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Effect of laser-activated bleaching with 445, 915, and 970nm diode lasers on enamel color change: an *in vitro* study

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ABSTRACT

Considering the increasing use of esthetic treatments, one of which is bleaching treatment, choosing the different wavelengths and parameters for this treatment can help in choosing the best treatment. Based on this, this study aimed to investigate bleaching with three wavelengths of 445nm, 915nm, and 970 nm on the amount of teeth discoloration. In this study**,** 77 human permanent teeth without caries were selected and randomly divided into 7 groups as control, 445 nm (1 and 1.5 W and time 20 seconds), 915 nm (2 and 2.5 W and time 30 seconds) and 970 nm (1.5 and 2 W and time 30 seconds). The bleaching gel used was 40% hydrogen peroxide bleaching gel(Ultradent-Opalescence, USA). All groups were subjected to laser irradiation with a 0.5 cm2 area with continuous wave mode radiation at a distance of 1 mm from the bleaching gel. Before starting the study, all the samples were subjected to calorimetry using a spectrophotometer. After bleaching with the said wavelengths, Color change data on the CIE L * a * b* system was analyzed statistically by the one-way ANOVA and Tukey's HSD test. Based on the findings, ΔE was positive in all groups. The highest amount was in the 445nm 1.5w group and the lowest was seen in the control group and then in the 970nm 2w group (P<0.05). The highest dispersion of color change is related to the 445nm 1.5w group (P<0.05). In general, the results showed that the use of 445nm diode laser 1.5w (ΔE=12) and 970nm diode laser 2w (ΔE=37.5) was the most and least effective in teeth bleaching, respectively. According to the results of the present Invitro study, the 445 nm laser with a power of 1.5 watts had the most effect in changing tooth color, and the 970 nm group with a power of 2 watts showed the least effect.

Key words: bleaching, diode laser, tooth color change.

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Introduction

The beauty of teeth and their color is an important issue for many people. That includes dentists who want to choose tooth shade and aesthetic restorative materials to maximize restoration of natural tooth structure, dental technicians who want to replicate the shape and quality of tooth appearance, and patients who want to beautify their smile.[1] So that in recent years, patients have been visiting dentists not only for good oral health, but also for beauty and an attractive smile, and this trend is growing.[2] Among the ways to whiten teeth, we can mention teeth bleaching, which is one of the beauty treatments and the request for doing it is growing more and more.[2]
During tooth bleaching, hydrogen peroxide acts as a strong oxidizing agent with free radical action that attacks complex pigment molecules responsible for tooth discoloration. Chromophores are broken and carbon ring compounds with more pigment They turn into carbon chains that have a lighter color. The carbon double-bond chains are converted to hydroxyl groups, which are essentially colorless.[3]
Bleaching can be done both in the doctor's office and at home. However since the use of bleaching at home requires daily use for at least 2 weeks for the white results of bleaching to appear, patients usually request another option for the results to appear faster; bleaching in the office is more popular than the at-home method due to advantages such as the possibility of dentist supervision, protection of soft tissue, prevention of unwanted ingestion of substances, and detectable discoloration of teeth even after a treatment session; these factors cause more satisfaction of the patient and also more effort of the patient to maintain the color of his teeth.[3] Teeth whitening agents in whitening gels can be affected by temperature, light, or laser, which increase their temperature, and as a result of this increase in temperature, the rate of conversion of hydrogen peroxide into free radicals increases, which ultimately leads to the faster loss of carbon chains that cause tooth discoloration.[4]
The main difference between the laser and other light sources (such as LEDs) for activating the bleaching gel is that the laser emits a single light beam with a specific wavelength, which reduces the risk of excessive pulp temperature increase and irreversible damage to the pulp.[5]
FDA has approved the use of CO_2, argon, and diode lasers for the bleaching treatment process. The main advantages of diode lasers compared to other lasers are their small size and portability, the flexibility of diode laser fiber, and their easier access.[6]
Despite research, there is still no agreement on a specific protocol for laser irradiation during bleaching treatment, while laser devices are used in dental clinics. Also, due to the difference in radiation power and wavelength of lasers, it is challenging to compare different lasers. Since bleaching is done in dental offices the use of lasers in dental and beauty treatments is increasing 445 nm laser is new and not many studies have been done on its bleaching effect, this study aimed to compare the effectiveness of activated bleaching with 445 nm, 915 nm and 970 nm diode lasers with different powers on tooth color changes.
The null hypothesis is: that laser-activated bleaching with the diode laser 445 nm, 940 nm, and 970 nm bleaching outcome results have no difference than conventional bleaching without light activation and with each other.

Materials and Methods

Sampling

This study was done on the faculty of dentistry at Tehran University of Medical Sciences in 2023. In this study, 77 human anterior permanent teeth without caries were selected. The inclusion criteria were permanent teeth without caries and crashes. The exclusion criteria was suffering from diseases that cause structural disorders of the teeth, such as osteoporosis and osteogenesis imperfect. According to the results of the Saberi 2020 study and using the one-way ANOVA power analysis option in the PASS11 software, considering alpha=0.05 and beta=0.2 and the average standard deviation equal to 18.4 and effect size=0. 44 The minimum sample size required for each of the studied groups is equal to 11 samples. The teeth randomly divided into 7 groups: Group 1: whitening gel activated with 445nm diode laser (power of 1 watt with radiation for 20 seconds, energy density 40 J/cm^2 and using Sirona laser device, Germany), siroblue laser, dentsply; Group 2: whitening gel activated with a 445nm diode laser (power 1.5 watts with radiation for 20 seconds and energy density 60 J/cm^2, using a Siroblue laser de-

vice, dentsply Sirona, Germany); Group 3: whitening gel activated with a 915nm diode laser (power of 2 watts with radiation for 30 seconds and 120 J/cm ^{2} energy density, using a laser device 88dent-pocket laser, Italy); Group 4: whitening gel activated with 915nm diode laser (power of 2.5 watts with radiation for 30 seconds, 150 J/cm^2 and using the laser device 88dent-pocket laser, Italy); Group 5: whitening gel activated with 970nm diode laser (power of 2 watts with radiation for 30 seconds, 120 J/cm ^{2} energy density and using Siroblue laser device, dentsply Sirona, Germany); Group 6: whitening gel activated with a 970nm diode laser (power 1.5 watts with irradiation for 30 seconds, 90 J/cm ^{2} energy density and using the Siroblue laser device, dentsply Sirona, Germany); Group 7 (control group): whitening gel without laser activation. The bleaching gel was the same in all the studied groups and of the type (Boost, chemical activation-H2O2 40%-Ultradent-Opalescence, USA). All groups were subjected to laser irradiation with a 0.5 cm^2 area with continuous wave mode radiation at a distance of 4 mm from the bleaching gel.

Study protocol

All teeth were extracted within the last month because of surgical reasons and included human teeth number 1 to 5, which were kept in normal saline between tests. The teeth were cleaned with pumice paste and using a manual toothbrush before the experiment. After that, the samples were immersed in 0.5% chloramine solution for one week and placed in distilled water at room temperature (25°C) and standard conditions before testing. Polyvox wax (modeling wax) was used to fix the samples.[7] According to the results of the previous studies that were conducted on these wavelengths and the heat increase was investigated, the parameters of this study were selected.[2,4,8]
All the samples were subjected to calorimetry before starting the study using a spectrophotometer (Vita Zahnfabrik, Bad Säckingen, Germany). According to previous studies, a single-tooth laser was applied at a distance of 4 mm from the tooth surface. For each sample, the laser was used 3 times, with an interval of 30 seconds between them.[2,4,9] In all groups, an 8 mm laser head was used. After that, 15 minutes after applying the laser, the bleaching material was removed from the tooth and washed,[2,4] then using the VITA Easyshade intraoral dental spectrophotometer the color changes of the buccal surface Each sample was recorded and compared (before and after the intervention).[9]
The device was calibrated before each measurement according to the manufacturer's instructions. In recent years, the tristimulus calorimetry developed by the International Commission on Illumination (CIE L*a*b*) has been widely accepted as the reference method for color analysis. In the L*a*b* color space, L* represents brightness from 100 (white) to 0 (black), while a* and b* represent chrominance. a* and b* are the color direction: -a* is the green axis, +a* is the red axis, -b* is the blue axis and +b* is the yellow axis.[10] According to ISO 7491, the teeth were placed on a white background, and parameters b, a, and L were measured three times for each sample, and the average of the three measurements was considered.[7] After the intervention, color changes (ΔE) were measured by the formula $\Delta E=[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]^{1,2}$ using the CIE measurement system.[7]

Statistical analysis

After recording the results of interventions in different groups, statistical analysis was performed using SPSS 22 statistical software (SPSS, Chicago, IL, USA). A two-way variance test was applied to detect any differences between groups. Multiple comparisons were performed using the Tukey HSD test according to the test data. $P< 0.05$ were considered statistically significant.

Results

Based on the findings, ΔE was positive in all groups. As seen in Table 1, The highest amount was in the 445nm 1.5w group and the lowest was seen in the control group and then in the 970nm 2w group ($P<0.05$). The highest dispersion of color change is related to the 445nm 1.5w group ($P<0.05$).
As seen in Table 2, the results of multiple comparisons showed that the use of 445nm diode laser 1.5w (ΔE=12) and 970nm diode laser 2w (ΔE=37.5) was the most and least effective in teeth bleaching, respectively. However, except for the 445nm1.5w group, the other groups did not have a significant difference in terms of whitening effect.

Discussion

Based on the results of the present study, ΔE was positive in all groups. The color change in the 445 nm group was 1.5 W more than the other groups, and the lowest color change was observed in the control group and the 970 nm 2 W group (P<0.05).

In previous studies, the use of a spectrophotometer for calorimetry has been recommended, which is very accurate and is usually used for this purpose.[11] In this study,

Table 1. The description of ΔE between the experimental groups.

	N	Mean	Standard deviation	Standard error	95% Confidence interval for mean		Minimum	Maximum
					Lower bound	Upper bound		
control	11	4.11	1.65	0.50	3.01	5.22	1.33	7.16
445nm.1w	11	7.39	3.27	0.99	5.20	9.59	3.10	12.92
445nm.1.5w	11	12.03	5.50	1.66	8.33	15.72	3.61	19.29
915nm.2w	11	7.94	3.64	1.10	5.49	10.38	2.10	13.59
915nm.2.5w	11	6.59	2.84	0.85	4.69	8.49	2.41	11.01
970nm.2w	11	5.37	2.26	0.68	3.85	6.89	0.96	8.55
970nm.1.5w	11	5.38	2.32	0.70	3.82	6.94	1.68	8.04

Table 2. The results of multiple comparisons of ΔE between groups using ANOVA by Tukey HSD.

Group	Group	Mean difference	Standard error	Sig.*	95% Confidence interval	
					Lower bound	Upper bound
Control	445nm.1w	-3.281	1.399	0.238	-7.529	0.967
	445nm.1.5w	-7.913	1.399	<0.001	-12.160	-3.665
	915nm.2w	-3.823	1.399	0.106	-8.070	0.425
	915nm.2.5w	-2.476	1.399	0.573	-6.724	1.772
	970nm.2w	-1.256	1.399	0.972	-5.504	2.992
	970nm.1.5w	-1.267	1.399	0.971	-5.515	2.981
445nm.1w	915nm.2w	-0.542	1.399	1.000	-4.789	3.706
	915nm.2.5w	0.805	1.399	0.997	-3.443	5.053
	970nm.2w	2.025	1.399	0.774	-2.223	6.272
	970nm.1.5w	2.014	1.399	0.779	-2.234	6.262
445nm.1.5w	915nm.2w	4.090	1.399	0.067	-0.158	8.338
	915nm.2.5w	5.437	1.399	0.004	1.189	9.685
	970nm.2w	6.657	1.399	<0.001	2.409	10.904
	970nm.1.5w	6.646	1.399	<0.001	2.398	10.894
915nm.2w	915nm.2.5w	1.347	1.399	0.960	-2.901	5.594
	970nm.2w	2.566	1.399	0.530	-1.681	6.814
	970nm.1.5w	2.556	1.399	0.535	-1.692	6.803
915nm.2.5w	970nm.2w	1.220	1.399	0.976	-3.028	5.467
	970nm.1.5w	1.209	1.399	0.977	-3.039	5.457
970nm.2w	970nm.1.5w	-.0107	1.399	1.000	-4.258	4.237

**Statistical significance.*

we also used a spectrophotometer for calorimetry. According to some authors, ΔL is a more important parameter for examining color change, and the human eye can see and understand this color parameter. Because the quality of the rods responsible for distinguishing black and white colors is much higher than the rods responsible for color vision.[12] In another study, it has been stated that ΔE is usually used in studies to evaluate bleaching quality. According to past studies, we also used ΔE in this study to evaluate the quality of bleaching.[3,7,13,14]

It is reported that Δ> 3.3 is an acceptable clinical discoloration threshold. So ΔE between 3 and 8 can be detected by the eye on average and ΔE>8 refers to a very perceptible color change by the human eye.[7] Based on this value, the results in all groups show a perceptible color change. and all techniques were effective for teeth whitening (ΔE≥3). However, a statistically significant difference compared to the control group was seen only in the 445nm1.5w group with 40% hydrogen peroxide gel. In the study by Möbius *et al.* (2024), the Evaluation of tooth color change after a bleaching process with different laser wavelengths was examined, the wavelength of 445 had the most effect, but the laser radiation was done with fiber and the type of bleaching gel and laser parameters used was different from our study.[14] A study by Marzieh Rohaninasab *et al.* (2020) aimed to compare the effectiveness of 940 nm diode laser, 980 nm diode laser, and whitening gel in teeth bleaching, in which the study found that all bleaching techniques effectively whiten teeth to a clinically perceptible level (ΔE* > 3.3) and no significant difference was seen between the groups.[15] Here, we obtained almost similar results and all the different wavelengths of the diode laser during bleaching effectively whitened the teeth to a clinically perceptible level. In a study conducted by Ergin *et al.* (2018) to compare the effect of the Er: YAG laser with other light-activated bleaching systems, it showed that all the light-activated bleaching systems, including the diode laser (940 nm, 7 W) were effective on the change of tooth color (ΔE>3.3), but the color changes in all systems were not significantly different from each other, but there was no comparison between the controlled methods of different lasers with the group without laser.[3] In our study, a comparison was made with the group without laser, which shows that even though bleaching was effective in all groups, except for one group (445nm1.5w), there was a significant difference between the laser groups. with different wavelengths and powers and it was not seen in the group without laser. In the above study, we used teeth with natural color, which can be the reason for the less color change of our teeth compared to some studies that use teeth placed in coffee or tea for their study.[7,16] In a study conducted by Kiomars *et al.* (2016) to compare the effect of 810nm laser and 980nm laser on tooth color change, a significant color change was seen in all groups (with laser and without laser) (ΔE≥3), which It is similar to the results of our study; But in the above study, there is a significant difference between the groups with laser and the group without laser in the amount of whitening, which is different from the results of our study, and we found a significant difference between the group without laser and the groups with laser except for the group (445nm1 .5w), we did not observe.[13]

In past studies, different bleaching gels have been used,[3,7,13] and due to the absorption of different wavelengths in different pigments, the type of gels used in the study can affect the final result. The gel used in the above study is red, and this pigment is very well absorbed by the 445nm laser, this point can explain the better results of this wavelength compared to the other 2 wavelengths. One of the limitations of the above study was the immediate examination of color change after bleaching, which is recommended to be examined in future long-term follow-up studies. Also, in future studies, it is better to use different gels suitable for each of the wavelengths and check the results.

In conclusion, the results showed that the use of 445 nm diode laser 1.5w (ΔE=12) and 970nm diode laser 2w (ΔE=37.5) was the most and least effective in teeth bleaching, respectively. However, except for the 445nm1.5w group, the other groups did not differ significantly from each other and the control group in terms of whitening effect.

Contributions: all authors contributed equally to the work. All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of interest: the authors declare no potential conflict of interest, and all authors confirm accuracy.

Ethics approval and consent to participate: this project is approved by the Ethics Committee of Tehran University of Medical Sciences with code IR.TUMS.DENTISTRY.REC.1401.133. The study is conformed with the

Helsinki Declaration of 1964, as revised in 2013, concerning human and animal rights. All patients provided consent to participate.

Availability of data and materials: all data generated or analyzed during this study are included in this published article.

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