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Comparison of Tooth Color Change After Bleaching With Conventional and Different Light-Activated Methods

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Abstract

Introduction: The demand for esthetic dental treatments is increasing in recent years mainly due to improved oral hygiene and better maintenance of oral health and teeth in older individuals. Bleaching of discolored anterior teeth is the most popular among esthetic dental treatments. Even individuals with sound teeth and adequate esthetics seek to have whiter teeth in the anterior region. The aim of this study was to evaluate tooth color changes following conventional in-office bleaching techniques compared to light-activated methods using different light sources.

Methods: Seventy sound anterior teeth (devoided of caries and/or fracture), extracted for periodontal and orthodontic reasons were selected and allocated to 7 groups: (A) control, (B) conventional bleaching (C) LED-activated bleaching, (D) KTP laser-activated bleaching, (E) diode laser-activated bleaching, (F) Nd:YAG laser-activated bleaching and (G) CO2 laser-activated bleaching. Colorimetric evaluation was carried out before and after treatment using a spectrophotoradiometer. Data were analyzed by one- and two-way analysis of variance (ANOVA) as well as multiple comparison methods.

Results: The results showed that all bleaching procedures were effective in reducing the yellowness index. However, the KTP laser-activated bleaching was significantly more effective than the other techniques in 95% confidence level. It was also seen that CO2 laser activated method has outperformed groups E, F and G and the conventional bleaching without light activation was not effective at all and represented similar results with the control group. Furthermore, the groups E and G had almost the same results in decreasing the yellowness index.

Conclusion: The results showed that all bleaching techniques were effective however, the KTP laser-activated bleaching was significantly more efficient, closely followed by the CO2 laser-activated bleaching technique.

Keywords: Laser bleaching; Tooth color change; Spectroradiometer.

Introduction

A beautiful smile plays a pivotal role in social interactions, furthermore, a large number of people are influenced by mass media to seek an effective, enduring and effortless treatment plan.[1] Bleaching techniques can be a conservative method to provide patients with a beautiful smile[2-4] when compared to other techniques such as laminate veneers, composite facings or full-coverage restorations.

Tooth color is determined by different chromatic characteristics of enamel, dentin and pulp.[4,5] However, tooth discolorations vary in etiology, appearance, location, severity, and are dependent on tooth structure. Such discolorations are classified as internal and external. External tooth discolorations can be removed by prophylactic procedures, but treating internal discolorations requires chemical bleaching techniques.[4]

Today, various tooth whitening agents with different concentrations are commercially available, like 3% to 38% hydrogen peroxide (HP), 10% to 30% carbamide peroxide or a mixture of sodium peroxide and HP.[6]

HP is the major component and chemical activator of bleaching agents by virtue of its reactional chemistry, particularly with organic chains of stains and pigments.

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HP can be used in its pure form or as the breakdown product of other bleaching agents such as sodium perborate and carbamide peroxide.[7]

One of the most accepted theories on the mechanism of action of bleaching agents is that free radicals liberated from HP attack organic molecules and sets them into a stable condition. This causes other free radicals to react with unsaturated chemical bonds and alter their electron arrangement and therefore transform the energy absorption of organic molecules, this is the underlying process which is seen in enamel. These changes in energy absorption create simpler molecules that reflect less light and therefore makes enamel appear brighter.[8]

Usually in-office, home bleaching or over the counter (OTC) products are used for bleaching of vital teeth.[9] In-office bleaching uses high-concentration HP (i.e., 15%-40%) that can be activated by light or heat. This method is suitable for patients with severe discolorations or even a single discolored tooth in the arch. It also can be beneficial for uncooperative patients.[4,10]

Different light sources can be used to activate bleaching agents such as halogen, plasma arc lamp, LED, and lasers (argon, diode, KTP, Nd:YAG, CO_2, etc) or a combination.[11-14] Various studies have shown different tooth color changes following bleaching. Kiomars et al evaluated 2 different wavelengths of diode laser ($\lambda = 810$ nm and $\lambda = 980$ nm) for teeth color changes. They concluded that there was no statistical difference between the 2 laser bleached groups.[15]

The aim of this study was to evaluate tooth color changes, following conventional and light-activated in-office bleaching techniques, by different light sources, using a spectrophotoradiometer.

Methods

The study was carried out in an experimental in vitro design.

Sample Preparation

Seventy sound anterior teeth (devoided of caries and/or fracture) which had been extracted for periodontal and orthodontic reasons were selected. The teeth were cleansed by ProphyPaste (Prophylaxis, Golchadent, Iran) using a brush slow-speed hand-piece. Thereafter, all samples were immersed in Chloramine T for 1 week and stored in distilled water at room temperature (25°C) before the experiment. The color of each sample was assessed by VITA Easyshade Compact (Vident, USA) before random allocation to the groups. The teeth were mounted in a self-cure transparent acrylic resin (TR.II. Acropars, Iran) with a background of TiO2 (the whitest material). This was done to create a peripheral environment which is as neutral and achromatic as possible. Each sample was marked in its upper, middle and lower third for further evaluations.

Spectrophotoradiometer was used to evaluate tooth color changes following different office bleaching techniques. The bleaching techniques included (A) no treatment, (B) bleaching without light-activation (conventional) (C) LED-activated bleaching, (D) KTP laser-activated bleaching, (E) Diode laser-activated bleaching, (F) Nd:YAG laser-activated bleaching and (G) CO_2 laser-activated bleaching.

Bleaching of the Samples

The bleaching agent used in all experimental groups was Xtra Boost 40% (Opalescence, USA). In all experimental groups, (except for the control, i.e., group A), the base and activator were mixed and then a 2 mm-thick piece of the resultant red gel was applied on each tooth. In group B (conventional technique), the gel was washed away after 20 minutes. The process was repeated 2 more times with 1-minute rest intervals. Then the teeth were dried. In other groups, different (LED, KTP laser, diode laser, Nd:YAG laser, CO2 laser) lasers were applied for 30 seconds. This procedure was also repeated 3 more times with 1-minute rest intervals. Then, following a 3-minute rest time, the gel was removed and the sample rinsed. LED activation (group C) of the bleaching agent was done at a distance of 5-6 mm between the bleaching handpiece and the sample so that the light would cover the whole tooth surface. Group D was exposed to KTP laser ($\lambda = 532$ nm) (Starline, Lambda Physik, Germany) under the following parameters: energy = 4 mJ, pulse width = 20 ns, power = 4/20 = 0.2×106 W, repetition rate = 10 Hz, beam diameter = 1.5 mm. In group E, the bleaching gel was activated by diode laser (810 nm) (Gigaa laser, China) using a Biostimulation handpiece, at a power of 1.5 W in continuous wave (CW) at a distance of 5-6 mm between handpiece and the tooth so that the laser light would cover the whole tooth surface. In group F, the bleaching agent was activated by Q-Switched Nd:YAG laser ($\lambda = 1064$ nm) (Fotona, Slovenia, EU) using the following parameters: repetition rate = 20 Hz, pulse width = 20 ns, energy = 100 mJ, beam diameter = 3 mm, pulse power = E/ζ = (100 mJ/20 ns) = 50 mW. In group G, activation of the bleaching gel was done by the CO_2 laser ($\lambda = 10600$ nm, Deka, Italy), using the following parameters: power = 0.6 W, repetition rate = 20 Hz, level 3 (current pulse length = 1.5 ms) at a distance of 1-2 mm between handpiece and the tooth so that the laser light would cover the whole tooth surface.

Colorimetry

The devices used for the colorimetric procedure included:

- A spectrophotoradiometer (Konica Minolta CS2000, Japan) (wavelength range: 380-780 nm. FWHM: 5 nm) was used. Light and device set ups were done according to the manufacturer's instructions.
- A rectified incandescent light source

The samples were placed in front of the spectrophotoradiometer (common name is spectroradiometer). The light source was placed at a

45-degree angle with respect to the axis perpendicular to the sample surface, whereas the spectroradiometer was placed at a zero-degree angle with respect to the axis perpendicular to the sample surface and at approximately 70 cm distance. These arrangements simulate $45^0/0^0$ geometry.[16] The viewing angle of the device was set at 0.1 degrees. This viewing angle resulted in an area of measurement of about 0.8 mm in diameter at the middle of the samples. To avoid reproducibility errors, measurements were repeated 3 times for each sample and the mean was used for further analyses.

The samples were evaluated in three zones of cervical, middle and incisal before and after bleaching. Viewing condition used for the colorimetric evaluation was (D65/20) according to the corresponding and pertinent literatures.[17,18] The yellowness and whiteness indices were calculated according to ASTM E313-10 standard.[19] Viewing conditions were set to $D65/2^0$ for calculation of indices. Data were statistically analyzed by two-way analysis of variance (ANOVA) as well as post hoc ANOVA test.

Results

Since the ASTM E313 whiteness formula scope is for samples with whiteness numbers within the range 40 < WI < (5Y−280) and the calculated values do not meet such requirements, two-way ANOVA test was used to evaluate the values of yellowness index differences. H0 (the null hypothesis) is "different bleaching techniques and different locations of teeth have quite the same results" and consequently H1 would be all possible conditions except as defined in H0. A sufficiently small *P* value for both factors in the two-way ANOVA suggests significant difference between different levels of factors.

The more negative the yellowness index difference, the more influential the bleaching process. As yellowness index difference is studied under the 2 factors, namely, region of tooth (the cervical, the middle and the incisal) and Laser type, a two-way ANOVA test has been applied to the test. Results have been illustrated in Table 1.

The values shown in the right column in Table 1 show the significance of the test. Using two-way ANOVA test, it has been observed that different laser bleaching techniques show different bleaching capabilities ($P=0$).

Results also showed an insignificant effect of treatments on the different part of tooth ($P=0.2507$). It has also been observed that there is no interaction between the 2 studied factors ($P=0.5384$).

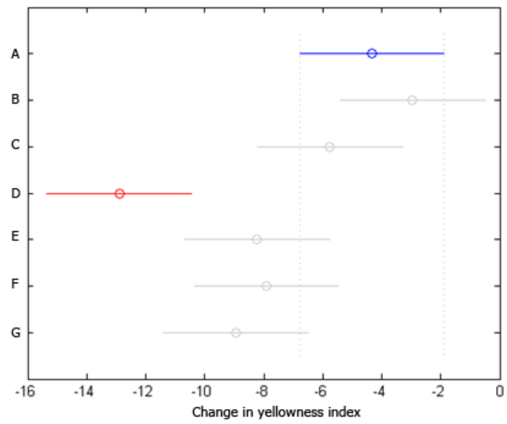

Figure 1. Post Hoc ANOVA Test.

Post hoc ANOVA test has been applied to the data. *multcompare* command in MATLAB programming software carries out multiple comparisons between laser types.

Post hoc ANOVA test results have been depicted in Figure 1. This plot could be used for the comparison of all 7 laser types that have been used in this study. Comparison has been done for the group "A" (shown in blue) as an example. It could be seen that, in the studied significance level, just the laser type KTP treatment (shown in red) has been better in decreasing yellowness index than control group (group A), though no significant statement could be made for other bleaching techniques (groups).

The results showed that all bleaching procedures were effective in reducing the yellowness index. However, the KTP laser-activated bleaching was significantly more effective than other techniques in 95% confidence level as compared to control group. It can also be seen that KTP laser activated method has outperformed groups of E, F and G. However this improvement is insignificant. The statistical analyses showed that conventional bleaching without light activation was not effective at all and represented similar results with the control group. It could also be seen that the groups E, and G have almost the same results with regard to decreasing the yellowness index.

Discussion

Various methods have been proposed to evaluate tooth color changes following bleaching techniques. These

Table 1. The results of Two-Way ANOVA Test to Evaluate the Combined Effect of Bleaching and Different Tooth Parts

Source	Sum of Squares	*df*	Mean Square	F	Probe >F
Columns	1958.8	6	326.468	7.93	0
Rows	475.6	9	52.841	1.28	0.2507
Interaction	2157.4	54	39.953	0.97	0.5384
Error	5761.4	140	41.153		
Total	10353.2	209			

methods are categorized into subjective, including visual analysis according to a standard shade guide, and objective methods such as using a spectrophotometer,[20] colorimeter and software analysis.[21] Visual methods lack adequate accuracy.[21] While using colorimeters and spectrophotometers have limitations related to the light beams evaluating the borders of the aperture penetrating into the semitransparent bed of the tooth, (due mainly to the nature of the tooth structure) thereby resulting in underestimation of the reflected light by the system.[22] In various studies where subjective and objective methods were used in vivo, although the area of discoloration was limited, the influence of the dark background of the oral cavity behind the tooth (which is a translucent object) and the pink color of the gingiva in the vicinity of the cervical area of the tooth of interest could not be overlooked. Hence, in order to avoid such interactions in the current investigation, extracted teeth were mounted in TiO_2 incorporated acrylic resins to equalize the environmental contrast in all samples.

Since the tooth color is determined by a combination of optical properties of enamel, dentin and pulp, and on the other hand it is influenced by the percentage of these structures in different regions of each tooth, each sample was divided into 3 parts for separate and independent chromatic analysis.

It is demonstrated in the relevant literature that the most common bleaching technique used in dental offices is chemical (conventional) followed by LED activated techniques. This was the reason why these 2 techniques were taken into account in this study to be compared with laser-assisted methods.

Although it is claimed by the manufacturer and is supported by another study[4] that Xtra Boost bleaching material does not require external energy source for activation, some authors believe that external energy sources improve whitening efficiency of the bleaching material.[12,13]

Effectiveness of different lasers in tooth whitening has extensively been investigated worldwide. However, it is not possible to compare these results, due to the diversity of the consequent results, lack of equality in irradiation parameters and selected samples, as well as differences in research methodology and evaluations. In the current investigation, all energy sources were equalized on the samples and were applied under similar conditions. Also all samples were assessed by a single evaluation technique and data analysis which makes it possible to compare different lasers with each other as well as visible LED light and conventional method. Each parameter used in this investigation was employed according to the best previous results. In a study by Wetter et al[23] in 2004, the bleaching efficacy of LED was compared with diode laser while using Xtra Boost. In all parameters, the laser group outperformed the other modalities used in comparison except for luminosity, which concurs with the results of our investigation.

In the current study, CO_2 provided acceptable bleaching results. It should be remembered that (as stated by Luk et al[24] in 2004) temperature rise following CO_2 laser application can have deleterious effects on the dental pulp. Therefore, such treatment is not recommended in vivo. In this study, the best tooth whitening results were obtained by KTP laser which was in accordance with the study by Kuzekanani and Walsh in 2009.[25] Correspondingly, the results of our investigation were in accordance with Fornaini et al[1] in 2013, who compared KTP and diode lasers in terms of tooth color changes and the resultant temperature rise. Also, in another 2007 study by Zhang et al[26] pulpal temperature changes were compared following use of diode and KTP lasers in comparison with LED light using HP. The authors revealed that LED and diode laser imposed minimal and maximal temperature increments, respectively. In light of the minimal temperature increase on using the KTP laser as compared to the diode laser (as confirmed by Fornaini et al[1] and Zhang et al[26]), moreover, the presence of such temperature changes being within the scope of reversible pulpal inflammatory reactions, it can be stated that KTP laser can provide more acceptable results with less hazards to the dental pulp in comparison with other lasers.

Strobl et al[27] in 2010 used a hand-made bleaching gel containing 35% HP and concluded that laser intervention in the bleaching process did not necessarily provide more successful clinical results in comparison with conventional methods. In contrast, our study showed that the conventional technique did not show any difference with the group in which no intervention was contemplated in terms of tooth color change. On the other hand, Nd:YAG laser group resulted in whiter teeth, which although was not statistically significant. In that study, VITA color scale and dental chromometer ShadeEye NCC were used to evaluate tooth color changes. However, in the current study, tooth color changes were recorded spectrophotometrically. This technique can be more reliable like in the in vivo study by Strobl et al.[27] However, the differences in the results of the 2 studies mentioned can be attributed to the minute differences in the power and frequency of the devices used and the methods employed.

Marcondes et al[28] in 2009 evaluated the effect of different thicknesses of HP gel when exposed to halogen light and Nd:YAG laser. In this study, VITA color scale was used to evaluate color changes. The results showed similar bleaching effects of halogen light and Nd:YAG laser. The results concur with our findings that Nd:YAG laser can produce whitening effects when used in combination with HP gel.

Conclusion

Although all bleaching procedures were effective in reducing the yellowness index, activation of the bleaching agent by KTP laser could reduce the yellowness of the teeth at 95% confidence level. CO2 laser-assisted bleaching could also be effective in providing whiteness albeit at a lower confidence level. However, this technique is not recommended due to the resultant increases in pulpal temperature.

Conflict of Interests

None.

Ethical Considerations

None to be declared.

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