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Does the hybrid light source (LED/laser) influence temperature variation on the enamel surface during 35% hydrogen peroxide bleaching? A randomized clinical trial

Patricia Moreira de Freitas, DDS, PhD[1]/Andressa Nery Menezes, DDS[2]/Ana Carolina Costa da Mota, DDS[2]/Alyne Simões, DDS, PhD[3]/Fausto Medeiros Mendes, DDS, PhD[4]/Andrea Dias Neves Lago, DDS, PhD[5]/Leila Soares Ferreira, DDS, PhD[6]/Thayanne Monteiro Ramos-Oliveira, DDS, MSc[7]

Objective: The present study investigated how a hybrid light source (LED/laser) influences temperature variation on the enamel surfaces during 35% hydrogen peroxide (HP) bleaching. Effects on the whitening effectiveness and tooth sensitivity were analyzed. **Method and Materials:** Twenty-two volunteers were randomly assigned to two different treatments in a split-mouth experimental model: group 1 (control), 35% HP; group 2 (experimental), 35% HP + LED/laser. Color evaluation was performed before treatment, and 7 and 14 days after completion of bleaching, using a color shade scale. Tooth sensitivity was assessed using a visual analog scale (VAS; before, immediately, and 24 hours after bleaching). During the bleaching treatment, thermocouple channels positioned on the tooth surfaces recorded the temperature. Data on color and temperature changes were subjected to statistical analysis (α = 5%). Tooth sensitivity data were evaluated descriptively. **Results:** Groups 1 and 2 showed mean temperatures (± standard deviation) of 30.7 ± 1.2°C and 34.1 ± 1.3°C, respectively. It was found that there were statistically significant differences between the groups, with group 2 showing higher mean variation ($P < .0001$). The highest temperature variation occurred for group 2, with an increase of 5.3°C at the enamel surface. The color change results showed no differences in bleaching between the two treatment groups ($P = .177$). The variation of the average temperature during the treatments was not statistically associated with color variation ($P = .079$). Immediately after bleaching, it was found that 36.4% of the subjects in group 2 had mild to moderate sensitivity. In group 1, 45.5% showed moderate sensitivity. In both groups, the sensitivity ceased within 24 hours. **Conclusion:** Hybrid light source (LED/laser) influences temperature variation on the enamel surface during 35% HP bleaching and is not related to greater tooth sensitivity. *(Quintessence Int 201#;VOL:1–13; doi: ##.####/j.qi.a#####)*

Key words: color, dental bleaching, dental enamel, laser, tooth sensitivity, temperature

[1] Associate Professor, Special Laboratory of Lasers in Dentistry, Department of Restorative Dentistry, School of Dentistry, University of São Paulo, SP, Brazil.

[2] Research Student, Special Laboratory of Lasers in Dentistry, Department of Restorative Dentistry, School of Dentistry, University of São Paulo, SP, Brazil.

[3] Assistant Professor, Division of Oral Biology, Department of Dental Materials, School of Dentistry, University of São Paulo, São Paulo, SP, Brazil.

[4] Associate Professor, Department of Pediatric Dentistry, School of Dentistry, University of Sao Paulo, São Paulo, SP, Brazil.

[5] Assistant Professor, Center of Biological Sciences and Health, University of Maranhão, São Luiz, MA, Brazil.

[6] Assistant Professor, Biodentistry Master Program, School of Dentistry, Ibirapuera University (UNIB), São Paulo, SP, Brazil.

[7] PhD Student, Special Laboratory of Lasers in Dentistry, Department of Restorative Dentistry, School of Dentistry, University of São Paulo, SP, Brazil.

Correspondence: Dr Patricia Moreira de Freitas, Special Laboratory of Lasers in Dentistry (LELO), Department of Restorative Dentistry, School of Dentistry, Av. Prof. Lineu Prestes, 2227 University of São Paulo, São Paulo, SP 05508-000, Brazil. Email: pfreitas@usp.br

Esthetics is increasingly prominent in dentistry, reflecting a growing demand by patients who seek an enhanced appearance, and the patients' smile has assumed significant relevance.[1] At present, the color of the teeth associated with the esthetic harmony of the smile seems to be one of the factors that make it easier for individuals to integrate into the social environment in which they live.

Often, vital teeth present color changes that substantially compromise esthetics.[2] According to the etiology of dental discoloration,[3] bleaching may be the treatment of choice, as it is a conservative approach, efficient, and in most cases, avoids invasive procedures involving the preparation of healthy dental structures, such as those required for direct and/or indirect restorations.[2,4]

The mechanism by which bleaching results in whiter teeth is not fully understood, but it is known that it is related to the decomposition of hydrogen peroxide (H_2O_2), the active agent of whitening gels. As a result of the hydrogen peroxide breakdown, free radicals are formed and diffused through the enamel and dentin structures, oxidizing complex organic molecules (which absorb light) into smaller molecules that absorb less light, resulting in bleaching effects.[3]

There are basically two techniques commonly used for tooth bleaching: at-home and in-office bleaching.[5] Considering in-office bleaching, the decomposition reaction of the gel can be catalyzed with the use of heat and/or light.[6] Halogen lamps, plasma arc, high-power laser with different wavelengths, light emitting diodes (LEDs), and hybrid light sources (LED/Laser) have been proposed to accelerate the decomposition reaction of the bleaching agent.[6] It has been reported that light sources have a positive influence on bleaching effectiveness.[7] However, several studies contradict this finding, stating that no differences in the final esthetic result are seen when using light sources, and that these lights have not demonstrated the ability to increase the effectiveness of bleaching with 35% to 38% hydrogen peroxide.[1,8-15] Furthermore, some authors have suggested that there is a possible increase in temperature generated during the use of some light sources, and have associated this with one of the most commonly reported adverse effects in bleaching, namely post-bleaching tooth sensitivity.[12,16]

LED is one of the light sources currently used, sometimes associated with low-power lasers (hybrid equipment).[8,19,12-14,17-19] Given the controversies related to the possible benefits arising from the use of these light sources in bleaching treatment,[8,10,12-14,18] it is important to analyze the color change of tooth surfaces and sensitivity when performing in-office bleaching associated with the use of this light source (LED/laser). Moreover, little is known about the temperature variation on the enamel surface during the use of light sources associated with the in-office bleaching technique.[17,20,21] To date, there are no in vivo reports of the temperature rise generated with the use of hybrid light sources on the enamel surface during tooth bleaching with 35% hydrogen peroxide.

Considering this background, the present clinical study investigated how the hybrid light source (LED/laser) would influence temperature variation on the enamel surface during 35% hydrogen peroxide in-office bleaching. Moreover, effects on whitening effectiveness and tooth sensitivity were analyzed. The null hypotheses tested were that the 35% hydrogen peroxide in-office bleaching associated to the use of a hybrid light source (LED/laser):

- does not lead to a higher temperature variation on the enamel surface when compared to the bleaching without the light
- does not influence bleaching effectiveness
- does not lead to greater tooth sensitivity compared to the conventional treatment (without light).

METHOD AND MATERIALS

Ethical aspects and participant selection

This clinical study was submitted to the Research Ethics Committee of the School of Dentistry of the University of São Paulo, being approved under Protocols #11/07 and #12/07. The design of the experimental groups followed the standards of CONSORT [Consolidated Standards of Reporting Trials].[22] This study was a randomized, blinded clinical trial in which 26 patients were

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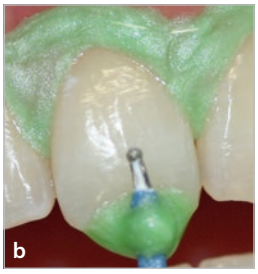

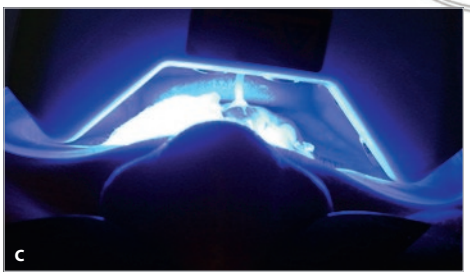

Figs 1a to 1e *(a)* Initial closed-up view of the anterior teeth (tooth color shade A3). *(b)* Thermocouple channel positioned on the central incisor teeth. *(c)* Bleaching session: control group was kept hydrated with moist gauze (left side), which shrouded the entire tooth surface while bleaching was completed in the experimental group (right side). *(d)* Temperature registration during bleaching. *(e)* Final closed-up view of the anterior teeth (tooth color shade A1).

evaluated at the Special Laboratory of Laser Dentistry (LELO, Department of Restorative Dentistry) of the School of Dentistry of the University of São Paulo (FO-USP), of whom 22 volunteers were selected (four were excluded as they did not meet inclusion criteria). Sample size was determined based on previous study data,[12] which reported that in-office bleaching with 35% hydrogen peroxide (one session) without application of light produces a bleaching of approximately 3.8 Shade Guide Units (SGU). This was substantiated with a group size of 17, under the assumption that $\alpha = .05$ and $\beta = .2$. Participants were adult undergraduate students of the University of São Paulo (10 male and 12 female), aged between 18 and 25 years (mean age 20.5 years). The inclusion and exclusion criteria considered for the study are described below.[10]

Inclusion criteria:

- minimum age of 18 years and maximum age of 25 years
- presence of all teeth, without restorations in maxillary and mandibular anterior teeth
- lack of tooth sensitivity (stimulated with air jet)
- patients with tooth color A2 or darker, according to Color Scale VITA® Classical
- without having undergone bleaching prior to the experiment.

Exclusion criteria:

- presence of any systemic pathology
- presence of periodontal disease
- systematic use of tobacco and alcoholic beverages
- patients with tooth color changed by tetracycline
- patients with a history of tooth sensitivity.
- pregnancy or lactation.

All volunteers were informed about the nature of the study, the procedures involved, discomforts, risks, and benefits. The volunteers were asked to sign a term of free and informed consent, previously approved by the Research Ethics Committee of the School of Dentistry (USP), which they did before participating in the study. Figure 1 illustrates some of the clinical steps performed in the research protocol.

Run-in period

In a first clinical session, oral hygiene instructions were given to the volunteers and each one received an oral hygiene kit containing a soft toothbrush (Colgate Classic, Colgate-Palmolive), fluoridated toothpaste (Colgate Total 12, 1450 ppm F, Colgate-Palmolive) and tooth floss (Colgate-Palmolive). The run-in period consisted of 7 days before tooth whitening began,[23,24] during which volunteers were committed to using only the

Table 1 Composition and characteristics of the product used for teeth whitening

Product	Composition	pH
Lase Peroxide Sensy (DMC)	33% to 35% Hydrogen peroxide, thickener, dye (annatto and juá), plant extracts, amide, glycol, and water	Phase peroxide, pH ≅ 2.5; phase thickener, pH ≅ 10; after mixture of phases, pH between 6.5 and 7.5

Table 2 Description of treatments performed in each maxillary hemi-arch of the study volunteers

Treatment	Group I (control): bleaching with 35% hydrogen peroxide without association with hybrid light source	Group 2 (experimental): bleaching with 35% hydrogen peroxide associated with hybrid light source
1	Application of 35% hydrogen peroxide gel in maxillary hemi-arch	Application of 35% hydrogen peroxide gel in maxillary hemi-arch
2	Gel maintained at rest for 15 mins	Application of gel for 6 mins, interspersing 1 min of rest with 1 min of activation; after this, 2 mins of rest
3	Removal of excess gel with high power suction appliance and dry gauze	Removal of excess gel with high power suction appliance and dry gauze
4	Repetition of process two more times	Repetition of process two more times
5	Abundant washing with water	Abundant washing with water
Time	Total: 45 mins (3 bleaching gel applications of 15 mins each)	Total: 24 mins (3 bleaching gel applications of 8 mins each)

products supplied by the researcher, throughout the entire period of the experiment. They were instructed to avoid the use of mouthwashes, desensitizing products and other oral hygiene products that could influence the results of the study.[23] Volunteers were also counseled with regard to dietary habits, in order to minimize or avoid tooth pigmentation during the experimental period.[14,15,24]

Bleaching treatment

A single researcher (ADNL), specialist in Restorative Dentistry and with proven clinical experience, conducted the tooth bleaching procedures of all volunteers. The treatment groups were randomly distributed in the volunteers' hemi-arches (split-mouth design) by a researcher (PMF) not involved in any of the stages of the experiment, and recorded in spreadsheets (Microsoft Office Excel, Microsoft), which were only seen at the time of the bleaching procedure. The split-mouth design has been reported by several authors[4,5,8,10,11,14,25] and allows the comparison of two whitening techniques in one volunteer, thereby reducing the influence of variables related to the individual.[10,26]

After the volunteers' teeth had been submitted to prophylaxis with pumice and water, a gingival barrier (Protect Lase, DMC) was placed to protect both soft tissues and exposed root dentin. Hydrogen peroxide gel (35%; Lase Peroxide Sensy, DMC) was applied on the enamel surface (second premolar to second premolar), in accordance with the manufacturer's instructions. The composition of the bleaching agent used in the study is shown in Table 1. Bleaching was performed in the maxillary arch, which was divided into two groups (n = 22), one in each hemi-arch (split-mouth experimental design): control (no association with the light source) and experimental (associated with the hybrid light source, LED/laser). In each volunteer, the hemi-arches submitted to bleaching with and without light were determined randomly. The treatments carried out in each group are shown in Table 2.

The hybrid light source used consisted of an LED that generates blue light at a wavelength of 470 nm and irradiance of 350–400 mW/cm^2, and has three infrared diode laser points (810 nm), each with a power of 0.2 W (Whitening Lase II, DMC).

Bleaching was performed in the experimental group before the procedure in the control group, in order to prevent the interaction of hybrid light with the whitening gel that may possibly have remained on the tooth structure of the control group. Furthermore, the

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control group was kept hydrated with moist gauze, which shrouded the entire tooth surface while bleaching was completed in the experimental group. Bleaching consisted of one clinical session for both bleaching techniques.[1,4,5,11,14,15,18,19,25,27] After the bleaching procedure, the enamel surface was polished with a felt disc (Lase Peroxide Sensy, DMC), in accordance with the manufacturer's guidelines.

Tooth color change

Tooth color evaluation was performed by two calibrated blinded examiners (κ = .92), in predetermined time intervals (before the treatment, and 7 and 14 days after completion of bleaching). The shade was recorded while the patient sat on the dental chair, facing the office window, with the light coming from behind the examiner, always between noon and 2:00 p.m.[1] The color measurements were made on the central incisors and canines (middle third of the labial surfaces) using a tooth color scale (VITA Classical Shade Guide, Vita Zahnfabrik).

The VITA Classical Shade Guide was arranged in order of luminosity (scores 1 to 16), as described in previous studies.[5,10,15,24,28] The 16 Shade Guide Units (SGU) were organized from the highest luminosity (B1) to the lowest luminosity (C4). The ΔSGU (represented by the difference between the initial and final SGUs) were considered for the statistical analysis. Although this scale is not quantitative in its truest sense, the changes were treated as linear data for the purposes of statistical analysis.[29]

As all subjects received both treatments, the cluster nature of the data (treatments clustered in the volunteers) was considered. Therefore, tooth color changes were statistically analyzed using multilevel Poisson Regression analysis. The software program MedCalc 12.1.3.0 (MedCalc Software) was used to verify the data normality and homoscedasticity, and the software program MLwiN 2.10 (Centre for Multilevel Modelling, University of Bristol) to perform the analysis of variance and multilevel tests. For all analyses, the significance level was set at 5%.

Tooth sensitivity

For the tooth sensitivity evaluation, a Visual Analog Scale (VAS) was used, which recorded the degree of tooth sensitivity. The scale was represented by a horizontal line of 10 cm, with two expressions at its extremities, with the words "no sensitivity" at one extremity and "maximum sensitivity" at the other. This type of analysis established the degree of sensitivity before and immediately after the clinical bleaching session, and 24 hours after completion thereof. The volunteer was instructed to draw a vertical line on the horizontal pain scale, representing his/her tooth sensitivity at each assessment point.[19] After recording the sensitivity, the distance (mm) from the starting point ("no sensitivity") to the extent that the volunteer drew the vertical line was measured with the aid of a ruler, recording values from 0 mm to 100 mm. The recorded values (mm) were considered for interpretation by a blinded examiner, as:

- 0 to 4 mm: no sensitivity
- 5 to 44 mm: mild sensitivity
- 45 to 74 mm: moderate sensitivity
- 75 to 100 mm: maximum sensitivity.

Data from tooth sensitivity in predetermined time intervals (before, immediately after tooth whitening, and 24 hours after completion of bleaching treatment) were subjected to statistical analysis, considering the values measured in millimeters. The Wilcoxon statistical test was performed.

Temperature analysis

The temperature was recorded during the whitening session for 24 minutes for both the control group and the experimental group. Although the total time of bleaching for the experimental group was 45 minutes (three applications of 15 minutes each), the temperature evaluation was considered only in the first 24 minutes, in order to make comparisons between the groups in the same time periods.

The temperature was evaluated in the canine and incisor teeth of both hemi-arches, using two thermocouples channels (TM-744D, Tenmars Electronics). Therefore, for each volunteer a silicone barrier (extend-

Table 3 Distribution of susceptibility results of the volunteers before, immediately after bleaching and 24 hours after completion of bleaching

	Number of volunteers/evaluation time intervals				
		Immediately after bleaching		24 h after bleaching	
Sensitivity	Before bleaching	Group 1	Group 2	Group 1	Group 2
No sensitivity	22	12 (54.5%)	14 (63.6%)	22	22
Light	NA	8 (36.4%)	7 (31.8%)	NA	NA
Moderate	NA	2 (9.1%)	1 (4.6%)	NA	NA
Maximum	NA	NA	NA	NA	NA
Total sensitivity (%)	0	45.5	36.4	0	0

ing to the lingual surface of the maxillary teeth) was made, similar to those used for esthetic reconstruction of anterior teeth, in which two holes were made in the incisal region of the silicone, one on the central incisor and the other on the canine, in order to fix the thermocouple channels in the correct position to prevent them from moving during whitening.

The temperature variation data were tested for normality and homoscedasticity by the Kolmogorov-Smirnov and Levene tests, respectively. As the data were normally distributed and homogenous, the two-way ANOVA for repeated measures was used to detect differences between treatments throughout the period of hybrid light source (LED/laser) use. In addition, the change in temperature total mean (°C) was calculated. The paired Student's *t* test was used for comparison between groups. The level of statistical significance was set at 5%.

Monitoring after the experimental phase

After completion of the trial period, the bleaching treatment was continued in order to obtain uniformity of color between the maxillary and mandibular arches (not bleached).

RESULTS

Tooth color changes

From the scores recorded for the variable "color", the Poisson multilevel analysis was performed, which allowed separate assessment of the independent variables ("treatment group", "initial color", "temperature variation", and "type of tooth") and their influence on each other.

The initial tooth colors were compared (recorded in SGU) within the different treatment groups. For group 1 (control), descriptive analysis of the data showed an initial mean value of 6.06 ± 3.85 (between C1 and C2 of the VITA Classical Shade Guide), and for group 2 (experimental) this was 6.40 ± 4.05 (between C1 and C2 of the VITA Classical Shade Guide), with no difference between the groups at baseline ($P = .522$).

Considering the difference in color between the initial (baseline) and the final (14 days after bleaching) periods, for group 1, a mean ΔSGU value of 3.3 was found, and for group 2, a ΔSGU of 3.8 was observed, with no difference between groups ($P = .177$). Out of the 22 volunteers, irrespective of treatment group, 19 (86.4%) showed central incisor tooth color results lower than or equal to A1 (A1 or B1), while for canines, only 14 (63.6%) volunteers presented this final tooth color.

Tooth color variation (ΔSGU) in canines was statistically higher than in the central incisors ($P < .001$). Similarly, teeth in which an initial color of lower luminosity was recorded (greater SGU), had a higher ΔSGU compared with teeth in which a color of higher luminosity (lower SGU) was recorded ($P < .001$). The variation in mean temperature throughout the bleaching treatments was not statistically associated with color variation ($P = .079$).

Multiple analyses were performed using the "treatment group" as a variable set by other independent variables, but the trend of significance did not change.

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For all variables entered, the group continued to show that it did not significantly influence the color change.

Tooth sensitivity

There was no significant difference in sensitivity between the treatment groups immediately after bleaching ($P = .151$). Comparison of the sensitivity recorded for each treatment group was extracted from the data shown in Table 3.

All 22 volunteers (100%) had initial sensitivity (before bleaching) recorded as "no sensitivity". Immediately after bleaching it was found that 8 (36.4%) volunteers in group 2 showed mild (31.8%) or moderate (4.6%) sensitivity. In the group in which the light source was not used (group 1), 10 (45.5%) volunteers showed mild (36.4%) or moderate (9.1%) sensitivity. In both groups the sensitivity of the volunteers had ceased within 24 hours. Tooth sensitivity was reported only in central incisors, lateral incisors, and/or canines without predominance of any set of teeth; however, no sensitivity was reported in premolars.

Temperature analysis

In order to compare the mean temperatures by treatment group, the mean temperatures were recorded from the beginning of the treatment to the end of 24 minutes (every 1 minute). It was found that group 1 showed a mean temperature (± standard deviation [SD]) of 30.7 ± 1.2°C, and group 2 of 34.1 ± 1.3°C. There were statistically significant differences between the two groups, with group 2 showing a higher mean variation ($P < .001$).

In order to compare the mean temperature throughout the treatment period (every 1 minute) of hybrid light source (LED/Laser) application, a model of two-way analysis of variance (ANOVA) ("treatment" and "time") with repeated measures was used. The first result to be noted was the effect of treatment × time interaction ($P < .001$). This interaction indicated that the behavior of temperature over time differed according to the treatment received. Figure 2 shows the variation of temperature (°C) throughout the tooth whitening period in the two groups. The temperatures in group 1 remained almost constant over time whereas temperatures in group 2 were higher and presented greater variability over time.

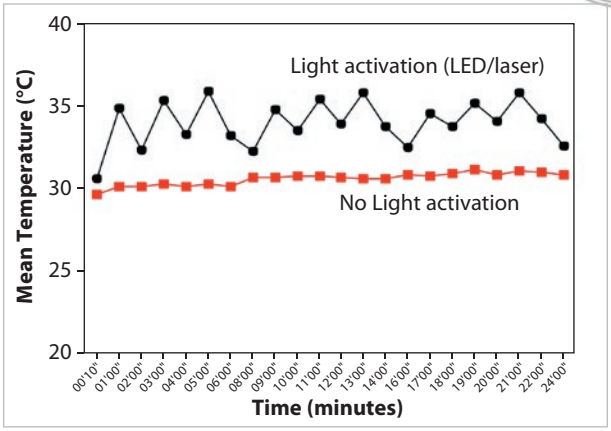

Fig 2 Temperature variation recorded throughout dental bleaching.

The behavior of temperature variations showed that for the control group, temperature increases occurred over the time of whitening gel application. In group 2, in which there was association with the hybrid light source (LED/laser), the highest mean temperatures were found during the light emission period, although some maximum temperature values were measured immediately after the light emission period, the period in which the gel was not exposed to the light source.

Since this was an interaction effect (treatment × time), two other analyses of variance were performed, one for each treatment group, and then the effects of temperature in each group were observed. In each group there was significant variation in temperature ($P < .001$), and therefore the Dunnett multiple comparisons test was used, at a significance level of 5%, in order to compare all temperatures with baseline (temperature reading time 10 seconds). In group 1 only the data measured at the times 1, 2, 4, and 6 minutes were similar to the baseline temperature (at 10 seconds). The highest temperature variation occurred at the time of 19 minutes, with an increase of 1.5°C. In group 2, all temperature measurements were significantly different (higher) than the baseline temperature. The highest temperature variation occurred at the time of 5 minutes, with an increase of 5.3°C.

DISCUSSION

In the current study, the null hypotheses tested were in part rejected. Hydrogen peroxide in-office bleaching associated with the use of a hybrid light source (LED/laser) did not influence bleaching effectiveness and tooth sensitivity compared to the conventional treatment (without light). However, it led to a higher temperature variation on the enamel surface when compared to bleaching without the light.

Comparison between the results of clinical studies in the literature as regards bleaching effectiveness is limited, among other factors, by the use of different evaluation methods for tooth color changes. There is controversy regarding the most appropriate method for the evaluation of tooth color changes[30-33] and the visual scale color continues to be widely used.[11-13,24,27,29,34,35]

In this study, the tooth color scale (VITA Classical), considered a subjective method,[14,15] was used to assess the effectiveness of whitening, which consists of a method widely used in clinical practice[22] and reported by several studies.[10,11,22] Significant differences between bleaching periods (initial and final) were observed, and the results confirm some findings in the literature, in which there is no difference in tooth color changes when considering objective or subjective methods,[1,4] irrespective of the accuracy or reliability of the evaluation method chosen.[30] However, methods considered objective (or also called quantitative) have been considered more reliable for the evaluation of tooth color changes,[29,30,36,37] and allow a better comparison of the results of dental bleaching.[7,9,14] Some authors[36,37] have also reported that visual assessment can lead to significantly darker ratings than spectrophotometry.

In the present study, the results revealed that the color variation (ΔSGU) of 3.3 and 3.8 for the control and experimental groups, respectively, did not differ significantly. Some authors report a color difference of at least two units of the visual tooth color scale[23] while others show changes in color ranging from 5 to 9 SGUs.[1,24,29] However, differences in SGU values are rather controversial in the literature, and the studies do not have a standardized protocol with regard to the use of whitening gel, whitening product used, and participant characteristics, making comparisons difficult.[15] The differences in ΔSGU between the present study and others in the literature may also be related to a greater lightness (lower SGU) of the teeth of the volunteers initially selected. According to some authors,[5] the lower lightness of the tooth (higher SGU) influences the perception of whitening by the human eye. In some studies, the inclusion criteria considered volunteers with tooth color of C1 (SGU = 6), C2 (SGU = 7), or higher,[15,29] while in other studies this value was set at A3 color (SGU = 9).[14,23] In the present study, the inclusion criteria included subjects with tooth color set at A2 or higher (SGU = 5 or higher), with mean baseline value of 6, which may therefore have influenced the perception of color variation that occurred at the end of the bleaching, reaching ΔSGU values lower than those described in the literature. Additionally, authors have considered only one bleaching session. Corroborating the present findings, some authors[24] selected volunteers with tooth color set at A1 or higher and the variations were shown to be 3 to 7 SGUs when 38% peroxide hydrogen bleaching was performed.

In this regard another finding of this clinical study, in which teeth with the highest SGUs (central incisors or canines) underwent greater color change, may be translated into a higher degree of bleaching. Corroborating these results, other authors[5] have revealed that teeth with a more yellow initial color exhibited the greatest variation in color after bleaching.

With regard to the group of teeth examined, it was found that the canines underwent greater color change than the central incisors, irrespective of the technique used. This difference may be attributed to the greater thickness of dentin present in canines, a substrate in which the whitening product possibly has its greatest effectiveness.[38] Some authors[11] similarly related that there was no difference between the hemi-arches bleached in association with a light source (LED), or without it. However, the authors found that when groups were separately analyzed by tooth group (central incisors, lateral incisors, and canines), significant

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differences were observed and the side of the hemiarch in which the light source was used showed a higher degree of bleaching.

The relevant aspect to be considered is that regardless of the color variation found, most subjects reached low values of SGU at the end of treatment (lower than or equal to A1), corroborating the results of other authors,[29] and this can be interpreted as a good esthetic result. Considering that 86.4% of the volunteers had final tooth color lower than or equal to A1 for the central incisors and 63.6% for canines, it is believed that a single clinical session of bleaching was enough to determine the factors under study. In this clinical study, both the bleaching product and the light source (LED/laser) are produced by the same company, which produces bleaching gel components (chromophores) that have high affinity for the light used, an important item to consider in the optimization of bleaching when combined with a light source.[15]

The bleaching carried out without association with the light source was performed in three applications of 15 minutes each, totaling 45 minutes.[10,14,28,29,34,39] As recommended by the manufacturer, the bleaching product used in the current study should be used for a total time of 24 minutes in combination with the light source. For comparison with other techniques not associated with light sources,[14,28,29,39] the authors considered performing the bleaching in the control group for 45 minutes. The experimental group was carried out with three applications of 8 minutes each, totaling 24 minutes of exposure to bleaching agent, as reported previously.[8,14,16,40]

Recently, some authors[40] have performed a microbiopsy on the surface of dental enamel bleached with 35% hydrogen peroxide, with total application time of 24 minutes per session, and observed no significant change in the calcium and phosphorus content, suggesting that this time of clinical exposure to the bleaching gel is not sufficient to promote chemical changes in the enamel, which supports indication of the technique used in this study.

The option to perform a single bleaching session with three applications of whitening gel was based on methods described previously.[4,5,9,11,14,27] In clinical follow-up of volunteers, only three volunteers participated in a second in-office bleaching session or asked for a home whitening tray for the maxillary arch, and therefore did not represent a significant proportion of the sample (13.7%). Although some authors have suggested that a single bleaching session is not sufficient to achieve the expected esthetic result,[24,26,28,40] several recent clinical studies have considered only one session and have achieved good esthetic effects.[4,5,9,11,14,27]

The analysis of temperature on the tooth surface and the final color of the teeth showed that the peak temperature generated in the group in which the light source was used, was unable to enhance the effectiveness of bleaching. The results of this study are in agreement with previous studies.[10,12] The temperature increase generated in the enamel surface in contact with the bleaching gel is able to accelerate the decomposition reaction of the bleaching gel;[41] however, it seems to imply greater diffusion of byproducts through the enamel and dentin. Thus, the contribution made by the light source is to reduce the clinical whitening time, in addition to the possible effect on the reduction of sensitivity[42] or effectiveness of such treatment.[8,9,14]

The color measurement was performed before bleaching and 7 and 14 days after its conclusion. Although some authors have made the color evaluation 24 hours after bleaching,[4] color measurements immediately after bleaching or after 24 were not considered for analysis in this study, avoiding possible errors in interpretation of the results when color is evaluated in those periods due to tooth dehydration,[43] which may be even more evident due to exposure to light and heat.[11] Studies have shown that the color stability of in-office bleaching, with high concentrations of carbamide peroxide or hydrogen peroxide, is similar to that obtained with the home bleaching technique, considering evaluations at 20 days,[4] at 3 and 6 months,[10,15] and at 9 months after completion of tooth whitening treatment.[5] When light sources were used, including the hybrid light (LED/laser), the results were controversial, ranging from days to months.[10,15] One limitation of the present clinical study was not consid-

ering the long-term results of bleaching, an analysis that could check the color stability of the proposed treatments, comparing it with the results in the literature. Further studies should therefore be performed, considering longer evaluation periods for bleaching associated with a hybrid light source, as reported previously.[5,14]

An important result of this study is that although there was no color difference between the treatment with or without the light source, the bleaching protocol used in combination with the hybrid light source took 24 minutes, while the control protocol took 45 minutes to perform. In this sense, one can say that the same esthetic results can be achieved with 47% shorter clinical time for the bleaching with a light source when compared with bleaching without it. This finding is in agreement with previous studies, in which a reduction in bleaching time with the use of a hybrid light source (LED/ laser) has also been reported.[8,14]

Tooth sensitivity was assessed by VAS,[1,4,10,24] and considered any tooth sensitivity reported by the volunteers. The results showed no differences in tooth sensitivity between groups, and 24 hours after the completion of bleaching there was no more reported sensitivity.[15] In other studies, this period lasted up to 7 days[10,14,19] or 1 to 3 weeks.[1,4] There was no influence of the light source in increasing post-bleaching sensitivity, unlike some previous reports.[9] The sensitivity, as reported previously, was seen to be transitory.[1,4,9,10,15]

Some authors have reported high rates of sensitivity after in-office bleaching with hydrogen peroxide, in some cases, in excess of 70% of patients.[1,29] However, these data are rather variable,[4,19,24,29] hindering a more conclusive demonstration of this side effect in the population subjected to bleaching.[19] Whereas sensitivity is an effect arising from pulp changes,[19] such as a response to contact with byproducts of the bleaching agent that were able to spread partially through dentin and reach the pulp tissue cells, it can be offset by the pulp defense mechanisms[19] and will no longer be reported within 24 hours after completion of bleaching.

Corroborating the findings of other authors,[39] sensitivity was reported primarily in anterior teeth (central incisors, lateral incisors, and canines) and not in premolars. Some authors[39] suggest that the difference between the thickness of the enamel/dentin in a tooth could justify the anterior pulp response to bleaching, whereas smaller thicknesses associated with increased permeability of the dental structure may allow easier penetration of byproducts of the hydrogen peroxide degradation into the dental pulp. Although the dental pulp has defense mechanisms that promote the enzymatic degradation of peroxide, they may not be sufficient to prevent irreversible damage to the pulp.[39] In some cases, a lower thickness of dentin may lead to pulp necrosis[39] when using the same bleaching gel for three consecutive 15 minutes (single session), as recommended by several other authors.[1,8,10,12,14]

The sensitivity reported in this study in lateral incisors can therefore be attributed to the lower thickness of enamel/dentin in this group of teeth,[39] and consequently greater permeation of the hydrogen peroxide byproducts into the dental pulp; in the canine, although this tooth has a thicker layer of dentin than the incisors, sensitivity may be due to cracks in the tooth surface, not detected by the human eye.[19]

An important factor to consider with regard to tooth sensitivity is the patient's age.[15] According to the literature, with dental aging there is an increase in dentin thickness due to the continuous deposition of intratubular and secondary dentin, and reduction in the internal diameter of dentinal tubules.[39] Both physiologic mechanisms reduce dentinal permeability and can prevent or minimize the diffusion of whitening gel components through the tooth structure.[39] In the present study, volunteers aged between 18 and 25 years (young adults with a mean age of 20.5 years) were included, as was the case in several other clinical studies.[5,14,15,24,29,40] Therefore, considering the characteristics of dentin in young patients, the positive response to the sensitivity may be higher compared with older patients, whose teeth have been in the oral cavity for a longer time. In contrast, the pulp of a young tooth seems to be able to respond rapidly to attacks from outside, as seen in this study, since in 24 hours after bleaching there were no reports of sensitivity.

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Although most individuals are usually able to tolerate the dental post-bleaching sensitivity, it is critically related to the treatment.[24] Due to several reports of sensitivity after in-office bleaching, some authors have proposed the use of desensitizing products (such as potassium nitrate),[1,24] associations with products containing phosphate or amorphous calcium fluoride,[43] dental adhesives,[15] and most recently laser therapy.[14] In order to verify the potential of low-power laser in reducing tooth sensitivity, the hybrid light source (LED/laser) has been associated with bleaching using 15%, 25%, and 35% hydrogen peroxide.[42] The authors reported that all teeth showed mild signs of pulp inflammation, with no significant differences between groups, except for groups that used the hybrid light source (LED/laser) associated with bleaching, which showed considerable reduction in pulp inflammation. Based on susceptibility results obtained in their clinical studies, others[8,14] have suggested that the laser light present in a hybrid light source could make an important contribution to reducing tooth sensitivity after whitening. Although the low-power laser has anti-inflammatory and biomodulation potentials,[43] when considering its association with LEDs in bleaching equipment, there is still no scientific evidence of its effect on reducing post-bleaching sensitivity.

To date no other in vivo study has evaluated the temperature variations during in-office bleaching with 35% hydrogen peroxide associated with a hybrid light source (LED/laser). In the present study, the highest mean value of temperature variation found in the enamel surface was 5.3°C when using the hybrid light source (LED/laser). The bleaching gel present on the tooth surface is responsible for the absorption of light that is transformed into heat. It has been suggested[17] that the presence of the bleaching gel on the enamel surface plays an important role because it can minimize the variation in temperature that occurs in the pulp chamber.

Some authors[45,46] have also emphasized the importance of combining the use of a specific dye in the bleaching gel and the resonant wavelength of the light used, suggesting that this relationship produces good results of bleaching with a smaller temperature increase. In the present study, the dyes present in the whitening gel were annatto and juá, which have high affinity for the wavelength emitted by the hybrid light source (LED/laser) used, favoring the maximum light absorption and subsequent conversion into heat.[14] However, even if the interaction of light with the whitening gel may have influenced the speed of whitening, there was no difference between the effectiveness of treatment in the two groups.

The literature reveals that the change that occurs in the tooth surface with the LED light with the use of 35% to 38% hydrogen peroxide ranges from about 2.6°C to 12.3°C.[20,21] These temperature changes may be related to the power intensity of the light source used.[17,21] A few studies have evaluated the intrapulpal temperature using LEDs in in-office bleaching,[20,21] irrespective of the protocol for the use of the bleaching material, and the variation in the region of the pulp chamber was smaller than on the tooth surface and did not exceed safe limits, so there was no irreversible damage to the dental pulp.[47]

Recently, an in vitro increase on the tooth surface and in intrapulpal temperature when using LED and laser (Er:YAG and diode laser) associated with dental bleaching with 35% hydrogen peroxide was reported.[20] This study showed the lowest intrapulpal temperature variations for light sources compared with other studies, and for the group in which bleaching was associated with LED the mean change was 1.02°C. In this study, the authors simulated the microvasculature of the pulp tissue in the laboratory using water flow in the pulp chamber. Although the exposure time was only 20 seconds for each light source, the results suggest that the method used to simulate the conditions of the pulp tissue may have had a cooling effect, with most of the temperatures approaching clinical conditions. Unlike laboratory conditions, under in vivo conditions it must be considered that despite the possibility of the temperature rise occurring during the use of light sources in tooth whitening and that this variation could be considered an insult to the pulp tissue, pulp has a high capacity to respond to injury via its own defense sys-

tem.[17] In addition, the microvascular site, dentinal fluid flow, and adjacent periodontal tissues are capable of minimizing the heat transferred to the pulp.[20]

Changes in the enamel surface temperature are expected to be greater than the variations in the region close to the pulp chamber;[20,21] therefore, the use of a hybrid light source (LED/laser) under the conditions tested in the present study does not represent a negative point with regard to the vitality of the pulp tissue, in which the temperature was lower, not exceeding 5.5°C.[47] According to a study conducted by Zach and Cohen,[47] a temperature increase of 2.77°C inside the pulp chamber can lead to a reversible nature of response, and an increase of 5.55°C compromises tooth vitality in 15% of dental pulps.

Thus, although the esthetic results obtained in the present study are similar between the bleaching techniques with and without the use of a light source, the use of a hybrid light appears to assist the chemical reaction and to accelerate the decomposition of hydrogen peroxide. However, it is necessary to emphasize the importance of the choice of adequate parameters and safe protocols for its correct use.

CONCLUSION

Within the limitations of this clinical study, it can be concluded that the hybrid light source (LED/laser) led to a higher temperature variation on the enamel surface during bleaching with 35% hydrogen peroxide. The technique using the LED/laser light source, however, did not influence bleaching effectiveness and tooth sensitivity compared to the conventional treatment.

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