Effect of Different Laser Wavelengths on Temperature Changes During Tooth Bleaching

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Abstract: The aim of this study was to evaluate the thermal effects of different light sources used for in-office bleaching by simulating intraoral conditions and measuring temperature changes within the pulp chamber. Thirty recently extracted human teeth were used in this experimental study. The roots were sectioned approximately 2 mm below the cementoenamel junction (CEJ), and a K-type thermocouple was inserted into the pulp chamber through the root canal access to record temperature variations. Each tooth was exposed to four different light sources: Nd:YAG laser (1064 nm; 200 mJ, 5 Hz, 30 s), KTP laser (532 nm; 200 mJ, 5 Hz, 30 s), diode laser (810 nm; 10 Hz, 100 ms, 30 s), and diode laser (980 nm; 10 Hz, 100 ms, 30 s). The temperature changes were recorded during irradiation and statistically analyzed. The highest temperature increase was observed with the 980 nm diode laser (1.8 °C), followed by the Nd:YAG laser at 1064 nm (1.7 °C), diode laser at 810 nm (1.07 °C), and KTP laser at 532 nm (0.37 °C). Although significant differences were observed among the tested groups, all temperature increases remained below the critical threshold of 5.6 °C associated with irreversible pulpal damage. These findings indicate that the investigated laser systems can be considered thermally safe for in-office bleaching procedures under the applied experimental conditions. However, appropriate selection of laser parameters is essential to minimize thermal stress on dental tissues.

1 INTRODUCTION

Due to increased demand for brighter teeth which have long been seen as aesthetically pleasing tooth whitening procedures have gained popularity in dentistry over the past few decades. Although there have been concerns about the safety of tooth bleaching procedures in the past, numerous studies have shown that any possible negative effects on dental tissues are negligible, quickly reversible, and therefore not clinically significant [1]. Additionally Tooth whitening is a conservative dentistry technique that can be done to brighten stained teeth at home, in-office, or under the supervision of a dentist using over-the-counter (OTC) medications and night guard bleaching [2], [3]. Hydrogen peroxide (25–38%) is typically selected due to the benefits of a shorter overall treatment duration [4] and a higher possibility for quick outcomes that could improve patient satisfaction and motivation. Additionally, the dentist's control prevents soft tissue exposure [5]. As a result, the patient appreciates the in-office bleaching procedure that uses light sources to achieve faster outcomes than the other two bleaching methods [6], [7]. Elevated levels of hydrogen peroxide and active carbamide peroxide, which can generate superoxide Clinical teeth-whitening methods usually start with the breakdown of $\bullet O_2^-$ and •OH radicals. Staining macromolecules are transformed into light compounds by these radicals, which also break the conjugated double bonds of organic pigment molecules [8]. The bleaching mechanism is the breakdown of hydrogen peroxide into free radicals that react with chromogens consisting of colorful dual-bond molecules and/or metallic compounds [9], [10]. This type of chromogen builds up on the tooth (extrinsic) or inside the tooth (intrinsic) [10]. Tooth bleaching results from the colorless chemical structures that are created during the reaction [11]. Theoretically, light sources can boost the bleaching process's chemical reaction rate by generating heat [12] or improve the bleaching materials' effectiveness by activating photocatalysts with light [12], [13]. and, as a result, to shorten the bleaching procedure. Suyama and associates [14] Recent research has shown that light-activated bleaching greatly improves the hydrogen peroxide reaction kinetics, especially when photocatalysts are used. [15]. Photocatalysts and exposure to bright light or laser radiation also resulted in higher bleaching effects and a higher temperature rise [16], [17]. The bleaching impact is influenced by numerous elements, such as temperature, photocatalyst, pH, light or energy sources, hydrogen peroxide content, and the number of bleaching cycles [18], [19]. In-office bleaching necessitates direct clinician supervision to prevent soft tissue injuries and gel ingestion, reducing treatment time and yielding faster results in terms of bleaching efficacy, even though using gels with high concentrations of hydrogen or carbamide peroxide can cause hypersensitivity during and after the procedure. Dental sensitivity, which affects 8% to 66% of patients and usually produces significant discomfort in the early stages of therapy, is the most detrimental side effect of teeth bleaching [20]. When the temperature rises, the pulp responds by increasing blood flow. The pulp chamber's temperature rise brought on by heat is lessened by blood flow. The temperature rise decreases with increasing flow rate. As a result, the pulp has its own defense system against rising temperatures. Consequently, the blood flow should not be disregarded [21]. By lowering the pulp's temperature rise by up to 30%, the bleaching agent provides protection in this situation [22]. As tooth whitening methods have developed, cutting-edge technology has been used to maximize clinical outcomes. In particular, applying different laser sources has emerged as a popular method for bleaching agent activation. The following list of the most popular lasers for this activation is arranged according to their particular wavelengths:

- KTP laser with (wavelength 532 nm);
- Diode laser with (wavelength 810 nm);
- Diode laser with (wavelength 980 nm);
- Nd-YAG laser with (wavelength 1064 nm).

In addition to application of bleaching gel only.

Photodynamic bleaching with the KTP (potassium-titanyl-phosphate) laser, which generates visible green light at a wavelength of 532 nm, is useful for correcting discoloration brought on by dental sclerosis from age without having an adverse effect on the oral soft tissues, dental pulp, or tooth structure [23]. Similarly, the monochromatic nature of diode lasers would lower the possibility of pulpal injury from overheating [24]. It is necessary to look at the risks connected to the increasing usage of lasers in dentistry. Finding laser settings where the pulp's temperature rises by less than 5.6 °C is the aim of this study. Temperature increases of ≥5.6 °C produce irreversible pulpitis [21].

2 MATERIALS AND METHODS

2.1 Specimen Preparation

The samples first cleaned using an appropriate brushed and polished, and then they were kept in distilled water until needed. Each tooth's root was cut off by two to three millimeters. The apical aperture of the root canal was then mechanically enlarged using a high speed turbine hand piece, this mechanical component was accompanied by a continuous flow of water spray integrated into the tool, this was done to provide the necessary cooling and prevent any thermal or mechanical damage to the tooth. The pulp tissue that remained in the canal was removed, and thermal conductivity compound (thermal paste) was used to fill the empty pulp chamber as a heat-conducting medium in place of the pulp tissue (Fig. 3).

Secondly, after applying the heat compound to The Type K thermocouple, the probe was inserted via the apical foramen into the coronal pulp chamber until resistance was felt.

Thirdly, the distance of 3 cm between the laser point and the bleaching gel surface was maintained. In order to determine the heating rate, the thermal sensors continued to record temperature changes for 30 seconds following laser irradiation. Every ten seconds, the thermal sensors' immediate temperature values were captured. To ensure a consistent comparison across the different laser systems, each group's spot size was fixed at 3 mm.

2.2 Laser Irradiation

As seen below, in addition to the gel alone, four different kinds of lasers are employed to expedite the bleaching process. The types of lasers and the conditions that are used to initiate the teeth-whitening process are described in this section.

1) KTP laser (SHG) (532nm);
2) Diode Laser (810nm);
3) Diode Laser (980nm);
4) Nd:YAG laser (1064nm);
5) Control group (Gel only) The conditions of the lasers that used in this activation are shown in Table 1.

Table 1: The condition of lasers.

Items	KTP Laser (SHG)	Diode laser	Diode laser	Nd:YAG Laser
Wavelengt (nm)	532	810	980	1064
Spot size (mm)	3	3	3	3
Output power(w)	1	1	1	1
Exposure Time(s)	30	30	30	30
Mode	Pulse (200mJ x 5Hz)	Pulse (10Hz x100ms)	Pulse (10Hz x100ms)	Pulse (200mJ x 5Hz)
Fluence Cm^2/J	424.32	424.32	424.32	424.32
Distance between laser and sample (cm)	3	3	3	3

Table 2: Temperature rise meanwhile irradiation.

Laser Source	T(initial) (°C)	30s (peak Temp) (°C)	Mean Temp. Rise (ΔT)(°C)	(SD)	2min(post-laser)
KTP (532 nm)	37.0	37.37	0.37	0.15	37.1
Diode (810 nm)	37.0	38.07	1.07	0.12	37.3
Diode (980 nm)	37.0	38.8	1.8	0.3	37.6
Nd:YAG (1064nm)	37.0	38.7	1.7	0.35	37.4
Control (Gel without laser)	37.0	37.04	0.04	0.02	37.0

2.3 The Pulp Chamber Measurements

Temperature Through the cut root area, a thin K-type thermocouple was placed inside the pulp chamber. The thermocouple was positioned at the pulp chamber's maximum coronal level. During the test, the tooth's root surfaces were partially immersed in a water bath at 37 °C. As seen in Figure 1, this technique successfully maintained the internal baseline temperature at 37°C, reducing the impact of variations in the surrounding air temperature and providing a constant starting temperature for every data set.

2.4 Statistical Analysis

To evaluate the differences in temperature changes among the four laser wavelength groups, a one-way analysis of variance (ANOVA) was performed, followed by Tukey's post-hoc test for pairwise comparisons. Statistical significance was set at $P < 0.05$. The analysis revealed statistically significant differences in temperature changes across the evaluated laser groups ($P < 0.05$), with all values remaining well below the critical biological threshold of 5.6°C.

3 RESULTS AND DISCUSSION

Four different light sources, the pulp chamber's temperature increased. Along with the control group in the spot size (3 mm), it was found that the average temperature increase was a function of exposure time to four distinct wavelengths. During the course of the treatment, there was an increase in temperature; the diode laser (980 nm) recorded the largest temperature rise, while the SHG Nd:YAG laser (532 nm) recorded the lowest. As for the control group, the increase in core temperature was very slight and almost negligible, as shown in the Table 2.

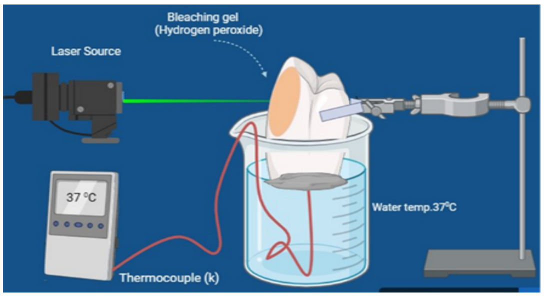

Figure 1: Schematic of pulp chamber temperature monitoring during laser bleaching.

The study's findings demonstrate that the greatest rise in tooth root temperature brought on by laser application in four conditions (as illustrated in the device setups in Fig. 2) was (1.8 °C) for 980 nm, followed (1.7 °C) for1064 nm, (1.07 °C) for 810 nm and (0.37 °C) for 532 nm, each of them measured at 30 s after starting emission of the laser (Fig. 4).

Figure 2: Diode laser, Nd:YaG laser.

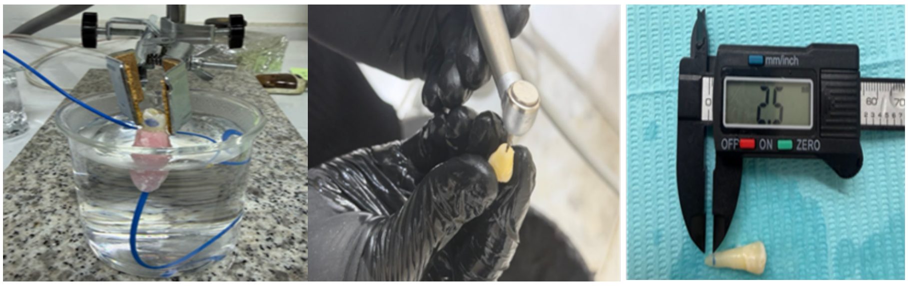

Figure 3: Sample preparation: a) Measure 2-3 mm, b)the root canal expansion, c) Temperature measurement setup.

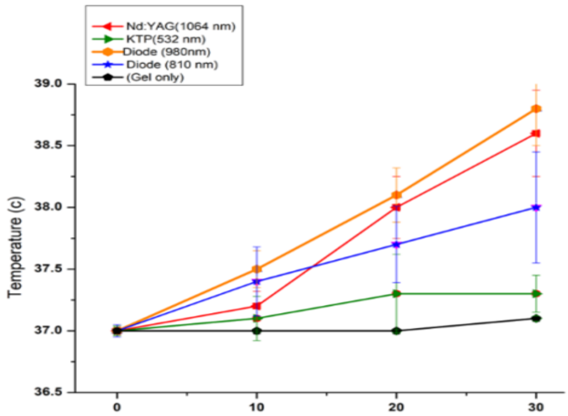

Figure 4: Rise in pulp temperature during a 30-second trial in five distinct conditions.

Zach and Cohen demonstrated that an increase in pulpal temperature of ≥5.6 °C may result in irreversible pulp injury, including pulpal necrosis [25]. Therefore, thermal safety represents one of the most important considerations when applying lasers for dental whitening procedures. In the present study, the maximum recorded temperature increase was 1.8 °C, which is considerably below the critical threshold and remains within the accepted biological safety range. These findings indicate that the applied Nd:YAG and diode laser systems, when used with the recommended whitening gel, do not pose a risk of thermal damage to the pulp tissue.

The wavelength of the laser significantly influenced the generated temperature. The 980 nm diode laser and Nd:YAG laser showed the highest temperature increases, which may be attributed to their deeper penetration ability and greater absorption by dental tissues and/or pigment components of the whitening gel, resulting in more efficient conversion of optical energy into thermal energy. However, despite producing the highest temperature values among the tested groups, the 980 nm diode laser remained far below the level associated with pulpal injury, suggesting its suitability for clinical whitening applications where faster bleaching effects are desired.

Furthermore, the control group exhibited only a minimal temperature increase (0.04 °C), despite prolonged exposure of the whitening agent without laser activation. This indicates that the chemical reaction of the bleaching agent alone contributes negligibly to heat generation and that the temperature changes observed in the laser-treated groups are primarily related to laser energy absorption. Overall, the findings confirm that the investigated laser-assisted whitening protocols provide effective activation of the bleaching process while maintaining thermal safety for the dental pulp.

4 CONCLUSIONS

The present study evaluated the thermal effects of different laser wavelengths used for dental bleaching activation by monitoring temperature changes inside the pulp chamber. The results demonstrated that all tested laser systems produced temperature increases significantly below the critical threshold of 5.6 °C associated with irreversible pulpal damage. Therefore, the investigated laser-assisted bleaching protocols can be considered thermally safe under the applied experimental conditions.

The magnitude of temperature elevation was influenced by the laser wavelength. The 980 nm diode laser produced the highest temperature increase (1.8 °C), followed closely by the Nd:YAG laser at 1064 nm (1.7 °C), whereas the KTP laser (532 nm) showed the lowest thermal effect (0.37 °C). Despite the higher heat generation observed with the 980 nm diode and 1064 nm Nd:YAG lasers, their temperature changes remained within biologically acceptable limits, indicating no expected risk of thermal injury to the pulp tissue.

The minimal temperature change observed in the control group confirms that the heat generated during laser-assisted bleaching is mainly related to laser energy absorption rather than the chemical reaction of the bleaching gel alone. Overall, the findings suggest that laser activation can enhance the bleaching process while maintaining pulp safety, provided that appropriate laser parameters, including wavelength, power, and exposure time, are carefully controlled.

Further clinical studies are recommended to evaluate the relationship between thermal effects, bleaching efficiency, and long-term pulpal responses under in vivo conditions.

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