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A Novel Er:YAG Laser-Assisted Tooth Whitening Method

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ABSTRACT

In this paper we describe a novel, erbium laser-assisted whitening method, TouchWhite™, which pertains to chemical strategies for removing tooth stains by means of laser-activated aqueous gels or pastes.

The TouchWhite™ method makes use of the fact that the Er:YAG laser wavelength has a water absorption peak in the vicinity of 3 μm. Since water is the major component of the aqueous bleaching gels, this eliminates the need for any additional absorbing particles in the bleaching gels. More importantly, taking into account thermal burden considerations, the TouchWhite™ procedure represents the most effective and least invasive laser-assisted tooth whitening method possible. Due to its high absorption in bleaching gels, the Er:YAG laser beam is fully absorbed in the gel and does not penetrate to the hard tissue or the pulp. All of the laser energy is thus effectively used for the heating of the gel. There is no direct heating of the dental tissue and the pulp, as is the case with other laser-assisted whitening methods. As a consequence, the procedure can be performed with a minimal undesirable thermal burden on the tooth, and the tooth whitening speed can be safely increased by 5 – 10 times.

Key words: teeth whitening; teeth bleaching; laser whitening; laser bleaching; Er:YAG; TouchWhite; dental lasers.

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I. INTRODUCTION

a) General

White teeth have long been considered cosmetically desirable. For this reason, methods have been introduced to whiten teeth that are naturally off-white or have become stained by smoking or food intake [1, 2]. Teeth whitening can be achieved in two ways: firstly, with gels, pastes or liquids (including toothpastes) that are mechanically agitated at the stained tooth surface in order to effect tooth stain removal through abrasive erosion of the stained acquired pellicle; and, secondly, with gels, pastes or liquids that accomplish the tooth bleaching effect by a chemical process while in contact with the stained tooth surface for a specified period of time, after which the formulation is removed [3].

Bleaching gels typically consist of water and at least one bleaching agent selected from the group consisting of hydrogen peroxide and compounds that release hydrogen peroxide (H_2O_2) in water. In addition, the gels contain some or all of the following compounds: a thickening agent (for example, polyacrylic acid); a stabilizing agent (for example, amino carboxylic acid/salt); and a neutralizing agent that serves to neutralize the thickening agent. Water is the principal component of the aqueous gel and is most commonly present in an amount of more than 50% by weight. The bleaching agent is present in an amount ranging from 3% to 50% (most commonly 35%) by weight of the aqueous gel.

In a typical treatment process, the dental bleaching gel is brought into contact with the teeth that are to be bleached. The dental bleach is then allowed to remain in contact with the teeth for a residence time ranging anywhere from 10 minutes to one hour. The bleaching effect depends on the duration of the residence time and on the rate of activation. The rate of activation of the gel can be increased by increasing the temperature. The use of high-intensity light for raising the temperature of hydrogen peroxide to accelerate the rate of chemical bleaching of teeth was first reported in 1918 by Abbot [4]. The heat and light serve to increase the rate of bleaching of the hydrogen peroxide, providing a shorter period of time in which whitening of the teeth is achieved [5-6]. Typical temperature increases (ΔT) that are desirable in such procedures are between 10 °C and 40 °C.

When laser light is used for the amplification of the bleaching effect, typically laser-absorption-enhancing particles are added to the gel. The particles are capable of absorbing the light energy from the wavelength of light emitted from the laser and of re-transmitting the light energy as thermal energy. These particles are dispersed throughout the bleaching compositions so that the laser beam can pass through the surface of the tooth while the particles absorb a portion of the light energy from the laser and retransmit it as thermal energy, thus increasing the effectiveness of the bleaching composition. For example, an argon ion laser utilizes a blue light with a wavelength in the range of 470 nm to 520 nm. The complementary color to blue is orange, and thus an orange or red-colored or pigmented particulate material that absorbs in this range would be suitable. Also preferred are other colors that absorb at the wavelength of the utilized laser light. For example, a black particulate material absorbs across all wavelengths and would thus also be suitable. Other typically used lasers for heat-enhanced teeth whitening are diode lasers with a wavelength of 810 nm or Nd:YAG lasers with a wavelength of 1064 nm [7-20].

Some of the disadvantages of the existing laser light enhancing methods are as follows [2]. A special bleaching gel that contains additional laser light absorbing particles must be used. A special laser device that emits at the absorbing wavelength of the enhancing particles must be used. Special care must be taken that the laser-enhancing particles are non-poisonous and biocompatible. It may be difficult to clean the teeth colored by the laser enhancing particles after the procedure. And most importantly, the density of the added absorbing particles is typically such that the laser light is not fully absorbed in the relatively thin layer of the gel that is deposited on the tooth surface. As a result, the laser is transmitted into the dental tissue. This can lead to an undesired heating of the whole tooth and of the dental pulp, possibly leading to pain and irreversible damage. Indeed, some of the treatment procedures recommend applying laser light to a tooth until the patient reports feeling pain.

b) TouchWhite™ – Er:YAG laser-assisted tooth whitening method

In this paper, we introduce a novel TouchWhite™ proprietary tooth-whitening method that avoids the above disadvantages of laser-assisted whitening [21, 22]. With the TouchWhite™ method, a water-containing bleaching agent applied to the teeth is heated by means of a pulsed Er:YAG laser beam that is strongly absorbed by water.

The TouchWhite™ method makes use of the fact that the Er:YAG laser wavelength is at the water absorption peak in the vicinity of 3 μm (See Fig. 1) [23].

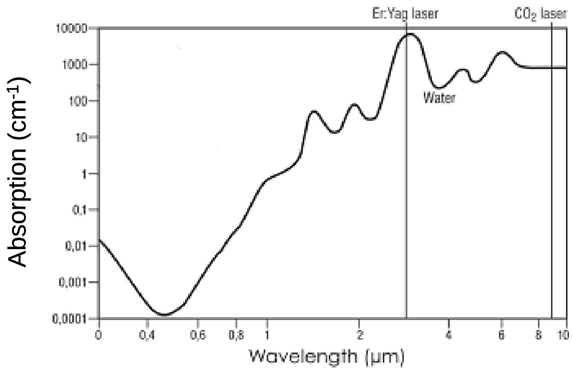

Fig. 1: Absorption spectra of water. The absorption is highest at 3 μm.

The laser parameters are adjusted for the bleaching treatments so that the laser fluence of every laser pulse is below 0.5 J/cm² which is significantly below the ablation threshold of dental tissues. Since the ablation threshold for enamel is in the range of 3.5 J/cm² [23] there is no risk of accidentally damaging the hard dental tissue.

The erbium laser-whitening method offers solutions to problems which are related to the use of laser sources for heat activation of a teeth whitening process. The use of the Er:YAG laser wavelength that is absorbed in the major component of the aqueous bleaching gel, i.e., in water, eliminates the need for any additional absorbing particles in the gel. Also, due to the high absorption in bleaching gels, the Er:YAG laser beam is absorbed already in the first 10-50 microns of the gel. Deeper gel layers are then heated up by means of heat diffusion away from the laser heated surface layer. The Er:YAG light does not penetrate through the gel and consequently does not directly heat the hard dental tissue or the pulp. All of the laser energy is thus effectively used for the direct heating of the gel.

II. MATERIALS AND METHODS

a) Measurement of the temperature dependence of the whitening rate

The degree of whitening, provided by the gel, increases with the time of contact between the reactive species of peroxide and the tooth enamel surface. The activation of the gel consists of the oxidation of available peroxide (H_2O_2) and/or its reactive species

(OH and O) [2]. Due to its chemical structure, the peroxide must produce transient species, such as OH and O, before the final products, H_2O and O_2 are generated.

The presence of the active transient species plays the most important role in the whitening process due to the high reactivity of the transient species.

The bleaching effect depends on the duration of the residence time and on the rate of activation, determined by the activation time T_a. In a simplified model, the gel activation process dynamics can be described by the following equation:

$$dP/dt = - P / T_a \qquad (1)$$

where P is the density of the available still un-oxidized hydrogen peroxide.

The rate of chemical reactions can be increased, and consequently the activation time T_a shortened, by increasing the temperature. The increased effectiveness and speed of the whitening process at higher temperatures is due to the faster generation and mobility of H_2O_2 in the peroxide gel, the decomposition of H_2O_2 to OH and O, the enhanced diffusion rate into the tooth as well as the enhanced reaction time between the active peroxide species (which can be radicals of OH or atomic oxygen O) and the compounds of the enamel and dentin.

Published measurements of temperature dependence for the gel activation time are lacking. It has been reported, however, that a 10 °C rise can double the rate of reaction [2]. In order to obtain a more precise dependence of the activation time on the gel temperature, we placed a thin layer of HiLite gel (manufactured by Shofu) that was freshly mixed according to manufacturer's instructions, on a temperature-stabilized metal surface. The whitening time $T_{w,}$ defined as the time the gel required to be completely activated, was then measured depending on the metal surface temperature. The HiLite gel contains a color indicator that changes color from green to white as the hydrogen peroxide is being activated. The whitening time T_w was thus obtained by observing the time when the freshly mixed gel changed its color from the initial green to completely white.

Note that the activation time T_a represents a theoretical time when the density of the un-oxidized peroxide falls below 1/e, i.e. when 37% of the peroxide has remained un-oxidized. If we make a somewhat arbitrary assumption that the HiLite gel stops changing color when 95% of the peroxide has been oxidized, the experimentally measured whitening time T_w measures the time when 95% of the peroxide has been oxidized. The approximate relation between the whitening time and the activation time is then $T_w \approx 3 \times T_a$.

b) Measurement of the gel whitening dynamics under laser irradiation

Measurements were made of the bleaching time and temperature evolution during and after exposure of a tooth to irradiation by three different lasers – a diode laser with a wavelength of 810 nm, an Nd:YAG laser with a wavelength of 1064nm, and an Er:YAG laser with a wavelength of 2940 nm (Fotona AT dental laser). The extracted human tooth was on the front surface covered by a freshly mixed gel (HiLite, Shofu), and illuminated by a laser beam. For all wavelengths, the laser spot size on the tooth surface was 7 mm. The temperature rise was measured with a FLIR ThermaCam P45 thermal camera (See Fig. 2). Thermal images were taken frontally and from the side. The gel whitening time, T_w, was obtained by observing the time when the HiLite gel changed its color from green to completely white.

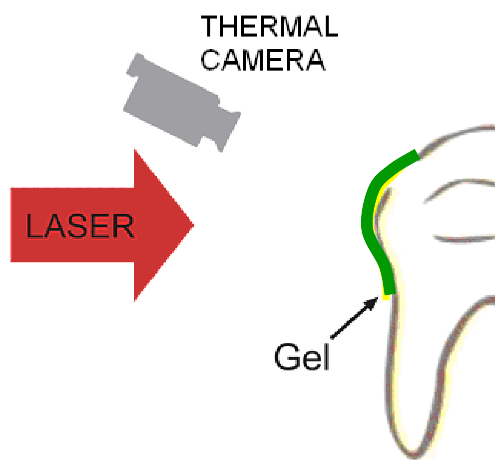

Fig. 2: Experimental set-up for measuring gel temperature dynamics during laser-assisted tooth whitening.

The following laser illumination modes were applied:

a) Er:YAG mode 1: 0.79W, 10Hz, pulse duration 700 µsec, 5 mm spot size; two 10-second illumination periods with a 30-second waiting time between periods. Total energy delivered: 15.8 J.

b) Er:YAG mode 2: 0.59W, 10Hz, pulse duration 700 µsec, 5 mm spot size; three 20-second illumination periods with 10-second waiting times between periods. Total energy delivered: 35.4 J.

c) Er:YAG mode 3: 0.59W, 10Hz, pulse duration 700

μsec, 5 mm spot size; one 60-second illumination period. Total energy delivered: 35.4 J.
d) Nd:YAG: 5.6 W, 60Hz, 5 mm spot size; three 10-second illumination periods with 15-second waiting times between the periods.
Total energy delivered: 168 J.
e) Diode laser (808 nm): 4.9W, 5 mm spot size; three 10-second illumination periods with 15-second waiting times between the periods.
Total energy delivered: 147 J.

c) Measurement of pulp temperature during Er:YAG laser-assisted whitening procedures

Pulpal changes caused by bleaching agents have been investigated by several authors [24-32]. Seale et al [29] found that histological damage to dog teeth from hydrogen peroxide used alone or with heat activation is reversible after 60 days. Robertson and Melfi have indicated that these pulpal alterations appear to be reversible [30]. In addition to the presence of a bleaching agent, temperature elevations during light assisted bleaching can also be critical for pulp tissue.

For measuring the pulp temperature during the bleaching procedure under laser activation by an Er:YAG laser, the root tip of an upper lateral incisivus was cut and the root channel was widened with Gates-drills of a size 1-3. After removal of all pulp tissue with a 3% NAOCl solution, a thermal conductance paste was injected in the root channel for better transmittance of temperature. The temperature measurement was made with a thermocouple that was placed within the pulp chamber and linked to a digital thermometer. Finally, the opening of trepanation was sealed with Ivoclar TetricFlow.

The tooth was embedded together with the thermocouple in a block of gyps (MoldanoBlau from Heareus Kulzer) in such a manner that only the crown and the cervix of the tooth extended out of the block

The radiation was produced by an Er:YAG laser with the R11 handpiece set to a 7 mm spot size. (Fotona Fidelis Plus III). Laser power was set to 1.2 W. The pulse duration was 700 μsec and the individual laser pulse fluence on the tooth was 0.4J/cm^2. This ensured that the laser fluence was below vaporization threshold of the enamel. Three sequences of laser irradiation were tested: a) 1x30 sec of illumination (total treatment time of 30 sec); b) 3x10 sec of illumination with 30 sec waiting time between the illumination periods (total treatment time of 90 sec); and c) 6 x 5 sec of illumination, with 15 sec waiting time between the illumination periods (total treatment time of 105 sec). The total delivered laser energy unto the tooth was 36 J for all three modes. For each sequence, the measurement was repeated ten times. During each measurement, the temperature was recorded for the duration of 200 sec from the onset of the first illumination period.

d) Clinical study of mode 1 Er:YAG laser-assisted whitening

In the first clinical study, we tested the mode 1 Er:YAG laser-assisted whitening procedure (10Hz, VLP pulse duration; two 10-second illumination periods with a 30-second waiting time between periods). Since a 7 mm instead of a 5 mm spot size was chosen, the laser power was increased to 1.2 W to compensate for the difference in laser power density. The delivered laser energy during each session was 36 J. The laser used was a Fotona Fidelis Plus III with the R11 handpiece.

The difference between laser activated and non-activated in-office bleaching was analyzed in a group of 27 patients in a "split-mouth" design. The patient population had to meet the following criteria: a) age 18 years or an informed consent by the parents; b) no extensive fillings on the labial surfaces of the tested teeth, no crowns in the frontal teeth area; c) sufficiently provided denture (sufficient fillings, no decays, good oral hygiene).

The patients were treated in two sessions separated by one week. During each session, the bleaching treatment was performed twice with a duration of 5 minutes with Er:YAG laser activation and 10 minutes without laser activation. In all four quadrants, the HiLite bleaching agent was applied starting on the middle incisors till the first premolar. The gel was mixed according to the manufacturer's instructions and applied with a small brush on the labial and buccal surfaces of the treated teeth with a thickness of 3 mm. Only the first and third quadrant was activated by the Er:YAG laser.

At the beginning of the first session, calculus was removed with a sonic scaler (type Cavitron® by KaVo, Germany). Afterward, coatings and discolorations were removed by Airflow (type Prophyflex®, KaVo). The colorimetry of all treated teeth was made with Easyshade®, a computer assisted colorimetric system.

The laser parameters were used as described above and each tooth was irradiated for 10 seconds. The radiation began at tooth 11, respectively 31, and ended at tooth 14, respectively 34. This procedure was repeated once after the radiation of tooth 14, respectively 34. So each tooth was radiated for 2 x 10 seconds with a pause of 30 seconds in each bleaching treatment. Five minutes after application, the laser-activated bleaching agent was removed with pallets of foam. The non-activated agent was removed after ten minutes. After the removal the procedure was repeated again.

e) Clinical study of mode 2 Er:YAG laser-assisted whitening

In the second clinical study, we tested the mode 2 Er:YAG laser-assisted whitening procedure (three 20-second illumination periods with 10-second waiting times between periods, laser power 0.59W, repetition rate 10-20 Hz). The Fotona Fidelis Plus Er:YAG laser with a R093 collimated handpiece set to a 5 mm spot size was used in the study. Five patients with 16 intrinsically stained teeth (12 vital and 4 non-vital) were treated with the Fotona teeth whitening gel (35% H_2O_2). Between one and three treatment sessions were made depending on the intensity of discoloration.

III. RESULTS

a) Temperature dependence of the gel whitening time

Figure 3 shows the measured dependence of the gel whitening time, T_w on the gel temperature. In agreement with previous reports, [2] the whitening time is reduced by approximately a factor of 2 when the gel temperature is raised from 30 ^{0}C to 40 ^{0}C. And when the temperature of the gel is raised from 30 ^{0}C to 70 ^{0}C the whitening time becomes approximately seven times shorter.

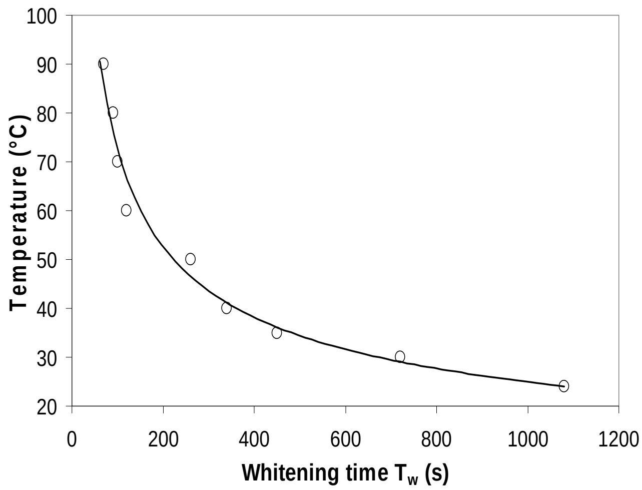

Fig. 3: Measured temperature dependence of the gel whitening time. The fitting line is represented by the function T_w = 1.057 x 10^6 /T $^{2.164}$, where T is the gel temperature in deg. C.

b) Whitening dynamics under laser illumination

Figure 4 shows the thermal image of the tooth during Er:YAG or diode laser illumination of the bleaching gel.

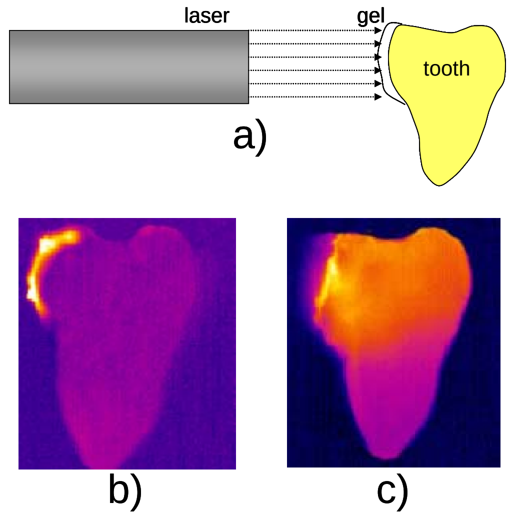

Fig. 4: Measurement set-up (a). Thermal image of the tooth during b) Er:YAG whitening, and c) diode whitening. The Er:YAG laser directly heats the gel only, while the diode laser directly heats the whole tooth.

Since the Er:YAG wavelength is fully absorbed in the gel, there is no direct heating of the underlying tooth. On the other hand, the diode wavelength is relatively weakly absorbed in the gel, and the transmitted light directly heats up the whole tooth. For this reason, the Er:YAG laser power is utilized more effectively, and the gel can be heated to higher temperatures, without compromising the safety of the tooth or of the pulp.

Figures 5 (a-e) show the measured evolution of the HiLite gel temperature during the following laser illumination modes: Er:YAG mode 1, Er:YAG mode 2, Er:YAG mode 3, Nd:YAG mode and diode laser mode (for details see section II b):

The measured whitening times corresponding to different laser activation modes are shown in Fig. 6.

The oxidation dynamics and the density of the available (still un-oxidized) hydrogen peroxide, P, during a whitening process can be obtained by integrating Eq. 1 as:

$$P(t) = 1 - \int_0^t P/T_a \, dt \qquad (2)$$

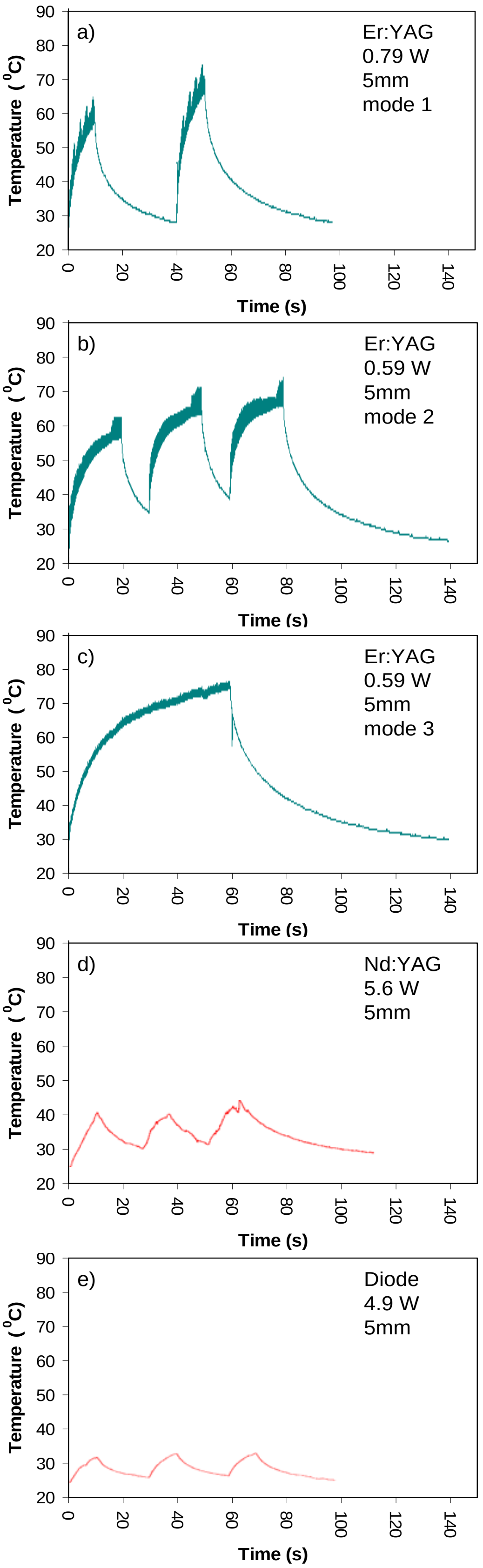

Fig. 5: Measured evolution of the bleaching gel temperature during and following laser activation for: a) Er:YAG mode 1, b) Er:YAG mode 2, c) Er:YAG mode 3, d) Nd:YAG mode and e) diode laser mode.

Under laser illumination the activation time T_a is not constant but gets shorter as the gel is heated up. Using the relation $T_a = T_w/3$, the temperature dependence of the gel activation time can be obtained from the measured temperature dependence of the whitening time (Fig. 3). Figure 7 shows the calculated oxidation dynamics, where the temperature changes during the whitening process were taken from the measurements shown in Fig 5. The calculated whitening times are in good agreement with the measured values shown in Fig. 6.

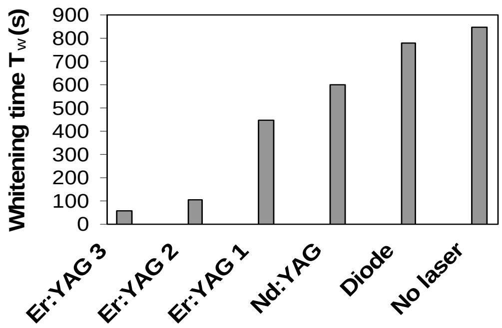

Fig. 6: Measured whitening times of the HiLite gel for different modes of laser activation. The whitening time in the absence of laser illumination is also shown.

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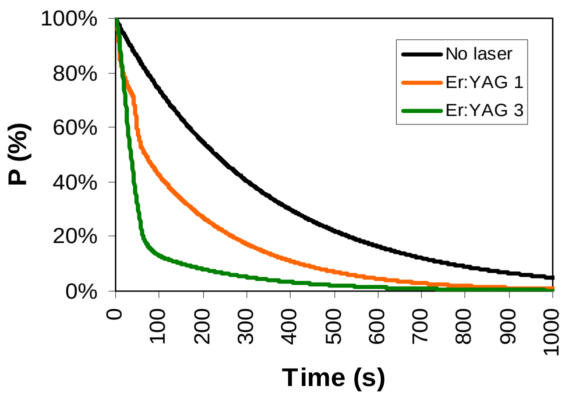

Fig. 7: Calculated reduction of hydrogen peroxide during the whitening process under Er:YAG laser illumination using modes 1 and 3 (see Fig. 5), and without laser activation.

c) Pulp temperature increase during Er:YAG laser-assisted whitening procedures

Table 1 shows the measured maximum temperature increase in the pulp chamber for the three tested illumination sequences and for two types of gel: HiLite and Fotona gel.

Table 1: Maximal temperature rise in the pulp chamber for the three chosen sequences of irradiation.

		Irradiation Sequence		
Gel Type		**1 x 30 s**	**3 x 10 s**	**6 x 5 s**
HiLite	ΔT_{max} (at 35J)	2.6 K	2.15K	1.82K
HiLite	ΔT_{max} /Energy	0.072 K/J	0.060 K/J	0.051 K/J
Fotona	ΔT_{max} (at 35J)	1.95 K	1.86 K	1.51 K
Fotona	ΔT_{max} /Energy	0.056 K/J	0.053 K/J	0.043 K/J

Our measurements show that for short, 30 s Er:YAG laser irradiation times the temperature increase depends on the delivered cumulative laser energy as ΔT_{max}/Energy = 0.072 K/J for HiLite gel, and 0.056 K/J for the Fotona whitening gel. For longer irradiation times, the temperature increase becomes even smaller. Since for all three proposed modes of Er:YAG laser-assisted whitening the deposited laser energy is below 36 J, and the total activation times are longer than 30 s, the expected maximal pulpal temperature increase during Er:YAG laser-assisted whitening is at least two times below the critical threshold of 5.6 ^{0}C.

d) Mode 1 Er:YAG assisted whitening

As expected from our previous measurements and calculations for the mode 1 Er:YAG laser-assisted whitening procedure (See Figs. 6 and 7), a complete change of the initial green color of the freshly mixed bleaching agent into white was observed after 5 minutes for the laser-activated gel, and after 10 minutes for the non-activated gel.

No subjective or objective difference in the whitening effect was observed between the activated and non-activated quadrants after both bleaching sessions.

No difference was observed also in the reported pain following the treatments. When patients were asked about spontaneous pains after a bleaching session, 12 patients reported spontaneous pain on laser-activated teeth, and equal number of patients (12) reported spontaneous pain on non-activated teeth (control group). In both cases, the pain ended 1.5 days after a bleaching session, showing therefore no difference between the laser and the control group. Similarly, there was no difference in hypersensitivity. Feelings of hypersensitivity after bleaching were reported by 8 patients on laser-activated teeth and by 8 patients on non-activated teeth.

The study shows that using the mode 1 Er:YAG laser-assisted whitening procedure, the treatment time can be safely reduced by a factor of two.

e) Mode 2 Er:YAG laser-assisted whitening

Results of the clinical study of the mode 2 Er:YAG assisted whitening procedure are shown in Table 2 below.

Table 2: Summary of the clinical results for the mode 2 Er:YAG laser-assisted tooth whitening. Tx is an abbreviation for "treatment".

Patient	Tooth	Tooth vitality before Tx	Color before	Color after	No. of Tx	Gel Type	Tooth sensitivity after Tx
No.1	1.1	Non-vital	**D4**	**D2**	3	Fotona 1	No
No.2	1.1	Non-vital	**D4**	**D2**	2	Fotona 2	No
No.3	2.2	Non-vital	**C4**	**D2**	2	Fotona 2	No
No.4	1.1-1.4 2.1-2.3 3.1-3.3 4.1-4.3	Vital	**A3 A3 A3**	**A1 A1 A1**	2	Fotona 2	Yes (sensitivity passed after one week)
No.5	1.1	Non-vital	**A4**	**A2**	1	Fotona 2	No

As an example, Fig. 8 shows pre-, during and post-treatment photos for patient No. 4.

The results confirm that the Er:YAG laser applied in mode 2 can be safely and effectively used for teeth whitening of vital and non-vital tooth discoloration. None of the patients felt any heating of their teeth or pain during the treatment. Only one patient developed a temporary hypersensitivity after the bleaching, however, we attribute this sensitivity to the gel activity itself. Since this study we have performed the TouchWhite™ tooth bleaching procedure on more than 40 patients (results to be reported elsewhere). According to the personal experience of the investigator (J. Jovanović) with the diode and Nd:YAG bleaching, the Er:YAG laser bleaching was found to be more comfortable for the patients while achieving the same or better whitening efficacy.

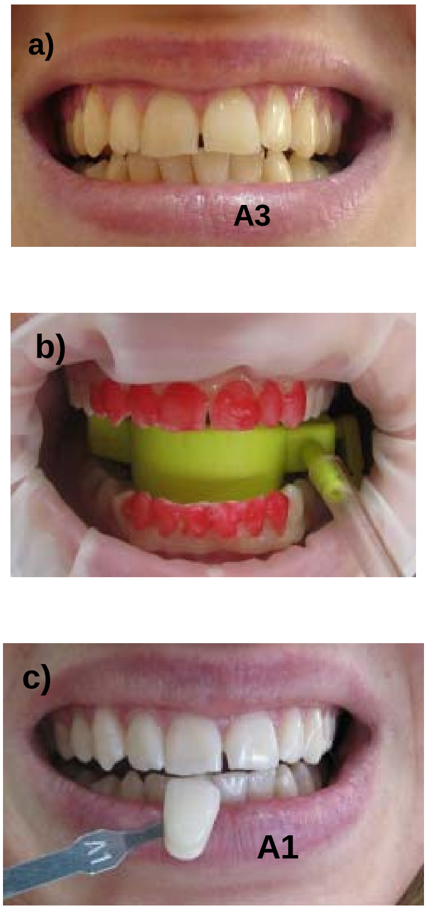

Fig. 8: Before (a), during (b) and after (c) the Er:YAG laser-assisted whitening treatment (patient 4).

IV. DISCUSSION

a) General

Zach and Cohen reported irreversible pulpal damage in 15% of rhesus monkeys for temperature increase elevations of 5.6 ^{0}C, in 60% of monkeys from temperature elevations of 11 ^{0}C, and in 100% of monkeys for temperature elevations of 16.6 ^{0}C [31]. Even though their experimental setting was different from this study, their results can be suggested as a baseline for potential histopatological changes in pulpal tissues when the temperature rise exceeds 5.6 ^{0}C. The total duration of the temperature increase is also important. Erickson et al stated that 42 ^{0}C was a critical temperature when maintained for 1 minute [32].

Our measurements show that for 35 J of delivered Er:YAG laser energy during a treatment time of 30 s the maximal temperature increase in the pulp chamber is below 2.6 ^{0}C. And for longer treatment times, the temperature increase is even smaller. For the studied Er:YAG laser cumulative energy of 35 J, the temperature increase in the intra-pulpal chamber is thus below the 5.6 ^{0}C that is thought to cause an irreversible damage to the pulp.

Measurements with the diode (810 nm) and the Nd:YAG (1,064 nm) laser (that are typically used for heat-enhanced teeth whitening) show that, in order to achieve the same reduction of the whitening time as with an Er:YAG laser, much larger cumulative energies are required. For example, in order to achieve the same temperature increase of 40 °C of the HiLite gel as with the 35 J of Er:YAG laser light, a cumulative energy of approximately 450 J of the Nd:YAG laser light and 840 J of the diode laser light would have to be applied. This is more than ten times higher, and in the case of a diode even more than twenty times higher compared to the treatment with an Er:YAG laser. This is due to the fact that these laser wavelengths are not fully absorbed in the bleaching gel but are transmitted into the tooth. Therefore, energy is wasted for undesirable and potentially painful and/or damaging heating of the tooth and the pulp.

b) Clinical guidelines for the TouchWhite™ whitening procedure

Based on the results of this study we introduce the following Fotona's proprietary Er:YAG laser-assisted tooth whitening procedure, TouchWhite™:

Fotona whitening gel
Pulse duration: VLP
Pulse energy: 40 mJ
Pulse repetition rate: 10 – 15 Hz
Power: 0.4-0.6 W
Handpiece: i) Handpiece R09 (available on laser system models Fidelis AT, Fidelis HT, LightWalker ST and LightWalker DT); ii) R16 (available on laser system model LightWalker AT). See Fig. 9.

Fig. 9: Fotona R09 collimated Er:YAG whitening handpiece.

For the shortest whitening time (< 80 s) the following activation mode is recommended: one 60-second illumination period.

For moderate whitening speeds (whitening time < 150 s) the following activation sequence is recommended: three 20-second illumination periods with 10-second waiting times between periods.

V. CONCLUSIONS

Our in-vitro measurements and clinical studies show that with the TouchWhite™ method the whitening treatment times can be safely shortened to 1–2 minutes, down from 10–15 minutes when no laser activation is applied. The method is effective and safe, as confirmed by our measurements of the temperature in the pulpal chamber.

The use of the Er:YAG laser wavelength, which is strongly absorbed in the major component of the aqueous bleaching gel, i.e., in water, eliminates the need for any additional absorbing particles in the gel. Due to the high absorption in the bleaching gel, the Er:YAG laser beam is fully absorbed in the gel. The Er:YAG light does not penetrate through the gel and consequently does not directly heat the hard dental tissue or the pulp. All the laser energy is thus effectively used for the direct heating of the gel. The TouchWhite™ procedure thus represents the most effective and least invasive laser-assisted tooth whitening method possible.

It is also important to note that for the TouchWhite™ treatments the laser parameters are adjusted so that the laser fluence of every laser pulse is significantly below the ablation threshold for dental tissues. There is therefore no risk of accidentally damaging the hard dental tissue.

Overall, an efficient heating of the bleaching gel and thus an efficient teeth whitening method has been introduced that overcomes the drawbacks of the previous laser-assisted whitening methods. An additional advantage is that the Er:YAG laser is becoming a standard laser tool in dental practices for treating hard and soft dental tissues. Adding another application for use (i.e., teeth whitening) for this laser is beneficial to dentists as they do not have to acquire an additional special laser to be used only for teeth whitening.

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