

# Comparison of the Effectiveness of Bleaching Treatment with Activation Using Polywave LED Light, Diode Laser and Er, Cr:YSGG Laser: An *in Vitro* Study

## Polywave LED Işığ, Diyet Lazer ve Er, Cr:YSGG Lazer Kullanılarak Aktivasyon ile Ağartma Tedavisinin Etkinliğinin Karşılaştırılması: Bir *in Vitro* Çalışma

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### ABSTRACT

**Objective:** This study aimed to evaluate the efficacy of non-vital bleaching treatments activated by laser systems and polywave LED light.

**Methods:** Forty-eight extracted maxillary incisors were artificially stained using sheep blood and then the initial colour values of the stained teeth were measured and recorded with a spectrophotometer. The teeth were randomly assigned to four groups (n = 12 per group): Group 1 (control) received 30-minute non-vital bleaching treatments with 35% hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>); Group 2 received 35% H<sub>2</sub>O<sub>2</sub> with a diode laser (940 nm); Group 3 received 35% H<sub>2</sub>O<sub>2</sub> with an Er,Cr YSGG laser (2780 nm); and Group 4 received 35% H<sub>2</sub>O<sub>2</sub> with polywave LED light (480 nm). Spectrophotometric evaluation of color change ( $\Delta E_{00}$ ) was performed on days 1, 3, and 7 post-treatment.

**Results:** Intergroup comparisons showed significantly lower  $\Delta E_{00}$  values in Group 1 (control) and Group 4 (H<sub>2</sub>O<sub>2</sub> + polywave LED light) compared to Groups 2 (H<sub>2</sub>O<sub>2</sub> + diode laser) and 3 (H<sub>2</sub>O<sub>2</sub> + Er,CrYSGG laser) across all time points ( $P < .05$ ). No significant difference in  $\Delta E_{00}$  was observed between Groups 2 and 3 at any time point ( $P > .05$ ).

**Conclusion:** Both the diode laser and Er,CrYSGG laser significantly enhanced the efficacy of non-vital bleaching. Although polywave LED light achieved adequate bleaching results, its activation was less effective than that of laser systems.

**Keywords:** Color change, laser, LED, spectrophotometric analysis, teeth bleaching, nonvital

### Öz

**Amaç:** Bu *in vitro* çalışmanın amacı, lazer ve polywave LED ışığı ile aktive edilen non-vital beyazlatma tedavilerinin etkinliğini değerlendirmektir.

**Yöntemler:** Kırk sekiz adet çekilmiş maksiller kesici diş koyun kanı kullanılarak yapay olarak renklendirilmiş ve daha sonra renklenmiş dişlerin ilk renk değerleri spektrofotometre ile ölçülmüş ve kaydedilmiştir. Dişler rastgele dört gruba ayrılmıştır (n = 12): Grup 1'e (kontrol) %35 hidrojen peroksit (H<sub>2</sub>O<sub>2</sub>) ile 30 dakikalık vital olmayan beyazlatma uygulanmıştır; Grup 2'ye diyet lazer (940 nm) ile %35 H<sub>2</sub>O<sub>2</sub> uygulanmıştır; Grup 3'e Er,CrYSGG lazer (2780 nm) ile %35 H<sub>2</sub>O<sub>2</sub>; ve Grup 4'e polywave LED ışık (480 nm) ile %35 H<sub>2</sub>O<sub>2</sub> verilmiştir. Renk değişiminin ( $\Delta E_{00}$ ) spektrofotometrik değerlendirilmesi tedavi sonrası 1, 3 ve 7. günlerde yapılmıştır.

**Bulgular:** Gruplar arası karşılaştırmalar, tüm zaman noktalarında Grup 2 (H<sub>2</sub>O<sub>2</sub> + diyet lazer) ve Grup 3 (H<sub>2</sub>O<sub>2</sub> + Er,CrYSGG lazer) ile karşılaştırıldığında Grup 1 (kontrol) ve Grup 4'te (H<sub>2</sub>O<sub>2</sub> + polidalgı LED) önemli ölçüde daha düşük  $\Delta E_{00}$  değerleri göstermiştir ( $P < .05$ ). Grup 2 ve 3 arasında hiçbir zaman noktasında  $\Delta E_{00}$  açısından anlamlı bir fark gözlenmemiştir ( $P > .05$ ).

**Sonuç:** Hem diyet lazer hem de Er,CrYSGG lazer non-vital beyazlatmanın etkinliğini önemli ölçüde artırmıştır. Polywave LED ışığı yeterli ağartma sonuçları elde etmesine rağmen, aktivasyonu lazer tedavilerinden daha az etkili olmuştur.

**Anahtar Kelimeler:** Renk değişimi, lazer, LED, spektrofotometrik analiz, diş beyazlatma, nonvital

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## INTRODUCTION

Intrinsic discoloration is often observed in non-vital teeth for various reasons following endodontic treatment. Contributing factors include pulp damage, infection within the pulp cavity, residual pulp tissue, and materials used in root canal fillings.<sup>1</sup> These internal discolorations can cause significant aesthetic concerns for patients.<sup>2</sup> Non-vital bleaching, a minimally invasive and low-cost treatment, is commonly used to eliminate the discoloration in non-vital teeth.<sup>3</sup> While bleaching treatments for vital teeth can be performed either in-office by a dentist or at home by the patient, non-vital bleaching treatments must be administered by a dentist.<sup>4</sup>

In-office bleaching procedures for vital teeth typically involve the use of high-concentration bleaching agents, such as 25–40% H<sub>2</sub>O<sub>2</sub> or 35–38% carbamide peroxide, due to their short-term application. In contrast, low-concentration bleaching agents are preferred for at-home treatments that require longer durations.<sup>5</sup> For non-vital, root canal-treated teeth, H<sub>2</sub>O<sub>2</sub> or sodium perborate is commonly utilized. These agents may be applied either individually or in combination.<sup>6</sup> Research indicates that increasing the concentration of the bleaching agent, as well as extending the application time, enhances the bleaching effect and leads to more noticeable color changes. Furthermore, the energy from a light source absorbed by the bleaching gel is converted into heat, which accelerates the decomposition of H<sub>2</sub>O<sub>2</sub>, thereby amplifying the bleaching effect.<sup>7</sup>

To enhance the efficacy of bleaching agents through the application of heat, dental bleaching treatments have increasingly incorporated light-curing and laser systems.<sup>8</sup> Theoretically, the activation of H<sub>2</sub>O<sub>2</sub> by light or laser systems a significant benefit: the heat produced during activation promotes the formation of oxygen free radicals and accelerates the decomposition of oxygen. However, excessive heat application can damage the structural integrity of the tooth and increase tooth sensitivity.<sup>9</sup> As a result, light or laser-activated H<sub>2</sub>O<sub>2</sub> is suggested to improve the overall bleaching effectiveness.<sup>10,11</sup> Additionally, this method provides a substantial advantage by achieving desired outcomes more quickly, thus reducing the amount of time the patient spends in the dental office.<sup>12</sup>

The application of lasers in clinical practices, such as tooth bleaching, can lead to more efficient and comfortable treatments.<sup>13</sup> Historically, lasers have been utilized in various dental procedures and are now also incorporated into bleaching protocols.<sup>14</sup> Dental lasers emit a monochromatic wavelength, which results in less thermal stress on the pulp compared to other light sources.<sup>10</sup> The effectiveness of these lasers in tooth whitening varies based on specific parameters, including wavelength and power.<sup>15</sup> Diode lasers operating within the 810–980 nm wavelength range exhibit significant absorption in pigmented tissues, whereas their absorption in water and minerals is comparatively low. Elevated temperatures can potentially harm the dental pulp.<sup>9</sup> Among the available laser types, Erbium lasers are characterized by their high absorption coefficients for water.<sup>16</sup> Specifically, the Er,Cr:YSGG laser demonstrates superior water absorption, albeit with limited penetration depth in dental hard tissues, thereby mitigating the risk of pulp damage. This feature is particularly significant when tooth hard tissues interact with aqueous bleaching gels during treatment.<sup>17</sup>

Light-emitting diode (LED) light curing devices generate lower energy output compared to laser systems, and they are generally more cost-effective.<sup>18</sup> The LED systems utilized in bleaching procedures fall under the category of broadband light sources, emitting light primarily in the blue spectrum, without extending significantly into the

infrared (IR) range, unlike quartz-tungsten-hybrid (QTH) or plasma arc systems.<sup>10</sup>

This in vitro study aims to assess the effectiveness of non-vital bleaching treatments for endodontically treated teeth using two distinct laser systems (Er,Cr:YSGG and Diode laser) alongside a Polywave LED light. The uniqueness of this research is the evaluation of the efficacy of a Polywave LED light for intracoronal bleaching of non-vital teeth in comparison with two different laser systems, a subject that, to the best of knowledge, has not been previously explored. Prior to conducting the study, a null hypothesis (H01) was established, postulating that the bleaching efficacy of the Polywave LED light curing would not significantly differ from that of the laser systems.

## METHODS

The study was approved by the Research Ethics committee at Afyonkarahisar University (2021/221, date: April 2, 2021). The sample size for the study was determined using the G\*Power software (Version 3.0.10, Franz Faul, Germany) with 80% statistical power, a 0.05 significance level, and an effect size of 0.5 (medium).<sup>19</sup>

### Preparation of Samples

Forty-eight adult incisors from the maxilla that had been collected within six months. Informed consent was obtained in writing from patients over the age of 18. Teeth were checked under a stereo microscope with a rise of 4× (Euromex, New York, USA). Decayed, deformed and broken teeth were identified and replaced with new ones. The selected teeth were disinfected with chloramine-T solution and then kept in distilled water. Normal oval coronal access to the root canals was achieved and the thickness of the buccal wall of the teeth was reduced with a carbide bur. Buccal wall thickness was standardized to 2.6±0.3. Endodontic access cavities were prepared in the teeth. After the root canals of the sample teeth were expanded with rotary instruments, coronal expansion was also performed. During the expansion of the root canals, the root canals were washed with sodium hypochlorite (2 ml 2.5 percent). Finally, the root canals were washed using distilled water and dried using paper dots. The apical openings were closed using a packable dental composite resin.

### Tooth Staining

The artificial staining of the specimens was performed using a modified method based on the procedure described by Freccia and Peters<sup>20</sup> in line with protocols from previous studies.<sup>21,22</sup> Initially, the specimens were placed in Eppendorf tubes containing sheep blood and centrifuged at 3,400 rpm for 20 minutes at 37 °C (Micro 220R; Hettich, Germany). After centrifugation, the plasma (supernatant) was separated from the sediment, and the plasma was discarded. The tubes underwent a second centrifugation under the same conditions for another 20 minutes, followed by a series of centrifugations performed twice daily for three consecutive days. After each centrifugation, the specimens were rinsed with distilled water, returned to the tubes, and stored at 37°C in 100% humidity. On the fourth day, the teeth were removed from the original blood-containing tubes and transferred to clean tubes. To promote hemolysis of the erythrocytes, 0.5 mL of distilled water was added to the original tubes, followed by another 20-minute centrifugation. This process resulted in a membranous precipitate and hemolysate, with the supernatant discarded. The teeth were then returned to these tubes and centrifuged once daily for three days, with each session lasting 20 minutes. After completing the artificial staining procedure, the specimens were washed under running water and dried with an air spray. No root canal filling with sealer or gutta-percha was applied to the teeth. Instead, 2 mm-thick

glass ionomer cement (Equia Forte HT, GC, Japan) was placed 1 mm apical to the cementoenamel junction (CEJ).

#### Basic Color Calculation

The color of the teeth was measured in a circular area of 5 mm in diameter on the buccal, coronal part of the teeth each time. Basic color measurement was carried out on a white background using a spectrophotometer (Vita Easyshade, VITA Zahnfabrik, Germany). Samples were equally distributed into four groups based on their initial color measurements. A one-way ANOVA was conducted to assess whether there were statistically significant differences in initial colors among the groups. The results of the analysis indicated that there were no significant differences in initial color values across the groups ( $P=0.633$ ).

#### Bleaching Procedure

The bleaching activation systems employed in this research are outlined in Table 1. A devital bleaching protocol was applied to samples divided into four groups ( $n = 12$ ), as described below:

Group 1: A 35%  $H_2O_2$  (pH: 5.0, Opalescence Endo; Ultradent, USA) was introduced into the pulp chambers of the specimens. The solution was mixed using a bonding brush for one minute and left to act for 10 minutes, with the procedure repeated three times, totaling 30 minutes. After each session, the pulp chambers were thoroughly cleaned of residual bleaching agent and dried. Temporary restorations were placed, and the specimens were stored in artificial saliva.

**Table 1.** Characteristics of the bleaching activation systems used in the study

Device	Type	Wave length	Intensity	Manufacturer
Er,Cr:YSGG laser	Laser	2780 nm	2,5 W	Waterlase MD turbo, BIOLASE, Irvine, CA, USA
Diyod laser	Laser	940 nm	2 W	Epic, iLase by BIOLASE, Irvine, CA, USA
LED light curing unit	Polywave LED	395-480 nm	1 W	Ultradent Products Inc, South Jordan, UT, USA

Group 2: Following the initial placement of the bleaching gel as described in Group 1, it was left for two minutes before laser activation. A diode laser (940 nm, Epic, iLase, BIOLASE, USA) operating at 2 W was applied without direct contact with the bleaching agent for one minute (40 Hz frequency, 50 mJ energy). This protocol was repeated three times. Upon completion, the bleaching agent was removed, and temporary restorations were placed.

Group 3: The bleaching procedure followed the same initial steps as Group 1. After two minutes of exposure to the bleaching gel, Er,Cr:YSGG laser activation (2780 nm, Waterlase MD Turbo, BIOLASE, USA) was applied for one minute. This process was repeated three times. The laser system was equipped with a Z-type glass tip (MZ8) with an 800  $\mu\text{m}$  diameter and 6 mm length. The laser parameters included 2.5 W output power, 700  $\mu\text{s}$  pulse duration (S-mode), 10 Hz pulse frequency, and an energy density of 0.9  $\text{J}/\text{cm}^2$ , without water or air cooling, based on the protocol described by Dionysopoulos et al.<sup>6</sup>

Group 4: As in Group 1, the bleaching agent was applied to the pulp chamber and allowed to act for two minutes. Subsequently, a Polywave LED light (Valo LED, Ultradent, USA) was used at an intensity of 1000  $\text{mW}/\text{cm}^2$  in standard mode for 15-second intervals. This light activation was repeated with five-minute breaks, totaling two minutes of cumulative exposure.<sup>23</sup>

All bleaching procedures were conducted by a single operator to ensure consistency throughout the experiment.

#### Evaluation of Color Change

Color measurements were performed on day 1, day 3, and day 7 following the bleaching procedures. Immediate post-bleaching measurements were avoided, as the dehydration of dental tissues during treatment could temporarily alter the color perception. Instead, sufficient time was allowed for the tooth color to stabilize. To maintain consistency across all groups, the temporary filling materials placed in the specimens were left intact throughout the evaluation period.

Baseline color measurements were performed using a spectrophotometer (Vita Easyshade). A white background ( $L^* = 92.3$ ,  $a^* = 1.4$ ,  $b^* = -5.6$ ) was used when determining the CIELAB coordinates of each sample. Each sample was measured in triplicate for mean  $L^*$ ,  $a^*$ , and  $b^*$  values. The color coordinates of the samples treated with bleaching were measured one day after the bleaching treatment (T0-T1), three days after the bleaching treatment (T0-T2), and seven days after the bleaching treatment (T0-T3). The color differences ( $\Delta E_{00}$ ) of the specimens were quantified in accordance with the CIEDE2000 formula, as outlined below<sup>24</sup>:

$$\Delta E_{00} = \left[ \left( \frac{\Delta L'}{K_L S_L} \right)^2 + \left( \frac{\Delta C'}{K_C S_C} \right)^2 + \left( \frac{\Delta H'}{K_H S_H} \right)^2 + R_T \left( \frac{\Delta C'}{K_C S_C} \right) \left( \frac{\Delta H'}{K_H S_H} \right) \right]^{1/2}$$

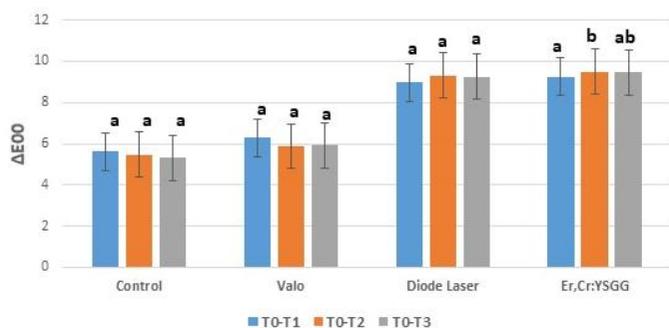
where lightness, chroma, and hue differences between color measurements are expressed by  $\Delta L'$ ,  $\Delta C'$ , and  $\Delta H'$ .  $K_L$ ,  $K_C$ , and  $K_H$  were used as parametric factors for the effect of imaging and lighting conditions, and these were accepted as 1 in this study. The weighting functions for the color difference adjustment that take into account the position change of the  $L^*$ ,  $a^*$  and  $b^*$  coordinates are indicated by  $S_L$ ,  $S_C$  and  $S_H$ .<sup>24,25</sup> The parametric factors of the CIEDE2000 color difference formula were determined as 1.<sup>26</sup>

#### Statistical Analysis

The obtained data were analyzed using SPSS 20 (IBM SPSS Corp., Armonk, NY, USA) software. Firstly, Kolmogorov-Smirnov test and Levene test were used to control the distribution of data and homogeneity of variances. Repeated Measures ANOVA and Bonferroni tests were used to compare the  $\Delta E_{00}$  values obtained with the measurement periods of each group and analysed using Huynh-Feldt corrections, if required. One-Way ANOVA and Tukey post-hoc tests were used to compare the  $\Delta E_{00}$  values of the groups at each measurement period.  $P$ -values  $< .05$  were considered statistically significant.

## RESULTS

The results of the Repeated Measures ANOVA test performed to compare the  $\Delta E_{00}$  values obtained for three separate measurement periods for each group are given in Table 2 and Figure 1. According to test findings, no significant difference was found between all time periods measured in all groups except the Er,Cr:YSGG group ( $P > .05$ ). In the Er,Cr:YSGG group, a significant increase was observed in the T0-T2 period, but no significant difference was found in the T0-T3 period. This shows that the bleaching effect continues after seven days. In addition, significant differences were found between the groups according to the One-Way ANOVA test results used to compare the bleaching groups for each time period ( $P < .05$ ). In all three time periods,  $\Delta E_{00}$  values of the control group and Polywave LED light group were significantly lower than Er,Cr:YSGG and Diode laser groups ( $P < .05$ ). However, no significant difference was found between these binary groups ( $P > .05$ ). In this study, Er,Cr:YSGG and Diode Laser applications resulted in significantly better bleaching outcomes compared to the other groups.



**Figure 1.** Graph of color changes ( $\Delta E_{00}$ ) after 1 (T0-T1), 3 (T0-T2) and 7 (T0-T3) days of different bleaching procedures. Different letters indicate a significant difference between groups at a 5% significance level.

**Table 2.** Results Of Repeated Measures Anova

Groups	Source	SS	df	MS	F	P
Diode Laser	Huynh-Feldt	0.855	2	0.428	1.254	.305
Er,Cr:YSGG	Huynh-Feldt	0.482	1.804	0.267	8.350	.003*
Led light curing unit	Huynh-Feldt	1.292	1.771	0.729	2.257	.136
Control	Huynh-Feldt	0.614	1.305	0.470	0.938	.375

SS: Sum of squares, df: degrees of freedom, MS: mean of squares, F: F distribution, \* $P < .05$  significant

**Table 3.** Mean and standard deviation of  $\Delta L$ ,  $\Delta a$ ,  $\Delta b$  colour indices and  $\Delta E$  values for subgroups of the bleaching different activator systems

GROUPS		N	Mean $\pm$ Std. Deviation	
Diode Laser	T1-T0	$\Delta L$	12	7.08 $\pm$ 1.73
		$\Delta a$	12	-1.96 $\pm$ 0.66
		$\Delta b$	12	-11.49 $\pm$ 1.69
		$\Delta E_{00}$	12	8.97 $\pm$ 1.36
	T2-T0	$\Delta L$	12	7.20 $\pm$ 1.88
		$\Delta a$	12	-2.21 $\pm$ 0.46
		$\Delta b$	12	-12.07 $\pm$ 1.34
		$\Delta E_{00}$	12	9.32 $\pm$ 1.29
	T3-T0	$\Delta L$	12	7.18 $\pm$ 1.67
		$\Delta a$	12	-2.25 $\pm$ 0.39
		$\Delta b$	12	-12.04 $\pm$ 1.60
		$\Delta E_{00}$	12	9.26 $\pm$ 1.45
Er,Cr:YSGG	T1-T0	$\Delta L$	12	7.48 $\pm$ 1.10
		$\Delta a$	12	-1.94 $\pm$ 0.91
		$\Delta b$	12	-11.48 $\pm$ 1.54
		$\Delta E_{00}$	12	9.24 $\pm$ 0.87
	T2-T0	$\Delta L$	12	7.48 $\pm$ 1.07
		$\Delta a$	12	-2.27 $\pm$ 0.85
		$\Delta b$	12	-12.02 $\pm$ 1.61
		$\Delta E_{00}$	12	9.50 $\pm$ 0.71
	T3-T0	$\Delta L$	12	7.42 $\pm$ 1.12
		$\Delta a$	12	-2.28 $\pm$ 0.80
		$\Delta b$	12	-12.02 $\pm$ 1.68
		$\Delta E_{00}$	12	9.46 $\pm$ 0.72
Led light curing unit	T1-T0	$\Delta L$	12	4.66 $\pm$ 1.70
		$\Delta a$	12	-3.07 $\pm$ 0.51
		$\Delta b$	12	-7.79 $\pm$ 1.36
		$\Delta E_{00}$	12	6.30 $\pm$ 1.13
	T2-T0	$\Delta L$	12	3.73 $\pm$ 2.18
		$\Delta a$	12	-3.06 $\pm$ 0.59
		$\Delta b$	12	-7.71 $\pm$ 1.41
		$\Delta E_{00}$	12	5.88 $\pm$ 1.31
	T3-T0	$\Delta L$	12	3.45 $\pm$ 2.14
		$\Delta a$	12	-3.03 $\pm$ 0.63
		$\Delta b$	12	-8.05 $\pm$ 1.82
		$\Delta E_{00}$	12	5.92 $\pm$ 1.42
Control	T1-T0	$\Delta L$	12	4.37 $\pm$ 1.37
		$\Delta a$	12	-1.81 $\pm$ 0.71
		$\Delta b$	12	-7.29 $\pm$ 1.34
		$\Delta E_{00}$	12	5.62 $\pm$ 1.09
	T2-T0	$\Delta L$	12	4.14 $\pm$ 1.46
		$\Delta a$	12	-2.16 $\pm$ 0.63
		$\Delta b$	12	-7.03 $\pm$ 1.63
		$\Delta E_{00}$	12	5.48 $\pm$ 1.32
	T3-T0	$\Delta L$	12	3.46 $\pm$ 1.42
		$\Delta a$	12	-2.58 $\pm$ 0.64
		$\Delta b$	12	-7.27 $\pm$ 1.54
		$\Delta E_{00}$	12	5.30 $\pm$ 1.24

## DISCUSSION

Based on the findings of this study, the null hypothesis ( $H_{01}$ ) was rejected. The hypothesis proposed that the use of a Polywave LED light, intended to enhance the effectiveness of bleaching treatment in non-vital teeth, would show no significant difference compared to laser-assisted bleaching treatments. However, at all evaluated time points following the bleaching procedures, the Er,Cr:YSGG laser exhibited the most substantial color change. Furthermore, the  $\Delta E_{00}$  values in both the control group and the Polywave LED light group were significantly lower compared to the Er,Cr:YSGG and Diode laser groups across all three time intervals. These results indicate that Polywave LED light is less effective than laser-assisted bleaching treatments for non-vital teeth.

In this study, clinical discoloration was simulated by staining the teeth with sheep blood. The samples were incubated in Eppendorf tubes containing sheep blood to ensure thorough staining. After centrifugation, the hemoglobin-rich precipitate was separated, and the plasma was carefully removed from the tubes.<sup>20</sup>

The present study has been found to have similar results with studies investigating the effectiveness of Er,Cr:YSGG laser and Diode laser activation in non-vital bleaching treatments.<sup>6,27</sup> The laser radiation absorbed by the bleaching gel enables the bleaching process to be accelerated and a more effective bleaching process by converting the light energy into heat energy.<sup>10</sup> The wavelength of the laser and the composition of the bleaching gel significantly influence the gel's absorption of laser radiation. Notably, when the Er,Cr:YSGG laser is operated at a wavelength of 2780 nm, it demonstrates superior absorption in water-based bleaching gels due to its high affinity for water molecules. This interaction leads to an increase in the gel's temperature during the procedure.<sup>28</sup> A study evaluating the bleaching efficiency of the Er,Cr:YSGG laser at varying power settings reported a significant increase in color change when the laser was used at 2.5 W.<sup>6</sup> The effectiveness of the Er,Cr:YSGG laser in office bleaching has also been examined, with findings indicating superior outcomes compared to conventional methods.<sup>28</sup> However, research on the use of the Er,Cr:YSGG laser for bleaching non-vital teeth remains scarce in the literature.

Diode lasers are commonly employed in bleaching treatments with wavelengths typically ranging from 790 nm to 980 nm.<sup>29</sup> Primary advantages of diode lasers include compact size, portability, and the use of flexible optic fibers.<sup>30</sup> In a study comparing the bleaching efficiency of a 1.6 W diode laser (808 nm) and LED light (470 nm), the diode laser demonstrated superior performance over both LED light and bleaching gel alone.<sup>29</sup> Similarly, in research evaluating diode lasers at 810, 940, and 980 nm wavelengths, no statistically significant difference in bleaching efficiency was observed among the different wavelengths ( $P > .05$ ). However, it was noted that the diode laser operating at 940 nm exhibited the highest bleaching efficiency.<sup>27</sup>

A study comparing polywave LED light, halogen, and diode lasers for the activation of in-office bleaching reported no significant difference between the light-activated and non-activated groups at the end of the treatment.<sup>31</sup> In the clinical study by Grgan et al.<sup>32</sup>, spectrophotometric evaluation of office bleaching revealed that the  $\Delta E_{00}$  value in the diode laser group was statistically higher than in the non-activated group and the LED light group. However, in the present study, a direct comparison could not be made, as no prior research was found in the literature comparing polywave LED light with various laser systems in the bleaching of non-vital teeth.

Laser systems are not always available in clinics for bleaching treatments; however, LED used for the polymerization of composite resins are more commonly accessible. These light-curing units provide a more cost-effective and practical alternative to laser systems.<sup>33</sup> In a study investigating the activation efficiency with polywave LED light in office bleaching, it was observed that the colour change increased.<sup>33</sup> Ragain et al.<sup>34</sup> investigated the impact of polywave LED light on the proliferation of gingival epithelial cells, reporting no adverse effects on cell proliferation within 24 hours following an 18-second exposure. In the present study, the polywave LED light (Valo LED) was applied for 15 seconds, followed by a 5-minute interval, and then reapplied for another 15 seconds, resulting in a total exposure time of 2 minutes. This protocol was implemented to minimize any potential negative effects on epithelial cells. Additionally, the use of a rubber dam during clinical bleaching procedures serves to protect the gingival tissue from heat exposure.

Investigating the results of the study, it was found that the colour change of the samples in all groups far exceeded the thresholds of detectability ( $\Delta E_{00} > 1.2$ ) and acceptability ( $\Delta E_{00} > 2.7$ ). The detectability threshold refers to the smallest color difference that can be perceived by an observer. The acceptability threshold denotes the color change that is deemed acceptable to an observer in comparison to a reference color.<sup>26</sup> Optical thresholds are very important in evaluating treatments and comparing different treatments in dentistry.<sup>35</sup> Therefore, the effectiveness of the teeth bleaching treatments tested in this study was confirmed.

The results from this in vitro study indicated that polywave LED light exhibited less activation strength compared to the Er,Cr:YSGG laser and Diode laser in non-vital bleaching. Nonetheless, a satisfactory color change was noted in teeth treated with polywave LED light. Furthermore, no significant differences were observed between the activation effects of the Er,Cr:YSGG laser and the Diode laser in non-vital bleaching treatments.

**Ethics Committee Approval:** Ethics approval for the study incl. usage of retrospective anonymized data was obtained through the Ethics Committee of Afyonkarahisar University of Health Sciences (No: 2021/221, date: April 2, 2021).

**Informed Consent:** Consent was obtained from the patients for the use of their extracted teeth.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – L.A.U., C.Y.; . Design –L.A.U., C.Y 3.; Supervision –L.A.U.; Fundings - L.A.U., C.Y.; Materials - L.A.U., C.Y.; Data Collection and/or Processing – L.A.U., P.G.; Analysis and/or Interpretation - P.G.; Literature Review - L.A.U.; Writing - L.A.U.; .Critical Review- L.A.U.

**Conflict of Interest:** The author (Pınar Gül) of this article is also the associate editor of this journal. This situation is considered to be a relationship that may create a conflict of interest. In order to ensure an impartial and transparent refereeing process, the refereeing and publication decision regarding this article was carried out by the guest editor assigned to the journal. The guest editor was appointed by the Atatürk University Coordinatorship of Scientific Journals Office. Blind refereeing was applied during the evaluation of the article and the author's editorial position was not disclosed to the referees. In addition, all stages of this process were managed in accordance with the journal's ethical rules and international ethical guidelines such as COPE and ICMJE in order to prevent conflicts of interest.

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