Study the hardness and temperature changes during tooth bleaching using different Laser Sources

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ABSTRACT
Background: Today, the processes of teeth bleaching by utilizing oxidation chemical components became a public and important as a cosmetically operative. Particularly the demanding on these processes increased with the developing in bleaching techniques, where laser light is used as catalyst agent to increasing the efficiency and speed of these processes, and the latter known as office bleaching. In this paper, we evaluate the effect of different laser wavelengths of bleaching on the surface hardness of the tooth and the temperature rise of the pulp due to the influence of laser light in conjunction with the bleaching gel.

Materials and methods: Three different laser sources (KTP 532nm, LD 810nm and Nd:YAG 1064nm) were used as accelerator agent in-office bleaching utilizing Hydrogen Peroxide at 37.5%, where the enamel micro hardness measurements in the teeth (invitro study) pre and post operative was done.

Results: Then by using analysis of variance (ANOVA-Tukey’s test \( p = 0.05 \)) the results shows there are insignificant effects on tooth hardness due to the changes in the laser wavelengths in both pre and post bleaching.

Conclusion: Thereafter to evaluate the pulp chamber temperature rise induced by three different light sources employed in this laser-activated tooth bleaching, the pulp chamber temperature was measured during the radiation processes and the results shows that the minimum temperature rise was seen at the 532nm. So, we can say that the KTP (SHG) Nd:YAG laser at the wavelength (532 nm) represent the best choice to use in-office bleaching processes.


INTRODUCTION
Bleaching corrects or improves the color of teeth. The indications are acquired superficial stains, penetration and absorbed stains, age-related stains, patients who desire conservative treatment to improve appearance, color change related to pulp trauma and necrosis, and inter proximal discolorations.

The current techniques involve a broad-spectrum approach utilizing hydrogen peroxide (3-38%) with or without heat or laser, carbamide peroxide (10-30%), or a mixture of sodium perborate and hydrogen peroxide(3).

Since the early 1980's, the heat lamp and heated spatula have been used as a heat source to accelerate the bleaching process of concentrated hydrogen peroxide. This has been shown to be effective, but it also causes pulp irritation. The process of controlling the caustic 35% hydrogen peroxide liquid has been challenging (2).

Laboratory studies were performed by Donald J. (3), to assess the impact of peroxide bleaching on enamel surface and subsurface physical and ultrastructural properties. Tatjana D. (11), described a preclinical investigation with laser-activated bleaching agent for discolored teeth.

Two different laser systems and light emission diodes for activation of the bleaching agent were used: diode laser, wavelength 970 nm, and infra-red diode laser, wavelength 790 nm, with eight blue light emission diodes of wavelength 467 nm.

The enamel surface was evaluated with the scanning electron microscope. Nadia M. (4), evaluated the effect of at-home and in-office bleaching on the surface hardness of the tooth colored restorative materials. T. Al-Qunaian(5), estimated whether the treatment of human enamel with whitening agents containing different concentrations of carbamide or hydrogen peroxide changes the susceptibility of enamel to caries. Wolfgang Buchalla(6), summarized and discussed the available information concerning the efficacy, effects and side effects of activated bleaching procedures. K. Sakai (7) evaluated the efficacy of dental bleaching with a 405nm diode laser irradiation on titanium dioxide and 3.5% hydrogen peroxide by measuring the generation of hydroxyl radicals. A. Ruya Yazici (8) measured the temperature increase in the pulp chamber and to investigate the influence of light in conjunction with the bleaching gel on pulp temperature rise. Chengfei Zhang (9) examined the whitening efficacy of a light-emitting diode (LED), a diode laser and a KTP laser irradiation in dental bleaching by analyzing the change in color.
achieved from the treatment, the temperature increase induced in the pulp cavity, as well as enamel microhardness measurement after treatment. In vivo assessment of two whitening techniques was introduced by Isa T. Gontijo(10) with the variable being the source of energy activation. Assessment of whitening was done by color analysis with the Vita 3D scale at 3 different times: before whitening, immediately after whitening, and 1 week after whitening. William Kabbach(11) investigated the surface temperature variations in the cervical region via infrared thermography, as well as the temperature within the pulp chamber via thermocouples. Maryam Kuzekanani(12) examined the outcomes of photodynamic bleaching for treatment of confirmed cases of tetracycline discoloration, when used as a single-appointment procedure.

The aims of this study are to evaluate the capability of three different laser wavelengths to activate the whitening chemical in bleaching treatment with it is effect on the surface hardness of the tooth and the temperature rise of the pulp due to the influence of laser light in conjunction with the bleaching gel.

MATERIALS AND METHODS

The procedure used in the preparation of samples, exposure conditions of teeth by laser, preoperative and postoperative steps adopted in measuring the enamel hardness and pulp temperature with necessary illustrations is described in this section as shown in figure 1.

Preparation of Samples:

Six extracted human teeth, caries-free (sound teeth), were selected as samples for our search. First the samples were cleaned with a suitable polish and brush then they were stored in distilled water until used. The root of each tooth was cut 2-3 mm apically to the cementoenamel junction (CEJ) as shown in figure 2. The apical orifice of the root canal was enlarged. The remaining pulp tissue was removed from the canal, the empty pulp chamber was filled with ZP heat sink compounds which replaced the pulp tissue as a heat conducting medium (Thermal Conductivity > 1.22 W/m.k & Thermal Resistance < 0.201°c-in²/W).

Photographic Record

This step represents the photographic recording for all samples before the treatment by H\textsubscript{2}O\textsubscript{2} agent and laser beam. To fulfillment this step a digital camera at 5 Mega Pixels was used.

The Vikers Enamel Microhardness (VHN) Measurements

In this step the VHN was measured using a (Digital Micro Vikers Hardness Tester TH714) as shown in figure 3. Vickers Hardness Indenter set to indent for 15 seconds at a 500-g load (three measurements per specimen per measurement point).

Irradiation by Laser:

This section describes the types of lasers and the conditions that used to activated the bleaching teeth process, where three types of lasers used to accelerate the bleaching process as shown below:

1. KTP laser (SHG) (532nm).
2. Diode Laser (810nm).

The conditions of the lasers that used in this activation are shown in table 1:

Pulp chamber Temperature Measurements

A thin K-type thermocouple was inserted into the pulp chamber through the cut root area. The thermocouple was placed at the most coronal level of the pulp chamber. The root surfaces of the tooth were partially submerged in a water bath (37 °C) during the testing procedure.

This method effectively stabilized the internal baseline temperature at 37°C and was done to minimize the effects of ambient temperature changes and to provide a consistent initial temperature for each data set, as show in figure 4.

RESULTS

Enamel Microhardness Measurements

The results of Vicker’s micro hardness testing are presented in Table(2). All results were statistically analyzed with one way analysis of variance (ANOVA), Tukey tests (P<0.05), and percentage changes for Tukey. The tests showed there were insignificant different between the micro hardness before and after treatment.

Pulp Temperature Measurements

The temperature rise in pulp chamber induced by three different light sources employed in laser-activated tooth bleaching was measured. Figures 5 and 6 show the mean temperature rise as a function of exposure time for three different wavelength at spot size (0.75, 1 mm) respectively.

The maximum temperature rise was seen in the first five minutes of the treatment for both groups then the temperature decreased. The highest temperature rise was recorded using the Nd:YAG laser and the lowest one using the SHG of Nd:YAG laser as shown in Table 3.
Figure 1: Procedure chart.

Figure 2: Tooth sample after Preparation

Figure 3: Digital micro Vikers hardness tester TH714
Table 1: The conditions of the lasers used.

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Power Density (W/cm²)</th>
<th>Pulse Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>KTP laser (SHG)</td>
<td>532</td>
<td>1 (200 mJ x 5Hz)</td>
</tr>
<tr>
<td>Diode Laser</td>
<td>810</td>
<td>CW</td>
</tr>
<tr>
<td>Nd:YAG laser</td>
<td>1064</td>
<td>1 (200 mJ x 5Hz)</td>
</tr>
</tbody>
</table>

Table 2: Vicker’s micro hardness of teeth before and after whitening for 30 second exposure time

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Power Density (W/cm²)</th>
<th>Groups</th>
<th>Mean of VHN before whitening (VHN)</th>
<th>Mean of VHN after whitening (VHN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nd:YAG (SHG) 532</td>
<td>226.35</td>
<td>A S1</td>
<td>263</td>
<td>259</td>
</tr>
<tr>
<td></td>
<td>127.32</td>
<td>S2</td>
<td>285.333</td>
<td>284.333</td>
</tr>
<tr>
<td>Nd:YAG (CW) 810</td>
<td>127.32</td>
<td>B S3</td>
<td>243</td>
<td>237</td>
</tr>
<tr>
<td></td>
<td>127.32</td>
<td>S4</td>
<td>286</td>
<td>282.333</td>
</tr>
<tr>
<td>Nd:YAG 1064</td>
<td>226.35</td>
<td>C S5</td>
<td>244</td>
<td>235</td>
</tr>
<tr>
<td></td>
<td>127.32</td>
<td>S6</td>
<td>277</td>
<td>266.666</td>
</tr>
</tbody>
</table>

Figure 5: Pulp chamber temperature versus exposure time curves caused by irradiation using three different laser wavelengths at spot size = 0.75mm (127.32 W/cm²).

Figure 6: Pulp chamber temperature exposure versus time curves caused by irradiation using three different laser wavelengths at spot size = 1mm (226.35W/cm²).
Table 3: Mean temperature rise meanwhile irradiation

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Spot Size (mm)</th>
<th>Mean Temperature Rise (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5 Minute</td>
</tr>
<tr>
<td>Nd:YAG (SHG) 532</td>
<td>0.75</td>
<td>1.2</td>
</tr>
<tr>
<td>LD (CW) 810</td>
<td>0.75</td>
<td>1.4</td>
</tr>
<tr>
<td>Nd:YAG 1064</td>
<td>0.75</td>
<td>1.6</td>
</tr>
</tbody>
</table>

DISCUSSION

Tooth bleaching is the process of lightening the color of a tooth through the application of chemical agent to oxidize the organic pigmentation in the tooth, and when the process involve vital teeth it is known as vital bleaching. Almost without exception, all studies evaluating the micro hardness of bleaching enamel have reported that hardness of bleached enamel is similar to that of untreated enamel. However one study showed that 10% carbamide peroxide gel decreased enamel hardness to a depth of 25 µm below its surface (the gel had a pH of 5.3). While a similar material with a pH 7.2 had no effect on enamel hardness. This is agree with our study which showed there were insignificant different between the micro hardness before and after treatment by the three types of laser.

Generally, it should be noted that all bleaching activation modes mentioned may be accompanied by a temperature increase at the tooth surface, but also in the pulpal chamber. However, the bleaching gel usually applied may act as an isolator reducing intra-pulpal temperature increase as compared to activated bleaching performed without gel application. This means that laser activation (diode laser, 30 s, 3W, 830 nm) without the use of bleaching gel results in an intrapulpal temperature increase of about 16°C, whereas only an 8.7°C temperature increase was recorded when a gel was applied during activation.

Moreover, in an animal study it was proved that an intrapulpal increase in temperature of 5.5°C leads to irreversible pulp damage in 15% of the test animals (Macaca rhesus monkey). Even 60% of the animals showed irreversible pulp alterations in the treated teeth when the intrapulpal temperature increase amounted to 11.1°C, and in all examined teeth an irreversible necrotic response was observed when intra-pulpal temperature was elevated 16.6°C above normal level. Due to the results of these studies an intrapulpal temperature increase of 5.5°C is nowadays regarded as the threshold value, which should not be exceeded to avoid irreversible pulp damage.

In our study, according to the results obtained from the pulp chamber temperature measurements and within limitations of an in vitro investigation, it may be concluded that during laser activated tooth bleaching, with the three laser sources, the 1064nm promoted higher pulp chamber temperature rise than the 810nm, 532nm laser.

REFERENCES

3- Donald J. Peroxide interactions with hard tissues: Effects on surface hardness and surface/subsurface ultrastructural properties. Compendium / Special Issue 2002; 23: 1A.