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Color Change Stability Using Different Bleaching Gels and Light Sources: An in Vitro Study

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ABSTRACT

Objectives: The aim of this study was to assess the color change (ΔE) of teeth following the use of several bleaching protocols with power bleaching.

Materials and Methods: This in vitro study evaluated 50 sound incisors and premolars. After cleaning, the teeth were immersed in a 2g/100mL tea solution for 6 days. The samples were randomly divided into 5 bleaching groups: Snow L [containing 40% hydrogen peroxide (HP) and 20% carbamide peroxide] with 980nm diode laser, White Smile (containing 32% HP) with LED (Monitex), Boost (containing 40% HP) with 980nm diode laser, Boost (containing 40% HP) with LED (Monitex), and Boost without activation. Color parameters were measured before and after staining, immediately and 1 week after bleaching by a spectrophotometer, and their ΔE was calculated and compared by one-way ANOVA followed by the Tukey's test.

Results: All bleaching protocols improved the color parameters. The ΔE in each group was significant after bleaching compared to before bleaching in the cervical ($P<0.001$), middle ($P<0.001$) and incisal ($P<0.001$) thirds. The ΔE was significant at 1 week compared to before bleaching ($P=0.002$ for the cervical, $P<0.001$ for the middle, and $P<0.001$ for the incisal third, respectively), immediately after bleaching compared with after staining (all Ps<0.001), and also at 1 week compared with after staining (all Ps<0.001).

Conclusion: Within the study limitations, all power bleaching protocols caused color change of the teeth. The efficacy of Boost (conventional bleaching), Boost plus LED, and White Smile was better than Snow L regarding color change of teeth.

Keywords: Bleaching Agents; Diode Laser; Tooth Bleaching, Color change

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INTRODUCTION

The color of teeth is a significant factor contributing to an attractive smile. Tooth discoloration is a prevalent aesthetic issue and frequently serves as a primary concern for patients pursuing dental care. Bleaching is one of the acceptable approaches to improve teeth color and value. Chemically and light activated bleaching materials are commonly used in dental practices. Application of light can accelerate tooth bleaching process [1-3]; however, the efficacy of light in bleaching, post-op tooth hypersensitivity and soft tissue irritation are matters of concern [3,4].

In the process of tooth bleaching, hydrogen peroxide (HP), as a strong oxidizing agent, generates oxygen free radicals which interacts with pigments on tooth surface (that are composed of carbon chains and they are responsible for tooth discoloration) and it causes their degradation (cleavage of carbon chains) and it eventually results in tooth whitening [5].

The bleaching agents can be affected by heat and light. Thus, light-emitting diode (LED), diode laser, argon laser, and plasma arch lamp can be used to activate HP [1]. The mechanism of action of laser systems for bleaching purposes depends on the wavelength and power of laser light. Laser irradiation generates heat, raises the temperature of the bleaching agent, and eventually accelerates the generation of oxygen free radicals [1], leading to faster dissociation of pigmented carbon chains [6].

Light-activated tooth bleaching is referred to as photo-oxidation. The laser light used for tooth bleaching can be focused on one tooth or part of a tooth. Different laser wavelengths in the range of 810 to 980nm can be used for tooth bleaching [1,4,7]. As mentioned earlier, the efficacy of laser for tooth bleaching remains a matter of controversy [7]. Some lasers did not yield optimal results when used for tooth bleaching especially when the laser wavelength was out of the reported range [7]. Dionsopoulos et al. [8] (2017) evaluated the efficacy of bleaching with Er,Cr:YSGG laser by spectrophotometric analysis and showed that laser-assisted bleaching yielded superior results. Also, Kiomarsi et al. [9] (2016) assessed the efficacy of diode laser irradiation with 810 and 980nm wavelengths after external bleaching and showed that all bleaching techniques caused a color change in teeth with no significant difference between them.

Considering all the above, this study aimed to assess the color change (ΔE) of teeth following the use of several bleaching protocols with power bleaching.

MATERIALS AND METHODS

Sample size calculation and sampling:

The sample size was calculated to be 10 in each group according to a study by Kiomarsi et al. [11] (2016) assuming $\alpha=0.05$, $\beta=0.2$, mean standard deviation of 3.09, and effect size of 0.53 using one-way ANOVA power analysis feature of PASS 11.0 software. The teeth were selected by convenience sampling.

A total of 50 extracted human anterior and premolar teeth were used in this in vitro, experimental study. Teeth with cracks or structural defects were excluded. The teeth had been extracted within the past 3 months for orthodontic purposes or due to periodontal problems. The study was approved by the ethics committee of Tehran University of Medical Sciences (IR.TUMS.DENTISTRY.REC.1398.145).

The teeth were immersed in 0.5% chloramine T solution for 24 hours [10], and remained in saline until the experiment. The tooth crowns were cut at 2mm below the cementoenamel junction. To ensure surface integrity, the teeth were inspected under a stereomicroscope at x10 magnification. The tooth crowns were then mounted in putty (Speedex, Coltene, Switzerland) such that their buccal surface was exposed. To standardize the smear layer and create a smooth flat surface, the enamel surface was polished with 1200-grit abrasive paper and polishing paste with 0.1µm diamond particles. The polished surfaces were then inspected under a microscope to ensure absence of dentin residues and were then immersed in artificial saliva with the composition of 0.103g/L $CaCl_2$, 0.019g/L $MgCl_2.6H_2O$, 0.544g/L KH_2PO_4, 2.24g/L KCL, and 0.650g/L KOH, at 37°C for 24 hours.

Prior to bleaching treatments, the color parameters of the teeth were measured at the incisal, middle, and cervical thirds using a spectrophotometer (SpectroShade, MHD, Verona, Italy). The measurements were made at the center of the incisal, middle, and cervical thirds in the buccal surface of each tooth and repeated three times. The spectrophotometer automatically calculated the mean values and reported them for each specimen. Next, the teeth were immersed in 1% sodium hypochlorite solution to eliminate any external discoloration. The enamel surfaces were then etched with 37% orthophosphoric acid (3M, USA) and rinsed with water for 30 seconds. The tea solution (Ahmad, Iran) was prepared by immersing 2g of loose tea in 100mL of distilled water; the solution was heated for 10 minutes until boiling [8]. The solution was passed through sterile gauze for filtration and cooled down. The teeth were immersed in tea solution for 6 days for staining the teeth, and the solution was refreshed every 24 hours. Next, the teeth were randomly divided into five groups.

The teeth in group 1 were subjected to bleaching with Snow L bleaching agent (Navateb Pars, Tehran, Iran), which contains 40% HP along with 20% carbamide peroxide (reaching 35% when mixed with accelerator) plus titanium oxide chromophore. The bleaching agent was applied on the tooth surface with 1.5mm thickness, and irradiated with 980nm diode laser (Wiser, DoctorSmile, Italy) with 2W power in continuous-wave mode at 2mm distance from the surface. Laser was irradiated to the tooth surface with a 7-mm tip for 30 seconds. This process was repeated for 2 more times with 1 minute intervals (90 seconds of laser irradiation with 2-minute intervals for a total cycle of 3.5 minutes). Finally, the gel remained on the tooth surface for 7 minutes (a total of 10.5 minutes).

The teeth in group 2 were subjected to bleaching by using White Smile (Mani Schortz Co. Germany) bleaching agent, which contains 40% HP (its concentration reaches 32% when mixed with the accelerator). The bleaching agent was applied in 1.5mm thickness and irradiated with high-power Monitex LED blue (420-490nm) and red light (620-630nm) (Whiten MAX BR800, Taiwan) from the closest distance (1mm distance) for 20 minutes in high mode (3W). This procedure was repeated once (a total of 40 minutes).

The teeth in group 3 were subjected to bleaching with Boost bleaching gel (40% HP) (Ultradent, South Jordan, UT, USA). Laser was irradiated with the same exposure parameters as mentioned for group 1.

The teeth in group 4 were subjected to bleaching with Boost bleaching gel (Ultradent, South Jordan, UT, USA). Irradiation was performed with Monitex LED with the exposure parameters similar to those for group 2.

Group 5 served as the control group, and the teeth in this group were subjected to Boost bleaching gel (Ultradent, South Jordan, UT, USA), which contains 40% HP. The gel was applied in 1.5mm thickness on the surface of the teeth for 40 minutes (twice, 20 minutes each).

The specimens then underwent spectrophotometry (SpectroShade, MHD, Verona, Italy), and the color parameters were evaluated and compared before staining, after staining, immediately after bleaching and one week after bleaching using Vita color shade system. The ΔE of the specimens was calculated and reported using CIE 1976 formula by MATLAB software.

Statistical analysis:

Data were analyzed using SPSS version 25. The mean, standard deviation, minimum, and maximum values of L*a*b* color parameters and ΔE were reported separately for the 5 groups at different time points in the cervical, middle and incisal thirds. The five bleaching protocols were compared regarding ΔE, Δa, Δb, and ΔL at different time points using one-way ANOVA. Since the difference was significant among the groups, pairwise comparisons were carried out by the Tukey's test. Level of significance was set at 0.05.

RESULTS

One-way ANOVA showed a significant improvement in color in all groups ($P<0.05$). One-way ANOVA showed that the ΔE of the groups was significant immediately after bleaching compared with before bleaching in the cervical ($P<0.001$), middle ($P<0.001$) and incisal ($P<0.001$) thirds, at 1 week compared with before bleaching ($P=0.002$ for the cervical, $P<0.001$ for the middle, and $P<0.001$ for the incisal third, respectively), immediately after bleaching compared with after staining (all Ps<0.001), and also at 1 week compared with after staining (all Ps<0.001). The ΔE was greater in the cervical third compared with the middle and incisal thirds (Figures 1-4).

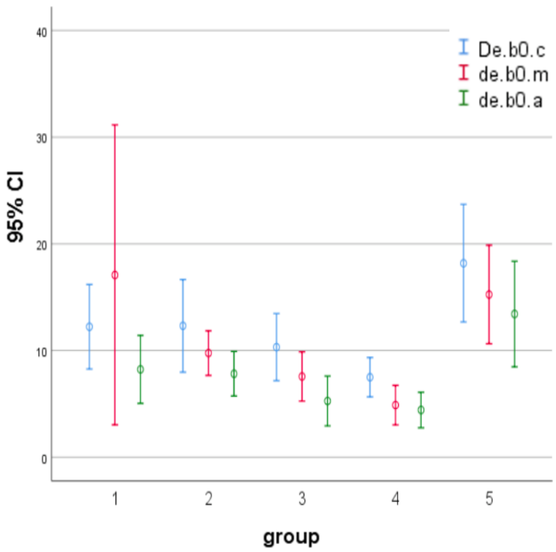

Fig 1. ΔE immediately after bleaching compared with before bleaching with 95% confidence interval in the cervical, middle and incisal thirds in the study groups. Group 1. Snow L bleaching agent plus 980nm diode laser; group 2. White Smile plus Monitex LED, group 3: Boost bleaching agent plus 980nm diode laser; group 4. Boost bleaching agent plus Monitex LED; group 5: Boost bleaching agent (control).

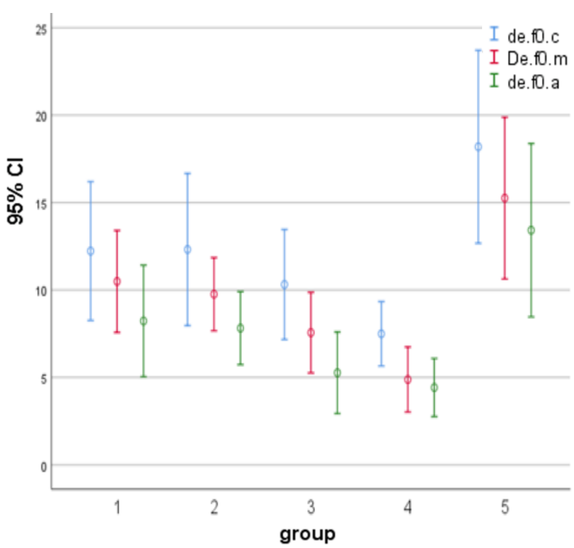

Fig 2. ΔE at 1 week after bleaching compared with before bleaching with 95% confidence interval in the cervical, middle and incisal thirds in the study groups. Group 1. Snow L bleaching agent plus 980nm diode laser; group 2. White Smile plus Monitex LED, group 3: Boost bleaching agent plus 980nm diode laser; group 4. Boost bleaching agent plus Monitex LED; group 5: Boost bleaching agent (control).

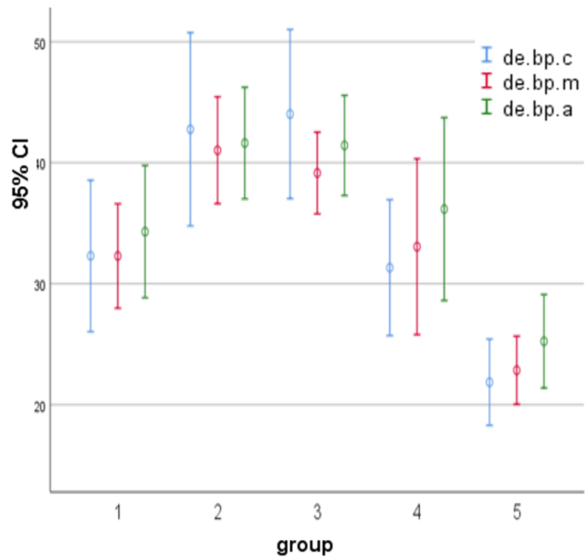

Fig 3. ΔE immediately after bleaching compared with after staining with 95% confidence interval in the cervical, middle and incisal thirds in the study groups. Group 1. Snow L bleaching agent plus 980nm diode laser; group 2. White Smile plus Monitex LED, group 3: Boost bleaching agent plus 980nm diode laser; group 4. Boost bleaching agent plus Monitex LED; group 5: Boost bleaching agent (control).

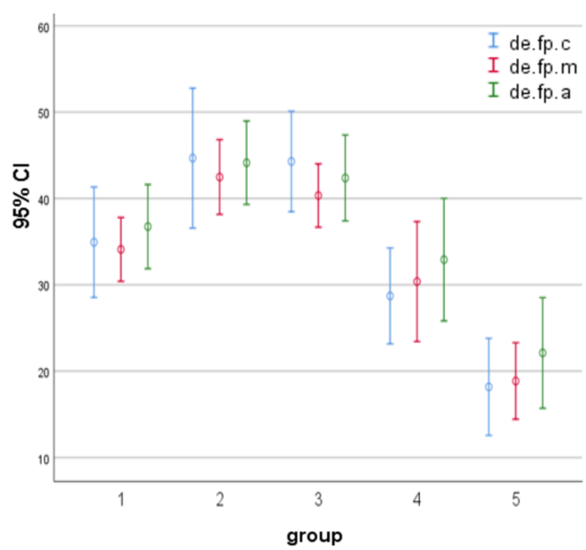

Fig 4. ΔE at 1 week after bleaching compared with after staining with 95% confidence interval in the cervical, middle and incisal thirds in the study group. Group 1. Snow L bleaching agent plus 980nm diode laser; group 2. White Smile plus Monitex LED, group 3: Boost bleaching agent plus 980nm diode laser; group 4. Boost bleaching agent plus Monitex LED; group 5: Boost bleaching agent (control).

Pairwise comparisons of the groups by the Tukey's test regarding ΔE immediately after bleaching compared with before bleaching in the cervical third revealed maximum difference between groups 4 and 5 (ΔE=10.55, P=0.001). Also significant differences were noted in ΔE between groups 2 and 5 (P=0.001), 3 and 5 (P=0.001), 1 and 4 (P=0.03), and 1 and 5 (P=0.04). No other significant differences were noted (P>0.05).

Pairwise comparisons of the groups by the Tukey's test regarding ΔE immediately after bleaching compared with before bleaching in the middle third showed maximum difference between groups 4 and 5 (ΔE=10.07, P<0.001) followed by groups 3 and 5 (P<0.001), 2 and 5 (P=0.001), and 1 and 4 (P=0.01). No other significant differences were noted (P>0.05). Pairwise comparisons of the groups by the Tukey's test regarding ΔE immediately after bleaching compared with before bleaching in the incisal third revealed maximum difference between groups 3 and 5 (ΔE=10.38, P=0.001). Also, significant differences were noted between groups 1 and 5 (P=0.001), 2 and 5 (P=0.001), and 4 and 5 (P=0.001). No other significant differences were noted (P>0.05).

DISCUSSION

Power bleaching has been used with different bleaching systems in the recent years to improve the efficacy of bleaching. Thus, it is important to assess the efficacy of power bleaching systems. Human central incisors and premolars were used in this study to assess the efficacy of different bleaching protocols. Despite the presence of some differences in human teeth due to genetic and environmental factors and age of the teeth, they are still superior to bovine teeth and can better simulate the clinical setting.

Laser has been used to improve the efficacy of in-office bleaching with controversial results. Some studies reported the optimal efficacy of laser-assisted bleaching [1,4,10-12] while some others reported no significant advantage of laser-assisted bleaching compared with other techniques [13,14,15].

Laser converts the radiation energy to heat in the process of application of bleaching agent. However, laser absorption depends on its wavelength and type of bleaching agent. Laser energy has photo-thermal effects, converting the radiation energy to heat, and accelerating the bleaching process as such [16,17]. In the recent years, 810 to 980nm diode laser has been used for power bleaching [4]. Accordingly, 980nm diode laser with 2W power was used in this study.

Snow L blue gel contains 40% HP and 20% carbamide peroxide (its concentration reaches 35% after mixing with accelerator). It also has titanium oxide pigments for laser absorption at 810, 940, and 980nm wavelengths. This gel is manufactured in Iran and since it has laser absorbing pigments, it was used in the present study.

The CIE L*a*b* color space was used in this study since it quantifies the color change and allows precise calculations [18]. However, use of spectrophotometer for assessment of tooth color change has some disadvantages such as the fact that the results are affected by translucency, contour and structure of teeth. Also, reproducibility of the measurements is difficult [18].

The present study revealed significant differences in ΔE among different groups when comparing the color parameters immediately after bleaching compared with before bleaching, at 1 week after bleaching compared with before bleaching, and at 1 week after bleaching compared with after staining in the cervical, middle and incisal thirds. Considering the present results, ΔE was greater in the cervical third compared with the middle and incisal thirds, and it appears that the tooth color in the incisal and middle thirds are lighter than in the cervical third, resulting in small difference in efficacy of different bleaching protocols.

In the present study, Snow L plus diode laser showed the lowest efficacy when comparing the results of color improvement in the incisal, middle and cervical thirds immediately after bleaching compared with before bleaching. White Smile showed a higher efficacy than Boost plus laser in the middle and cervical thirds. No significant difference was noted among Boost, Boost plus LED, and White

Smile. At 1 week after bleaching compared with before staining, Snow L plus diode laser had the lowest efficacy in the incisal, middle and cervical thirds. Also, White Smile showed higher efficacy in the middle third compared with Boost plus laser. No significant difference was noted among Boost, Boost plus LED, and White Smile. Regarding the changes in value, Snow L showed the lowest efficacy in tooth lightening in the incisal, middle and cervical thirds. Other modalities had similar efficacy in tooth lightening except in the cervical third, where Boost plus laser showed lower efficacy. It appears that light activation has no significant effect on Boost bleaching agent, probably because it has no pigment for absorption of 980 nm diode laser. Thus, application of laser decreased the efficacy of Boost. Snow L blue bleaching gel has 40% HP and 20% carbamide peroxide. It also contains titanium oxide pigments that absorb red light laser at 810, 940 and 980nm wavelengths. White Smile contains 40% HP (reaches 32% when mixed with accelerator) and has yellow pigments that absorb red and blue LED light at 630nm wavelength, which can improve the bleaching results. It appears that type of bleaching agent and the application method play an important role in color change of teeth. Considering the present results, color change in the middle and incisal thirds was lower than that in the cervical third. Snow L gel improved the tooth color after staining; however, it could not return the baseline color (prior to staining); whereas, other modalities improved the tooth color even better than the baseline color of the teeth.

Hahn et al. [13] evaluated the color stability after bleaching with 38% HP activated with halogen light, 980nm diode laser and 480nm LED. They reported that light-activated bleaching had no superiority to conventional bleaching in terms of stability of the results for up to 3 months; which was in line with the present results obtained at 1 week after bleaching. It appears that immersion of the teeth in an aqueous solution after the experiment prevents their dehydration and color change over time [13].

Luk et al. [19] assessed the color stability after bleaching with HP gel and 980nm diode laser. They reported significant color change over time, which was in line with the results obtained in the present study at 1 week after bleaching. It appears that not immersing the teeth in an aqueous solution during and after the experiment resulted in their dehydration and color change in their study. However, they reported lightening of teeth over time, which was in agreement with the present results. He et al. [20] evaluated the effects of light on the efficacy of vital in-office bleaching in a systematic review. They reported that LED and diode laser assisted systems had superior immediate results compared with conventional bleaching with 15-20% HP without light activation. In use of higher concentrations of HP (25-35%), no significant difference was noted between the immediate or short-term bleaching results of the conventional and light-activated systems. Fekrazad et al. [21] evaluated the efficacy of bleaching with Opalescence Xtra Boost® and bleaching with Laser Smile gel + 810nm diode laser. They found that laser-assisted bleaching yielded better results compared with conventional bleaching with regard to ΔE. Also, Dionysopoulos et al. [8] evaluated the efficacy of bleaching with Er,Cr:YSGG laser and conventional bleaching and reported that laser-assisted bleaching along with 35% HP had higher efficacy than the use of HP alone. The results of the abovementioned three studies were different from the present results, which may be due to higher temperature of the bleaching agent activated by light, which would lead to faster generation of singlet oxygen. Difference between their results and present findings can also be due to the use of different types and concentrations of bleaching agents. Alomari et al. [22] evaluated the effect of in-office bleaching on color change of teeth. They reported that light-activated bleaching had higher efficacy only in the short-term. Kiomarsi et al. [9] assessed the color change of teeth and the efficacy of 810 and 980 nm diode laser-activated bleaching with Heydent bleaching agent (30% HP), which also contains titanium oxide. They used Boost bleaching agent containing 40% HP as the control group (similar to the present study). They found that power bleaching with different wavelengths of diode laser yielded relatively similar results, and all protocols were equally effective for tooth whitening. In their study, the control group (Boost) caused greater tooth whitening, which was in line with the present findings, and can be due to high concentration of bleaching agent and duration of application of gel on the tooth surface. Considering the present results and those of Kiomarsi et al. [9] and Hahn et al. [13], it appears that the teeth became lighter, the value increased, and the chroma decreased over time due to the continued activity of singlet oxygen; however, the difference among the groups was not significant.

CONCLUSION

Within the limitations of this study, the following results were obtained:

All bleaching protocols caused color change in teeth.

Color change was greater in the cervical third and lower in the middle and incisal thirds.

Snow L gel showed the lowest efficacy followed by Boost plus laser regarding color change of teeth.

The efficacy of Boost (conventional bleaching), Boost plus LED, and White Smile was the same regarding color change of teeth.

Snow L gel improved the tooth color after staining; but other modalities improved the tooth color even better than the baseline color.

CONFLICT OF INTEREST STATEMENT

None declared.

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