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EFFECT OF DIODE LASER AND LIGHT ACTIVATED IN-OFFICE BLEACHING VERSUS HOME BLEACHING ON ENAMEL SURFACE ROUGHNESS: IN VITRO STUDY

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ABSTRACT

Aim: evaluate the enamel surface roughness before and after diode laser activated bleaching, light activated bleaching, and home bleaching.

Materials and Methods: A total of 30 human anterior teeth were placed in self-cured acrylic resin with the buccal surface facing upward. Surface roughness of all groups at baseline was measured. After measuring baseline surface roughness, the samples were divided into three groups, group (1) White smile Light whitening AC (32% hydrogen peroxide) was used plus activation with Diode laser light source, group (2) White smile Light whitening AC (32% Hydrogen peroxide) was used plus activation with LED source and group (3) White smile home whitening bleaching system (35% carbamide peroxide) was used. All samples were kept in distilled water after bleaching, and enamel surface roughness was tested again after 24 hours. A sample representing each group was randomly selected to observe the roughness of the enamel surface before and after bleaching under a scanning electron microscope.

Results: All three treatments resulted in a statistically significant increase in enamel surface roughness ($p < 0.05$ for all groups). Where group 1 (in-office bleaching activated using diode laser) was significantly different from group 2 (in-office bleaching activated using LED light) and group 3 (home bleaching), while group 2 and group 3 showed no significant difference from each other.

Conclusions: All bleaching protocols have a deleterious effect on enamel surface roughness varied according to material composition, concentration, exposure time, and activation mode.

KEY WORDS: Diode laser, hydrogen peroxide, bleaching, surface roughness.

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INTRODUCTION

Tooth bleaching is a popular dental procedure that improves tooth color to a brighter shade. Over the past years, there has been an increase in the demand for bleaching, leading to the availability of bleaching agents in a variety of forms, including in-office bleaching, dentist-supervised bleaching at-home, and over-the-counter bleaching agents. While bleaching is generally considered safe, its mechanism of action results in structural changes that may lead to some concerns. These changes include the loss of fluoride and minerals as well as increased surface roughness, decreased enamel hardness, and increased susceptibility to erosion or caries. Additionally, patients frequently worry about the negative effects of bleaching, such as tooth sensitivity and gingival irritation [(1)].

Two distinct treatment modalities have been used to whiten teeth. One approach is the in-office process, which is frequently referred to as power bleaching, and the other is home bleaching. The in-office bleaching uses high concentrations of carbamide peroxide (35–37%) or hydrogen peroxide (30–40%). While the home bleaching kits contain carbamide peroxide concentration ranging from(10% - 35%), and hydrogen peroxide between (3%-10%). The mechanism of bleaching depends on the oxidation of large chromophore molecules, which are responsible for the discoloration of enamel and dentin. Hydrogen peroxide is considered a strong oxidizing agent that generates highly reactive free radicals, disrupting the electron conjugation and leading to a change in the absorption energy, resulting in a lighter color [(2)].

Light sources have been used in tooth-whitening procedures. When the bleaching agent absorbs energy from a light source, a small fraction of that energy is converted into heat, which accelerates the breakdown of Hydrogen peroxide and improves the bleaching effect. Light sources can be LED or Laser with different wavelengths. LED sources can be used to assist bleaching due to their availability, low cost compared to laser devices, and lower risk of heating the tooth structure. While laser devices used in bleaching depend on the type and the wavelength of the beam, such as diode laser with different wavelengths as 810,940, and 980 nm[(3)].

Home whitening has recently become a choice for dentists and patients as it is effective, easy in application, safer, and lower cost compared to in-office bleaching. The most used product in home bleaching is carbamide peroxide, which is changed to free radicals (OH-) when it contacts saliva. One of the things that makes teeth more vulnerable to bacterial attachment and stains is the roughness of the enamel surface, which is caused by demineralization[(4)].

Demineralization is the loss of mineral ions in enamel, causing damage to hydroxyapatite, which is considered the main structure of enamel. Demineralization occurs by a diffusion process, through the movement of molecules or ions due to the difference in the concentration, and it also depends on the acidity of the whitening agent used on the enamel surface [(5)].

One of the disadvantages of bleaching is that it can change the surface of enamel, as the bleaching chemical agent change its morphology, roughness, and mechanical properties. Numerous techniques have been used for assessing the morphological, mechanical, or roughness changes of enamel. These techniques include profilometric analysis, Computerized roughness Tester, Atomic Force Microscope, and Scanning Electron Microscope [(6)]. Therefore, this study aimed to estimate the surface roughness of enamel before bleaching (baseline) and after bleaching with laser activated (diode laser) bleaching, LED light activated bleaching, and home bleaching after 24 hours.

MATERIALS AND METHODS

This invitro study was approved by the ethics committee of the Faculty of Oral and Dental Medicine. Ahram Canadian university research number IRB00012891#113

Bleaching agents used:

I. White smile Light whitening AC (32% hydrogen peroxide) (Power whitening YF, Whitesmile GmbH, Germany)

II. White smile home whitening bleaching system (35% carbamide peroxide)(Home whitening, Whitesmile GmbH, Germany)

Sample size calculation:

Sample size was calculated using G*Power version 3.1.9.2, FranzeFaul, University Kiel, Germany. Mean and standard deviations were determined according to surface roughness of a previous study [7]. According to the results, the sample size calculation using an effect size of 2.83 using an alpha level of significance (α) 0.05, and power of study 0.98 was 10 specimens for each group.

Study design:

A total of 30 Freshly extracted sound human anterior teeth were collected. Teeth cracks, fracture, caries, defects, any developmental anomaly or anatomical variations were not included in the study. Teeth were cleaned and scaled to remove any remnants of soft tissue, and then the teeth were stored in distilled water till the beginning of the study (within one month). Then all roots were removed about 2mm below their cemento-enamel junction by a double side-cutting course diamond disc (SS White, New Jersey, USA).

Each tooth was placed in a self-cured acrylic resin mold (Acrostone,cold cure, Egypt) with the buccal surface of the crown facing upward[8]. Then, a waterproof permanent marker was used to give a numerical code to all samples. Surface roughness of all samples at baseline was measured using SJ-210 Surface roughness tester(Mitutyoyo Japan). Device calibration was done by the standard specimen for calibration, then each specimen was fitted to the specimen holder, with which the surface to be measured was placed in a horizontal direction, then the holder was moved vertically up just touching the measuring tip.

The parameters used in testing were standardized: distance 12 mm, speed 0.5 mm/s, returning 1mm/s, force 0.75 MN, stylus profile: tip radius 2-micron, and angle of tip is 60 degrees. The surface roughness values were expressed in microns. Three readings for each specimen with a distance of 500 microns were recorded, and then the average of the readings was calculated.

Grouping of samples:

After measuring the surface roughness, the samples were randomly divided into three groups according to the type of bleaching protocol used.

Group (1) White smile Light whitening AC (32% hydrogen peroxide) was used plus activation with a Diode laser light source

Group (2) White smile Light whitening AC (32% Hydrogen peroxide) was used plus activation with an LED source.

Group (3) White smile home whitening bleaching system (35% carbamide peroxide) was used.

Bleaching procedure:

In group (1), White smile Light whitening AC (32% Hydrogen peroxide) was used plus activation with diode laser light, the laser device was set to bleaching mode, bleaching agent was applied on the buccal surface of the sample with 1-2mm thickness according to the manufacturer's instructions. Then the sample was irradiated with a diode laser

(Epic X, Biolase, CA, USA) at a wavelength of 940nm, 1.5W power, and 1mm distance. The irradiation was repeated three times for each sample, each time for 30 seconds. The time gap was one minute between irradiations to avoid the rise in temperature. After seven minutes of waiting, all group (1) samples were rinsed with distilled water for 30 seconds [9,10]. In group (2) White smile Light whitening AC (32% Hydrogen peroxide) bleaching gel was applied on the sample surface in a uniform thickness of 1 -2 mm then irradiated by LED light source of 465 nm, 190 mw/cm2, 100–240 Vand 1 mm distance [11,12] for 15 minutes, followed by the removal of the bleaching gel with cotton rolls and then repeating the steps two more times[13]. While in group (3) White smile home whitening bleaching system (35% carbamide peroxide) was applied following manufacturer's instruction for 60 minutes for three times for three consecutive days, then in the end all samples of the three groups were kept in distilled water for enamel surface roughness testing after bleaching within 24 hours.

Assessment of enamel surface roughness before and after bleaching protocols using scanning electron microscope

A representative sample was randomly selected to observe the enamel surface roughness before and after bleaching. A scanning electron microscope (Quanta 250 FEG (field emission gun) FEI Company, Oregon, USA) was used to observe the difference in enamel surface roughness among the three groups. The samples were dried using 100 % alcohol concentration, and then a thin gold film was applied on the surface for the preparation of scanning electron microscope examination. Images were taken at 3000x magnification and an acceleration voltage of 20 kV.

Statistical analysis

Statistical analysis was performed with SPSS 16 ® (Statistical Package for Scientific Studies). The data was explored by Shapiro-Wilk test and Kolmogorov-Smirnov test to check for normality, which showed that the data derived from a normal data distribution in the three groups. Comparison between the three groups was carried out using One Way ANOVA test, then Tukey`s Post Hoc test for multiple comparisons, while comparison was done between baseline and after by Paired t test. The significance level was $p \leq 0.05$.

RESULTS

Assessment of enamel surface roughness

Intragroup comparison (Table 1):

Table (1) represents the results of the enamel surface roughness before and after the three different teeth whitening treatments: in-office bleaching activated using Diode laser, in-office bleaching activated using LED light, and home bleaching. For each group, the table shows the minimum, maximum, mean, and standard deviation of surface roughness measurements at baseline and after treatment. It also provides paired differences statistics to compare the before and after results.

- Group 1 (in-office bleaching activated using Diode laser) showed the highest mean roughness both before (0.78 ± 0.41) and after (0.86 ± 0.41) treatment, with a mean increase of (0.08 ± 0.06).
- Group 2 (in-office bleaching activated using LED light) had moderate roughness values, with a mean of (0.59 ± 0.21) before and (0.66 ± 0.23) after treatment, increasing by (0.07 ± 0.04).
- Group 3 (home bleaching) had the lowest roughness values overall, with a mean of (0.39 ± 0.13) before and (0.47 ± 0.12) after treatment.
- All three treatments resulted in a statistically significant increase in enamel surface roughness ($p < 0.05$ for all groups).

TABLE (1) Descriptive results of enamel surface roughness at baseline and after treatment in all groups using Paired t test:

		Minimum	Maximum	Mean	Standard Deviation	Paired Differences					P value
						Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		
									Lower	Upper	
Group (1) in-office bleaching + diode laser	**Before (baseline)**	0.31	1.46	0.78	0.41	0.08	0.06	0.02	0.03	0.12	0.005*
	After	0.37	1.61	0.86	0.41						
Group (2) in-office bleaching + LED	**Before (baseline)**	0.22	0.87	0.59	0.21	0.07	0.04	0.01	0.04	0.10	0.001*
	After	0.25	1.01	0.66	0.23						
Group (3) home bleaching	**Before (baseline)**	0.24	0.56	0.39	0.13	0.09	0.03	0.01	0.07	0.10	0.0001*
	After	0.32	0.62	0.47	0.12						

Significant difference as P<0.05.

Intergroup comparison (Table 2) (Figure 1):

Table 2 compares the enamel surface roughness results across the three different teeth whitening treatments: in-office bleaching activated using Diode laser (Group 1), in-office bleaching activated using LED light (Group 2), and home bleaching (Group 3). The data was analyzed by one Way ANOVA, then by Tukey's Post Hoc test for multiple comparisons.

1. Baseline Roughness: There were significant differences between groups at baseline (p=0.012). Group 1 (in-office bleaching activated using Diode laser) had the highest initial roughness (0.78 ± 0.41), significantly different from Groups 2 and 3. Groups 2 and 3 showed no significant difference from each other at baseline.

2. Post-Treatment Roughness: Significant differences persisted after treatment (p=0.018). Group 1 still had the highest roughness (0.86 ± 0.41), which is significantly different from Groups 2 and 3, while Groups 2 and 3 showed no significant difference from each other.

3. Absolute Change (Difference between baseline and after): the difference in roughness was not statistically significant between groups (p=0.830). This suggests that although the groups started and ended at different roughness levels, the absolute change caused by each treatment was similar.

Table (2): Mean and standard deviation of enamel surface roughness before, after and the difference between baseline and after in all groups, comparison between groups using One Way ANOVA test, then by Tukey`s Post Hoc test for multiple comparisons:

	Group (1) in-office bleaching +Diode laser		**Group (2) in-office bleaching + LED**		**Group (3) home bleaching**		**P value**
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	
Before (baseline)	0.78 [a]	0.41	0.59 [ab]	0.21	0.39 [b]	0.13	0.012*
After	0.85 [a]	0.41	0.66 [ab]	0.23	0.47 [b]	0.12	0.018*
Difference	0.08 [a]	0.06	0.07 [a]	0.04	0.09 [a]	0.03	0.830

Significant difference as P<0.05.
Means with different superscript letters per row were significantly different as P<0.05.
Means with the same superscript letters per row were insignificantly different as P>0.05.

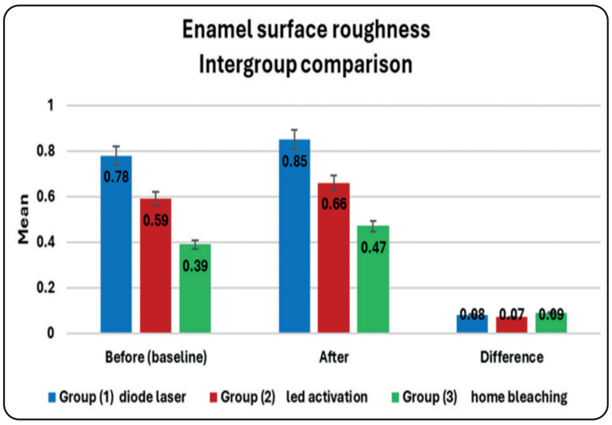

Fig. (1) Bar chart representing intergroup comparison regarding baseline, after, and the difference between baseline and after bleaching in all groups.

Scanning electron microscopy observations Figure 2 (2a,2b,2c,2d,2e,2f):

Scanning electron microscope photomicrographs of the enamel surface before bleaching (2a,2c,2e) showed a relatively smooth enamel surface with the presence of aprismatic enamel and relatively small porosities, while after three different teeth whitening treatments: in-office bleaching activated using Diode laser, in-office bleaching activated using LED light, and home bleaching respectively (2b,2d,2f) showed that alterations in morphology, areas of depressions, erosions and irregularities were most found in diode laser photomicrograph followed by LED photomicrograph which showed lesser morphological alterations, then the least alterations and minimum depressions were found in home bleaching group**.**

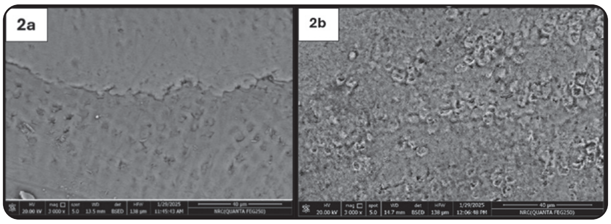

Figure (2a,2b) Enamel surface before(2a) and after(2b) White smile Light whitening AC (in-office bleaching activated using Diode laser).

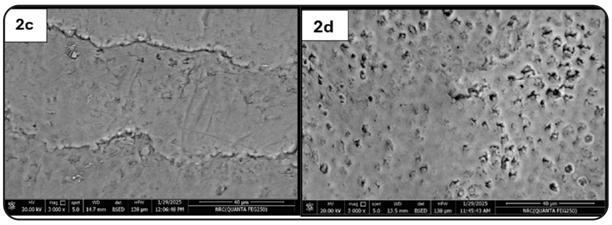

Fig. (2c,2d) Enamel surface before (2c) and after (2d) White smile Light whitening AC (in-office bleaching activated using LED light).

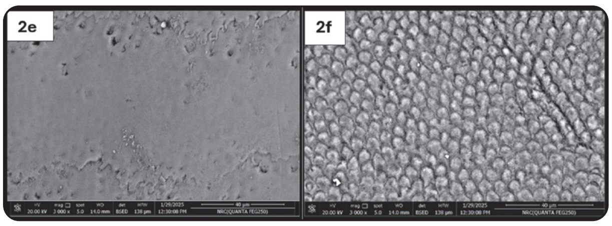

Fig. (2e,2f) Enamel surface before (2e) and after (2f)White smile home whitening bleaching system.

DISCUSSION

One of the least discomfort treatment options is to remove the discoloration of teeth by whitening. Numerous hypotheses explain how hydrogen peroxide bleaching works. The most widely recognized theory states that oxygen free radicals diffuse through enamel and interact with organic chromophores in discolored teeth leading to a lighter spectrum [2].

Different bleaching treatments are currently available, such as in-office bleaching that uses 20–38% hydrogen peroxide (HP), dentist-supervised home bleaching with 5–35 %, and over-the-counter bleaching products. Several studies revealed that the concentration of peroxide and its exposure to heat and/or light both have an impact on how quickly hydrogen peroxide breaks down. The bleaching gel's effect can be accelerated by using power sources such as tungsten halogen, plasma arc, light emitting diodes (LEDs), and lasers [14].

In recent years, laser dentistry has become widely popular. Depending on its wavelength, it can be used to whiten teeth to provide the desired cosmetic effects in just one session, making the initial color six shades lighter [15]. One of its main disadvantages is high cost and bleaching hypersensitivity. It has been scientifically known that the Epic 940 nm diode laser (US Biolase) is one of the laser devices used in dentistry. Tooth whitening and the management of hypersensitivity are two of its numerous clinical applications [16].

One of the undesirable effects of whitening treatments is surface roughness. Although whitening toothpastes and bleaching agents can improve tooth color, they may have an opposite effect on the roughness of the enamel, which increases the bacterial plaque retention and adhesion, resulting in a higher chance of dental decay [17,18].

Regarding effect of bleaching on enamel surface roughness, comparing enamel surface roughness before and after (in the three different teeth whitening treatments: in-office bleaching activated using Diode laser, in-office bleaching activated using LED, and home bleaching) showed that Group 1 (diode laser) had the highest mean roughness both before and after treatment, while Group 2 (LED activation) had moderate roughness values after treatment, and finally

Group 3 (home bleaching) showed the lowest roughness values overall. All three treatments resulted in a statistically significant increase in enamel surface roughness ($p < 0.05$ for all groups). The results of this study are in accordance with prior studies [2,19], which showed an increase in surface roughness. As enamel surface when exposed to carbamide peroxide and hydrogen peroxide in different concentrations, both showed alterations in the morphology of superficial dental enamel, which may be due to the complete removal of the aprismatic layer, leading to an increase in the number of pores, which subsequently increases the roughness of the enamel surface. Furthermore, hydrogen peroxide decomposes, releasing free radicals which increase the surface porosity, as those free radicals react with the organic components of hard tooth tissue.

Regarding Absolute Change (Difference between baseline and after) was not statistically significant between groups ($p=0.830$). This suggests that although the groups started and ended at different roughness levels, the absolute change caused by each treatment was similar was similar. These results are in accordance with the previous study [20] which stated that the outcome of surface roughness did not differ significantly between groups, and as the concentration of the peroxide increase, the surface roughness will increase, although in this study home bleaching was used, it was used with a high concentration of 35% carbamide peroxide.

The results of the current study are in contrast with the previous study [21], which showed no significant increase in surface roughness, which may be due to the use of chemical-activated bleaching agents with no Laser or LED activation and lower concentrations of hydrogen peroxide.

Also this study results are indisagreement with the previous studies [22,23] which showed no change in surface roughness due to the difference in storage medium used, as the storage medium was saliva instead of distilled water, so saliva will provide remineralization of the surface after bleaching, as the closer intra oral conditions are mimicked, the lesser surface roughness and alterations will be.

CONCLUSIONS

Within the limitations of the current study, it could be concluded that:

- All bleaching protocols had a deleterious effect on enamel surface roughness varied according to material composition, concentration, exposure time, and activation mode.
- Home bleaching had the least effect on enamel surface roughness compared to in-office bleaching activated using diode laser and LED light.

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