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Effect of Three Wavelengths of Diode Laser on the Efficacy of Bleaching of Stained Teeth

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A B S T R A C T

Objectives: Light irradiation and heat have been used to accelerate the process of tooth bleaching. This study aimed to assess the efficacy of conventional bleaching compared to laser-bleaching using three different wavelengths of diode lasers.

Materials and Methods: In this in-vitro experimental study, 40 extracted human central incisors were immersed in a coloring solution made of tea, coffee, and cola for 21 days. The L*, a*, and b* color parameters were measured before and after the immersion using spectrophotometry. The teeth were then randomly divided into four groups (n=10) as follows: group 1: 810-nm diode laser + Biolase Laser White 20, group 2: 940-nm diode laser + Biolase Laser White 20, group 3: 980-nm diode laser + Biolase Laser White 20, and group 4: conventional bleaching with Opalescence Boost without laser irradiation. One-way analysis of variance (ANOVA) was used to assess the effect of laser type and bleaching technique on color parameters.

Results: The 940-nm (ΔE=28.5896) and 810-nm laser groups (ΔE=21.2382) showed the highest and the lowest bleaching efficacy, respectively; however, the groups were not significantly different in terms of bleaching efficacy (P>0.05).

Conclusion: Laser-bleaching with 810-, 940- and 980-nm wavelengths of diode laser has an efficacy similar to that of conventional bleaching but in a shorter period. No difference was noted between different laser wavelengths in terms of bleaching efficacy.

Keywords: Diode Lasers; Tooth Bleaching Agents; Color; Spectrophotometry

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INTRODUCTION

Having whiter teeth is always demanded by patients and plays an important role in smile aesthetics [1-3]. Tooth bleaching is a popular technique to resolve internal tooth discoloration and to achieve whiter teeth [4,5]. It is effective, safe, relatively non-invasive, and affordable [1-3]. Since many patients demand to save time and achieve more immediate results, different types of activating sources have been used to accelerate the bleaching process [6,7].

Lasers are a hot topic in bleaching, and many types of laser have been used for laser bleaching, such as potassium titanyl phosphate (KTP), argon laser, and erbium-doped yttrium aluminum garnet (Er:YAG) laser [8-10]. The Food and Drug Administration (FDA) has

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approved argon, carbon dioxide (CO2), and diode lasers for dental applications [10]. Diode lasers have a monochromatic characteristic that would reduce the risk of pulpal damage due to overheating [7]. Different powers and wavelengths of diode lasers (800 to 980 nm) are used for laser bleaching. By an increase in wavelength from 800 to 980 nm, the frequency of laser beams and subsequently their penetration depth decreases [11]. Thus, laser energy at an 800-nm wavelength is more absorbed by the pigments; by an increase in the wavelength to 980 nm, laser energy is more absorbed by water. Thus, due to different wavelengths, different interactions of the laser with tissues and surface modifications are expected [6].

Despite its increasing popularity, information about the efficacy of diode laser bleaching with different laser wavelengths is scarce [6,7].

The efficacy of bleaching is often determined by the comparison of tooth color with tooth shade guides. However, considering the shortcomings of this method and its subjective nature, a spectrophotometer is commonly used for this purpose to minimize the effect of environmental factors on color perception. The CIEL*a*b* color space is often used to determine the color parameters of L*, a*, and b*, which indicate lightness, redness-greenness, and yellowness-blueness, respectively [2]. This study aimed to assess the efficacy of laser bleaching with three different wavelengths of diode lasers in comparison with conventional bleaching.

MATERIALS AND METHODS

In this in-vitro experimental study, the sample size was calculated to be 10 in each group according to a study by Wetter et al [12], assuming alpha=0.05, beta=0.2, standard deviation (SD)=1.58, and minimum difference of 2, using PASS software (NCSS, LLC. Kaysville, UT, USA). The ethics committee of our university approved the study.

Forty extracted human central incisors with intact crowns were collected. Tissue residues were removed by a scaler, and the teeth were immersed in a 0.5% chloramine-T solution for one week for disinfection. They were then stored in saline until the experiment. The buccal surface of the teeth was cleaned with a prophy brush and pumice paste. The color of the teeth was measured using the VITA Easyshade intraoral dental spectrophotometer (Vita Zahnfabrik, Bad Säckingen, Germany). The spectrophotometer was first calibrated according to the manufacturer's instructions. The teeth were placed against a white background according to ISO 7491, and the a*, b*, and L* parameters were measured for each sample three times, and the mean of each parameter was recorded as the baseline value. The dental crowns were cut at two millimeters (mm) under the cementoenamel junction (CEJ). They were then immersed in a coloring solution made of tea (Ahmad), coffee (Starbucks), and cola (Coca Cola) and were incubated at 37°C for 21 days.

The tea solution was prepared by placing a tea bag in 250 ml of boiling water for 5 minutes. The coffee solution was prepared by immersing 10 g of coffee in 100 ml of boiling water. The samples were completely submerged in the solution in a vertical position while held by a thread to minimize the deposition of the coloring agents on the surface of the samples. The samples immersed in the solutions had no contact with each other or with the container's walls. They were removed from the solution every day, rinsed with saline with mild pressure for one minute, and tooth-brushed to remove deposited debris. The solutions were refreshed daily and were incubated. Next, the dental crowns were rinsed with water, dried, and subjected to colorimetry using the spectrophotometer. The teeth were then fixed on a wax sheet to undergo bleaching. This was done to standardize the distance of the teeth from the laser handpiece. The teeth were then randomly divided into four groups of 10 as follows:

Group 1. Bleaching with Laser White 20 (containing 35% hydrogen peroxide (H2O2); Biolase, CA, USA) and an 810-nm diode laser

Group 2. Bleaching with Laser White 20 and a 940-nm diode laser

Group 3. Bleaching with Laser White 20 and a 980-nm diode laser

Group 4. Office bleaching with Opalescence Boost (containing 38% H2O2; Ultradent Products Inc., UT, USA) for 20 minutes.

Room-temperature Laser White 20 gel was prepared by mixing the contents of base and activator syringes 25 times such that the gel was homogenous according to the manufacturer's instructions. A thin layer of Laser White 20 gel with 1-mm thickness was applied and spread on the buccal surface of the teeth using the tip of a microbrush. The homogenous light violet color of the gel ensured its equal thickness. The buccal surface of each tooth was subjected to diode laser irradiation (Cheese TM, Wuhan Gigaa Optronics Technology Co, Ltd., China) at an 810-nm wavelength and 1.5-W power from a 1-mm distance using the single-tooth tip with a 1-cm^2 area. This procedure was repeated three times, each time for 30 seconds. The time interval between irradiations was one minute to control temperature rise. Next, the samples were allowed seven minutes, and after the removal of the bleaching gel, the samples were rinsed with distilled water for 30 seconds to eliminate the bleaching agent.

In the 940-nm diode laser group, Laser White 20 bleaching agent was prepared as explained earlier and applied on the buccal surface of the samples with 1-mm thickness. The buccal surface was then irradiated with a diode laser (Epic X, Biolase, CA, USA) at a 940-nm wavelength and 1.5-W power three times from a 1-mm distance, each time for 30 seconds. The time interval between irradiations was one minute. After seven minutes, the samples were rinsed with distilled water for 30 seconds. In the 980-nm diode laser group, Laser White 20 bleaching agent was prepared as explained earlier and applied on the buccal surface of the samples with 1-mm thickness. The buccal surface was then irradiated with a diode laser (Wiser, Doctor Smile, Italy) at a 980-nm wavelength and 1.5-W power from a 1-mm distance three times, each time for 30 seconds using the single-tooth tip with a 1-cm^2 area. The time interval between irradiations was one minute. After seven minutes, the samples were rinsed with distilled water for 30 seconds. Room-temperature Opalescence Extra Boost was used in the in-office bleaching group. The contents of the two syringes were mixed for a minimum of 25 times. The bleaching agent was then applied on the labial surface of the teeth with 1-mm thickness and gently extended towards the incisal edge or occlusal surface. The surface of the teeth was bleached for 20 minutes. In this group, the teeth did not undergo laser irradiation. The bleaching agent was agitated every 5 minutes according to the manufacturer's instructions. After the removal of the bleaching agent, the samples were rinsed with distilled water for 30 seconds. The teeth were then stored in saline for seven days and were then dried and subjected to colorimetry using the spectrophotometer. Colorimetric assessments were made at three time points: at baseline before immersion of the samples in the coloring agent, after immersion in the coloring agent and before bleaching, and after bleaching.

The L*, a*, and b* color parameters in the CIE L*a*b* system were measured, and the overall color change (ΔE) was calculated using the formula below [13]:

$$\Delta E=[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1.2}$$

Data were analyzed using SPSS (version 18; SPSS Inc., Chicago, IL, USA). The mean, SD, minimum, and maximum of color parameters were reported for the four groups. One-way analysis of variance (ANOVA) was used to assess the effect of laser type and bleaching technique on color parameters.

Repeated-measures ANOVA was used to assess the change in color parameters after the intervention, and the intervention was used as the between-subject factor. $P<0.05$ was considered statistically significant.

RESULTS

Table 1 shows the mean, minimum, and maximum values of a*, b*, L*, and ΔE parameters before and after bleaching. As shown, the L* value after bleaching increased compared to that before bleaching in all groups. The b* value decreased after bleaching in all groups while the a* parameter was not affected by the bleaching as did the L* and b* parameters. The results showed no difference in ΔE among the groups before or after

Table 1. Mean and standard deviation (SD) of L*, a*, b*, and ΔE parameters in the studied groups before and after bleaching

Groups	"L"		"a"		"b"		ΔE
	before	after	before	after	before	after	
810-nm laser	65.76±10.68	74.86±8.12	0.78±2.19	1.44±1.48	17.18±8.28	13.22±7.93	21.23±5.39
940-nm laser	59.04±11.32	66.60±3.83	3.36±4.53	0.640±1.86	21.93±10.24	8.89±8.19	28.58±6.72
980-nm laser	61.15±8.43	65.62±4.31	3.21±3.73	0.73±2.02	17.41±9.05	11.42±6.42	23.76±8.33
Office bleaching	56.68±4.80	68.13±6.18	1.25±1.51	1.36±1.83	24.37±12.13	11.52±9.29	27.60±11.52

staining; in other words, the color change was the same in all groups (P>0.05). The highest efficacy of bleaching was noted in the 940-nm laser group (ΔE=28.58) while the lowest efficacy belonged to the 810-nm laser group (ΔE=21.23).

DISCUSSION

This study assessed the efficacy of bleaching with 810-, 940-, and 980-nm diode laser compared to conventional bleaching. The color change was measured on the stained teeth seven days after the bleaching procedure to prevent any misinterpretation due to dehydration of teeth immediately after bleaching, especially following light activation [2,13,14-18]. The roots of the teeth were cut at 2 mm under the CEJ before staining to induce internal staining. The surface was cleaned to remove external stains.

The results showed that the 940-nm (ΔE=28.5896) and 810-nm lasers (ΔE=21.2382) had the highest and the lowest efficacy, respectively; however, the groups were not significantly different in terms of bleaching efficacy.

The effect of light sources on bleaching efficacy has long been a controversial topic. Evidence shows that activation of bleaching agents with an energy source accelerates the course of bleaching although the outcome may be different or the same as that of conventional bleaching [14,19].

Colorimetry can be performed using spectrophotometry, spectroradiometry, colorimetry, and software analysis [19].

A spectrophotometer was used for colorimetry in our study, which is highly accurate and is commonly used for this purpose [20]. The CIE L*a*b* color parameters were measured in this study [21]. According to some authors, ΔL is a more important parameter, and the human eye more clearly observes and perceives this color parameter because the quality of the rods that are responsible for the detection of black and white colors is much higher than that of the rods responsible for color vision [22]. However, another study showed that patient satisfaction mainly relates to changes in the b* parameter rather than L* and a* parameters [2,23]. Based on spectrophotometric findings, further whitening occurs with an increase in lightness (higher L* parameter) and reduction in redness (lower a* parameter) and yellowness (lower b* parameter) [24]. However, there are limitations regarding the comparison of Δa, Δb, and ΔL in the clinical settings compared to in vitro. Thus, interpretation of the results should be done with caution [24].

ΔE is commonly used in studies for evaluation of the quality of bleaching [17,24]. Some studies have shown that ΔE > 3.3 is the acceptable clinically color change threshold. Evidence shows that ΔE between 3 to 8 is moderately detectable while ΔE >8 refers to highly perceivable color change by the human eye [25,26]. Based on this value, the results in all of the groups showed a perceivable color change.

In the present study, the a* parameter did not change significantly after bleaching. The L* parameter significantly increased while the b*

parameter significantly decreased. In other words, the teeth became lighter after bleaching, and their yellowness decreased. Assessment of ΔE revealed that bleaching in all groups significantly whitened the teeth with no significant difference. However, it should be noted that in the clinical setting, light and laser irradiation may increase patient cooperation and satisfaction [6].

In this study, Laser White 20 was used in conjugation with diode lasers; this bleaching gel has been made to be used by the Biolase diode laser system at a 940-nm wavelength. Since all diode laser systems have the same absorption capability in pigments, this gel can be used with other diode laser systems as well [6].

One of the important factors in bleaching is the H2O2 concentration in the bleaching gel. The bleaching gels selected for this study had the same concentration of H2O2 (about 40%) [6].

Laser irradiation yielded a similar outcome to the control group but in a shorter period. In other words, laser irradiation leads to the release of free radicals from the bleaching agents in a shorter time. There was no difference in color change between different diode laser systems; this is in accordance with other studies [20,6]. However, in a study by Kiomarsi et al [6], conventional office bleaching yielded better results compared to laser bleaching; this may be due to the method of their office bleaching. They repeated the bleaching process three times while we used the minimum recommended time in all groups.

Comparison of the results of studies on this topic is difficult considering different bleaching protocols, bleaching agents, and methodologies [27]. Controversy in this respect is probably due to inadequate knowledge about the performance of different bleaching agents.

In the present study, the use of different wavelengths of diode laser yielded similar ΔE values, which indicates that using a diode laser as a light source did not improve bleaching efficacy. The type of bleaching agent, the concentration of H2O2, and the increase in pulp temperature during bleaching are more important parameters to be considered when selecting a bleaching protocol [27].

Fornaini et al [28] compared the effect of KTP and diode lasers on bleaching efficacy and showed that both lasers at 4-W power had significant differences with the conventional bleaching control group in terms of color change but at 2-W power, only KTP laser had a significant difference with the non-laser-treated control group. The highest ΔE was achieved in the KTP laser group at 2-W power while the lowest ΔE belonged to the non-laser-treated control group. We used 1.5-W diode lasers, and our results regarding the efficacy of diode laser were comparable to the results of the mentioned study [28].

One limitation of this study was the short duration of follow-up (seven days), which did not allow the assessment of the stability of color change following bleaching treatment. Future studies with longer follow-ups are required to assess the long-term outcome of different bleaching protocols. In addition, clinical studies are required to confirm in-vitro findings.

CONCLUSION

Within the limitations of this study, the use of different wavelengths of diode lasers to enhance bleaching has similar efficacy to that of conventional bleaching but in a shorter period. No significant difference was noted in the efficacy of bleaching assisted with irradiation of different laser wavelengths.

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CONFLICT OF INTEREST STATEMENT

None declared.

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