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Original Article

Efficacy of diode laser irradiation during dental bleaching in preventing enamel damage caused by bleaching

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ABSTRACT

Background: Evidence on the protecting effect of laser on bleached enamel is scarce and controversial. Therefore, we aimed to test for the first time whether different wavelengths of diode laser (810 and 980 nm) can prevent enamel surface corrosion. We also tested for the first time whether such therapeutic effects of laser are limited to specific "laser-activated" bleaching gels or both conventional and laser-activated gels.

Materials and Methods: In this qualitative experimental study, ten intact human teeth were randomly assigned to five Groups. They were sectioned into twenty buccal/lingual pieces. The groups were: (1) laser-activated gel + 810 nm laser, (2) laser-activated gel + 980 nm laser, (3) conventional gel + 810 nm laser, (4) conventional gel + 980 nm laser, (5) conventional gel only, and (6) laser-activated gel - no irradiation. Buccal sections in each group were subjected to bleaching (according to the stated protocols), and later subjected to field-emission scanning electron microscopy (SEM) and X-ray diffraction (XRD). The lingual pieces were used as "before-treatment" negative controls for XRD.

Results: XRD showed an increase in the mineral phase and crystallinity of the enamel in all bleaching groups. This was stronger in the laser-irradiated groups with conventional bleaching agent. SEM showed a complete etched surface in the positive control groups (i.e., bleached using conventional agent). However, all four laser groups had almost intact surfaces.

Conclusion: This study showed the positive effect of diode laser irradiation at 810 nm or 980 nm wavelengths on the prevention of bleaching damage, irrespective of the activation mechanism of the bleaching gel in use.

Key Words: Bleaching, diode laser, scanning electron microscopy, photobleaching, X-ray diffraction

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INTRODUCTION

Esthetic dental treatments using less aggressive approaches are increasingly gaining popularity.[1,2] Dental bleaching is a clinically effective treatment for tooth discoloration.[2,3] However, it has its own limitations and adverse effects such as morphological alterations in enamel structures and enamel rod destruction.[2,3] Changes in the chemical composition

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of tooth include demineralization, damage to cellular DNA, protein denaturation in the enamel, decrease of the proportion of minerals to protein, and reducing the strength of hydrogen bonds in the NH groups of enamel molecules.[4-8] Bleaching is primarily performed with 35%–37% carbamide peroxide or 30%–40% hydrogen peroxide.[2,9] Based on the type, concentration, and working time of bleaching, it might damage the enamel surface in a varying degrees and predispose it to relapse of discoloration or caries.[2,9-19]

Chemical methods such as fluoride therapy might reverse this. However, a new, much faster, and more convenient method to prevent enamel surface roughness in the first place might be the irradiation of the bleaching agent using diode lasers.[2] However, this field is quite new and open to investigation. The only available studies in this regard are two controversial pilot studies published in 2015. Anaraki *et al*.[2] showed that although both groups were damaging, the damage caused by bleaching with a 810 nm diode laser was less than that caused by conventional bleaching without any laser activation.[2] On the contrary, Dionysopoulos *et al*.[20] reported a nonsignificant increase in the enamel roughness when applying a Er, Cr:YSGG laser, compared with the roughness of enamel caused by nonlaser bleaching.[20] Furthermore, there is no study on microscopic (field emission-scanning electron microscopy [FE-SEM]) properties or on X-ray diffraction (XRD) analyses of laser-bleached teeth.

Therefore, we aimed to test for the first time whether different wavelengths of diode laser (810 and 980 nm) can prevent enamel surface corrosion. We also tested for the first time whether such therapeutic effects of laser are limited to specific "laser-activated" bleaching gels or both conventional and laser-activated gels.

MATERIALS AND METHODS

Samples of this qualitative experimental *in vitro* study consisted of ten intact human premolar teeth removed for orthodontic reasons from teenagers or adolescents. Tooth surfaces were carefully cleaned using a dental scaler and were rinsed clean off material alba under high-pressure water. All teeth were inspected both macroscopically and microscopically, under a ×10 stereomicroscope for the exclusion of samples with microcracks. The included teeth were free of caries, stains, enamel hypoplasia, cracks, microcracks, or other defects. Included specimens were disinfected by 24 h of storage in 0.1% thymol solution. They were stored in distilled water at 4°C until the experimentation.

Overview

The teeth were randomly assigned to five experimental groups of two teeth each. The teeth were splat mesiodistally by a water-spraying sectioning device (Bohler, Germany) into buccal and lingual halves, creating twenty samples (each experimental group would have two teeth sectioned into a total of four buccal/lingual pieces). All the ten lingual halves in the five experimental groups were reserved as negative controls, without any treatments. There remained two buccal sections in each group. They were bleached with different methods and then randomly assigned to SEM and XRD. Of the ten lingual pieces (negative controls), the five (1 from each group) lingual sections pertaining to the teeth, the buccal side of which had been assigned to the XRD analysis, were selected to act as the negative (before-bleaching) XRD controls for their buccal sections (before bleaching). Of the remaining five lingual sections, one was randomly selected to act as a negative control for the SEM analysis. Of the remaining four lingual sections, one was randomly selected to be bleached by the laser-activated bleaching gel but without laser irradiation (only for SEM analysis, as a negative control 2). A final lingual piece was used as a negative control for SEM (no treatments at all).

Experiments

- Group 1: The two buccal sections in Group 1 were bleached using laser-activated bleaching gel containing TiO_2 particles that are specific absorbents for diode laser (Heydent JW Power Bleaching Gel, Heydent GmbH, Germany) and was laser-irradiated from a 2 mm distance with 1.5 W 810 nm diode laser (Cheese, Wuhan GigaaOptronics Technology, China) using the kit's head designed for single-tooth irradiation
- Group 2: The two buccal sections in Group 2 were bleached using the same bleaching agent (Heydent JW) and irradiated from a 2 mm distance with 1.5 W powered 980 nm diode laser (Wiser, Doctort Smile, Italy) using the kit's single-tooth irradiation handpiece tip
- Group 3: In Group 3, the two buccal sections were bleached using a conventional office bleaching gel (Opalescence Xtra Boost, Ultradent, USA) irradiated from a 2 mm distance with 1.5 W 810 nm

diode laser (Cheese, Wuhan Gigaa Optronics Technology) using the kit's single-tooth irradiation tip
- Group 4: In Group 4, the two buccal sections were bleached using a conventional office bleaching gel (Opalescence Xtra Boost) irradiated from a 2 mm distance with 1.5 W 980 nm diode laser (Wiser, Doctor Smile, Italy) using the kit's single-tooth irradiation handpiece
- Group 5: The two buccal sections in Group 5 were the positive controls, bleached with conventional office bleaching gel (Opalescense Xtra Boost) but not laser-irradiated (one for SEM and one for XRD)
- Group 6 (only SEM): A lingual piece was bleached with the laser-activated gel (Heydent JW) but was not laser irradiated.

Details of laser bleaching

Surfaces of the buccal sections in Groups 1 and 2 were covered with laser-activated JW Power Bleaching gel (Heydent GmbH). Diode laser (Cheese) was radiated three times from a 2 mm distance at a power of 1.5 W and a wavelength of 810 nm for 30 s using a continuous mode. The energy was 45 J/30 s, amounting to 135 J for each tooth. The bleaching process was repeated thrice with 60 s rest intervals. Then, the bleaching gel remained on the tooth surface for 5 min. After that, the surface of each sample was rinsed to remove the bleaching gel completely. The handpiece tips were of the same diameter for both lasers.

Details of conventional bleaching plus laser irradiation

Surfaces of the buccal sections in Groups 3 and 4 were covered with about 2–3 mm of 40% Opalescence Xtra Boost gel (Ultradent) for 10 min. Then, the surfaces were irrigated and stored in distilled water according to the manufacturer's instructions. Afterward, the buccal sections in Groups 3 and 4 were, respectively, irradiated with the above-mentioned 810 and 980 nm lasers. The protocol for laser irradiation was standardized as three periods of 30 s irradiation for each specimen, with two rest periods of 60 s each between each two irradiation intervals, followed by a 5 min rest after the last irradiation, and then rinsing the bleaching agent with distilled water.

Positive control groups

In Group 5, surfaces of the buccal sections were covered with about 2–3 mm of 40% Opalescence Xtra Boost gel (Ultradent) for 2 min. They were rinsed with distilled water. This procedure was repeated for three times. In Group 6, a similar procedure was repeated with the laser-activated gel (no laser).

X-ray diffraction analysis

In each of the five experimental groups, one of the two bleached buccal sections was randomly assigned to the XRD analysis. The lingual section of the same tooth was as well examined with XRD, as the negative control (and pretreatment reference) for the evaluated buccal section. The procedure was for XRD analysis included the removal of dentin from the dental specimens, using a sharp round bur attached to a low-speed water-spraying handpiece. The remaining enamel of each buccal or lingual specimen was then grinded to homogeneous powder. Then, they were subjected to XRD analysis using an X-ray diffractometer (EQUINOX 3000, Inel, France).

Field emission-scanning electron microscopy examination

The remaining intact buccal in each experimental group and a randomly selected specimen from their negative controls (the lingual sections) were coated with a thin layer of gold. Then, they were subjected to field emission electron microscopy (Mira 2 XMU, Tescan, Brno, Czech Republic) at × 300, ×600, ×5000, and ×15000 magnifications.

RESULTS

Field emission-scanning electron microscopy

The FE-SEM analyses showed no cracks at any magnifications in any of the specimens. Since the teeth had been acquired from orthodontic patients and had been evaluated to be caries-free and intact, it might be assumed that the SEM changes reported below are caused by the bleaching procedures.

In the negative control group, no attritions or porosities were seen on the surface [Figure 1]. In the first group (laser-activated bleaching [Heydent JW] with 810 nm laser), the bleaching procedure created clear porosities on the enamel surface plus some degrees of attrition and removed the interlamellar enamel at some points [Figure 2]. In the second group (laser-activated bleaching [Heydent JW] with 980 nm laser) surface alterations were slighter: less porosity, mild fissures, and almost no attrition [Figure 3]. The third group (810 nm laser used to irradiate conventional bleaching [Opalescence Xtra Boost]) demonstrated results similar to the first group [Figure 4]. In the 4th group (Opalescence Xtra Boost – 980 nm laser),

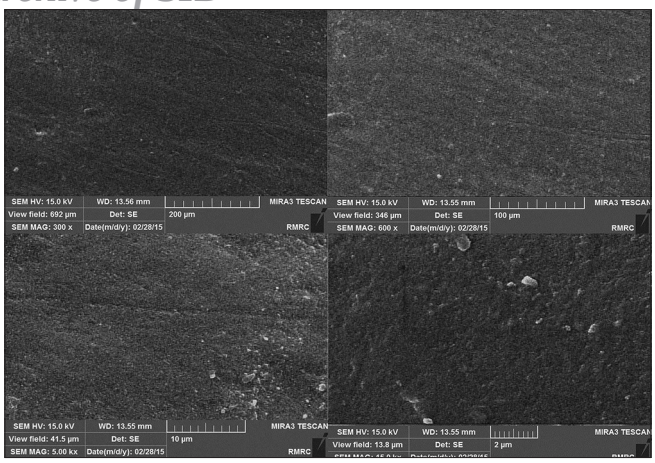

Figure 1: The scanning electron microscopy micrographs taken from the negative control (untreated tooth surface) at various magnifications.

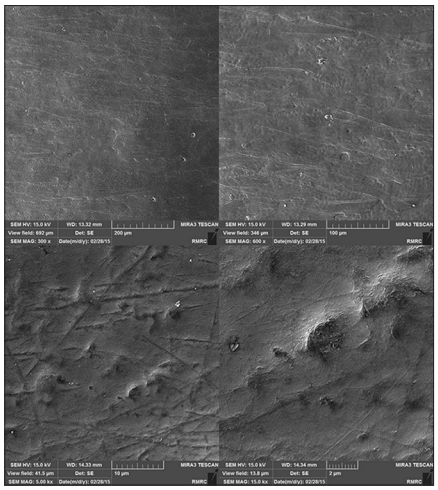

Figure 3: The scanning electron microscopy micrographs taken from the Group 2 (laser-activated gel + 980 nm laser).

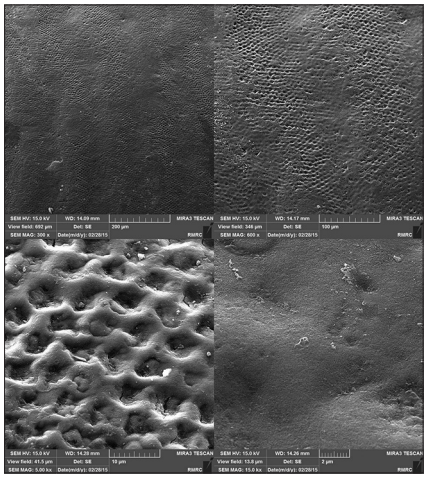

Figure 2: The scanning electron microscopy micrographs taken from the Group 1 (laser-activated gel + 810 nm laser).

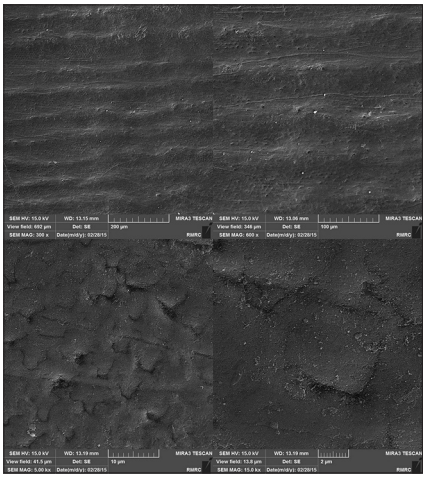

Figure 4: The scanning electron microscopy micrographs taken from the Group 3 (conventional gel + 810 nm laser).

surface irregularities were slightly lower than what was observed in the third group [Figure 5]. The positive control (Group 5, Opalescence Xtra Boost, no laser) showed irregularities and notable enamel dissolution compared to the four groups involving laser; however, enamel destruction and crack formation were not observed again [Figure 6]. The positive control 2 (Group 6, Heydent JW, no laser irradiation) showed notable enamel dissolution rather similar to what was seen in the Group 5 (the positive control) although not as complete dissolution seen in Group 5 [Figure 7].

X-ray diffraction analysis

In the first group (laser-activated bleaching with 810 nm laser), the XRD peaks corresponding to the mineral phase of enamel (i.e. nonstoichiometric apatite) showed an increase [Table 1]. This phenomenon either suggests an increase in the size of apatite crystals on the a axis after laser-activated bleaching or an increase in their crystallinity (probably because of the removal of proteins attached to apatite plates which limited them to grow in certain directions, allowing the apatite crystals to grow in all directions). In the second group (laser-activated bleaching with 980 nm laser) as well as an increase in the mineral phase (nonstoichiometric apatite) and crystallinity was observed [Table 1]. The third group (810 nm laser used to irradiate conventional bleaching gel) demonstrated increases in the mineral phase (nonstoichiometric apatite) and crystallinity though more noticeable than the Groups 1 and 2 [Table 1]. This implies a better interaction of the conventional bleaching gel with diode laser compared to the interaction of laser with the used laser-activated gel and hence a better removal of

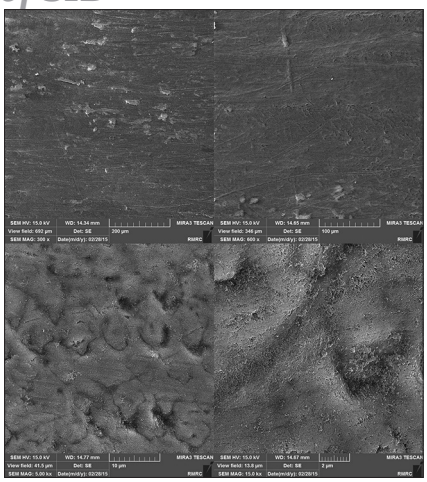

Figure 5: The scanning electron microscopy micrographs taken from the Group 4 (conventional gel + 980 nm laser).

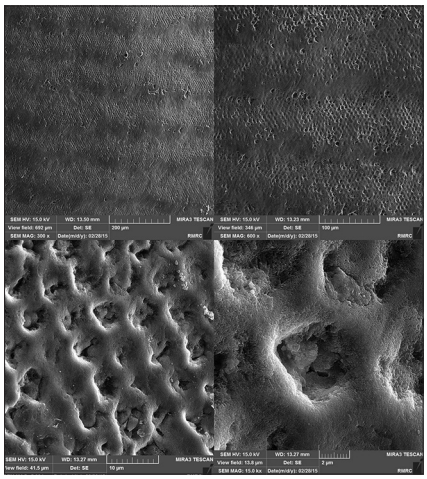

Figure 6: The scanning electron microscopy micrographs taken from the positive control (conventional bleaching).

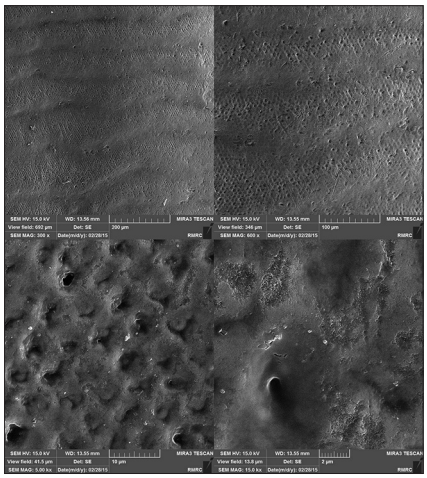

Figure 7: The scanning electron microscopy micrographs taken from the positive control 2 (laser-activated gel but without laser irradiation).

Table 1: X-ray diffraction peaks obtained from different groups

Time	2θ (°)	Heydent JW		OpalescenseXtraboost		
		810 nm	980 nm	810 nm	980 nm	No laser
Before bleaching	26°	77	81	110	100	-
	32°	352	285	397	296	-
	46°	116	95	108	124	-
After Bleaching	26°	110	95	127	141	72
	32°	357	304	552	429	302
	46°	130	103	166	156	104

attached proteins. In the 4th group (980 nm laser used to irradiate conventional bleaching) as well, a considerable increase in the mineral phase and crystallinity was observed [similar to the Group 3, Table 1]. In the positive control group, a degree of mineralization similar to Groups 1 and 2 was observed [Table 1].

DISCUSSION

The XRD signatures corresponding to the increase in the nonstoichiometric apatite phase of enamel observed in the experimental groups either suggests an increase in the size of apatite crystals on the a axis after laser-activated bleaching or an increase in their crystallinity (probably because of the removal of proteins attached to apatite plates which limited them to grow in certain directions, allowing the apatite crystals to grow in all directions). The third and fourth experimental groups showed more noticeable increases in the nonstoichiometric apatite phase and crystallinity. This implies a better interaction of the conventional bleaching gel with diode laser compared to the interaction of laser with the used laser-activated gel and hence a better removal of attached proteins.

Our findings confirmed previous research exhibiting an increase in the enamel roughness after conventional dental bleaching.[2,9-18] Nevertheless, it was in contrast with few findings stating that bleaching might not roughen the enamel surface.[21,22] The reason for controversy might be the methodological limitations of the opposing studies such as immersing the teeth in saliva (which is known as an active remineralization factor) or using bovine teeth.[2,22-24]

Clinicians used to accelerate the speed of bleaching by activating the oxidation reaction with heat/light application.[2,25,26] Bleaching materials are now activated mostly by erbium-doped yttrium aluminium garnet (YAG), Neodymium-doped YAG, or diode lasers[27,28] with the advantage of reduced working time

and postoperative hypersensitivity.[2,29] The findings of this study also indicated that diode laser irradiation can reduce or prevent the surface etching of the enamel.[26] This confirmed previous studies on the effect of diode laser on preventing the roughening of enamel during bleaching.[2,30] This might be attributable to the in-depth activity of the laser-activated bleaching agent, in comparison to the unspecific effect of conventional bleaching on the surface and depth. Furthermore since the chromophores existing in the laser-activated gels can absorb the narrow wavelength of diode lasers, the efficacy of bleaching increases (less heat), which is another advantage for this method.[2] This study showed that conventional bleaching gel (which does not have chromophores capable of absorbing diode laser) resulted in high mineralization and crystallinity after being laser irradiated. This implies that the effect of laser on the enamel surface is not only because of the chromophores existing in laser-activated gels, but it might also have direct effects on the enamel structure regardless of the used bleaching agent being enhanced for laser absorption or not, as suggested before.[26] Still, another study failed to find significant reductions in surface roughness of bleached teeth using materials activated by an Er, Cr: YSGG laser.[20] The dispute might be caused by different methodologies such as differences in the power and wavelengths of Er, Cr: YSGG lasers in comparison with diode lasers.

Limitations and advantages

A limitation of this study was the lack of quantitative methods for surface roughness assessment. The current methods of surface evaluation were qualitative and based on subjective interpretation of the observer. Future quantitative studies (such as three-dimensional profilometry) with sample sizes predetermined based on power calculations are warranted to assess our results. As an advantage, we used premolar teeth, which reflected the clinical condition better than human third molars and bovine teeth studied in some previous studies, as the extent of enamel crystals can differ in teeth with different speeds of maturation.[2,28] On the other hand, it should be noted that the findings of *in vitro* researches might not be necessarily generalized to the oral environment, in which saliva flow might reduce or reverse the etching process.[2,8,13] Moreover, XRD results do not yield standard deviations to make statistical comparison of different groups possible. Another limitation was the timing of conventional bleaching which had been shortened, to match that of laser bleaching. Finally, the results found for a particular brand and type of material cannot be necessarily generalized to other types or brands.

CONCLUSION

Within the limitations of this qualitative study, it seems that the application of diode laser at both wavelengths of 810 and 980 nm might reduce the extent of enamel surface alteration that happens during bleaching. This phenomenon was observed not only in the case of the laser-activated bleaching gel but also in the case of the conventional bleaching agent.

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Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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