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Cover Page Footnote

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In vivo comparative study between different light activated bleaching systems in terms of color and sensitivity

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1. Introduction

Shade of every tooth is determined by a mixture of the different optical characteristic of enamel, dentin and pulp [1]. Tooth stains vary in cause, appearance, localization, difficulty and adherence to tooth structure. Tooth discoloration is usually various, multifaceted and has been classified as extrinsic, intrinsic, and internalized discoloration. Adult teeth often become darker due to changes in enamel and dentin properties, losing their natural white look [2].

Due to technological advances in dentistry, there is also an increased patients' awareness of oral appearance. Most people are looking for "whiter" teeth to improve their overall smile [3,4].

There are many protocols to remove tooth stains, which include air polishers, microabrasion, or vital tooth lightening which has been approved to be the most preservative methods for treating stained teeth [5]. Success of tooth bleaching procedure is influenced by many factors: type of bleaching system, concentration of the bleaching material, time of application as well as light application. In the case of light powered bleaching, it's used to activate peroxide to accelerate the chemical redox reactions of the bleaching agent [6,7]. Hydrogen peroxide (H₂O₂)-based bleaching agents at high concentrations (typically 15–38%) are widely used for in-office techniques due to their high oxidizing ability [8,9].

Many light sources have been used for acceleration chair-side bleaching procedure, including, halogen lamps, plasma arc lamp, metal halide lamp, light emitting diode, and laser [10,11].

The in-office bleaching has become a commonly used procedure and remarkably popular among individuals because of the following advantages: minimally invasive, immediate results and no need for the patient assistance [12].

However, chair-side whitening procedure may result in local side effects on oral mucosa and the dental tissues, such as pulp sensitivity, oral mucosa burns, and alteration of enamel surface [7]; with tooth sensitivity during the bleaching period, described as the biggest problem by many authors [13].

As whitening time is one key factor in determining the overall tooth-lightening outcome from peroxide-containing products, the effects of different light sources and different light intensities on color change

and tooth sensitivity are still unclear [14].

The target of this in vivo study was to compare the efficacies of different light sources and intensities, on tooth color change and post bleaching sensitivity.

2. Materials and methods

Sixty patients were nominated using certain inclusion criteria: having all anterior teeth (Upper and lower) sound, to agree to sign the consent form, 18–30 years old, color A3 in at least incisor teeth; and to agree for follow-up examinations. The exclusion criteria were: any systematic disease that can interfere in the research; gingivitis or periodontitis; smokers; any reaction to peroxides; use of any bleaching agents within the last year; tooth sensitivity of less than one on the VAS scale (visual analog scale); pregnant or lactating women; tetracycline stained teeth, and any patients under long term medications that can interfere with the bleaching materials or activating methods [15,16].

The 60 patients selected were randomly divided into four groups (n = 15), depending on the method of activation and the concentration of the gel used. All bleaching gels were used according to the manufacturer's instructions as noted in Table 1.

Full mouth debridement was done to all patients prior to any bleaching procedure. Extrinsic tooth stain was removed using a dental prophylaxis paste fluoride free (*Proxyt RDA 36, medium, Ivoclar Vivadent AG, Bendorerstrasse 29494 Schaan*). The prophylaxis was done a week before the start of the study [17].

The study design was explained to all patients then they were asked to sign a written consent. After liquid dam positioning, the patients, were subjected to the designated whitening protocol according to manufacturer's instructions. If patient experiences tooth sensitivity or irritation at any time during the bleaching procedure such as redness, swelling, soreness of the gums or the mouth, the procedure was stopped and the patient's condition was evaluated. The procedure was ended whenever the discomfort or irritation continued and the patient was excluded from the study.

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Table 1
Materials used and their specifications.

Company	Product	Material	Application
White Smile Gmbh	Power	40% HP	3 sessions
Weiheiner Strat 696488 Birkenau Germany	Bleaching	Activated by: Light Whitening lamp high power LED, light spectrum 465 nm, 190 mW/cm ² , 100–240 V	15–20 min each
Biolase San Clemente, California, USA	Laser white 20	35% HP Activated by: Diode Laser lamp activated (λ = 810 nm)	2 sessions 4–7 min each
Philips Zoom	Zoom	25% HP Activated by: LED Lamp with low intensity 420 nm	3 sessions 15 min each
Philips Zoom	Zoom	25% HP Activated by: LED Lamp with high intensity 480 nm	3 sessions 15 min each

Teeth color was assessed using a spectrophotometer (*VITA EasyShade -Vita Zahnfabrik, Bad Säckingen, Germany*). In order to standardize the location of color recording at all times, a custom-positioning tray was made for each patient (Fig. 1). The tip of the spectrophotometer was placed perpendicular to the tooth surface in the space created in the positioning tray. Color was measured before the beginning of the procedure and when bleaching was finished [18]. Three measurements were taken for each tooth to standardize the results recording and mean calculated [18]. These values were converted in numeric code using the conversion table proposed by Brenna (Table 2). In the spectrophotometric assessment change in color was expressed using the CIELAB (*Commission Internationale de l'Éclairage*) color coordinates, and color difference ΔE. The ΔE: indicates change in color. Values equal to or less than 1 showed that no color change occurred. Values more than one declare more marked color change. ΔE* is a parameter related to the changes in the values of L*, b* and a* according to the following equation [19].

For tooth sensitivity examination, the patients were evaluated according to the VAS questionnaire before bleaching (baseline), as well as immediately and 24 h post bleaching. This examination indicated differences in sensitivity between the evaluation periods and the bleaching gels tested. Participants were informed to indicate any tooth or oral sensitivity by marking the degree of sensitivity on the horizontal line, which ranges from 0 to 10, where results of 10 indicating being most sensitive [15].

Table 2
Conversion table proposed by Brenna.

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

Range of sensitivity scores used:

0–1	No pain
2–3	Mild pain
4–6	Moderate pain
7–8	Severe pain
9–10	Intolerable pain

Table 3
Color measurements results before and after different bleaching systems application.

Bleaching system	White smile tooth bleaching results		Laser white 20 tooth bleaching results		High intensity Zoom lamps results		Low intensity Zoom lamps results	
	Before	After	Before	After	Before	After	Before	After
Patient number								
1	2L1.5	1M1	2R1.5	1M1	3M1	0M2	3M1	1M1
2	2L2.5	1M2	2R1.5	0M3	2R1.5	0M2	3M2	0M3
3	3M1	1M1	3M1	1M1	3M1	0M1	3M1	1M1
4	3L1.5	1M1	2M1	0M1	3M1	0M1	2R1.5	0M3
5	3M1	2M1	3M1	1M1	3M1	0M2	3M1	1M2
6	3M1	0M2	3M1	1M1	2L1.5	0M2	2L1.5	0M2
7	3M2	0M3	3M2	0M3	3L1.5	0M2	3L1.5	1M1
8	3R1.5	2L1.5	3R1.5	1M1	3M2	1M1	3M2	1M1
9	2M1	0M2	2M1	0M1	2R2.5	1M2	2R2.5	1M1
10	2R1.5	0M3	2R1.5	0M3	3M1	1M1	3M1	1M1
11	3M2	1M1	3M2	0M3	3R1.5	1M1	3R1.5	1M1
12	2M1	1M1	2M1	0M1	3M1	1M2	3M1	1M2
13	3M1	0M1	3M1	0M3	2L1.5	0M2	3L1.5	1M1
14	3L1.5	1M1	3L1.5	2M1	2L1.5	0M2	2L1.5	0M3
15	3M1	0M1	3M1	0M3	3R1.5	0M3	3R1.5	0M3
16	3L1.5	1M1	3L1.5	2M1	3M2	2M2	3M2	2M2
17	3M2	1M1	4R1.5	0M3	2M1	1M1	2M1	0M3
18	3M2	1M1	3M2	1M2	4M1	0M3	4M1	1M2
19	4M1	2M1	4M1	0M3	3M3	0M2	3M3	1M1
20	4M1	2M1	3M1	0M3	3L1.5	1M1	2L1.5	0M3



Fig. 1. The custom-positioning tray for the color measurement standardization.

Table 4

Tooth Sensitivity Results for different bleaching systems used before, immediately post, and 24 h after bleaching procedures.

Bleaching system	White smile tooth bleaching results			Laser white 20 tooth bleaching results			High intensity Zoom lamps results			Low intensity Zoom lamps results		
	Before bleaching	Immediately post bleaching	24 h after bleaching	Before bleaching	Immediately post bleaching	24 h after bleaching	Before bleaching	Immediately post bleaching	24 h after bleaching	Before bleaching	Immediately post bleaching	24 h after bleaching
1	0	5	3	0	7	2	1	8	2	0	6	1
2	0	4	1	0	7	0	1	7	2	1	5	1
3	1	4	1	0	8	1	0	7	1	0	4	0
4	0	4	0	1	7	1	0	6	1	0	4	0
5	1	5	1	1	6	1	0	6	0	1	5	1
6	1	6	1	0	5	0	0	5	0	0	4	0
7	1	4	1	1	6	1	0	5	1	0	3	0
8	0	3	0	0	4	0	1	6	2	1	4	0
9	0	6	0	1	4	1	0	3	0	0	3	1
10	0	7	2	1	5	1	0	3	0	0	4	1
11	0	6	1	0	4	0	1	5	1	1	5	0
12	0	4	0	0	7	1	1	5	0	1	6	0
13	1	4	1	0	7	0	1	4	1	1	6	1
14	1	3	1	0	8	2	1	3	1	0	5	1
15	1	5	1	1	7	1	1	8	2	1	6	1
16	1	5	1	1	5	1	0	5	0	0	4	0
17	0	5	0	1	5	1	0	4	0	0	3	0
18	0	7	1	1	5	1	1	6	1	1	4	0
19	0	7	1	0	4	0	1	5	1	0	4	1
20	1	6	1	0	4	0	1	5	1	1	4	1

3. Results

The study included 4 groups of whitening systems in vivo as follows: For the first group was made with White smile, for the 2nd group with laser white 20 whitening, for the 3rd group zoom high intensity and for the 4th group zoom low intensity. Color was evaluated before and after treatment with spectrophotometer (Table 3). Sensitivity was measured before, immediately after and after 24 h s with VAS scale for each group (Table 4). The results were as follow:

3.1. Statistical analysis

Numerical data were explored for normality by checking the data

Table 5

Median, Inter-Quartile Range (IQR), results of Kruskal-Wallis test for comparison between shade scores of the four groups and Wilcoxon's signed-rank test for the changes by time within each group.

Time	Whitesmile		Laser		Zoom High Intensity		Zoom Low Intensity		P-value (Between groups)
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	
Before bleaching	11	10–13	11	8–11	11	8–12.5	11	8–13	0.841
After bleaching	16	15.25–16	16	16–16	16	16–16	16	16–16	0.771
P-value (Within group)	< 0.001*		< 0.001*		< 0.001*		< 0.001*		

*: Significant at P ≤ 0.05.

distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Sensitivity scores data showed non-normal (non-parametric) distribution. Data were presented as median and Inter-Quartile Range (IQR) values.

Kruskal-Wallis test was used to compare between the four groups. Wilcoxon signed-rank test and Friedman's test were used to study the changes by time within each group. Dunn's test was used for pair-wise comparisons.

The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

3.2. Demographic data

The sixty patients selected were from both genders with age ranging from 18 to 30 with A3 shade for at least four anterior teeth.

3.3. Color results

Either before or after whitening, there was no statistically significant difference in between median shade scores in the four groups, results shown in Table 5 and Fig. 2 (P-value = 0.841 and 0.771, respectively).

As regards the changes after whitening within each group; all groups showed a statistically significant increase in median shade scores after whitening (P-value < 0.001 for each group).

3.4. Sensitivity results

Before bleaching, there was no statistically significant difference between the four groups (P-value = 0.898).

Immediately after whitening, there was a statistically significant difference between the four groups (P-value = 0.030). Pair-wise comparisons between the groups revealed that there was no statistically significant difference between White smile, Laser and Zoom High Intensity groups; all showed the statistically significantly highest median sensitivity score. Zoom Low Intensity group showed the statistically significantly lowest median sensitivity score.

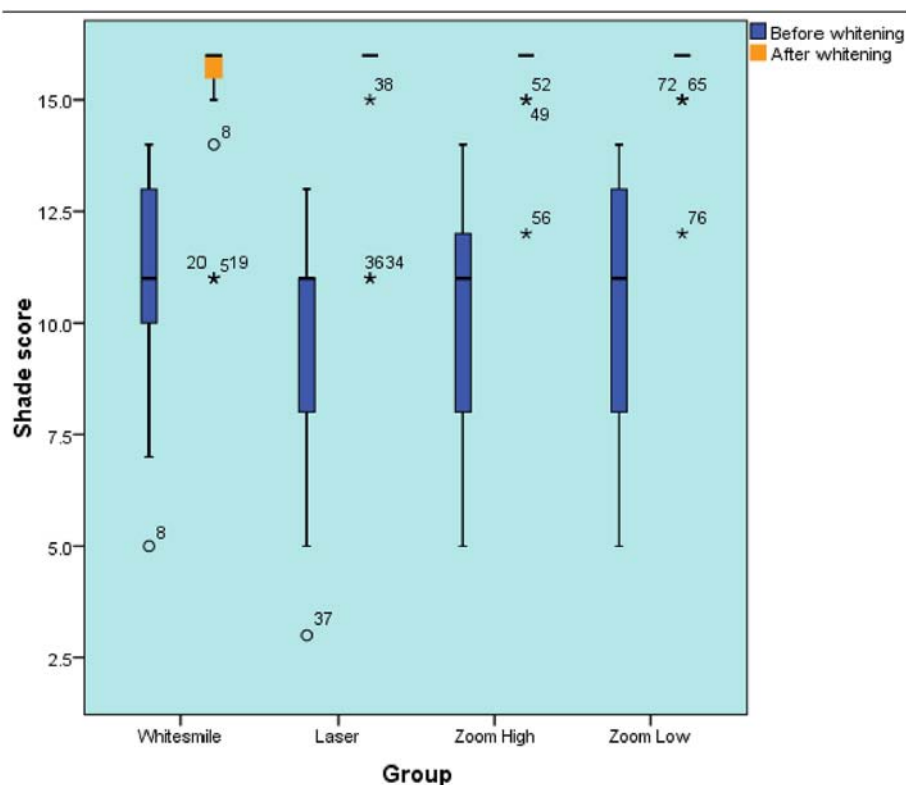


Fig. 2. Box plot representing median and IQR values for shade scores in the four groups (Circles and stars represent outliers).

After 24 h, there was no statistically significant difference between the four groups (P -value = 0.280).

As regards the changes within each group in respect to time; all groups showed a statistically significant change in median sensitivity scores (P -value < 0.001 for each group). Pair-wise comparisons revealed the same pattern of change within each group; there was a statistically significant increase in median sensitivity scores immediately after whitening followed by a statistically significant decrease in median score after 24 h. There was no statistically significant difference between median sensitivity score before whitening and after 24 h (see Table 6).

4. Discussion

Teeth discolorations are seen very often in dental clinics and present a great challenge to operators. Stains may be limited to a single tooth or several teeth in a single arch. Generally, dentists' interference is mandatory for treating substantial tooth discoloration. One of the conservative treatment options include vital bleaching with more successful outcome [20]. The most popular tooth lightening is performed

in the dental office, and done with 35% hydrogen peroxide. The oxygen released from the hydrogen peroxide releases oxygen that breaks down conjugated bonds in protein chains associated with stain into a single bond. This might result in more absorption of color wavelengths and resulting in the reflection of little color (i.e., Lightening effect) [21]. However, the usefulness of light source in the in-office systems has been controversial all over the previous researches. Companies have introduced “bleaching” lamps claimed that light accelerate the bleaching process by generating more oxygen molecules [22]. These results are in parallel with the studies of Torres et al. 2011, [23] Domínguez et al. 2011, [24] and Luk et al. 2004 [25] who found that light application has markedly enhanced the lightening efficacy of bleaching materials. This could be attributed to tooth dehydration [26] that probably is greater with increased tooth exposing to light activation source.

In our study we have compared the effect of the different light source intensities on the efficiency of the bleaching results. There was no statistically significant difference between the different systems used in median shade scores after bleaching (P -value < 0.001 for each group). (Table 5). This finding can be explained by the fact the main success of the bleaching agents depend mainly on the nascent oxygen

Table 6

Median, Inter-Quartile Range (IQR), results of Kruskal-Wallis test for comparison between the four groups and Friedman's test for the changes by time within each group for sensitivity.

A, B superscripts in the same row indicate statistically significant difference between groups

C, D superscripts in the same column indicate statistically significant difference between follow up times

Time	Whitesmile		Laser		Zoom High Intensity		Zoom Low Intensity		P-value (Between groups)
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	
Before bleaching	0 ^D	0-1	0 ^D	0-1	1 ^D	0-1	0 ^D	0-1	0.898
Immediately after bleaching	5 ^{AC}	4-6	5 ^{AC}	4-7	5 ^{AC}	4.25-6	4 ^{BC}	4-5	0.030*
24 h after bleaching	1 ^D	0.25-1	1 ^D	0-1	1 ^D	0-1	0.5 ^D	0-1	0.280
P-value (Within group)	< 0.001*		< 0.001*		< 0.001*		< 0.001*		

*: Significant at $P \leq 0.05$.

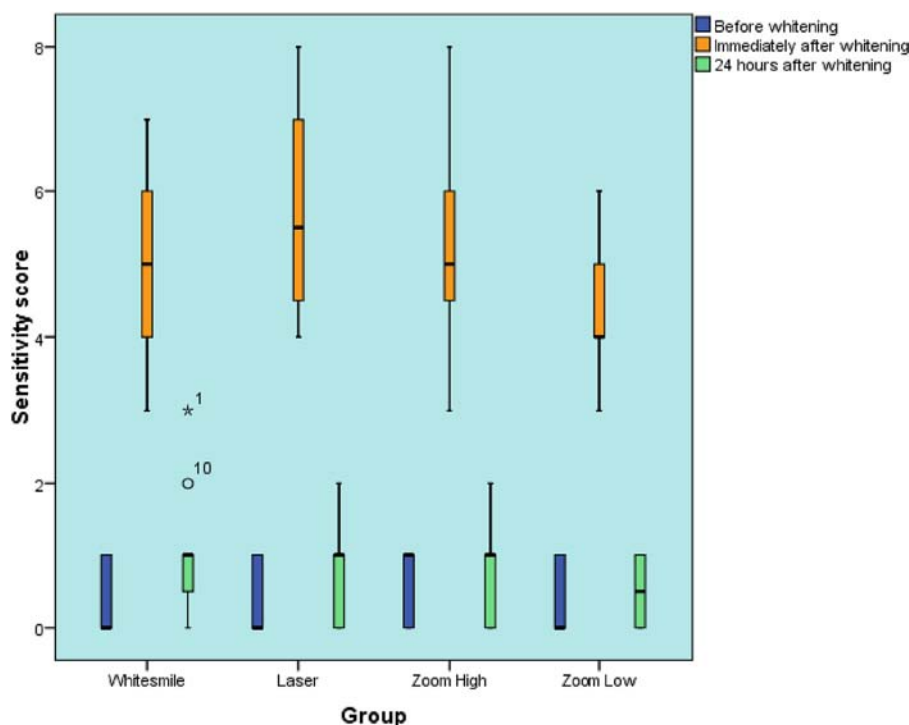


Figure 3. Box plot representing median and IQR values for sensitivity scores in the four groups (Circle and star represent outliers).

produced from the hydrogen peroxide during the oxidation reaction and not on the light source either LED lamps with the different intensities used (420–480 nm) or the diode laser ($\lambda = 810$ nm) [27]. The main advantage of a light source is to heat the hydrogen peroxide with high concentrations increasing the rate of forming oxygen free radicals from the bleaching agent in a process known as thermocatalysis and improving the breakdown of stain containing molecules [28–30].

Many ways have been used to measure the tooth color changes following whitening procedures: Objectively and subjectively. Spectrophotometry has been considered as an objective standard method for color evaluation in all most all researches related to color before and after tooth bleaching. It has some benefits including lack of operator interference, reproducibility, and reliability in calibration and excluding the environmental light interference [31]. This method is used universally as it is standardized and software-dependent in data recording and analysis, minimizing personal evaluation bias. But it also has some shortcomings as well. For instance, it is influenced by tooth translucency, texture and contour. In addition, repeatable tooth positioning was difficultly achieved which was solved in the current study by the standardized window performed in the customized trays. This explain why in some other researches it was proven by Reza et al., in 2017, that laser showed better tooth bleaching values [29]. This is not matching with the results found by Rafael et al., in 2012 [42], may be due lack of old lamps used as many modifications were made in the lamps used later on as those made by R. Lo Giudice et al., in 2016 [30] Angelo et al., in 2016 [43] (see Fig. 2).

Tooth sensitivity in our study was measured by VAS scale before tooth bleaching showing that there was no statistically significant difference between the four groups (P -value = 0.898) (Fig. 3). As, in patients' selection criteria, all possible causes of tooth sensitivity were excluded on the spot. For the measures immediately after bleaching, there was a statistically significant difference between the four groups (P -value = 0.030), the highest values were recorded for the white smile followed by the laser white20, followed by the high intensity zoom lamps. The lowest were recorded for the low intensity zoom lamps. After 24 h, there was no statistically significant difference between the four groups (P -value = 0.280). This might be due to the easy

penetration of peroxide through enamel and dentin to the pulp; this takes approximately 5–15 min to occur [32]. Further proof of this rapid penetration of peroxide is seen in research findings showing that the dentin color changes next to the pulp as fast as it does next to the dentin-enamel junction. Thus, sensitivity results from the insult of the peroxide on the nerve may be considered a reversible pulpitis [33]. These findings are in agreement with previous studies using light activating high hydrogen peroxides bleaching agents [34–37]. For the low intensity zoom lamps, the sensitivity were the least and this might be explained by the lower rate of production of the free radicals produced, allowing a rapid and large arrival of inflammatory cells to react, although the bleaching results was with no clinical significance [38]. Furthermore the FDA has recently cleared that the LED light was also believed to promote the healing of mouth ulcers, cold sores and periodontal diseases [39].

After 24 h the sensitivity scores have been decreased in all groups (P -value < 0.001 for each group) (Fig. 3) with the same pattern of change. This might be attributed to the role of the desensitizer applied after each bleaching protocol following the manufacturer instructions and to the protective role of human saliva, in terms of its mineral composition, flow rates and buffering activity [40,41].

5. Conclusions

Within the limitations of our study we can conclude the following:

1. All light activated bleaching systems used were effective in teeth lightening, with no distinguish difference between all the systems used in our study, regarding (ΔE).
2. The spectrophotometer is a valid method for tooth color change measurement.
3. Regarding the tooth sensitivity, proper desensitizing protocol should be followed post tooth bleaching.

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