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ORIGINAL ARTICLE

Effect of low-level laser therapy on tooth sensitivity induced by in-office bleaching

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Abstract This study aimed to investigate the effect of low-level laser therapy (LLLT) on tooth sensitivity induced by in-office bleaching. Sixty-six patients enrolled in this randomized clinical trial. Following the in-office procedure with 40 % hydrogen peroxide, the participants were randomly divided into three groups. The patients in group 1 received irradiation from a low-level red laser (LLRL; 660 nm, 200 mW, 15 s, 12 J/cm^2), whereas participants in group 2 were subjected to a low-level infrared laser (LLIL; 810 nm) under similar conditions as in group 1. In group 3 (placebo), the laser treatment was the same as that in groups 1 and 2, but without energy output. The degree of tooth sensitivity was recorded at 1, 24, and 48 h after bleaching using a visual analog scale (VAS). The change in tooth shade was measured 30 days after tooth whitening. The intensity of tooth sensitivity was not significantly different between groups at 1 h after bleaching ($p > 0.05$). At 24 h after therapy, pain level was significantly lower in the LLIL group compared to the LLRL and placebo groups ($p < 0.05$). At 48 h after bleaching, VAS scores in the LLIL and LLRL groups were comparable to each other ($p > 0.05$) and both were significantly lower than that of the placebo group ($p < 0.05$). There was no significant difference in the efficacy of tooth whitening among groups ($p > 0.05$). LLLT with an infrared diode laser could be recommended as a suitable strategy to reduce the intensity of tooth sensitivity after in-office bleaching.

Keywords Bleaching · Hydrogen peroxide · Tooth sensitivity · Low-level laser · Low-power laser · Therapy · In-office bleaching · Pain

Introduction

Bleaching is one of the most frequently prescribed procedures in esthetic dentistry, which can have a great impact on the appearance of the teeth by removing extrinsic and intrinsic stains. Various techniques have been developed to provide efficient tooth whitening including in-office bleaching, night-guard or home-applied bleaching, and over-the-counter systems. Although the application of home bleaching technique is remarkably increased in recent years, in-office bleaching still remains a viable option for patients requesting immediate treatment results or do not tolerate wearing the trays or ingesting bleaching products [1, 2].

The reactive oxygen species released by bleaching materials is responsible for oxidizing dentin chromogens and causing whitening effect. It has been demonstrated that hydrogen peroxide (HP) and its byproducts could pass easily through enamel and dentine and reach pulp tissue [3], causing structural damage and inflammatory reactions [4]. The adverse effects of bleaching agents including cytotoxicity and DNA modification have been demonstrated in several in vitro studies [5, 6]. Tooth sensitivity is the most common clinical consequence of in-office procedure with 35 % HP. The occurrence and degree of tooth hypersensitivity depends on several factors including the pain threshold of the patient, the concentration of the bleaching agent, and the use of light/heat for accelerating the process.

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Previous studies [7–10] reported the incidence rate of 67–87 % for tooth sensitivity after the in-office bleaching procedure using high concentrations of hydrogen peroxide with/without heat. Although pain and discomfort is generally mild and transient, in some cases, it may be severe and irritating, leading to withdrawal from the whitening treatment.

There have been great attempts to reduce tooth sensitivity associated with bleaching procedures. Some authors suggested the application of different products containing potassium nitrate and fluoride [10–14] or casein-phosphopeptide amorphous calcium phosphate [8, 15–17] before, during, or after completion of tooth whitening. Others investigated the effectiveness of non-steroidal anti-inflammatory drugs (NSAIDs) [18–21] such as ibuprofen or antioxidants [22] such as ascorbic acid for decreasing bleaching-induced sensitivity. Although the use of desensitizing agents indicated successful results in reducing tooth sensitivity after bleaching [9–14], the administration of NSAIDs [18–21] or ascorbic acid [22] was incapable of attenuating post-bleaching complications in most studies.

Low-level laser therapy (LLLT) has been increasingly employed in medicine and dentistry due to its analgesic, anti-inflammatory, and biostimulative effects. These excellent properties suggest that LLLT may be capable of attenuating the damage and inflammation induced by in-office bleaching products in pulp tissue, and in this way, can possibly reduce the risk and intensity of tooth sensitivity arising from bleaching. A few in vitro studies evaluated the effects of LLLT on viability of cells exposed to bleaching agents and reported controversial outcomes. Dantas et al. [23] indicated that irradiation from a low power 780-nm laser at energy density of 10 J/cm^2 was capable of compensating the cytotoxic effects of 35 % HP on human pulp fibroblasts. In contrast, Lima et al. [24, 25] concluded that both hydrogen peroxide and carbamide peroxide reduced cell activity of odontoblasts, and their detrimental effects could not be compensated by LLLT at defined parameters. To the extent of the authors' knowledge, no randomized clinical trial investigated the effectiveness of LLLT in reducing pain and discomfort after in-office bleaching. Most of the previous studies on the use of lasers in association with bleaching agents evaluated the benefit from applying high power lasers in accelerating the whitening process. However, high power lasers have different mechanisms of action from low power lasers and are used for a different purpose than affecting pain perception. Therefore, this study was conducted to determine the effect of low power red and infrared lasers on tooth sensitivity arising from in-office bleaching.

Materials and methods

This study was a randomized double-blind and placebo-controlled clinical trial. The sample consisted of 66 volunteers, referring to the Department of Restorative Dentistry of Mashhad Dental School, Mashhad University of Medical Sciences, Mashhad, Iran. The patients were in good general health and oral hygiene status and their maxillary and mandibular anterior teeth were without caries, visible defects, or any restoration on the labial surface. The inclusion criteria dictated that the patients should be at least 18 years old and their central incisors should be shade C2 or darker, as judged by comparison with a value-oriented shade guide (Vita Classical, Vita Zahnfabrik, Bad Sackingen, Germany). Participants who used analgesics, anti-inflammatory, or antioxidant medicine as well as pregnant and lactating women and those who were smoking were excluded from the sample. The exclusion criteria also involved subjects who had a background of tooth-whitening procedures or received any treatment for reducing tooth sensitivity within the last 6 months. Patients with bruxism habits or any pathologic defect such as gingival recession or dentin exposure that could cause tooth sensitivity and those with severe intrinsic discoloration resulting from tetracycline, fluorosis, or pulpless teeth in the anterior parts of the dentition were also excluded from the sample.

Two weeks before the bleaching treatment, the participants underwent prophylaxis with water slurry of pumice and rubber prophylactic cups and received oral hygiene instructions to brush their teeth twice per day with similar toothbrush and toothpaste during the experiment. Each patient was informed about the treatment procedures and was asked to sign an informed consent document before the study commencement.

The in-office bleaching procedure

Before bleaching, the patients were randomly divided into three groups. The randomization was performed by a computer generated table of random numbers. Bleaching was carried out by a single operator.

Initially, the gingival tissues of the teeth to be bleached were isolated from the bleaching gel using a light-cured resin dam (Gingival protector, WHITEsmile GmbH, Birkenau, Germany). A 40 % HP-containing gel (Power Whitening YF; WHITEsmile GmbH) was then applied on the canine to canine teeth of both jaws for a total period of 45 minutes, according to the manufacturer's instructions. The bleaching agent was refreshed every 15 minutes during the in-office process. Two bleaching sessions was assigned with a 1-week interval for each participant. Following the bleaching treatment, the gel was rinsed off and the participants in the study groups ($n = 22$) underwent the following treatments.

1. Low level red laser (LLRL): The patients in this group received irradiation from a low level red laser (Thor DD2 Control Unit, Thor, London, UK). The laser apparatus was an indium-gallium-aluminum-pohosphide (InGaAlP) diode laser and emitted a wavelength of 660 nm. The laser operated at the maximum power of

200 mW and continuous wave mode. To standardize the area of irradiation, a piece of an aluminum foil was placed over the cervical area of the tooth with a 5 × 5-mm aperture inside to allow laser radiation (Fig. 1). The laser probe was positioned in contact with the cervical part of the tooth and scanned the irradiation window for 15 s. Each tooth received 3 J of energy with energy density of 12 J/cm^2 and power density of 800 mW/cm^2. LLLT was performed once during the experiment. Both patient and laser therapist wore safety goggles during treatment.

2. Low level infrared laser (LLIL): The patients in this group received irradiation from a low level infrared laser (Thor DD2 Control Unit, Thor). The device was a gallium-aluminum-arsenide (GaAlAs) diode laser, emitting a wavelength of 810 nm. The laser operated at the maximum power of 200 mW and continuous wave mode, and the irradiation was performed similar to that described in the LLRL group. The energy delivered to each treatment window was 3 J with energy density of 12 J/cm^2 and power density of 800 mW/cm^2.
3. Placebo group: In this group, the treatment procedure was the same as that described in LLLT groups (groups 1 and 2), but the device was turned off.

Tooth sensitivity assessment

The participants were asked to record the degree of tooth sensitivity perceived within the first 1 h, from 1 to 24 h and from 24 to 48 h after the bleaching treatment. A visual analog scale (VAS) was employed for pain assessment, consisting of a 100-mm horizontal line with 0 (the left side) indicating no pain and 100 (the right side) representing the worst possible pain. The degree of tooth sensitivity was recorded at both bleaching sessions and the mean value was calculated for each time point and considered in the statistical analysis. Both the participant and the operator who distributed and gathered the VAS questionnaires were blinded to the group allocation.

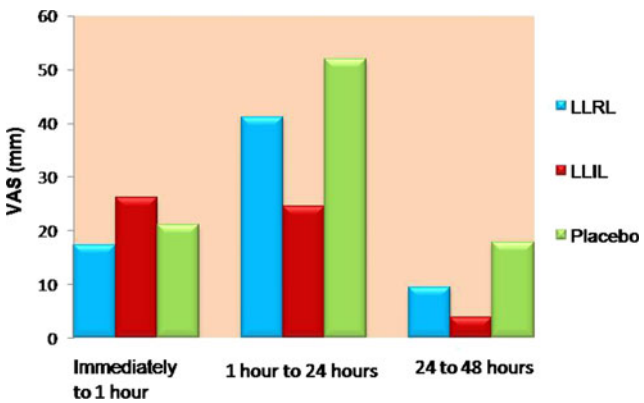

Fig. 1 Comparison of tooth sensitivity scores in the study groups over the experiment

Shade measurement

Shade measurement was accomplished before the bleaching procedure (baseline) and 30 days later by using two instruments including a Vita shade guide for subjective assessment and an Easyshade spectrophotometer (Vita Zahnfabrik, Bad Säckingen, Germany) for objective evaluation. Both measurements were accomplished by an experienced operator who was blinded to the patient assignment. The measurement area of interest was the middle one third of the labial surface of the central incisors.

For subjective examination, the 16 shade guide tabs were arranged from the highest (B1) to the lowest (C4) value, so that the shade C2 was set as number 7 (seventh tab on the value-ordered arrangement) [22]. Shade assessment was performed under daylight and external visual influences such as lipstick and unit's light were eliminated for allowing precise selection. For the purpose of statistical analysis, the scale was assumed to be linear and the changes were considered to be continuous. The measurements obtained at baseline and 30 days later were used to calculate the shift in the number of shade guide units (ΔSGU) for each participant.

The objective shade evaluation was performed by an Easyshade spectrophotometer before and 30 days after the bleaching treatment. For this purpose, a preliminary impression of the maxillary canine to canine arch was made using putty impression material (Speedex, Coltene, Alstatten, Switzerland). This impression served as a standard shade measurement guide for the spectrophotometer. A window was created on the labial surface of the molded guide for the central incisor to be evaluated using a metallic device with well-formed borders and 6 mm in diameter. Shade assessment was performed according to the Commission Internationale de l'Eclairage L*a* and b*(CIELAB) color space system, in which the L coordinate refers to the value or degree of lightness (0 = black, 100 = white), whereas the a and b values indicate positions on red/green (+a = red, −a = green) and yellow/blue (+b = yellow, −b = blue) axes, respectively. The shade change after treatment (ΔE) was calculated using the following formula:

$$\Delta E = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{1/2}$$

Statistical analysis

The VAS scores obtained at each measurement point were averaged between the two bleaching sessions, and the mean value was considered for the statistical analysis. Both the absolute risk of tooth sensitivity, i.e., the presence of sensitivity

at any time point throughout the experiment, and the intensity of tooth sensitivity were evaluated.

The differences in sex or frequency of patients with tooth sensitivity between groups were compared using a chi-squared test. As the Kolmogorov-Smirnov test confirmed the normal distribution of data, a repeated measures analysis was run to determine any significant differences in intensity of tooth sensitivity between the study groups and between the different evaluation times in each group. The difference in color change values (ΔE and ΔSGU) between the study groups was compared by one-way analysis of variance (ANOVA). If any significant difference was noted, pairwise comparison was performed by Tukey's post hoc test. The statistical analysis was performed with SPSS version 16.0 (SPSS Inc., Chicago, IL, USA.) and the significance level for all tests was predetermined at $P < 0.05$.

Results

All of the 66 participants completed the study period. The mean age of the patients was similar in the study groups (LLRL 28.4 ± 7.8; LLIL 32.6 ± 7.5; placebo 30.4 ± 9.2), and there was no significant difference in sex of the participants among groups (LLRL 14 females; LLIL 12 females; and placebo 15 females) ($p = 0.637$). The absolute risk of TS was 82 % in the LLRL group, 77 % in the LLIL group, and 77 % in the placebo group. No significant difference was observed in the absolute risk of TS between groups ($p = 0.913$).

Table 1 and Fig. 1 compare VAS scores for participants in the study groups at different time points during the experiment. Analyzing the data with repeated measures analysis revealed a significant interaction between the two variables of time and group ($p < 0.001$), so one-way ANOVA was run to compare pain intensity among the study groups at each treatment interval. The results showed no statistical difference in the intensity of tooth sensitivity among groups within the first 1 h after bleaching ($p = 0.542$), whereas significant between-group differences were noted at 24 h ($p < 0.001$) and 48 h ($p < 0.001$) later (Table 1). Pairwise comparisons by Tukey's test indicated that at 24 h after therapy, VAS scores were significantly lower in subjects exposed to the low level infrared laser (LLIL group) compared to those treated by the low level red laser (LLRL group) or placebo application ($p < 0.05$), who showed no significant difference to each other ($P > 0.05$) (Table 1). At 48 h after therapy, pain level in the LLIL and LLRL groups were comparable to each other ($p > 0.05$), and both were significantly lower than that of the placebo group ($p < 0.05$) (Table 1).

The repeated measures ANOVA indicated that in all groups, there were significant differences in the level of tooth sensitivity between the measurement points ($p < 0.001$). In the LLRL and placebo groups, pain level was significantly greater at 24 h compared to 1 h post-bleaching ($p < 0.001$), whereas in the LLIL group, the mean VAS scores at 1 and 24 h post-bleaching were not significantly different ($p = 0.735$). All groups showed a significant reduction in the intensity of tooth sensitivity between 24 to 48 h after bleaching ($p < 0.001$). At 48 h after treatment, the VAS scores in both the LLRL and LLIL groups reached a statistically lower level than that recorded at 1 h after bleaching ($p = 0.019$ and $p < 0.001$, respectively), whereas the placebo subjects experienced no significant difference in pain symptoms between 1 and 48 h after therapy ($p = 0.277$).

Table 2 indicates the descriptive statistics including means and standard deviations (SDs) regarding subjective and objective measurements of tooth shade. A variation of 6.58 to 8.0 SGU and 10.85 to 12.80 in ΔE were detected for the three groups (Table 2). Although ΔSGU and ΔE values were somewhat greater in the LLIL group than in the other groups, the difference between groups was small and not statistically significant as assessed by both methods ($p > 0.05$; Table 2).

Discussion

This study investigated the effects of low power red and infrared lasers on attenuating tooth sensitivity associated with in-office bleaching. The most sensitivity complaints occurred

Table 1 The means and standard deviations (SDs) of VAS scores (mm) in the study groups over the experiment

Group	Definition	Immediately to 1 h		1 to 24 h			24 to 48 h		
		Mean	SD	Mean	SD	Pairwise comparisons	Mean	SD	Pairwise comparisons
LLRL	Low level red laser	17.36	11.39	41.11	15.86	a	9.44	7.83	a
LLIL	Low level infrared laser	26.11	19.59	24.58	15.72	b	3.88	5.82	a
Control	placebo	21.11	18.19	51.94	20.80	a	17.77	13.52	b
Statistical significance		$p = 0.300$		$p < 0.001$			$p < 0.001$		

Tukey pairwise comparison test; the groups with different letters have statistically significant differences at $p < 0.05$, whereas those with the same letter are statistically comparable.

Table 2 The means and standard deviations (SDs) of color change values in the study groups

Group	Definition	ΔSGU		ΔE	
		Mean	SD	Mean	SD
LLRL	Low level red laser	6.76	2.68	10.97	3.50
LLIL	Low level infrared laser	8.0	1.90	12.80	4.45
control	placebo	6.58	2.89	10.85	3.75
Statistical significance		$p = 0.218$		$p = 0.278$	

within the first 24 h after bleaching, a finding that corroborated the results of previous authors [9, 19, 20, 22, 26]. The absolute risk of tooth sensitivity was 77 % in the placebo group, 77 % in the LLIL group, and 82 % in the LLRL group, a difference that was not statistically significant. Previous studies also reported the absolute risk of 67 to 87 % for tooth sensitivity after in-office bleaching [7–10]. The findings of this study indicate that LLLT cannot reduce the incidence of experiencing pain and discomfort after in-office bleaching.

Immediately to 1 h post-bleaching, all groups experienced a mild degree of sensitivity with no significant difference to each other, implying that LLLT had no immediate effects on reducing pain and discomfort perceived by the patients. Within the 24 h after bleaching, pain level increased in the LLRL and placebo groups, but actually decreased in those subjected to infrared laser radiation (LLIL group). At 24 h after bleaching, pain level was significantly lower in the LLIL group (24 mm) compared to those in the placebo (51 mm) and LLRL (41 mm) groups. The intensity of tooth sensitivity experienced at 48-h time point was mild in all groups, nearly zero in subjects exposed to infrared laser radiation. At 48 h after bleaching, participants in both the LLRL and LLIL groups indicated comparable pain level, which was significantly lower than that recorded in the placebo group.

Overall, at both 24 and 48 hours after bleaching, the lowest degree of tooth sensitivity was observed in participants treated with the infrared laser, followed by those exposed to red laser radiation, whereas the subjects exposed to placebo application experienced the maximum pain intensity. These findings indicate that LLLT should be considered as an effective strategy in alleviating pain and discomfort after in-office bleaching procedures. Since the maximal pain level generally occurs within the 24 h after bleaching, irradiation with a low power infrared laser should be preferred, as it was more effective than the red wavelength in reducing tooth sensitivity at this interval.

When pain degree at different measurement points was compared within each group, it was revealed that in both the placebo and LLRL groups, the intensity of tooth sensitivity reached the peak value at 24 h after bleaching and reduced thereafter. In the placebo group, the mean VAS score at 48 h was comparable to that recorded at 1 h after bleaching, but in the LLRL group, the laser therapy was effective so that pain level at 48 h was significantly lower than that of the 1-h interval. In contrast to the other groups, patients in the LLIL group perceived the greatest tooth sensitivity immediately after treatment and there was a continuous reduction in pin symptoms throughout the experiment.

The experimental groups in this study were compared with a placebo group. The assignment of a placebo group is necessary when one assesses the analgesic effects of low power lasers [27]. This is due to the psychological impact of treatment by a high technology apparatus, which can cause a reduction in pain symptoms of the patients [27–29]. In the present study, a significant improvement in discomfort also occurred in participants in the placebo group over the study period. This should be expected because post-bleaching sensitivity has a transient nature, not lasting more than 2 days after therapy in most cases. Since we did not include a control group without laser or placebo application, it is not possible to differentiate between the placebo effect of laser therapy and the spontaneous improvement in discomfort, which is usually noticed within a few days after in-office bleaching.

The efficacy of LLLT in reducing post-bleaching sensitivity could be attributed to the biomodulative, anti-inflammatory, and analgesic effects of low power lasers, which have been demonstrated in previous studies [30–33]. Laser therapy may restore the cell damage and accelerate the inflammatory process induced by HP byproducts in pulp tissue and could also suppress the passage of neurosensory impulses. These effects possibly appear after several hours of laser radiation, because the difference in pain scores among the study groups was not significant at 1 h after bleaching. The greater effectiveness of infrared versus red laser in reducing post-bleaching sensitivity could be related to the differences in the penetration depths of these wavelengths. It is believed that the red wavelength penetrates the tissue 8–10 mm, whereas the penetration depth of an 810-nm infrared laser is estimated to be 2–3 cm. In the present study, laser irradiation was performed over the cervical area of the tooth; therefore, the beam should pass through enamel/cement, dentin, and in some parts, gingival tissue to reach the pulp chamber, and thus the infrared laser could be more effective for this application.

Although most authors believe that the optimal therapeutic effects of low level lasers are obtained after several irradiations, the one-time laser application as employed in the present investigation also proved to be effective in reducing post-bleaching sensitivity. In fact, the experience of pain and discomfort usually persists for a few days after treatment, so further applications are not required. The energy density employed in this study was 12 J/cm^2 in both the 660 and 810-nm groups. It is possible that the therapeutic effects of the 660-nm wavelength is presented at lower or higher doses, so further studies are suggested to test different laser parameters to validate this assumption.

A few studies on the use of LLLT in association with bleaching agents reported controversial findings. Dantas et al. [23] evaluated the effect of a single irradiation with a visible red (660 nm) or infrared (780 nm) laser (energy densities of 4, 6, or 10 J/cm2) on viability of human dental pulp fibroblasts exposed to a 35 % hydrogen peroxide bleaching gel. The results showed that only infrared laser group at dosage of 10 J/cm^2 presented cell viability similar to that of the positive control group (cells cultured in ideal growth conditions). They concluded that LLLT at defined parameters is capable to compensate the cytotoxic effects of substances released by 35 % HP gel. In contrast, Lima et al. [25] reported that odontoblast-like cells exposed to carbamide peroxide indicated significant reductions in cell metabolism and alkaline phosphatase (ALP) activity. LLLT (780 nm; 4, 10, and 15 J/cm^2) did not affect the metabolism of the cultured cells, although the dose of 4 J/cm^2 increased the ALP activity in groups both with and without exposure to the bleaching agent. So far, no randomized clinical trial investigated the effect of LLLT on reducing post-bleaching sensitivity; therefore, direct comparison of the outcomes of this study with those of previous authors is not possible. There are some conflicting reports regarding the effectiveness of LLLT in alleviating dentin hypersensitivity in patients with non-carious cervical lesions or deep cavity preparations [27, 34, 35], but the mechanism of tooth sensitivity after in-office bleaching is assumed to be different from that of dentin hypersensitivity.

Regarding the bleaching outcome, all the study groups exhibited comparable shade improvement at 30 days post-bleaching. The changes in ΔSUG and ΔE were in the range of 6.58 to 8.0 and 10.85 to 12.8, respectively. These values indicate acceptable and observable color improvement in the participants and are in agreement with the results of previous authors who found an overall change of 5 to 8 shade guide units after two bleaching sessions [7, 9, 10, 19]. The lack of difference in color change between the study groups should be expected as we applied low power laser therapy after completion of the bleaching process. It should be considered that the lower intensity of pain symptoms in the LLIL and LLRL groups occurred in the presence of comparable color improvement to the placebo application.

The limitation of this study was the subjective nature of VAS questionnaires and the difference in pain thresholds of the subjects. The present study indicated that irradiation from a low power infrared laser could be effective in reducing the intensity of tooth sensitivity after in-office bleaching and so it could be recommended as a suitable alternative to conventional methods of controlling post-bleaching sensitivity. Although this approach can take a few minutes and adds another step to the bleaching treatment, the results are valuable and it is a safe and easy strategy for reducing pain and discomfort. Further clinical trials with larger sample size and different laser settings are warranted to detect optimum parameters and modes of irradiation for reducing tooth sensitivity after bleaching and to compare this method with other approaches of reducing post-bleaching sensitivity.

Conclusions

Under the conditions used in this study, the followings are concluded:

1. LLLT had no effect on reducing the intensity of tooth sensitivity immediately to 1 h after bleaching, but it decreased pain level at 24 and 48 h afterwards.
2. Irradiation from an 810-nm wavelength was significantly more effective than that of the 660-nm laser in attenuating the intensity of tooth sensitivity at 24 h after bleaching, although both laser groups experienced comparable and significantly lower pain level than the placebo group at 48-h interval.
3. LLLT with an infrared diode laser could be recommended as a suitable strategy to reduce the intensity of tooth sensitivity after in-office bleaching.

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Compliance with ethical standards The research protocol was reviewed and approved by the ethics committee of Mashhad University of Medical Sciences, and it was registered in the Iranian Registry of Clinical Trials (IRCT registration number: IRCT201408131509N2). The study was performed in accordance with the CONSORT statement.

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