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# EFFECT OF DIFFERENT ACTIVATION TECHNIQUES OF TWO IN-OFFICE BLEACHING SYSTEMS ON COLOR CHANGE OF ENAMEL SURFACE: AN IN-VITRO STUDY

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## *ABSTRACT*

**Objectives:** This in-vitro study was conducted to evaluate the effect of different activation techniques of two in-office bleaching systems on color change and degree of whiteness of enamel surface.

**Materials and Methods:** Thirty extracted human central incisors were collected, then embedded in a plastic mold using self-cure acrylic resin. Specimens staining was performed by immersion in red tea solution for 15 min/5 cycles per day for 5 days. Each 10 specimens were grouped according to the technique used for bleaching activation: Group A bleaching without light-activation (chemical conventional activation); Group B: LED-activated bleaching (BEYOND Polus Whitening Accelerator); Group C: Diode laser-activated bleaching (SIROLaser Blue). Each activated group was subdivided into two subgroups according to the bleaching agent used: Opalescence Xtra BOOST 40% for subgroups (A1, B1, and C1) and BEYOND MAX 5 for subgroups (A2, B2, and C2). Crystal Eye spectrophotometer was used to digitally analyze the tooth color changes following different bleaching techniques. Data was tabulated and statistically analyzed using IBM SPSS software package version 24.0 at $p \leq 0.05$, and comparisons were performed using One Way ANOVA followed by Tukey`s post hoc test.

**Results:** C2 exhibited the highest color change value ($\Delta E$) (10.89 to 15.85) with highest bleaching effect. Following closely was A1 (12.15 to 15.65). On the other hand group A2 exhibited the lowest color change (4.380 to 9.380) with the lowest bleaching results.

**Conclusion:** Diode laser at low power densities can be considered as an effective and reliable treatment option for bleaching of teeth.

**KEYWORDS:** Color change, Bleaching technique, Diode laser, spectrophotometer, SIRO Laser Blue.

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## INTRODUCTION

Healthy bright teeth are considered a crucial factor in a perfect confident smile. Smile indirectly affects personal acceptance and social interactions. Many people are influenced by mass media for the aim of adequate, enduring, effortless and esthetic dental treatment (*Lagori et al, 2014*; *Shahabi et al, 2018*).

Tooth discoloration is classified into intrinsic and extrinsic discoloration. Bleaching is considered to be the most conservative, simple and economical technique in the treatment of discoloration after the establishment of careful diagnosis and treatment planning (*Shahabi et al, 2018 ; Abouassi et al, 2011*).

Beverages such as black tea, coffee, and cola-based soft drinks are considered highly popular worldwide and they contain coloring agents that have a great influence on teeth staining (*Xie et al, 2010*).

Bleaching is considered the most conservative, easy, and least expensive method to provide patients with bright white teeth compared to others like laminate veneers, Lumineers, and resin composite facings (*Burrows, 2009*). Today, different in-office bleaching agents such as hydrogen peroxide (HP), carbamide peroxide, and sodium perborate or a blend of HP and sodium peroxide are available nowadays with different concentrations according to manufacturers' instructions (*Sulieman, 2008*).

Different theories adopted to explain the mechanism of action of bleaching agents, the change in energy absorption of the organic molecules of the enamel substrate which in turn creates simple molecules with less light reflection that results in a brighter enamel surface is considered as the most widely accepted theory about bleaching (*Mondelli et al, 2012*). The mechanism is that some free radicals liberated from hydrogen peroxide attack organic molecules and set them into a stable condition, While others react with unsaturated chemical bonds of some other organic molecules altering their electron arrangement and transforming their absorption energy (*Matis et al, 2009*).

In-office bleaching agents can be activated either chemically or by different light sources such as halogen, plasma arc lamp, LED, and lasers (argon, diode, KTP, Nd:YAG, CO2, etc) or a combination. Nowadays, many curing lights have emerged as a trial to enhance and accelerate the bleaching process but the action of this light energy to enhance bleaching performance still needs more investigations. The most accepted theory until now is that light energy can heat the active ingredient in the bleaching agent, increasing the rate of free radicals liberation with high kinetic energy improving the penetration and deoxidation of the stained organic molecules (*Shahabi et al, 2018*).

Multiple studies have shown different tooth color change results following bleaching application when using a diode laser for activation with different wavelengths of ($\lambda$ = 810 nm and $\lambda$ = 980nm) (*Joiner, 2007*). However, Sirona company has introduced a new innovative application technique with wavelength $\lambda$ = 445nm which is considered low power density and claims that this wavelength is more efficient.

Using shade guides for color determination has some limitations such as reliability, highly subjective, evaluator experience, ambient light condition, eye fatigue and background against which a tooth is compared that may lead to inconsistencies (*Ishikawa et al, 2004; Da Silva et al, 2008*). To overcome these limitations, a computerized assessment of tooth shade has been recommended.

The latest development in power bleaching is laser-activated bleaching, which offers speed and convenience. Earlier used lasers were argon laser and CO2, but now, diode laser and potassium titanyl phosphate (KTP) are also used. Diode laser (810–980 nm) has proved to be less harmful and more effective with short applications in the office (*Hahn et al, 2013*). A limited number of investigations have been published analyzing diode-laser efficacy using different HP concentrations during the tooth-bleaching process.

Thus this study was conducted to evaluate the effect of different activation techniques of two in-office bleaching systems on color change of enamel surface.

The null hypothesis claims that there is no difference in the final bleaching results or color change between chemical, light, or even laser-activated bleaching agents.

## MATERIALS AND METHODS

### Ethics committee approval

Approval of this study has been granted by Badr University In Cairo BUC Institutional ethical committee with approval number:BUC-IACUC-230827-35

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

### *A. Sample Size Calculation:*

Sample size was calculated depending on a continuous response variable from matched pairs in the previous study *(Kiomars et al 2016)* as reference. According to this study, matched pairs were normally distributed with a standard deviation (1.95). If the true difference in the mean response of matched pairs was (4.17), we need to study (5) pairs of subjects to be able to reject the null hypothesis that this response difference is zero with probability (power 0.8 = 80%).

### *B. Selection and preparation of specimens*

### 1. Teeth selection:

A total number of thirty extracted human central incisors were collected. Teeth were meticulously selected to be free of caries, restorations, cracks, or obvious defects all surfaces were carefully verified macroscopically and microscopically, under 10× stereomicroscope (Wild M5A, Wild, Heerbrugg, Switzerland) (*Azarbayjani et al, 2019*). A storage medium for the teeth was 0.5% chloramine at 4 ˚C for a maximum storage time of one month (*Nakajima et al, 1995; Ranadheer et al, 2011)*.The teeth were cleaned, polished using Prophy Paste (Prophylaxis, Golchadent, Iran), brushed on a slow-speed hand-piece and then embedded in a titanium oxide mold using self-cure acrylic resin (*Matis et al, 2009*).

### 2. Staining procedure:

Specimens staining was performed by immersion in red tea solution for 15 min/5 cycles per day for 5 days. Rinsing with copious amounts of water was done prior to any shade assessment (*Marson et al, 2008; Bernardon et al, 2010*).

### 3. Shade assessment:

Shade selection was performed before random allocation for the teeth. The teeth were mounted in a self-cure transparent acrylic resin (TR.II. Acropars, Iran). TiO2 (the whitest material) was used as background material in order to create; a neutral achromatic environment around the teeth during the shade selection. Shade selection for every tooth sample was done in its cervical, middle, and incisal one-third. Shade assessment was done for each tooth sample before and after the different bleaching protocols (*Shahabi et al, 2018*).

**Crystal Eye spectrophotometer (Olympus, Japan)** was used to digitally analyze the tooth color changes following different in-office bleaching techniques. This digital shade assessment device was used to measure shade of enamel surface before and after bleaching then the differences between pre-bleaching and post-bleaching readings were analyzed using the parameter ΔE.

**4. Grouping of specimens:**

The specimens were randomly divided into three main groups with 10 teeth each:

**Group A:** bleaching without light-activation (chemical conventional activation). **Group B**: LED-activated bleaching (**BEYOND Polus Whitening Accelerator) (**BEYOND Products Inc., MDSS GmbH 30175 Hannover, Germany). **Group C:** Diode laser-activated bleaching **(SIROLaser Blue)** (Sirona Dental Systems, GmbH Fabrikstr.31, 64625 Bensheim, Germany**).**

Each activated group was subdivided into two subgroups five teeth each according to the bleaching agent used. Subgroups ($A_1$, $B_1$, and $C_1$) where the (**Opalescence Xtra BOOST) 40%** (Ultradent Products Inc., Salt Lake, Utah, USA) was applied and subgroups ($A_2$, $B_2$, and $C_2$) where the (**BEYOND MAX 5) 35% (**BEYOND Products Inc., Stafford, USA) was applied.

**5. Bleaching procedure:**

Before using the bleaching materials, they were allowed to reach room temperature. Then, they were applied for three cycles according to the manufacturers' recommendations with one-minute rest intervals.

To apply the **opalescence Xtra Boost,** the gel was moved between the white and the red part of the unique double syringe configuration. Then 25 presses were applied from each side to reach a total of 50 presses. Finally, all mixed gel was kept into the red syringe. The two syringes were separated and the Micro 20 ga FX® tip was attached onto the red syringe. Afterwards, the gel flow was tested on a pad prior to applying it. Each tooth was dried with the air water syringe and a 0.5-1.0 mm thick layer of gel was applied to the labial surface of the tooth. While for the **BEYOND MAX 5** application, a 2-3 mm thick layer of gel was applied to the dry labial surface of the tooth.

In Group (A) conventional technique, the bleaching gel either **Opalescence Xtra Boost** in subgroup ($A_1$) or **BEYOND MAX 5** in subgroup ($A_2$) was applied as prescribed before and allowed for chemical activation. For both materials, allow gels to remain on the teeth for 20 minutes per application. The process was repeated two more times with one-minute rest intervals.

In Group (B) LED-activated bleaching **BEYOND Polus Whitening Accelerator** bleaching unit was used, the bleaching gel either **Opalescence Xtra Boost** in subgroup ($B_1$) or **BEYOND MAX 5** in subgroup ($B_2$) was applied as prescribed. The bleaching gels were activated with the blue LED light for10 minutes. The procedure was repeated for two more cycles with a one-minute rest time in between according to the manufacturers' recommendations.

In Group (C) Diode laser-activated bleaching **SIROLaser Blue** (Sirona Dental Systems GmbH Fabrikstr.31,64625 Bensheim, Germany**)** was radiated three times with one minute time interval minute from a 2 mm distance at a power of 1.1 W and a wavelength of 445 nm for 60 seconds using a continuous mode according to the manufacturer's recommendations (*Summitt et al, 2006; Joiner, 2007*), Followed by a 5 min rest after the last irradiation cycle, and then rinsing the bleaching agent with distilled water. Where subgroup ($C_1$) bleaching gel was **Opalescence Extra BOOST** while in subgroup ($C_2$) **BEYOND MAX 5** was applied.

***C. Statistical method:***

IBM SPSS software package version 24.0. (Armonk, NY: IBM Corp) and Graph Pad Prism 18 was used to perform statistical analysis of the given data.

Data revealed as means and standard deviations for groups and multiple comparisons were performed by One Way Analysis of Variance (One Way ANOVA) followed by Tukey`s post hoc test. Qualitative data will be presented as frequency & percentage. Quantitative data before and after teeth bleaching application was analyzed using paired t-test. p value$\leq$ 0.05 was considered significant.

TABLE (1) Materials used in this study

| Materials | Product Description | Principle components | Manufacturer | Lot Number |
|---|---|---|---|---|
| **Opalescence Xtra Boost Bleaching agent** | In-office bleaching gel supplied with two barrel jet mix syringe | sodium fluoride %1.1 One barrel contains .potassium nitrate %3 and hydrogen %40 The second barrel contains peroxide and a unique chemical activator | Ultradent Products Inc., Salt Lake, (Utah, USA | BF57N |
| **BEYOND MAX 5 Bleaching agent** | In-office bleaching gel in dual barrel jet mix syringe | Dual barrel syringe contains inactive ingredients: propylene glycol, deionized water, stabilizers (citric (acid,sodium calcium edetate, acetanilide Carbomer, trolamine, catalase, sodium .hydroxide, sodium benzoate %35 :Active ingredients hydrogen peroxide | BEYOND Products Inc., (Stafford, USA | 02152020 |

## RESULTS

In the descriptive analysis, group C2 exhibited the highest color change value (ΔE) within the range of 10.89 to 15.85, with a mean ± standard deviation of 13.98±1.911. Following closely was group A1, displaying a range of 12.15 to 15.65 and a mean ± standard deviation of 13.67±1.623. Group B2 demonstrated a comparatively lower color change value, ranging from 8.130 to 12.88, with a mean ± standard deviation of 10.36±1.749. These results are detailed in Table (2) and illustrated in Figure (1).

On the other hand, group A2 exhibited the lowest color change value within the range of 4.380 to 9.380, with a mean ± standard deviation of 6.540±1.807. Following this, group B1 displayed color change value ranging from 5.770 to 7.340, with a mean ± standard deviation of 6.634±0.6918. Group C1 fell in between, ranging from 8.340 to 10.53, with a mean ± standard deviation of 9.406±0.7898. These findings are presented in Table (2) and Figure (1).

To assess the significance among the different groups, a one-way analysis of variance (One Way ANOVA) was conducted, followed by Tukey's post hoc test for multiple comparisons. The results indicated significant differences between the groups (P-value < 0.05) except for the pairs (group A1 # group C2), (group B1 # group C1), (group B1 # group A2), (group C1 # group A2), and (group C1 # group B2), where no significant differences were observed (P-value > 0.05), as outlined in Table (3).

TABLE (2) Descriptive Statistics of Color Change (ΔE) among all the Groups:

| | A1 | B1 | C1 | A2 | B2 | C2 |
|---|---|---|---|---|---|---|
| **N** | 5 | 5 | 5 | 5 | 5 | 5 |
| **Min** | 12.15 | 5.770 | 8.340 | 4.380 | 8.130 | 10.89 |
| **Med** | 13.33 | 6.690 | 9.470 | 6.170 | 10.18 | 14.19 |
| **Max** | 15.65 | 7.340 | 10.53 | 9.380 | 12.88 | 15.85 |
| **M** | 13.67 | 6.634 | 9.406 | 6.540 | 10.36 | 13.98 |
| **SD** | 1.623 | 0.6918 | 0.7898 | 1.807 | 1.749 | 1.911 |
| **SEM** | 0.7256 | 0.3094 | 0.3532 | 0.8080 | 0.7820 | 0.8548 |
| **Lower 95% CI** | 11.65 | 5.775 | 8.425 | 4.297 | 8.191 | 11.61 |
| **Upper 95% CI** | 15.68 | 7.493 | 10.39 | 8.783 | 12.53 | 16.36 |

***N; Number, Min; Minimum, Med; Median, Max; Maximum, M; Mean, SD; Standard Deviation, SEM, Standard Error of Mean, CI; Confidence Interval A1: chemical activated opalescence boost A2: chemical activated Beyond max 5***

***B1: LED activated opalescence boost B2: LED activated Beyond max 5***

***C1: Diode laser activated opalescence boost C2: Diode laser activated Beyond max 5***

TABLE (3) Multiple Comparisons between Different Groups using Tukey`s Post Hoc Test:

| Groups | MD | 95.00% CI of diff. | Sig | P-value |
|---|---|---|---|---|
| **"A1 vs. B1"** | 7.034 | 4.078 to 9.990 | **** | <0.0001 |
| **"A1 vs. C1"** | 4.262 | 1.306 to 7.218 | ** | 0.0020 |
| **"A1 vs. A2"** | 7.128 | 4.172 to 10.08 | **** | <0.0001 |
| **"A1 vs. B2"** | 3.306 | 0.3499 to 6.262 | * | 0.0222 |
| **"A1 vs. C2"** | -0.3160 | -3.272 to 2.640 | ns | 0.9994 |
| **"B1 vs. C1"** | -2.772 | -5.728 to 0.1841 | ns | 0.0751 |
| **"B1 vs. A2"** | 0.09400 | -2.862 to 3.050 | ns | >0.9999 |
| **"B1 vs. B2"** | -3.728 | -6.684 to -0.7719 | ** | 0.0079 |
| **"B1 vs. C2"** | -7.350 | -10.31 to -4.394 | **** | <0.0001 |
| **"C1 vs. A2"** | 2.866 | -0.09006 to 5.822 | ns | 0.0611 |
| **"C1 vs. B2"** | -0.9560 | -3.912 to 2.000 | ns | 0.9134 |
| **"C1 vs. C2"** | -4.578 | -7.534 to -1.622 | *** | 0.0009 |
| **"A2 vs. B2"** | -3.822 | -6.778 to -0.8659 | ** | 0.0062 |
| **"A2 vs. C2"** | -7.444 | -10.40 to -4.488 | **** | <0.0001 |
| **"B2 vs. C2"** | -3.622 | -6.578 to -0.6659 | * | 0.0103 |

***MD; Mean Difference, Sig; Significance, CI; Confidence Interval, P; Probability Level***

***A1: chemical activated opalescence boost*** ***A2: chemical activated Beyond max 5***

***B1: LED activated opalescence boost*** ***B2: LED activated Beyond max 5***

***C1: Diode laser activated opalescence boost*** ***C2: Diode laser activated Beyond max 5***

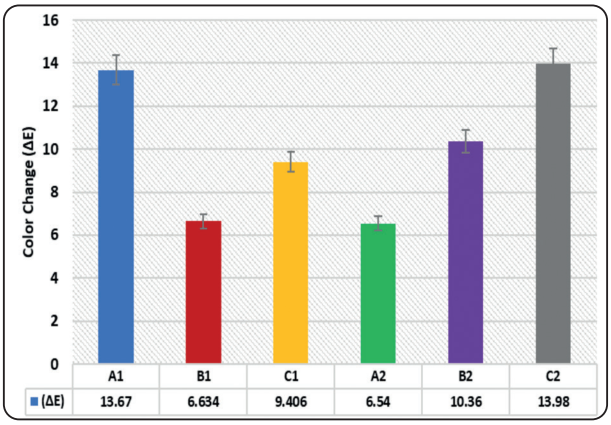


Fig. (1): Bar Chart revealing Descriptive Statistics of Color Change (ΔE) among all the Groups

## DISCUSSION

Evaluation of changes in teeth color after applying bleaching techniques can be done using different methods. To select teeth color, many studies used the subjective manual shade guide, unfortunately shade guides lack adequate accuracy and have many drawbacks (*Summitt et al, 2006*), part of which evaluator variations and only measures the overall color value of the subjects (*Nakajima et al, 1995*).

As a standard method for color evaluation, spectrophotometer is being used. Some of its features include reliability in calibration, reproducibility, lack of operator interference, and exclusion of the environmental light interference (*Tung et al, 2002*).

Spectrophotometry is a universally standardized technique in recording and analyzing data independent from personal evaluation bias. The Commission International de l'Eclariage (CIE)L* a* b* color order system is used to describe color dimensions mathematically within a color space of equally perceived gradations. (*Paravina et al, 2007*)

For analyzing the three color dimensions of the CIE L* a* b* system, the L* values denoted lightness and darkness of a color, while a* values determine the red-green axis and b* values describe the yellow-blue axis. ΔE integrates the three color dimensions of the CIE L* a* b* system to evaluate and compare of global color changes of different bleaching agents (*Dietschi et al, 2006*).

Two limitations have to be considered while using objective methods such as colorimeters or spectrophotometers. The first is related to the light beams of penetrating the tooth surface and the other is related to the dark background of the oral cavity behind the tooth, besides the pink color of the gingiva in the cervical area of tooth of interest (*Joiner, 2007*). And so to avoid such limitations in our current study extracted teeth were collected and mounted to TiO2 incorporated acrylic resin mold in order to standardize the environmental contrast in all samples.

It was shown, in this study, that all of the bleaching materials, protocols, and techniques studied resulted in whitening of teeth at different levels, since (ΔE) levels between baseline and after bleach application were greater than 3.3 for all tested groups.As revealed in Table (2) and figure (1), increasing color change values denotes more bleaching results occurred among different tested groups.

Patients reported with excessive teeth discoloration or single tooth discoloration need hydrogen peroxide with high concentrations that may reach up to 40% to give effective results. In-office bleaching methods activated either by light or heat could be beneficial (*AlSheikh & El-Embaby, 2018*). The aim behind using power bleaching is to activate the bleaching material using a source of light/heat energy. However, having effective results requires more exposure time of the bleaching material to the tooth, with increased possibility of pulp necrosis. Recently heat/light application can be applied with a specific wavelength that approximates the absorption spectrum of the bleaching agent, accelerating the speed of oxidation reaction, thereby decreasing exposure time of the bleaching agent to the tooth (*Joiner, 2006; Sulieman, 2008; Lagori et al, 2014*).

It has been shown in relevant literature that the most common in-office bleaching techniques used were chemical ones followed by LED activated ones where the effect of those two techniques were studied and compared with laser-assisted methods. In the current study, standardization of energy sources was performed on all the tested samples and was applied under similar conditions.

In a previous study, it was claimed by the manufacturer, that using external energy source for activation with Xtra Boost may improve whitening efficacy of such material (*Marson et al, 2008*; *Da Silva et al, 2008*; *Ontiveros et al, 2009; Azarbayjani et al, 2019*).

In this study the null hyposthesis was rejected as there are statistically significant difference in the color change between chemical, light, and laser-activated bleaching agents. Chemically activated method gives the lowest lightness and bleaching effect this could be attributed to that the chemical reaction occurring faster when using light activation where a light of a specific wavelength is used that approximates the absorption spectrum of the bleaching agent, thereby decreasing the teeth exposure time to the bleaching agent and give a more convenient results (*Lagori et al, 2014*).

There are three distinct phases which bring about a change in perception of teeth color: (a) diffusion of bleaching agent into tooth structure, (b) interaction of the whitening agent with the stain molecules, and (c) the double bonds are broken down and there is a change in the optical properties resulting in alteration of structure surface of the tooth such that it reflects light differently. This sequence of events would determine the final color change of teeth after bleaching (*Cavalli et al, 2004; Lagori et al, 2014*).

Since tea is a commonly consumed beverage causing stain in the different populations, in this present study, tea was selected as one of the staining agents and the compounds in the tea that are responsible for causing dental stains are tannins (*Nathoo, 1997*).

Dental lasers contribute to the field of tooth bleaching long time ago. Recently, laser has been proven to be the most reliable energy source for power bleaching due to simple and short in- office application. The mechanism behind the laser effect on the bleaching agent can be explained due to the ability of the laser beam to irradiate the chromophores like ferrous gluconate containing bleaching gel to enhance the photo-Fenton process. Laser removes proteins covering the apatite plates resulting in the limitation of its growth in certain directions, which in turn leads to the growth of apatite crystals in all directions. and also it was found in this study that conventional bleaching gel is capable of absorbing diode laser instead of containing chromophores in its composition (Saluja et al, 2022; Dostalova et al, 2004).

The phenomenon of enamel surface alteration was found to be reduced not only when using diode laser at wavelengths of 810 and 980 nm but also in case of using conventional bleaching materials.

In our present study, laser activation group with hydrogen peroxide showed the highest bleaching efficacy when compared to all other groups, which is in correlation with the results obtained by *Calatayud et al, 2010; Bhutani et al, 2016; Shahabi et al, 2018* whom they found increased lightness with bleaching method done by laser than chemical or LED activated groups and also In accordance to *Wetter et al, in 2004* who conducted an *in vitro* study which compared the bleaching efficiency between LED and diode laser irradiation using two bleaching agents, namely, Opalescence X-tra and HP Whiteness, and concluded that bleaching efficiency using diode laser was comparatively better than LED irradiation with Opalescence Boost in terms of changes in chroma and luminosity (*Wetter et al, 2004*).

The rationale behind high performance of the laser group over other modalities used in comparison may be attributed to the physical properties of laser of being monochromatic, coherent and collimated energy beam which improve tooth whitening ability when irradiated on bleaching material as the chromophores present in bleaching gel absorb light which in turn activate the molecules resulting in superior bleaching ability (*Lizarelli et al, 2002*).

Hence, LEDs and lasers have been used to heat the bleaching gel. This will increase the penetration of the bleaching gel into the tooth structures and enhance the bleaching efficiency because chemical reactions happen faster at elevated temperature (*Buchalla et al, 2007*).

Our results were contradicted with that of *Strobl et al in 2010* who found that application of laser on handmade bleaching material containing 35% HP did not yield successful clinical results when compared with conventional methods.

Since it is an invitro, one of the limitations of this study was the absence of the saliva. Studies have reported that the presence of saliva during the bleaching process would reduce the enamel susceptibility to demineralization and minimize the discoloration *(Al-Angari et al, 2019; Alqahtani, 2014; Cavalli et al, 2004).*

## CONCLUSION

All the tested groups produced significant increase in lightness of the shade and effective to bleach from baseline following bleaching.

Lasers are presently being used as a useful tool in dental practice. Based on the outcome of the current study, it can be concluded that diode laser at low power densities with wavelength 445nm can be considered as an effective and reliable treatment option for bleaching of teeth.

Effectiveness of bleaching is more related to time and method of activation rather than bleaching material itself.

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