irreversible damage.[5]

One cannot rule out the fact that the initial difference between tooth whitening that favored the LA group could be attributed to teeth dehydration caused by the generation of heat from the light source.[11] Thus, the recorded change in color appearance during bleaching treatment would be more accurately described as desaturation rather than bleaching/whitening.[14] This hypothesis is supported by clinical findings showing that light alone can produce an initial whitening effect, which, however, is not sustained for a long time.[13,16] This seems to be the most appropriate explanation for faster bleaching after one clinical appointment, because no significant benefit of light activation was found between groups after two bleaching sessions. This is consistent with findings of recent studies reporting that powerful light sources have no effect on the actual speed or extent of bleaching.[1,8-12,15]

However, some clinical studies have reported that the use of a light can improve bleaching efficacy.[13,14,16] Closer analysis of these studies reveals that they employed bleaching gels with lower hydrogen peroxide concentrations (15% to 25%). One may hypothesize that light activation may improve the whitening effect in this circumstance, because the quantity of available radicals produced only by the chemical degradation of hydrogen peroxide may be the limiting factor in the bleaching reaction. Because light can definitely improve the degradation rate of hydrogen peroxide,[30] a light source may be useful to activate the bleaching procedure for low–hydrogen peroxide bleaching gels; the increase in hydroxyl radicals compensates for the low concentration of the gel.

The beneficial effect of light activation likely is not perceived when 35% hydrogen peroxide is used,[1,9,15]

Table 3: *Median (Minimum and Maximum) of Intensity of Tooth Sensitivity Immediately After and 24 and 48 Hours After the Bleaching Regimen*[a]

	With LED/Laser		Without LED/Laser	
	Median (min/max)	Statistical Analysis	Median (min/max)	Statistical Analysis
Immediate	2 (0/4)	aA	2 (0/3)	dA
24 hours	1 (0/2)	bB	0 (0/1)	eC
48 hours	0 (0/1)	cD	0 (0/0)	eD

[a] *Similar lower case letters indicate groups with similar medians (Friedman repeated analysis of variance) within columns. Similar upper case letters indicate groups with similar medians within rows (Wilcoxon sign-rank test) ($p<0.05$).*

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because the quantity of radicals already produced by the chemical degradation of hydrogen peroxide is enough to react with pigments in the dentin structure and any further increase in this quantity will not accelerate bleaching. It is likely that in this situation, the limiting factor is no longer the quantity of the reagents, but the reaction time itself. Moreover, it has been suggested that use of a light source should be considered optional for in-office bleaching when higher concentrations of hydrogen peroxide are used.[9]

Tooth sensitivity seems to result from the easy passage of peroxide through enamel and dentin to the pulp; this takes approximately 5 to 15 minutes to occur.[31] Further proof of this rapid passage of peroxide is seen in research findings showing that the dentin changes color next to the pulp as fast as it does next to the dentin-enamel junction.[32] Hence, sensitivity results from the insult of the peroxide on the nerve and may be considered a reversible pulpitis.

The present investigation noted higher levels of tooth sensitivity for both groups immediately after the bleaching procedure. Based on previous studies, we may report that the overall percentage of patients who experience tooth sensitivity after in-office bleaching ranges from 50% to 80%, depending on the type and concentration of material used.[13,16,25] However, tooth sensitivity seemed to be less persistent when the light source was not used. Although tooth sensitivity in most patients resolved within 24 hours for the NA group, LA patients still presented higher levels of tooth sensitivity up to 48 hours. This finding was also reported by previous investigators.[8,13,14,16] Kugel and others[13] noted that although the use of light with peroxide gel resulted in immediate incremental whitening, this was largely offset by the increased occurrence and severity of tooth sensitivity.

It was previously demonstrated that in-office bleaching treatment seems to result in increased tooth sensitivity when compared with at-home bleaching,[9] mainly when light activation was used.[9,13,14,17] Although some *in vitro* studies have not found differences in the viability of pulp cells when 35% hydrogen peroxide was associated with light sources,[20,33] other *in vitro* studies have indicated that application of the bleaching gel associated with halogen light produced more severe cytotoxic effects to the cultured odontoblast than application of hydrogen peroxide alone.[19] Besides this, laser-activated tooth-bleaching systems increase expression of substance P (SP) in human dental pulp to significantly higher than normal values.[6] Substance P is, among others, an important neuropeptide that has the primary function to induce vasodilation, increasing pulpal blood flow and allowing rapid and large arrival of inflammatory cells. These increased levels of SP may be clinically relevant because they could cause a neurogenic inflammatory reaction in pulp tissue.[6] Perhaps this hypothesis can explain the higher levels of tooth sensitivity observed when the LED/laser was applied in the current study.

As yet, it is still debatable whether activation results in superior tooth brightening as compared with non-activated bleaching therapies. Therefore, application of heat and light-activated bleaching procedures should be critically considered, while the physical, physiologic, and pathophysiologic implications are kept in mind. If heat or light activation is applied, it is strongly advised to follow the manufacturer's recommendations with limited duration of heat activation, to avoid undesired pulpal responses.[26]

CONCLUSIONS

After two bleaching sessions, the use of light activation did not improve bleaching speed. Persistent tooth sensitivity and higher tooth sensitivity levels after 24 hours of bleaching were observed when LED/laser light activation was used.

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REFERENCES

1. Marson FC, Sensi LG, Vieira LCC & Araújo E (2008) Clinical evaluation of in-office dental bleaching treatments with and without the use of light-activation sources *Operative Dentistry* **33(1)** 15-22.
2. Luk K, Tam L & Hubert M (2004) Effect of light energy on peroxide tooth bleaching *Journal of the American Dental Association* **135(2)** 194-201.
3. Tay LY, Kose C, Loguercio AD & Reis A (2009) Assessing the effect of a desensitizing agent used before in-office tooth bleaching *Journal of the American Dental Association* **140(10)** 1245-1251.
4. Haywood VB & Heymann HO (1989) Nightguard vital bleaching *Quintessence International* **20(3)** 173-176.
5. Joiner A (2006) The bleaching of teeth: A review of the literature *Journal of Dentistry* **34(7)** 412-419.
6. Caviedes-Bucheli J, Ariza-García G, Restrepo-Méndez S, Ríos-Osorio N, Lombana N & Muñoz HR (2008) The effect

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of tooth bleaching on substance P expression in human dental pulp *Journal of Endodontics* **34(12)** 1462-1465.

7. Rosenstiel SF, Gegauff AG & Johnston WM (1991) Duration of tooth color change after bleaching *Journal of the American Dental Association* **122(4)** 54-59.
8. Alomari Q & El Daraa E (2010) A randomized clinical trial of in-office dental bleaching with or without light activation *The Journal of Contemporary Dental Practice* **11(1)** 17-24.
9. Bernardon JK, Sartori N, Ballarin A, Perdigão J, Lopes GC & Baratieri LN (2010) Clinical performance of vital bleaching techniques *Operative Dentistry* **35(1)** 3-10.
10. Gurgan S, Cakir FY & Yazici E (2010) Different light-activated in-office bleaching systems: a clinical evaluation *Lasers in Medical Science* **25(6)** 817-822.
11. Hein K, Ploeger BJ, Hartup JK, Wagstaff RS, Palmer TM & Hansen LD (2003) In-office vital tooth bleaching—What do lights add? *Compendium of Continuing Education in Dentistry* **24(4A)** 340-352.
12. Kugel G, Papathanasiou A, Williams AJ 3rd, Anderson C & Ferreira S (2006) Clinical evaluation of chemical and light-activated tooth whitening systems *Compendium of Continuing Education in Dentistry* **27(1)** 54-62.
13. Kugel G, Ferreira S, Sharma S, Barker ML & Gerlach RW (2009) Clinical trial assessing light enhancement of in-office tooth whitening *Journal of Esthetic and Restorative Dentistry* **21(5)** 336-347.
14. Ontiveros JC & Paravina RD (2009) Color change of vital teeth exposed to bleaching performed with and without supplementary light *Journal of Dentistry* **37(11)** 840-847.
15. Papathanasiou A, Kastali S, Perry RD & Kugel G (2002) Clinical evaluation of a 35% hydrogen peroxide in-office whitening system. *Compendium of Continuing Education in Dentistry* **23(4)** 335-338.
16. Tavares M, Stultz J, Newman M, Smith V, Kent R, Carpino E & Goodson JM (2003) Light augments tooth whitening with peroxide *Journal of the American Dental Association* **134(2)** 167-175.
17. Amengual J & Forner L (2009) Dentine hypersensitivity in dental bleaching: case report *Minerva Stomatology* **58(4)** 181-185.
18. Nathanson D & Parra C (1987) Bleaching vital teeth: a review and clinical study *Compendium* **8(7)** 490-497.
19. Ribeiro APD, Sacono NT, Lessa FCR, Nogueira I, Coldebella CR, Hebling J & Costa CA (2009) Cytotoxic effect of a 35% hydrogen peroxide bleaching gel on odontoblast-like MDPC-23 cells *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* **108(3)** 458-464.
20. Trindade FZ, Ribeiro AP, Sacono NT, Oliveira CF, Lessa FC, Hebling J & Costa CA (2009) Trans-enamel and trans-dentinal cytotoxic effects of a 35% H2O2 bleaching gel on cultured odontoblast cell lines after consecutive applications *International Endodontics* **42(6)** 516-524.
21. Baik JW, Rueggeberg FA & Liewehr FR (2001) Effect of light-enhanced bleaching on in vitro surface and intrapulpal temperature rise *Journal of Esthetic and Restorative Dentistry* **13(6)** 370-378.
22. Leonard RH, Smith LR, Garland GE, Tiwana KK, Zaidel LA & Pugh G (2007) Evaluation of side effects and patient's perceptions during tooth bleaching *Journal of Esthetic and Restorative Dentistry* **19(6)** 355-66.
23. American Dental Association Council of Scientific Affairs (2006) *Acceptance Program Guidelines: Dentist-Dispensed Home-Use Tooth Bleaching Products* ADA, Chicago, Ill.
24. Mokhlis GR, Matis BA, Cochran MA & Eckert GJ (2000) A clinical evaluation of carbamide peroxide and hydrogen peroxide whitening agents during daytime use *Journal of the American Dental Association* **131(9)** 1269-1277.
25. Strobl A, Gutknecht N, Franzen R, Hilgers RD, Lampert F & Meister J (2010) Laser-assisted in-office bleaching using a neodymium:aluminum-garnet laser: an in vivo study *Lasers in Medical Science* **25(4)** 503-509.
26. Buchalla W & Attin T (2007) External bleaching therapy with activation by heat, light or laser—a systematic review *Dental Materials* **23(5)** 586-596.
27. Eldeniz AU, Usumez A, Usumez S & Ozturk N (2005) Pulpal temperature rise during light-activated bleaching *Journal of Biomedical Material Research Part B Applied Biomaterials* **72(2)** 254-259.
28. Hofmann N, Hugo B & Klaiber B (2002) Effect of irradiation type (LED or QTH) on photo-activated composite shrinkage strain kinetics, temperature rise and hardness *European Journal and Oral Science* **110(6)** 471-479.
29. Usumez A & Ozturk N (2004) Temperature increase during resin cement polymerization under a ceramic restoration: Effect of type of curing unit *International Journal of Prosthodontics* **17(2)** 200-204.
30. Hanks CT, Fat JC, Wataha JC & Corcoran JF (1993) Cytotoxicity and dentin permeability of carbamide peroxide and hydrogen peroxide vital bleaching materials, in vitro *Journal of Dental Research* **72(5)** 931-938.
31. Cooper JS, Bokmeyer TJ & Bowles WH (1992) Penetration of the pulp chamber by carbamide peroxide bleaching agents *Journal of Endodontics* **18(7)** 315-317.
32. McCaslin AJ, Haywood VB, Potter BJ, Dickinson GL & Russell CM (1999) Assessing dentin color changes from nightguard vital bleaching *Journal of the American Dental Association* **130(10)** 1485-1490.
33. Coldebella CR, Ribeiro AP, Sacono NT, Trindade FZ, Hebling J & Costa CA (2009) Indirect cytotoxicity of a 35% hydrogen peroxide bleaching gel on cultured odontoblast-like cells *Brazilian Dental Journal* **20(4)** 267-274.

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