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Evaluating the effectiveness of two wavelengths of 810 and 980 nm Diode laser with two different beam profiles on tooth discoloration in bleaching: an experimental study

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ABSTRACT

Teeth color has a significant impact on facial aesthetics. Tooth bleaching is the safest way to lighten the color of your teeth. Today, hydrogen peroxide is the most commonly used bleaching agent. The diode laser is one of the light sources that speeds up the bleaching process. One of the laser beam features is the laser beam profile, which depicts the distribution of laser intensity across the beam section. The goal of this study is to look into the effectiveness of Gaussian and Flat top beam profiles on tooth shade using two diode laser wavelengths of 810 and 980 nm in the tooth bleaching process. Fifty human anterior and premolar teeth were extracted and placed in a tea and coffee solution for three weeks before being divided into five groups. The first group did not receive laser radiation because 40% hydrogen peroxide was used; in the second and third groups, the profile of the flat top beam and the wavelength were 810 and 980 nm, respectively; and in the fourth and fifth groups, the wavelength of the Gaussian beam profile was 810 and 980 nm. The shade of the samples before and after bleaching was measured with a CIELab-based spectrophotometer, and the results were analyzed using one-way ANOVA and Tukey's multiple comparison test. All bleaching methods resulted in a significant change in tooth color ($\Delta E>3.3$). There was a significant difference in average shade changes across groups ($P<0.001$). The highest degree of shade change was observed in two groups of lasers with a wavelength of 980 nm and profiles of Flat top beam ($\Delta E=5.35$) and Gaussian ($\Delta E=5.02$). There were no differences between the remaining groups. We conclude that the 980 nm wavelength produces a greater shade change than the 810 nm wavelength and chemical method. The diode laser's 810 nm wavelength has no effect on the shade of teeth.

Key words: tooth bleaching, diode laser, color change, spectrophotometry, laser beam profile.

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Introduction

The color of one's teeth is a major concern for many individuals. Those with whiter and brighter teeth tend to have greater social appeal, leading to an increase in requests for teeth whitening.[1] The factors that contribute to tooth discoloration can be divided into external and internal factors.[2] Internal factors are caused by changes in the composition and thickness of tooth tissue which result in tooth discoloration. The cause of internal color change may be related to processes before or after tooth eruption. Some examples of factors that cause internal color change include alkaptonuria, amelogenesis imperfecta, dentinogenesis imperfecta, fluorosis, tetracycline, hypoplasia of enamel, pulp hemorrhage, and root resorption. External factors are those that deposit on the enamel over time and change the color of teeth. Examples of external factors include improper oral hygiene techniques, smoking, consumption of colored foods and liquids (such as tea and coffee), aging, and exposure to iron salts and chlorhexidine.[1,3-5] Various methods exist for treating tooth discoloration, such as bleaching, restorative treatment (composite and ceramic veneers), and full dental coverage.[3] Bleaching is the most cautious method for whitening teeth. It involves brightening the color of teeth by breaking down chromogens and disrupting double carbon-carbon bonds through free radicals released from oxidizing agents. Bleaching can be performed in the office or at home.[2,6] Throughout history, various oxidizing agents, such as calcium hypochlorite, acetic acid, oxalic acid, carbamide peroxide, and hydrogen peroxide, have been used.[2,7] Today, the most commonly used agent for in-office bleaching is high-concentration hydrogen peroxide, which is accelerated with various sources of light and heat to release free radicals faster.[2,5,6,8]

Light sources for activating the bleaching process include LED, laser, plasma, and halogen lamps.[7] The photoreceptor molecules in the bleaching gel absorb the light, increasing the temperature of the gel and resulting in the release of free radicals from hydrogen peroxide at a faster rate.[7-9] KTP, Nd:YAG, argon, carbon dioxide, and diode lasers are used in the bleaching process.[5,10,11] The diode laser is a semiconductor laser with different active mediums. It is typically available in wavelengths of 810 and 980 nanometers and widely used in dentistry. The energy produced by the diode laser is mainly absorbed by pigmented tissue and hemoglobin and has less absorption in water and hydroxyapatite (teeth), causing no damage to tooth tissue. The 980-nanometer wavelength of the diode laser has higher absorption in water than the 810-nanometer wavelength. The diode laser increases the temperature of the bleaching gel in a short time and accelerates its activation.[12-15]

When it comes to laser radiation, one crucial parameter is the intensity of the laser beam, which is determined by the ratio of the laser power to the cross-sectional area of the beam and the distribution of its intensity across that area. This distribution is what gives the beam its unique radiation profile.[16,17] The beam profile is important because it affects energy density and concentration, which in turn determine how the beam propagates. There are two main types of beam profiles: Gaussian and Flat top. In Gaussian mode, the beam intensity is highest at the center of the beam and decreases symmetrically towards the edges. One drawback of this profile is that the intensity at the edges can be low, resulting in energy loss and unwanted heat generation in surrounding tissues if it falls outside the required range. In cutting applications, the Gaussian profile can also lead to irregular and rough edges. In contrast, the Flat top profile maintains a constant, uniform beam intensity across the entire width of the beam, with a homogeneous distribution of intensity in the beam's cross-sectional area. Because there are no low-intensity margins with this profile, it's more energy efficient and has fewer unintended effects on surrounding tissue. However, producing a Flat profile requires specialized tools and equipment, making it less economically feasible.[16-18] To date, no studies have looked at the effect of beam profile on tooth bleaching. That's why the main goal of this study is to compare the effects of two different profiles - Gaussian and Flat top - on in-office teeth bleaching.

Materials and Methods

This research has been approved by the Ethics Council in Research at Alborz University of Medical Sciences under the code IR.ABZUMS.REC.1401.159. For this comprehensive laboratory-based study, we extracted a sample of healthy human anterior and premolar teeth from our research population. To ensure adequate representation, we included 10 teeth in each group. Our inclusion criteria required that teeth have intact enamel on their incisal, canine, or molar cusps, as well as mandibular teeth. We excluded any teeth with caries lesions, visible cracks or hypoplastic lesions, or severe color changes within the tooth.

After selecting our sample, we removed any remaining soft tissue and debris from the teeth using an ultrasonic scaler. Then, we soaked the teeth in a 0.5% chloramine T solution for one week to ensure disinfection. Following disinfection, we immersed the teeth in a solution consisting of equal parts tea and coffee. To prepare the solution, we brewed a bag of Ahmad tea (Iran) for five minutes in a cup of boiling water and added instant Nescafe coffee (3-in-1; Iran) to 180 milliliters of boiling water in equal proportions. We changed the solution daily. Finally, we polished the teeth using a low-speed handpiece, brush, and Prophy-Mor Micro Black prophylaxis paste (Morvabon, Iran) and stored them in normal saline until the study's commencement.

The samples were dried and divided into five random groups. To ensure consistency in the angle before and after bleaching when determining the color inside the silicone impression, a fixed density was used. Opalescence™ Boost™ PF 40% (Ultradent, USA) was used as the bleaching gel in all groups for this study. In the first group, the teeth were exposed to the bleaching gel for 20 minutes without any laser irradiation. The other groups used Diode (Wiser 3, Doctor Smile, Italy) laser to activate the bleaching gel. In groups two through five, the laser had an irradiance of 2 watts, and the regime involved placing the bleaching gel on the specimens. The laser was then irradiated three times for 30 seconds each time with a one-minute interval between each irradiation. After the third laser irradiation, the gel remained on the teeth for seven minutes before being rinsed with water and dried for color evaluation. The second group used a laser with a wavelength of 810 nanometers and a Flat beam profile. The third group used a laser with a wavelength of 980 nanometers and a Flat beam profile. The fourth group used a laser with a wavelength of 810 nanometers and a Gaussian beam profile, while the fifth group used a laser with a wavelength of 980 nanometers and a Gaussian beam profile.

Data collection involved determining the color of the teeth before and immediately after bleaching. For this study, the CIELAB system was used to determine tooth color. CIELAB is a quantitative index developed by the International Commission on Illumination (CIE) for expressing color. It is a three-dimensional space with three components: L*, a*, and b*. The L* index represents color brightness, with values ranging from zero (black) to 100 (white). The* index represents the amount of red-green color, where positive values indicate red and negative values indicate green. The b* index represents the amount of yellow-blue color, where positive values indicate yellow and negative values indicate blue.

The color change (ΔEab^*) in this system is calculated using the following formula:

$$\Delta Eab^* = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2]1/2$$

We utilized the SpectroShade Micro spectrophotometer (MHT Srl, Italy) to gather the necessary parameters. Before conducting the research, the color of the samples was measured twice using a calibrated spectrophotometer by the manufacturer's guidelines, and the mean of the two measurements was taken as the baseline tooth color. Post-bleaching, the color of the samples was again measured twice, and the average of the two readings was considered as the color after treatment, with the amount of color change in the samples being calculated via the ΔE formula.

The collected data were subjected to statistical analysis using SPSS version 24 software. Quantitative results were reported as 'mean ± standard deviation'. For comparison of mean CIELab parameters across groups, we employed one-way ANOVA followed by Tukey's multiple comparisons test if deemed significant. To evaluate the normality of the distribution of CIELab color parameters, we utilized the nonparametric Kolmogorov-Smirnov test, wherein no deviation from the assumption was observed ($P>0.05$). Additionally, we used the Levene test to assess variance homogeneity between groups, which was confirmed to be met ($P>0.05$). A significance level of 0.05 was set for the tests.

Results

In this experimental laboratory study, the control group, 810-nm wavelength laser with Flat top beam profile, 980-nm wavelength laser with Flat top beam profile, 810-nm wavelength laser with Gaussian beam profile, and 980-nm wavelength laser with Gaussian beam profile were investigated and compared. In each group, 10 anterior teeth and premolars were evaluated. In Table 1, the mean values of color parameters L, a, and b were compared among the studied groups.

In Table 2, the average values of color parameters ΔL, Δa, Δb, and ΔE have been compared among the studied groups. One-way analysis of variance showed that the mean values of ΔL, Δa, and ΔE for the examined groups have a statistically significant difference ($P<0.05$), while the mean value of parameter Δb did not show a statistically significant difference among the examined groups ($P>0.05$).

In all groups, the brightness of the teeth increased (ΔL>0), while the redness (Δa) and yellowness (Δb) decreased. Tukey's multiple comparison test results for ΔL showed that the mean ΔL was significantly higher in the 980-nanometer laser group with a flat top beam profile than the control group ($P=0.022$), the 810-nanometer laser group with a flat top beam profile ($P=0.010$), and the 810-nanometer laser group with a Gaussian beam profile ($P=0.020$). There was no statistically significant difference between the other groups ($P>0.05$). For Δa, Tukey's test showed that the mean Δa in the 980-nanometer laser group with a flat top beam profile was significantly higher than the 980-nanometer laser group with a Gaussian beam profile ($P=0.039$), but there was no significant difference between the other groups ($P>0.05$).

All groups had clinically detectable color changes (ΔE≥3.3). Tukey's test for ΔE showed that the mean ΔE was significantly higher in the 980-nanometer laser group with a flat top beam profile than the control groups

Table 1. The average and standard deviation of color parameters (L, a, and b) before and after bleaching.

Group number	Color parameter	Before bleaching		After bleaching	
		Average	Standard deviation	Average	Standard deviation
1	L	74.91	1.73	78.22	1.71
	a	1.66	1.24	1.01	1.11
	b	16.46	2.10	15.28	2.12
2	L	75.72	1.06	78.89	0.89
	a	1.97	0.97	1.63	0.89
	b	15.01	2.38	13.78	2.29
3	L	73.43	2.86	78.36	1.78
	a	1.71	0.99	0.99	0.83
	b	14.67	1.95	13.32	1.58
4	L	76.31	1.04	79.60	1.88
	a	1.58	1.03	0.95	0.96
	b	15.50	2.11	14.99	2.22
5	L	71.58	2.23	75.89	2.93
	a	0.66	1.33	0.48	1.32
	b	16.93	2.67	15.69	1.90

Table 2. Comparison of color parameter means (ΔL, Δa, Δb, and ΔE) in the examined groups.

	ΔL (variation range)	Δa (variation range)	Δb (variation range)	ΔE (variation range)
Group 1	3.31±0.31a (2.8- 3.8)	-0.65±0.3ab (-1.1- 0.2)	-1.18±0.52 (-2.0- 0.5)	3.62±0.37a (3.1- 4.1)
Group 2	3.17±0.56a (2.6- 4.4)	-0.34±0.16ab (-0.6- 0.1)	-1.23±0.54 (-2.0- 0.5)	3.47±0.52a (2.9- 4.5)
Group 3	4.93±1.49b (3.1- 6.8)	-0.72±0.64a (-2.3- 0.0)	-1.35±1.33 (-4.8- 0.4)	5.35±1.45b (3.3-6.8)
Group 4	3.29±1.24a (2.0- 5.7)	-0.63±0.13ab (-0.9- 0.5)	-0.51±0.47 (-1.3- 0.4)	3.42±1.20a (2.2- 5.7)
Group 5	4.31±1.54ab (2.2- 6.9)	-0.18±0.55b (-1.3- 0.6)	-1.24±1.25 (-4.9- 2.9)	5.02±1.44b (3.2- 7.5)
P- Value	0.003	0.021	0.567	0<0.001

**The table data is reported as "standard deviation±mean""and (range of variation).*
***In each variable, groups labeled with different English letters have a statistically significant difference in their means (P<0.05).*

(P=0.008), the 810-nanometer laser group with a flat top beam profile (P=0.003), and the 810-nanometer laser group with a Gaussian beam profile (P=0.002). The mean ΔE in the 980-nanometer laser group with a Gaussian beam profile was also significantly higher than the control groups (P=0.047), the 810-nanometer laser group with a flat top beam profile (P=0.022), and the 810-nanometer laser group with a Gaussian beam profile (P=0.017). No statistically significant difference was observed between the other groups based on the mean ΔE parameter (P>0.05).
By using a one-way analysis of variance and Tukey's multiple comparison test, it was found that the mean EΔ was significantly higher in the 980-nanometer laser groups with a flat top beam profile and a Gaussian beam profile than in the other groups (P<0.05).

Discussion

In this study, we investigated the impact of two different wavelengths (810 and 980 nanometers) of diode laser with both flat top and Gaussian beam profiles on dental bleaching in a clinical setting. We evaluated the color change of teeth immediately after bleaching using the CIELab color change system. One critical factor that affects bleaching is the concentration of hydrogen peroxide (19). To more accurately examine the effect of wavelength and beam profile, we used the same bleaching gel containing 40% hydrogen peroxide in all groups in this study.
Our results showed that the greatest amount of color change (ΔE) occurred in the two laser groups with a 980-nanometer wavelength, with the flat top beam profile (ΔE=5.35) and the Gaussian beam profile (ΔE=5.02). These changes were significant compared to other groups. Studies have shown that spectrophotometry is 2- 5 times more likely to achieve color matching than visual methods, and the reproducibility of color determination is also higher with spectrophotometry.[20-24] Therefore, in our study, we used a spectrophotometer to evaluate color changes.
The CIELab color classification system determines the degree of change using ΔE, which has a specific calculation formula. The color change ΔE must be at least 3.3 to be clinically detectable.[1,25] Based on this parameter, bleaching caused significant color changes in all study groups.
We found no difference in color changes between the 810-nanometer wavelength group and the control group in our study. However, in the 980-nanometer wavelength group, color changes were higher than in the 810-nanometer wavelength and control groups. This appears to be related to the principle that absorption of the Diode laser in water at 980 nanometers is higher than at 810 nanometers.[12] Higher laser absorption at 980 nanometers leads to a greater increase in the temperature of the bleaching gel and an increase in bleaching effectiveness.
Other similar studies have reported conflicting results. In Ahrari's study,[26] the 810-nanometer wavelength Diode laser with a power of 3 watts, and in Saeedi's study,[10] the 810-nanometer wavelength Diode laser with a power of 1.5 watts showed no significant difference in color change compared to the control group. In Ehrari's study, using the twice 30-second irradiation regimen with a 10-minute interval did not show a significant difference compared to the chemical activation method with a twice 20-minute gel application regimen. However, in Shababi's study,[11] the 810-nanometer wavelength Diode laser with a power of 1.5 watts, and in Fekr-Azad's study,[27] the 810-nanometer wavelength Diode laser had better results compared to the chemical activation group.
In a study conducted by Al-Karadaghi,[28] it was found that a 980-nanometer wavelength Diode laser with a power of 7 watts resulted in a greater color change compared to the control group. However, Surmelioglu's study[29] and Saeedi's study[10] showed no significant difference between the chemical activation method and a 980-nanometer wavelength Diode laser with a power of 7 watts or 1.5 watts respectively.
In this study, there was no significant difference in color change between the 810-nanometer wavelength Diode laser groups with flat top and Gaussian beam profiles. Similarly, there was no significant difference between the 980-nanometer wavelength Diode laser groups with flat top and Gaussian beam profiles, suggesting that beam profile type does not affect bleaching. At present, no studies have been found that compare the effectiveness of different laser beam profiles in bleaching.
One limitation of this study was the inability to follow up on long-term teeth changes to assess the stability of color changes. Additionally, no similar studies were found for comparison. Therefore, it is recommended that further studies be conducted to examine beam profile radiation in bleaching using various lasers and different implementation methods. Long-term follow-up studies should also be conducted to compare different beam profiles' effects on side effects such as increased

sensitivity after bleaching and increased pulp temperature. Various studies have reported different results for these side effects using different lasers; therefore, conducting studies on these side effects with different beam profile radiation types is advisable.

Conclusions

Based on the results of this study, it can be concluded that the use of a 980-nanometer wavelength Diode laser produces better results in dental bleaching in the clinic. The 810-nanometer wavelength did not show a significant difference in color change compared to the non-laser method. However, it should be noted that the bleaching time with laser use is less than without, which can make patients more comfortable. This study shows that beam profile radiation type does not affect the effectiveness of lasers in bleaching. Given the high cost of using flat-top beam profiles, a Gaussian beam profile can be used in Diode laser bleaching.

Contributions

MS and NC, conceptualization, methodology; SG and NP, writing—original draft preparation; writing—review and editing NC. All authors have read and agreed to the published version of the manuscript.

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Ethics approval

This research has been approved by the Ethics Council in Research at Alborz University of Medical Sciences under the code IR.ABZUMS.REC.1401.159.

Consent to participate

Informed consent was obtained from all patients for using their teeth in the study.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

References

1. Joiner A, Luo W. Tooth colour and whiteness: A review. J Dent 2017;67s:S3-s10.
2. Rodriguez-Martinez J, Valiente M, Sanchez-Martin MJ. Tooth whitening: From the established treatments to novel approaches to prevent side effects. J Esthet Restor Dent 2019;31:431-40.
3. Ibrahim MB, Dawood AAA, Fathi AA, et al. Causes and Management of Tooth Discoloration: A Review. J Pharmaceut Res Int 2021:969-76.
4. Kapadia Y, Jain V. Tooth staining: A review of etiology and treatment modalities. Acta Sci Dent Sci 2018;2:67-70.
5. Infantina V, Sidhu R, Savitha S, et al. Effectiveness of Various Types of LASER Therapy during In-Office Teeth Bleaching: A Systematic Review. Int J Curr Sci Res Rev 2022;5:3163-9.
6. Alqahtani MQ. Tooth-bleaching procedures and their controversial effects: A literature review. Saudi Dental J 2014;26:33-46.
7. Alshammery S. Evaluation of light activation on in-office dental bleaching: A systematic review. J Contemp Dental Pract 2019;20:1355-60.
8. De Moor RJ, Verheyen J, Verheyen P, et al. Laser teeth bleaching: evaluation of eventual side effects on enamel and the pulp and the efficiency in vitro and in vivo. Scient World J 2015;2015:835405.
9. Maran BM, Ziegelmann PK, Burey A, et al. Different light-activation systems associated with dental bleaching: a systematic review and a network meta-analysis. Clin Oral Invest 2019;23:1499-512.
10. Saeedi R, Omrani LR, Abbasi M, et al. Effect of three wavelengths of diode laser on the efficacy of bleaching of stained teeth. Front Dent 2019;16:458-64.
11. Shahabi S, Assadian H, Mahmoudi Nahavandi A, Nokhbatolfoghahaei H. Comparison of tooth color change after bleaching with conventional and different light-activated methods. J Lasers Med Sci 2018;9:27-31.
12. Martens LC. Laser physics and a review of laser applications in dentistry for children. European archives of paediatric dentistry. Offic J Eur Acad Paediatr Dent 2011;12:61-7.
13. Ibacache MCT, Arcos P, Sanchez S, Weinstein G. Use of diode lasers in dentistry. Clin Dent Rev 2020;4:1-7.
14. Luke AM, Mathew S, Altawash MM, Madan BM. Lasers: a review with their applications in oral medicine. J Lasers Med Sci 2019;10:324-9.
15. Hyder T, Resident M. Diode lasers in dentistry: current and emerging applications. J Pakistan Dent Assoc 2022;31:100-5.
16. Roundy CB, Kirkham K. Current technology of laser beam profile measurements. Laser Beam Shaping 2014:463-524.
17. Dickey FM. Laser beam shaping: theory and techniques: CRC press; 2018.
18. ISO 13694:2018 Optics and photonics — Lasers and laser-related equipment — Test methods for laser beam power (energy) density distribution: ISO; 2018; 3. Available from: https://www.iso.org/ standard/72945.html
19. Alkahtani R, Stone S, German M, Waterhouse P. A review on dental whitening. J Dent 2020;100:103423.
20. Bahannan SA. Shade matching quality among dental students using visual and instrumental methods. J Dent 2014;42:48-52.
21. Jaju RA, Nagai S, Karimbux N, Da Silva JD. Evaluating tooth color matching ability of dental students. J Dental Educat 2010;74:1002-10.
22. Tabatabaian F, Beyabanaki E, Alirezaei P, Epakchi S. Visual and digital

tooth shade selection methods, related effective factors and conditions, and their accuracy and precision: A literature review. J Esthet Restor Dent 2021;33:1084-104.
23. Judeh A, Al-Wahadni A. A comparison between conventional visual and spectrophotometric methods for shade selection. Quintessence Int 2009;40:e69-79.
24. Gehrke P, Riekeberg U, Fackler O, Dhom G. Comparison of in vivo visual, spectrophotometric and colorimetric shade determination of teeth and implant-supported crowns. Int J Comput Dent 2009;12:247-63.
25. Sakaguchi RL, Ferracane JL, Powers JM. Craig's restorative dental materials. 14th ed: Elsevier; 2019. 50-1 p.
26. Ahrari F, Akbari M, Mohammadipour HS, et al. The efficacy and complications of several bleaching techniques in patients after fixed orthodontic therapy. A randomized clinical trial. Swiss Dent J 2020;130:493-501.
27. Fekrazad R, Alimazandarani S, Kalhori KA, et al. Comparison of laser and power bleaching techniques in tooth color change. J Clinical Experiment Dent 2017;9:e511-e5.
28. Al-Karadaghi TS, Al-Saedi AA, Al-Maliky MA, Mahmood AS. The effect of bleaching gel and (940 nm and 980 nm) diode lasers photoactivation on intrapulpal temperature and teeth whitening efficiency. Australian End J 2016;42:112-8.
29. Surmelioglu D, Usumez A. Effectiveness of different laser-assisted in-office bleaching techniques: 1-year follow-up. Photobiomodul Photomed Laser Surg 2020;38:632-9.