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# Clinical Investigation of 940 nm Diode Laser Power Bleaching: An In Vivo Study

**Mohammed Abbood Al-Maliky***

Department of Biomedical Applications, Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, Iraq

***Correspondence to**
Mohammed Abbood Al-Maliky, MSc, BDS; Department of Biomedical Applications, Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, Iraq.
Tel: +9647723676000
Email: m.a.almaliky@gmail.com

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**Abstract**

**Introduction:** The increased demand by patient to whiten their teeth in short time had made in-office bleaching procedure the common one. The accompanying tooth sensitivity remains an important factor affecting patients physically and psychologically. The aim of this in vivo study was to observe the effectiveness of 940 nm diode laser in combination with bleaching gel by analyzing tooth sensitivity and colour change.

**Methods:** Fourteen patients treated by laser-assisted bleaching using diode laser at 940 nm and bleaching gel containing 38% hydrogen peroxide. Tooth sensitivity recorded during and after treatment at 6 hours and 1 day using visual analogue scale (VAS). Tooth shade had recorded before and after bleaching using Vita classical brightness scale.

**Results:** Patients whom did not experienced pain during and after the treatment were 78.60% and 92.90%, respectively. Tooth brightness change after treatment was statistically different ($P = 0.001$).

**Conclusion:** Diode laser of 940 nm is an effective adjunctive tool for reducing tooth sensitivity originated from high concentration $H_2O_2$ bleaching gel.

**Keywords:** Tooth sensitivity; Tooth bleaching; VAS; Diode laser; Shade evaluation.

## Introduction

The term "bleaching" was defined by the US Food and Drug Administration (FDA) as making tooth colour lighter than their natural one. Tooth bleaching offers simple, fast and affordable method to whiten tooth colour. Recently, vital tooth bleaching is carried out by in-office, at-home or by-over-the counter products.[1]

In-office which is also called professional bleaching was first described in 1867 by M'Quillen.[2] Then, in 1895 Pyrozone containing 25% hydrogen peroxide (HP) was the first commercially available bleaching product.[3] Heating of HP using electromagnetic radiation to increase bleaching effectiveness was introduced for the first time in 1937[4] and in the same methodology infrared lamps were used in 1980s.

The increased demand by patient to whiten their teeth in short time had made in-office bleaching procedure the common one. This procedure has many advantages over the at-home technique includes short treatment time, less material swallowing and soft tissue damage, no trays wearing.[5]

Currently, in-office bleaching procedure includes HP in high concentration in combination with light sources. Of these light sources are plasma arc and halogen lamps, light emitting diodes and lasers. The role of the light source is for heating the HP and consequently accelerating the release of oxygen free radicals which in turn removes stains molecules from dental enamel.[6] Physical heating technique of HP using light source is described by the term "power bleaching".[7] Power bleaching applying light source in the presence of added pigment in the bleaching gel leads to higher absorption of light by the gel.

This light absorption will increase the temperature of the gel photothermally and reduce the heat reaching the pulp chamber of the tooth by acting as a barrier on the tooth surface, thus reducing tooth sensitivity.[8] The mechanism of tooth sensitivity still not fully explained and may be caused either by heat generation during light activation or pulp irritation due $H_2O_2$ penetration to dental pulp.[9]

The aim of this in vivo study was to observe the effectiveness of 940 nm diode laser in combination with bleaching gel by analyzing tooth sensitivity and colour change.

## Methods

After having informed consent, 14 patients (13 women and 1 man) with an age ranging from 22-39 years old in good oral and systemic health were treated in this in vivo study.

Patients' teeth shade was A2 and darker on the Vita

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classical brightness scale (Vita Zahnfabrik H. Rauter GmbH & Co., Bäd Sackingen, Germany) were selected after being applied to the following inclusion criteria: no previous bleaching treatment, no caries or restoration or periodontal diseases and absence of crowns and bridges in their incisors and premolars of maxillary and mandibular teeth.

Laser system used in this study was diode of 940 nm wavelength (Epic™ 10, Biolase Technology, Irvine, CA, USA). A power of 7 W at CW mode delivered through whitening handpiece was applied according to manufacturer instructions. The laser irradiation area at the head of this handpiece was 2.8 $cm^2$ which designed to cover half arch starting from central to second premolar teeth. Reading of panel settings of the laser system was verified by measuring the output power by powermeter (Gentec Electrooptique Inc., QC, Canada) with both readings were equal.

### Study Design and Irradiation Protocol

After completing dental and medical history forms, patients' teeth were cleaned with non-glycerin based pumice (ALPHAPRO, West Collins, CA, USA) and a slow-speed rotary rubber cup. Vaseline was applied to upper and lower lips before cheek retractor insertion and a sucker device had been used throughout the treatment to remove the accumulated saliva. Afterward, a liquid dam is applied on the gingival margin and extended for 4 mm toward the vestibule and light cured from 1 cm distance. A bleaching gel (Laser White 20; BIOLASE, CA, USA) of 38% $H_2O_2$ after mixing with 0.2 mL activator gel, including ultramarine violet colorant was used in combination with the laser irradiation for the bleaching procedure. The upper and lower arches were divided into 4 quadrants of 5 teeth each. A layer of Bleaching gel with thickness of approximately 2 mm was applied to all 4 quadrants. Gel application was done for 2 sessions, 10 minutes each. For the first session each quadrant had been irradiated for 30 seconds, after 1 minute rest this irradiation was repeated for all quadrants. Afterwards, the gel was left in contact with the tooth surface until completing the 10-minute period. Parameters of laser irradiation are given in Table 1. Then, using a high vacuum sucker with small nozzle head the gel was removed from the teeth surface followed by wiping off with wet gauze to remove access material. Teeth rinsing with air water jet to assure complete removal of the bleaching gel. After teeth had been dried with dry gauze, the second session of gel application following the mentioned procedure and irradiation protocol was repeated. When treatment was accomplished, the barrier dam was removed.

The treating dentist, assistant and patient were wearing the laser wavelength-specific protection goggles during laser irradiation.

### Tooth Sensitivity Examination

Visual analogue scale (VAS) starting from 0 to 10 was explained and handed to the patients. Score 0 means no pain and score 10 represents worst pain.[10] The pain scores were recorded during and after treatment at 6 hours and 1 day.

### Shade Examination

According to manufacturer instructions the Vita classical brightness scale was used to measure tooth shade. The examiner measurements were verified by a second examiner and the degree of agreement was obtained using Kappa test. For standardization, measurements were done at indirect sun light between 10:00 AM and noon time. The Vita scale composed from 16 brightness degrees, C4 is the darkest and B1 is the brightest one (Figure 1). According to the method of Browning, Gurgan et al and Collins et al, these degrees were converted to scores with score 1 representing the brightest shade.[11-13]

### Statistical Testing

IBM SPSS version 21.0 software was used for statistical analysis of the obtained results (IBM Corp., Armonk, NY, USA). For both tooth sensitivity and colour change, descriptive parameters including median, mean rank, mean and standard deviation were made. Tooth sensitivity scores during and after treatment periods were analyzed via Friedman test. Difference in shade scores between before and after treatment were tested using Wilcoxon signed-rank test. Kappa test was employed for proving examiner reliability in shade selection. Sample size was selected using G power 3.0.10, both effect size and power = 0.8 and 2 tailed probability of error. A level of 0.05 was used as significance limit.

## Results

Regarding tooth sensitivity, the mean pain scores recorded

**Table 1.** Laser Irradiation Protocol for Each Quadrant

| Laser λ (nm) | Defocus (mm) | Power (W CW*) | Area ($cm^2$) | Pd** (W $cm^{-2}$) | Time (s) | Deposited Energy (J) | Dose (J $cm^{-2}$) |
|---|---|---|---|---|---|---|---|
| 940 | 1 | 7 | 2.8 | 2.5 | 30 | 210 | 75 |

* Continuous wave, ** Power density.

| Shade | B1 | A1 | B2 | D2 | A2 | C1 | C2 | D4 | A3 | D3 | B3 | A3.5 | B4 | C3 | A4 | C4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

**Figure 1.** Shade Ranging From C4 (Darkest) to B1 (Brightest) According to VITA Classical Brightness Guide.

using the VAS scale during treatment, 6 hours and 1 day after treatment were 1.43, 0.43 and 0.29, respectively (Table 2). Patient whom did not experienced pain during and after the treatment were 78.60% and 92.90%, respectively (Table 3). There was no statistical difference between the three times of pain scores recordings ($P = 0.06$).

The mean difference in shade scores before and after treatment was 6.29 ± 2.30 (Figure 2). The scores grades were 5 (A2) - 16 (C4) before treatment and 6 (C1) – 1 (B1) after the bleaching procedure (Table 4). This change was statistically different ($P = 0.001$). Kappa test showed good measure of agreement between the 2 examiners with Kappa value = 0.86.

## Discussion

Although tooth sensitivity after power bleaching procedure in majority of cases is reversible, it remains a main side effect which may last for 2 weeks after treatment and can cause psychological and physical discomfort.[14] This clinical study targeted to examine the effectiveness of bleaching gel containing $H_2O_2$ activated by 940 nm diode laser, by analyzing the possible side effect of tooth sensitivity and measuring shade change.

The recorded results of this study presented that 78.60% of patients did not experienced pain during the bleaching procedure. This percentage was reduced at 6 hours and in 1 day after treatment to 92.90%. This could be explained mainly due to the short time of laser-assisted bleaching procedure, which was 20 minutes as total time composed of 2 sessions of 10 minutes each.

Tooth sensitivity originated from peroxide penetration to the dental pulp is time dependent process.[15] Efficient absorption of laser power energy by the ultramarine violet colorant in the gel compared to conventional lamps leads to conversion of light energy to heat energy. Heating of bleaching gel up to 30-40°C will shorten the required whitening time by factor of 2.[16] In the current study achieving tooth shade brightness using high power laser light in decreased gel-tooth residence time of 20 minutes may be the cause of less recorded tooth sensitivity. Other possible factor explains the relatively low incidence of sensitivity is the biostimulation effect of transmitted laser energy through dental structure to dental pulp. Diode laser had been reported to induce postoperative relieve of tooth hypersensitivity at low-level laser settings of 40 mW and 200 mW.[17, 18] Having an absorption coefficient of ~ $10^0$ $cm^{-1}$, near infrared region of electromagnetic spectrum is expected to have direct transmission of part of laser energy to depth of ~1 cm through hydroxyapatite. Tooth sensitivity results of the current study come into agreement to Gurgan et al[12] and Calderini et al[19] who recorded low scores using 810 nm and 980 nm diode lasers. In this study, 3 out of 14 patients had sensitivity during the bleaching procedure, 2 of them the sensitivity was due to direct heat elevation as a result of the laser energy itself and not from the bleaching gel. This was evidenced while this sensitivity was relieved in less than 1 minute of stopping the lasing of the first session. In the second session, when the laser power was reduced to 6 W instead of 7 W, no sensitivity was mentioned by the patients.

The used bleaching system achieved significant shade

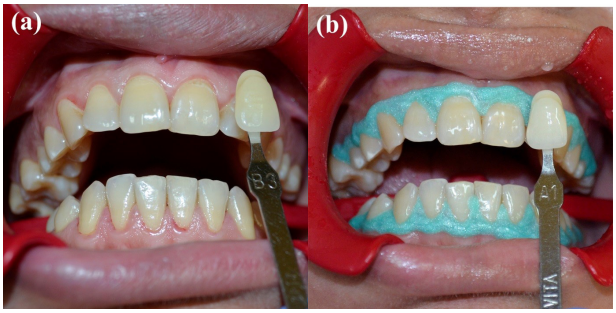


**Figure 2.** A 39 Years Patient Treated by 940 nm Laser-Assisted Bleaching. Initial teeth shade was B3 (a) and the final shade was A1 (b), with resulted 9 scores of shade improvement.

**Table 2.** Descriptive Results and Statistics of Tooth Sensitivity

| Statistics | Pain During | Pain After 6 h | Pain After 1 Day |
|---|---|---|---|
| Minimum | 0.00 | 0.00 | 0.00 |
| Maximum | 8.00 | 6.00 | 4.00 |
| Mean | 1.43 | 0.43 | 0.29 |
| Standard deviation | 2.87 | 1.60 | 1.07 |
| Median | 0.00 | 0.00 | 0.00 |
| Mean rank | 2.21 | 2.93 | 1.86 |
| Friedman test | Chi-square | 5.60 | |
| | *P* value | 0.061 | |

**Table 3.** Scores Frequency Distribution of Tooth Sensitivity

| Period | VAS score | No. | % |
|---|---|---|---|
| Pain during | 0.00 | 11 | 78.6 |
| | 6.00 | 2 | 14.3 |
| | 8.00 | 1 | 7.1 |
| Pain after 6 h | 0.00 | 13 | 92.9 |
| | 6.00 | 1 | 7.1 |
| Pain after 1 day | 0.00 | 13 | 92.9 |
| | 4.00 | 1 | 7.1 |

**Table 4.** Descriptive Results and Statistics of Tooth Shade Examination

| Statistics | Before | After |
|---|---|---|
| Minimum | 5 | 1 |
| Maximum | 16 | 6 |
| Mean | 8.29 | 2.00 |
| Standard Deviation | 3.63 | 1.75 |
| Median | 7.00 | 1.00 |
| Mean Rank | 0.00 | 7.50 |
| Wilcoxon signed ranks test | Z | 3.31 |
| | *P* value | 0.001 |

scores change compared to baseline recordings ($P$ = 0.001). A mean brightness improvement value of 6 scores which was reported in this study is more than the 3.3 significance value limit of Schwabacher and Goodkind.[20] Few studies addressed the topic laser-assisted bleaching in vivo. The current study results showed mean scores of 6 which comes into close agreement to those of Gurgan et al[12] who achieved mean scores of 8 using 810 nm diode laser. This difference in the mean scores is due to the difference in the exclusion criteria employed in both studies, they excluded patients with shades brighter than A3 (score 9) compared to A2 (score 5) in this study. To obtain standardization of lightening and to avoid eye fatigue, one patient treated a day in the same time between 10:00 AM and noon.

## Conclusions

1. Diode laser of 940 nm is an effective adjunctive tool for reducing tooth sensitivity originated from high concentration $H_2O_2$ bleaching gel.
2. Laser-power beaching can reduce bleaching gel-tooth contact time by half compared to conventional protocols with same bleaching efficiency.
3. It is recommended reducing the power settings of the laser system from 7 W to 6 W.

## Ethical Considerations

The university of Baghdad board approved the research proposal (ILPS board No. 17/2015).

## Conflict of Interests

The authors declare no conflict of interest.

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