

Whitening Efficiency of Laser 940 nm and LED (450-505) nm on Extrinsic Stained Teeth (*in vitro* study)

Ali A Hassab¹, Basima Mohammed Ali Hussein², Mohammed G Rzoqi³

¹BDS, H.D.P.D. Institute of Laser for Postgraduate Studies/University of Baghdad, ²Assist. Prof Dr; Institute of laser for Postgraduate Studies/University of Baghdad, ³Lecturer, M.Sc., BDS. Institute of Laser for Postgraduate Studies/University of Baghdad

Abstract

Background: Teeth staining is one of the esthetic problems faced by dentists and patients. Many methods have been suggested as crowns, restorations and bleaching. Dental bleaching effectiveness depends on many factors including technique and materials.

Objectives: Studying the effect of diode laser 940 nm and light emitting diode (450-505) nm in bleaching of stained teeth regarding : whitening efficiency; pulp temperature; surface roughness and topography.

Materials and Methods: 40 extracted anterior teeth divided into 6 groups immersed at 37 °C in either tea; coffee; cola ; juice for 14 days, tobacco stained teeth as well as control group were also included (immersed in distilled water). These groups were subdivided into laser group or light emitting diode group bleached according to manufacturer specifications. Shades of teeth were recorded before and after bleaching. Furthermore, temperature changes during bleaching were recorded using thermocouple Thermometer. All specimens were examined under light microscope, Atomic Force Microscope and Sectioning Electronic Microscope to study the surface roughness and topography.

Results: the light emitting diode group yielded slight significant whitening efficiency with more pulp temperature rise (3.4 °C) compared to the laser group (1.4 °C). Both groups showed non-significant effect on roughness and topography compared to control group.

Conclusion: Although light emitting diode group showed slightly significant shade improvement, but the increase in pulp temperature was greater than that of laser group indicated better prognosis and safety when diode laser 940 nm used. Conducting between efficiency and preservation, diode laser is superior in safety and slightly similar whitening efficiency.

Keywords: Whitening efficiency, laser 940 nm, LED (450-505) nm, *in vitro*.

Introduction

Teeth discoloration is one of old cosmetic problems that face both people and dentists for many years ago⁽¹⁾ therefore dentists developed various manners to overcome such aesthetic problem⁽²⁾, one of these manners was the bleaching of stained teeth,⁽³⁾ which is

a chemical removal of stains. Bleaching mainly depends on (1) concentration of bleaching agent (2) type and degree of tooth discoloration (3)time of application.⁽⁴⁾ One of the modifications in bleaching is the use of light source⁽⁵⁾ to accelerate the liberation of the free oxygen radicles⁽⁶⁾ accompanied by pulp temperature rising. Different sources of light used in the activation of bleaching^(7,8) considering not to exceed the critical pulp temperature rise (5.5 °C)⁽⁹⁾. Generally there are two main types of bleaching approaches⁽¹⁰⁾: in-office and home bleaching. The in-office method has more advantages over home bleaching including: control

Corresponding author:

Ali A Hassab

drsh25shawki@gmail.com

Tel. 009647704501119.

by the dentist, reduced treatment time, less chances of exposing soft tissues to chemical agents, less chances of ingestion of chemicals and great potential for immediate whitening results as well as patients satisfaction⁽¹¹⁾. Shortening of bleaching time may help to reduce teeth sensitivity and temperature rise due to chemicals.^(12,13)

The purpose of this in vitro study is to evaluate the effects of diode laser 940 nm and a light-emitting diode (LED) (450-505) nm on tooth bleaching regarding the whitening efficiency, intrapulpal temperature changes, and surface roughness and topography in both techniques.

Materials and Methods

Sample selection and preparation

40 extracted upper and lower anterior teeth from patients age ranging (25-45) years old, These teeth were free of any caries or restorations. The teeth were cleaned carefully and soft tissue was removed using dental scaler(

Woodpecker /China). Then teeth immediately immersed in thymol 10%. (MERCK, GERMANY) Their crowns were polished with prophylactic fine pumice slurry (PERFECTION, UK) with disposable rubber cup and rotary angle hand piece (W&H / Austria). The roots (apex) were cut off to have 17 millimeter(mm) tooth length using digital vernier (TOPEX / Poland). The apical foramen was enlarged by mechanical retrograde manner using Gate Glidden (THOMAS ,France) #5 and #6 as in routine endodontic treatment.

Shade assessment

The shades of the teeth were recorded using VITAPAN shade guide (Zahnfabrik , Germany) by two independent observers who made the viewing at the same environment, morning time (11 : 00 A.M.) under natural day light⁽¹⁴⁾. The shades were encoded into scores of Sixteen levels as in table 1.⁽¹⁵⁾

Table 1. Shade index according to VITA classical shade guide :

| | | | | | | | | | | | | | | | | |
|-------|----|----|----|----|----|----|----|----|----|----|----|------|----|----|----|----|
| Score | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Shade | B1 | A1 | B2 | D2 | A2 | C1 | C2 | D4 | A3 | D3 | B3 | A3.5 | B4 | C3 | A4 | C4 |

Artificial staining

These polished teeth were immersed identically in different artificial staining solutions^(16, 17) which are either:

(1) Tea solution which was prepared by adding 4 gram(gm) tea leaves (Mahmood brand, IRAQ) in 100 ml water.

(2)Coffee solution: prepared by adding 50 gm coffee (Alameed brand, JORDAN) in 400 milliter (ml) water. These two solutions boiled then cooled down to 25 °C.

(3)Juice solution which contain 100 ml pomegranate juice (Rawabi brand, IRAQ)

(4) Cola solution which contain 100 ml cola(PESPICOLA, IRAQ).

Furthermore, Tobacco stained teeth were also included with the control group (unstained teeth) which were immersed in distilled water. All were kept in an incubator(MEMMERT 854 Scawbach / Germany) at 37 °C for two weeks. After the 14 days incubation, the artificially stained teeth washed thoroughly under running water for 30 minuits (min.). Brushed by tooth brush and paste (Coalgate brand, CHINA) then washed again and kept within deionized water for 24 hours then the teeth were dried using towel and the shades were assesses .

Control group consist of 10 teeth which were kept within deionized water for 14 days then used later on for comparing them with the bleached group for assessing both surface roughness and topography using AFM and SEM respectively .

Absorption spectrum analysis

The bleaching gel 32% (Light White smile, GERMANY) examined by spectrophotometer (UVD 2950, USA) to evaluate the photoabsorbption of it for wavelength range of (300-1100) nm.

Temperature assessment

The temperature of the cores of teeth was assessed before and during the bleaching process using K type thermocouple (AmprobeTMD-56 / USA) with basic accuracy of 0.05. It inserted from the apical foramen to the pulp chamber of the tooth ⁽¹⁸⁾. The wire was fixed in the pulp chamber with thermal paste (HC131-TU1; Bonyx Factory, Guangdong, China) . A radiograph was taken to ensure that the thermocouple tip touches the highest position of the pulp chamber within the thermal paste. The apical foramen was sealed by light cure composite resin (Willmann & Pein GmbH, Germany). The teeth with their attached thermocouple wire were held to keep their roots immersed in a water bath set to a temperature of 37 °C and the data of thermocouple transferred to a computer (*hp*, AMERICA) .

Bleaching light systems:

The bleaching gel 32% was applied on the labial surfaces of teeth in approximately 2 mm thickness. The whitening of laser group was done using Diode laser 940 nm (Biolase Technology, Irvine, CA, USA) at 7 Watt (W)(table 2). According to the manufacture instructions, the gel was left on the teeth surfaces for one minute before laser irradiation. Laser application was for 30 second(s) with 2 millimeter(mm) distance from the hand piece bleaching head. This step was followed by rest for one min. Another 30 s. of laser radiation was done then the teeth were left for 7 min This cycle was repeated again to have 20 min. total bleaching procedure. The temperature of the cores were recorded during the procedure. In LED group, the bleaching procedure was done following the manufacturer instruction. The bleaching gel was applied on the teeth surface in about 2 mm thickness, then exposed to the light for 20 min. Pulp temperature assessment was done for such group in the same procedure as in the laser group. The shades of the teeth were assessed before and after treatment using VITAPAN shade guide.

Table 2. Laser Irradiation Parameters used

| Laser wavelenth (nm) | Defocus (mm) | Power (W CW) | Area (cm2) | Power density (W cm -2) | Time (s) | Deposited Energy (J) | Dose (J cm- 2) |
|----------------------|--------------|--------------|------------|-------------------------|----------|----------------------|----------------|
| 940 | 1 | 7 | 2.8 | 2.5 | 30 | 210 | 75 |

Effect of Thickness:-

10 teeth from each group were sectioned buccolingually from occlusal surface to cervical line by disc bur to measure the effect of thickness of teeth (from labial surface to pulp core) on the temperature rise that occurred after bleaching by the laser and LED. The thickness was measured by digital vernier caliper from the midpoint of the pulp core to the labial surface.

Assessment of surface roughness and topography:

The surface roughness of teeth of control group with teeth from each bleached groups (laser and LED

) was analyzed using Atomic Force Microscope (AFM) (PHYSWE / Germany)while the surface topography for the same teeth was investigated using Sectioning Electronic Microscope (SEM)(TESCAN MIRA / France).

Statistical Analysis

Using the package of software IBM, Spss 20 (IBM . Armonk, NY, USA) the descriptive and inferential data were statistically analyzed. Descriptive and inferential data of staining the teeth was done using kruskal-wallis test, t-test used for statistically analysis of temperature

rise after bleaching by both LED and laser techniques. Mann-Whitney U test used for analyzing shade change for different stained groups, while the LSD test used for comparing the results of AFM for both control, LED and laser groups. T-test used for the relation between thickness of each bleaching group with temperature rise.

Results

Shade change after artificial staining:

By using the VITAPAN shade guide we assessed the shade changes for the stained teeth after 14 days incubation at 37 °C immersion in staining solutions. The maximum, minimum, means and median values as well as statistical results were showed in table 3.

Table (3) descriptive and statistical analysis for shades of teeth before and after staining using Kruskal – Wallis test:

| stain | Shade 1 | | | | Shade 2 | | | |
|--------|---------|-----------|------------|-------------|---------|-----------|------------|-------------|
| | Median | Mean rank | Chi square | P value | Median | Mean rank | Chi square | P value |
| Coffee | 1.50 | 9.00 | 6.979 | 0.073 NS | 8.50 | 9.50 | 19.888 | 0.000 HS |
| Tea | 2.00 | 12.67 | | | 12.00 | 18.92 | | |
| cola | 2.00 | 17.50 | | | 11.50 | 18.08 | | |
| Juice | 2.00 | 10.83 | | | 6.50 | 3.50 | | |

Shade 1= color scores before staining Shade 2= color scores after staining

Absorption spectrum of the bleaching gel and water: The absorption spectrum of the light white smile gel within range of 200-1100 nm showed slightly more absorption for the LED at 450 nm more than 940 nm with high absorption at 300 nm (Figure 1).

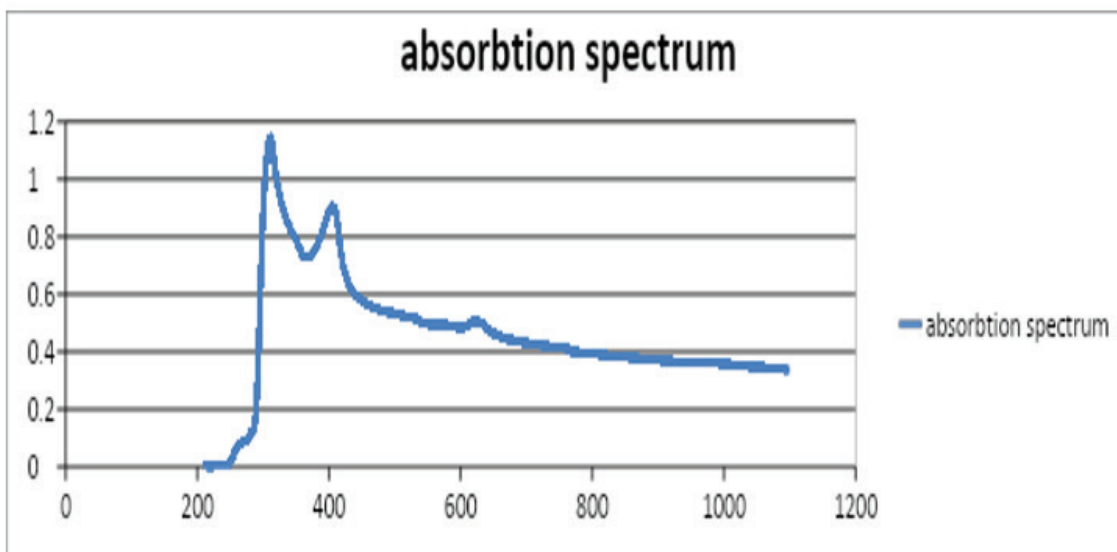


Figure (1) absorption spectrum of the bleaching gel within 200-1100nm

Temperature assessment

Table (4) shows the statistical analysis of mean temperature rise of laser group which was 1.19 degrees

while the in the LED group showed average increase in pulp temperature by 3.43 degrees. The LED group showed higher significant rise in pulp temperature than that of laser group.

Table (4) Descriptive and statistical analysis of temperature assessment within each group.

| | GROUPS | N | Means of T1 | Mean of T2 | SD | SE | T | P value |
|----|--------|----|-------------|------------|--------|--------|--------|-------------|
| T2 | LED | 10 | 37.2 | 40.6300 | .18886 | .05972 | 29.190 | 0.000 HS |
| | LASER | 10 | 37.2 | 38.3900 | .15239 | .04819 | | |

TI = temperature before bleaching T2 =temperature after bleaching

Shade analysis after laser and LED bleaching:

Shade scores of stained teeth groups before bleaching were compared with shade scores after bleaching. The statistical analysis in table 5 showed significant

reduction in shades of stained teeth bleached by LED compared to laser group beside that there were variation in shade reduction of shades for the stained groups that bleached by both bleaching techniques .

Table (5) Inferential statistical analysis for shade change of different stain groups before and after bleaching:

| stain | | bleaching | | Z | p |
|---------|--------|-----------|-----------|-------|-------|
| | | LED | Laser | | |
| | | Mean Rank | Mean Rank | | |
| Coffee | Before | 5.80 | 5.20 | 0.332 | 0.841 |
| | After | 3.00 | 8.00 | 2.668 | 0.008 |
| Cola | Before | 4.70 | 6.30 | 0.876 | 0.421 |
| | After | 3.00 | 8.00 | 2.739 | 0.008 |
| Juice | Before | 6.20 | 4.80 | 0.808 | 0.548 |
| | After | 3.40 | 7.60 | 2.324 | 0.032 |
| Tea | Before | 4.40 | 6.60 | 1.205 | 0.310 |
| | After | 3.40 | 7.60 | 2.324 | 0.032 |
| Tobacco | Before | 5.60 | 5.40 | 0.111 | 1.000 |
| | After | 4.30 | 6.70 | 1.302 | 0.222 |

Roughness and topography

The samples were examined for roughness and topography (by AFM and SEM respectively) ^(19,20) by

comparing the means of arithmetic mean height (Sa) results of control group with LED and laser groups, the results are illustrated in table 6 and figure 2.

Table (6) inferential analysis for Sa means of control, laser and LED groups:

| Multiple Comparisons using LSD | | | | | | |
|--------------------------------|---------|-------------|------------|------------|-----------------------|---------|
| Dependent Variable | group | Means of Sa | (I) groups | (J) groups | Mean Difference (I-J) | p value |
| Sa | control | 136.03 | control | Laser | 64.079 | .000 |
| | Laser | 71.951 | | Led | 58.02 | .000 |
| | LED | 78.01 | Laser | Led | -6.059 | .014 |

Discussion

The methodology of staining teeth was a trial to mimic the natural teeth staining using common staining beverages which were: tea, tobacco, coffee, cola and juices for 14 days in the incubator at 37 °C. The findings in this study indicated that the highest score of shade change after bleaching registered for the cola stained teeth which explain the sensitivity of such type of stain for dissociation due to the effect of free radicles from hydrogen peroxide in the bleaching gel.

The basic effect of bleaching in this study is light application on a chemical substance (bleaching gel) that reacts with the stain molecules to cause degradation of the stain. Such degradation occurs due to accelerating effect of light photons beside the assistance of heat generated during the bleaching process. The number of such radicles depends on the concentration of the hydrogen peroxide. Many researches indicated that high concentration of hydrogen peroxide causes teeth sensitivity ⁽²¹⁾ and trauma to the soft tissues during and after treatment. The rise in temperature during whitening process may traumatize the vitality of pulp tissues ^(22,23) especially when the procedure takes longer time. Therefore, proper selection of whitening technique and instrument is an ethical responsibility, solving

patient's complain without damage or poor prognosis is ultimate goal. For such demand we chose this type of bleaching gel with reasonable concentration of hydrogen peroxide (32%). high concentration of HP lead to more release of free radicles that may hurt the pulp due to penetration of excess of them inside the dentinal tubules leading to the irritation of the pulp, besides that, such high concentration of HP may also affect the surface roughness of the bleached teeth ^(24,25,26). This selected gel contains the chlorophyll which is the photocatalizers to achieve more absorption liability to the light photons. Although there is a harmony between light sources and such photocatalizers in hydrogen peroxide gel, a part of light intensity may pass through the enamel gel toward the pulp which may induce trauma. The maximum of the bleaching gel should be activated by the photoabsorption as possible to exclude the effect of any excess that may traumatize the pulp through the dentinal tubules. The temperature reports showed more rise in temperature (3.4 degrees) for LED that was near to critical hazardous temperature degree of the pulp (5.5 °C) compared to (1.19 degrees rise) for the laser (table 4). The use of coherent light to improve the bleaching effect was described by D. Yarborough and Smige ⁽²⁷⁾. The idea of using light and photosensitive ingredient to minimize the chemical constitute and reaction beside efficient results.

This study come in agreement with Arantza et and Sevil Gurgan et al^(28,29). Polydorou et. al in 2013 conducted similar results in whitening efficiency for halogen light compared to laser light 980 nm.

Results of our study showed significant whitening efficiency for the LED. This could be attributed to the longer time of exposure 20 min which gave more chances for absorption of light by the gel. Furthermore the prolonged time of thermal effect of the high power of the LED source (30 W) compared to the short exposure time of laser (2 min) and lower power (7 W). SEM investigations showed that both bleaching systems have no significant effect on the teeth surface topography while AFM results showed that the laser samples had the lowest Sa readings compared to control and LED groups which means that the laser bleached teeth had less roughness post bleaching which may lead to less reliability for relapse of extrinsic staining for such teeth in future (Table 6). The relation between thicknesses of teeth with the rise in pulp temperature was evaluated after sectioning the crowns of teeth. A highly significant relation between the thickness and temperature rise for the LED group while the laser group showed a little significant relation between the thickness and temperature rise (Table 7 &8). The long time exposure of LED with high power (30 W) caused increase the pulp temperature in direct relation with the thickness of thin teeth like laterals and central incisors.

Conclusion

Both LED and diode laser have good whitening results on extrinsic stained teeth although the LED showed significantly higher whitening efficiency than the diode laser. Regarding safety and prognosis, laser bleaching is more safe on the teeth that it causes no significant effect on pulp temperature rising compared to LED. AFM test showed that laser group have lower means of roughness than that of LED.

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Conflict of Interest: None to declare.

Ethical Clearance: All experimental protocols were approved under the University of Baghdad and all experiments were carried out in accordance with

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