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Original Article

Effect of Conventional in-Office Bleaching and Laser Assisted Bleaching at Two Different Wavelengths on Color Stability of Glass-Ionomers

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Abstract

Background and Aim: Bleaching can improve the color of restorative materials and resolve problems related to discoloration or color mismatch. This study evaluated the effect of in-office bleaching method in conjunction with two different laser wavelengths on color change of two types of glass-ionomer restorative materials (light-cure and self-cure).

Materials and Methods: In this experimental study, thirty samples were fabricated of Fuji IX, and FUJI II LC glass-ionomer restorative material and specimens of each glass- ionomer were divided into three subgroups (n=10) receiving the following treatments:1. Laser assisted in-office bleaching with Opalescence Boost® along with 980nm diode laser; 2. Laser assisted in-office bleaching with Opalescence Boost® along with 810nm diode laser; 3. Conventional in-office bleaching with Opalescence Boost ®. The color of all specimens was evaluated before and after bleaching with Spectro Shade. Data were analyzed using two-way ANOVA followed by Tukey's HSD test.

Results: Total color change (ΔE) was significantly different before and after bleaching in all groups ($P<0.001$). In Fuji IX group, there was no significant difference in ΔE between 980nm diode laser and control group ($P=0.14$). However, the control and 980 nm groups were significantly different with the 810nm diode laser group ($P<0.001$). No significant difference was found in ΔE of Fuji II LC groups ($P=0.082$).

Conclusion: Bleaching with or without laser results in a significant color change in light-cure and self-cure glass-ionomers.

Key Words: Glass ionomer, Lasers, Tooth Bleaching

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Introduction

Bleaching treatments are commonly performed to improve the appearance of natural teeth [1]. The mechanism of bleaching is based on the action of hydrogen peroxide or its derivatives like carbamide peroxide. Peroxide in bleaching agents breaks down and produces reactive oxygen species (ROS) which react with pigment molecules and change the tooth color [2]. Several factors affect the efficacy of bleaching including the concentration of hydrogen peroxide and the energy source used to reinforce chemical reactions [3]. History of power bleaching goes back to Abbot [4]. He used high-intensity light to heat up hydrogen peroxide

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and accelerate the chemical reactions involved in tooth whitening. In 1980, thermal sources were used to escalate the process of tooth whitening by high-concentration hydrogen peroxide. This procedure was effective but associated with the risk of tooth hyperthermia [5].

Application of direct heat was gradually replaced with activating lights like quartz lamps, tungsten, plasma arc, and laser at different wavelengths to enhance the efficacy of bleaching [6]. The laser has been increasingly used to boost the effects of bleaching in the recent years. Some lasers, including the diode laser with either 810 or 980 nm wavelength and 1064 nm Nd: YAG laser, have photothermal whitening effects. CO2 laser at the wavelength of 10,600 nm is absorbed within 0.1 mm of water-based solutions [7]. Such quick absorption heats up the whitening agent faster than any other conventional thermal source and does not have an unfavorable effect on tooth vitality [8]. High-intensity green lasers like argon laser and high-power potassium-titanyl-phosphate (KTP) have photochemical effects attributed to specific absorption of a narrow spectral range of green light (510-540nm) by chelating agents between hydroxyapatites, porphyrins and tetracycline compounds [9].

Some studies have demonstrated that bleaching can improve the color of discolored restorative materials and eliminate the need for replacement of restorations [10]. However, tooth whitening can change the structure of the tooth and restorative materials [2]. Literature shows that long-term exposure of composite and GI to bleaching agents increases the risk of their clinical failure [11]. Bleaching materials can affect the color of tooth-colored restorations in the oral cavity based on the type of restorative material. For example, the color change of polyacid-modified composites is greater than that of hybrid and microfilled composites [12]. Previous studies have demonstrated significant changes in the surface texture of bleached tooth-colored restorative materials. Jefferson et al. [13] evaluated changes in the surface texture and atomic weight percentages of elements in glass ionomer (GI) after exposure to 10% carbamide peroxide and reported that the matrix of exposed specimens had experienced surface abrasion and corrosion. Another study demonstrated increased roughness of GI specimens and formation of cracks which observed by a scanning electron microscope as the result of bleaching. They also reported that longevity of restorations might decrease following exposure to bleaching agents [11]. Chemical softening due to bleaching can potentially compromise the physical and mechanical properties of restorative materials such as microhardness and surface roughness [14].

The number of studies which evaluated the effect of bleaching on the color of restorative materials is limited, and only a few have analyzed the color changes of tooth-colored restorative materials following bleaching. The effect of home bleaching agents on composites has been the subject of numerous investigations. However, there is a gap of information about the in-office bleaching systems especially about glass-ionomers [2]. Glass-ionomers, due to their optimal clinical service, are the restorative material of choice for root surface restorations and are specifically indicated for lesions at the gingival margins due to their appropriate bond strength and less sensitivity to moisture. However, due to higher surface roughness, they are more susceptible to staining and thus, bleaching may be a good solution to overcome this problem [15].

This study aimed to assess the effect of Opalescence Boost bleaching agent as conventional in-office bleach alongside diode laser with two different wavelengths on the color change of GI restorative materials. The null hypothesis was that the bleaching methods do not have any effect on the color change of GI restorative materials.

Materials and Methods

In this experimental study, A2 shade of self-cure (powder-liquid) Fuji IX GP (GC Corporation, Tokyo, Japan) and light-cure Fuji II LC (GC Corporation, Tokyo, Japan) were used. The sample size was determined by considering the results of Rao et al. study and taking into account the minimum perceivable ΔE to be 2 [16] ($\beta=0.2$ and $\alpha=0.05$), using the Minitab software. Thus, the minimum sample size for each of the sub-groups was calculated eight.

A total of 48 specimens were fabricated (n=24 from each glass-ionomer), characteristics of the

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materials used in this study are demonstrated in Tables 1.

Each group, either Fuji IX or Fuji II LC GI restorative materials, divided into three subgroups as follows:

Subgroup 980 (IX 980 and II 980): samples were treated with bleaching material and 980nm diode laser.

Subgroup 810- (IX 810 and II 810): bleaching material and 810nm diode laser were applied to the specimens.

Subgroup IOP- (IX IOP and II IOP): specimens of each restorative materials were treated with bleaching material without any laser application.

Samples were prepared in a glass mold with 8mm diameter and 2 mm thickness, on a glass slab covered by a Mylar strip. One level scoop of the Fuji II LC powder was mixed with two drops of liquid according to the manufacturer's instruction. In order to obtain a smooth surface, a transparent Mylar strip and a glass slab were placed on top of each glass mold and cured for 40 seconds using Optilux (Kerr, USA) light curing unit with a light intensity of 400 mW/cm2. Then, to ensure complete polymerization, each sample was removed from the mold and cured from four directions for 20 seconds. The light intensity was controlled by radiometer (Bisco, USA) periodically. The surface of each specimen was finished and polished by Ultradent finishing and polishing kit (Ultradent, South Jordan, UT, USA) to achieve a smooth surface simulating the clinical setting.

For the preparation of Fuji IX GI specimens, one level scoop of powder and one drop of liquid were mixed, according to manufacturer’s instruction. Fuji varnish (GC Corporation, Tokyo, Japan) was applied to the surface. After 10 minutes, the surface of specimens was polished as described for Fuji LC specimens. All specimens were stored in distilled water at 37°C for 24 hours to ensure complete polymerization. Before initial color assessment, all specimens were rinsed with water for one minute and air dried.

The color was measured by SpectroShade Micro (MHT, Verona, Italy). The device was calibrated according to the manufacturer’s instructions before color measurement. Next, according to ISO 7491 standards [17], the specimens were placed on a white background, and the three color parameters of L, a, and b were separately measured for each specimen three times, and the mean value was recorded. “L” indicates lightness, “a” indicates redness-greenness and “b” indicates blueness-yellowness.

In this study, in-office Opalescence Boost (38%) bleaching agent (Ultradent Products, South Jordan, UT, USA) was used at room temperature according to the manufacturer’s instructions.

In "980" subgroups, the bleaching agent (1.5mm) was applied to the GI specimens and lasered for 30 seconds (Medical laser class II B/4, Code La3D0001.3, Doctor SmileWiser Laser, Italy) with the exposure settings of 980nm, 1.5 W, impulse mode: continuous. The radiation process was repeated for three times, and one-minute intervals were allowed between radiations. The bleaching agent remained for five minutes on restorative material. Each time, after removal of bleaching agent, the specimens were thoroughly rinsed with distilled water for 30 seconds.

In "810" subgroups, the bleaching agent was applied to the specimens in 1.5 mm thickness and laser was irradiated (Medical Laser class II B/4, GBOX 15AB, Wuhan Gigaa Optronics Technology Co., Ltd., China) for 30 seconds with the exposure settings of 810nm, 1.5W, impulse mode: continuous) as described above.

In the subgroups IOP, the bleaching agent was applied by its special syringe on the specimen surface in 1.5 mm thickness for 20 minutes. After its removal, specimens were thoroughly rinsed off.

After the interventions, color parameters of all samples were measured as mentioned above.

Statistical analysis:

Collected data were analyzed using SPSS 18 and $P<0.05$ was considered statistically significant. Two-way ANOVA was used to assess the effects of type of GI, bleaching, laser, and their interaction on the ΔE and three color parameters. One-Way ANOVA and Tukey’s HSD test were employed to compare these changes among different radiation modes based on the GI used. The independent t-test was carried out to compare changes between the two types of GI restorative materials based on the radiation mode.

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Table 1. Characteristics of the Glass-Ionomers used in this study

Material	Type	Mixing time (s)	Working time (s)	Setting time (s)	Batch number	Powder to liquid ratio	Manufacturer
Glass ionomer Fuji IX	Self-cure	10	120	360	002578	1.1	GC International Tokyo-Japan
Glass ionomer Fuji II LC	Light-cure	20-25	195	20	003254	1.2	GC International Tokyo-Japan

Results

Results of two-way ANOVA showed that interaction of the type of laser and glass ionomer was significant (p<0.001). The mean and standard deviations of ΔE, Δa, Δ b, and ΔL of different groups are shown in Tables 2.

Results of the statistical analysis revealed significant color change (ΔE) in all bleached subgroups (P<0.001). In Fuji IX subgroups there were significant differences between ΔE the 810 subgroup with other subgroups (P<0.001). In Fuji II subgroups there was no significant difference between Δ E in subgroups (p=0.082). Statistical analysis showed significant differences in ΔE between Fuji IX810 and Fuji II810 (P<0.001).

Discussion

The current mechanism of tooth bleaching is based on oxidation of hydrogen peroxide. Currently, tooth-bleaching procedures are often performed in conjunction with the use of an activating factor such as light [2]. The activating factor utilized in the current study was a 1.5W diode laser with a wavelength within the infrared spectrum. This type of laser has a photothermal effect. The whitening agent used with laser must be pigmented to absorb the laser. Opalescence Boost contains red pigments (carotene), and therefore it was suitable for the current study. [6] The manufacturer claims that this material does not need an activator, however, studies have shown that using diode laser in conjunction with this bleaching agent results in greater whitening efficacy at a shorter time [18].

Bleaching agents can be used in dental clinics, known as in-office bleaching, or by patients at home known as home bleaching systems which are usually supplied in the form of gel [2]. During bleaching treatments, restorations in the oral cavity are also exposed to the whitening agent and affected by it because it is almost impossible to control the flow of bleaching agents. As a result, changes may occur in the mechanical and physical properties of restorative materials. The color mismatch between the restorations and teeth after bleaching treatment may compromise esthetics [19]. Thus, the clinicians should be well aware of the effect of bleaching agents on restorative materials [20].

In the current study, spectrophotometry was used to measure color parameters using the CIE Lab color space (Commission International de L'Éclairage) because this system is capable of detecting the slightest changes in color parameters [16]. SpectroShade spectrophotometer version 2.4 (Medical High Technologies, Italy) has been used for color measurement, which has a reproducibility of 82.7% for color measurement [21].

Results showed that the greatest change in color was observed in the IX 810 subgroup and the least changes in color occurred in the II IOP subgroup. It should be noted that probably using the laser, results in more hydroxyl release. Additionally, the laser might increase the penetration depth of active bleaching molecules; thus, higher efficacy of bleaching in the presence of laser would be expected.

In this study, diode laser within the acceptable wavelength of 810-980 nm was used. This wavelength of the diode laser is easily absorbed within 0.1 mm of water-based materials [7]. Such quick absorption causes a faster increase in temperature of the bleaching agent while there is the least risk of thermal damage to the pulp [7].

Also, compared to the control group, the bleaching

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Table 2. Descriptive statistics of CIELAB parameters in each group. Values are presented as mean (standard deviation)

Groups	CIELAB color parameters			
	Δa	**Δb**	**ΔL**	**ΔE**
IX-980	-2.09 (0.76)	0.87(5.93)	-4.29(2.87)	7.56(2.59)
IX-810	-3.96 (1.04)	-14.74(4.42)	3.78(1.82)	15.86(4.37)
IX-IOP	-2.06 (0.55)	-2.86(1.41)	-3.18(0.81)	4.93(0.99)
II-980	1.24 (0.81)	-4.87(3.73)	-0.82(2.07)	6.93(3.2)
II-810	0.15(0.6)	-2.76(2.1)	-5.7(2.21)	5.73(0.92)
II-IOP	1.2(0.63)	-2.86(1.41)	-0.37(1.58)	4.56(2.36)

time significantly decreases. [7]

Among laser bleaching groups the shorter wavelength of 810nm had a greater effect on the color change of Fuji IX glass-ionomer compared to the longer wavelength of 980nm. Disparate effects of different bleaching protocols on similar specimens might be related to the various amount of hydrogen peroxide released by the bleaching agent. One likely reason might be the fact that 980nm laser has greater absorption in the water than 810nm laser which is mainly absorbed by pigments [22]. Accordingly, the 810nm laser is mostly absorbed by red pigments in the bleaching gel, that would result in more hydrogen peroxide release [22]. Another possible assumption is the penetration depth of laser; by increasing the wavelength the penetration depth of laser into bleaching gel decreases and subsequently, less hydrogen peroxide would be released, and its effect on the color of glass-ionomers would decrease [22].

ΔL is a major factor in dentistry because the human eye recognizes changes in lightness better than variations in hue. It has been documented that ΔL smaller than 2 is clinically acceptable for color matching. In the current study, specimens experienced a reduction in L* (indicative of lightness from white to black) value except for IX 810 Group. The decrease of L* might be related to an increase in surface roughness due to the effect of bleaching, in IX 810 subgroup the combination of surface roughness and effective whitening of bleaching process increased L* parameter. It must be noted that ΔL does not indicate that one shade is darker or lighter than the other [23].

In the current study, Δa* of self-cure GI shifted towards the negative; however, the "a*" value was positive (in the range of red) which indicates that the redness of the specimens decreased after bleaching. In light-cure GI, changes of the Δa were towards the positive; however, it was not significant. In both types of glass-ionomers, the b* parameter decreased within the range of yellow. This finding may be the result of breakage of pigments due to bleaching process and increasing the translucency of the specimens.

The clinically perceivable threshold of ΔE is a matter of controversy among researchers, and some consider it to be within the range of 1-2. It has been reported that ΔE>1 is perceivable by more than half the individuals [24]. Some others have discussed the clinically visible ΔE to be over 3 and occasionally 3.7 considered as unsuitable [25]. Some researchers have referred to ΔE>3.3 as clinically unacceptable and recommended to replace the restoration in this situation [26,27]. Considering the values reported in the current study, we may conclude that changes caused by bleaching in this study in all groups were clinically perceivable and both GI restorative materials experienced significant color changes following bleaching.

The current study had some limitations; the small size of specimens might have affected the efficacy

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of bleaching agent on GIs. The other limitation was that only 2mm thick specimens were evaluated. If thinner GI specimens had been used, color change might have been more significant [28].

The mechanism of the color change in tooth-colored restorative materials following the use of bleaching agents has yet to be fully understood and might be related to different issues including the following:

1- Free peroxide radicals can probably cause the oxidative cleavage of polymer chains and free radicals eventually break down into water and oxygen. This hydrolytic process facilitates the degradation of GI and causes color change [29].

2- Oxidation of superficial pigments might be responsible for the shade of restorative materials.

3- Oxidation of amine products could be the reason for the color instability of these materials over time.

In this study, 810nm diode laser might have increased the release of hydrogen peroxide and caused greater color change. Oxidation of superficial pigments may occur as the result of the effect of bleaching agents on the surface of restorations. The degree of oxidation depends on the penetration depth of bleaching agents into the surface structure of restorative materials. Therefore, in the case of restorative materials with greater cross-links and higher molecular weight, bleaching agents require more time to penetrate into the bonds. This reason may explain the higher color stability and less discoloration of methacrylate-based restorative materials after bleaching. The difference in color stability of restorative materials might be due to the size of stain particles and their constituents (water and monomer) [30].

Significant color change of GI and its low color stability may be due to its polyacid constituents and break down of metal salts of polyacrylate in GI [31]. The liquid component of light-cure GI contains 2-hydroxyethyl methacrylate (HEMA) in addition to polycarboxylate and methacrylate groups. Due to higher polymer content, light-cure GI has higher strength, less color susceptibility and lower stainability [16]. The penetration of bleaching agent into this material is less than self-cure GI causing lesser color change. However, overall, the color stability of self-cure and light-cure glass ionomers are much lower than composite resins which attributed to the chemical composition of composites and chemical instability of GIs; which confirms the results of the current study. Yalcin and Gurkan [32] in their study in 2005 have shown that the gloss and smoothness of restorative materials significantly decreased after bleaching. Therefore, before any bleaching treatment, a comprehensive evaluation of restorations must be conducted [19]. During the bleaching treatment, the surface roughness of restorative materials increases, as a result, the light reflection would increase and the gloss decrease [33] which subsequently darken the GI and reduce the L* parameter.

Bleaching agents are commonly used for tooth whitening purposes, and there is no way to prevent the exposure of restorations to the bleaching agent [34]. The interaction between bleaching agents and the restorative materials could become clinically significant and might result in patient dissatisfaction. Thus, in the case of bleaching with hydrogen peroxide, clinicians must be well aware of the color changes of tooth-colored restorative materials and inform patients about the possibility of the need for replacement of restorations. Further studies are required to assess the effect of diode laser on other tooth-colored restorative materials, and also the effect of laser-assisted bleaching on color changes of GI restorations relative to the teeth.

Conclusion

Within the limitations of this study, it might be concluded that bleaching with or without laser causes a color change in the GI restorations which might necessitate their replacement. Amending the wavelength of the laser could alter the efficacy of bleaching in GI, and 810nm diode laser has the most adverse effect on self-cure GI.

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