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ORIGINAL ARTICLE

Evaluation of the effects of conventional versus laser bleaching techniques on enamel microroughness

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Abstract Nowadays, bleaching of the teeth within the dental office is one of the most widespread techniques to correct tooth discoloration. Variability of the materials and techniques accompanied with the trend toward esthetic restorations with minimally invasive approaches are increasing. The use of laser in this regard has also been taken into consideration. The aim of this study was to evaluate the effects of in-office versus laser bleaching on surface roughness of enamel. Fifteen freshly extracted human molars were sectioned mesiodistally to produce 30 lingual and buccal enamel blocks. Samples were mounted in transparent acrylic resin blocks and polished before treatment. Samples were randomly assigned to laser bleaching (LB) and office bleaching (OB) groups (n=15 each). Pretreatment evaluation of microroughness was carried out for all samples using profilometer. Samples were treated twice in the OB group with Opalescent Xtra Boost and in the LB group using a laser-activated gel. Microroughness was evaluated after bleaching in both groups. Data were analyzed using repeated measure ANOVA. Both methods increased enamel surface roughness. Microroughness changes were significantly different between the two groups ($p<0.05$). Microroughness significantly increased in the OB group ($p>0.05$), but there was no significant difference in pre- and post-treatment roughness evaluation in the LB group ($p<0.05$). Laser was considered a safer technique because it demonstrated a less surface roughness increase in comparison with the conventional office bleaching procedure.

Keywords Laser bleaching · Conventional office bleaching · Microroughness

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Introduction

Increased tooth surface roughness is one of the complications following tooth bleaching [1–5]. In addition, the trend towards esthetic treatments with less aggressive approaches is increasing among the population [6]. All bleaching techniques induce changes in surface roughness of the teeth, depending on the concentration and properties of the oxidizing agent and its application time [4, 7]. Brushing, polishing, and wear are considered to be among influential factors in enamel surface roughness [8]. Increased enamel roughness can cause complications such as caries and discoloration [9]. A detailed knowledge concerning different bleaching methods can prevent complications. Recently, laser bleaching techniques have received popularity due to their ease of application and satisfactory results [10].

Up to the late1990s, vital in-office bleaching techniques involved application of heat or light for activation of the oxidation reaction. This idea dates back to 1918 when Abbot used high-intensity lights to increase hydrogen peroxide temperature, thereby accelerating the chemical reaction of bleaching [10, 11].

In most of the techniques, the bleaching gel comprised hydrogen peroxide with different concentrations and

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preparations [6]. Composition of the bleaching gel includes the bleaching agent, thickening agent, liquefying component, flavoring additives, ground substance, desensitizing agents, and other components.

Currently, in-office bleaching is principally carried out using 30 to 40 % hydrogen peroxide or 35 to 37 % carbamide peroxide [7, 12, 13] activated by lasers such as diodes, Nd:YAG and Er:YAG [14–16]. The only difference in laser bleaching technique with the conventional bleaching process is shorter working time and reduced postoperative hypersensitivity [17].

Several methods have been proposed to evaluate surface changes of enamel including scanning electron microscopy (SEM) [18, 19], microhardness and microroughness evaluation [3, 20, 21], atomic force microscopy [22, 23], profilometry [4, 24], infrared absorption spectroscopy correlated with X-ray analysis [25], plasma atomic emission spectrometric analysis associated with chromatography [26], and nanoindentation techniques [27].

Surface profile of the specimens is determined with a stylus probe that moves across the surface or using optical scanning methods in a profilometric evaluation. Pre- and post-treatment evaluations make it possible to determine changes following procedure of interest [28].

Currently, bleaching is considered a clinically effective remedy to resolve tooth discoloration, but concerns about its adverse effects on dental hard and soft tissues are still present and sometimes raise controversies in dental literature; for instance, morphological changes in enamel structure following tooth bleaching procedures are still a matter of debate [29].

The aim of this study was to evaluate and compare the effect of two different bleaching techniques (office bleaching and laser bleaching) on microroughness of enamel.

Materials and methods

Samples included 15 intact human molar teeth which were removed for surgical reasons. The teeth were free from caries or cracks. Samples were stored in normal saline and then split mesiodistally by a sectioning device (Bohler, Germany) into buccal and lingual halves, giving rise to 30 samples. They were randomly divided into two groups of A and B. Samples in group A were bleached using conventional office bleaching technique with Opalescence Xtra Boost (Ultradent, USA), and those in group B were subjected to laser bleaching using JW power bleaching gel (Heydent GmbH, Germany). Samples were then coded and mounted in transparent acrylic resin blocks (Bayer Dental, Germany) and then polished with 280 to 3,000 grit sandpapers. Surface roughness of the samples was evaluated before and after the bleaching procedure using a profilometer (TR200, Qualitest, USA).

Conventional office bleaching

Surfaces of the samples in group A which were out of the acrylic mounting were covered with 40 % Opalescence Xtra Boost gel (Ultradent) for 10 min. Then, the surfaces were rinsed and stored in distilled water according to the manufacturer's recommendations. Afterwards, samples were bleached one more time for 10 min. They were subsequently stored in normal saline until roughness evaluation.

Laser bleaching

The surface of each sample in group B was covered with the laser-activated JW power bleaching gel (Heydent GmbH). Diode laser (Denlase, China) was radiated three times with a power of 1.5 W and a wavelength of 810 nm for 15 s using a continuous mode. The total energy was 22.5 J per irradiation time. The thickness of the bleaching gel was 1 mm, and the distance between the fixed 400-μm fiber probe tip and the tooth surface was 1 cm to cover a square cross section (3× 3 mm). The bleaching process continued for two times more with a 1-min rest interval. Then, the bleaching gel remained on the tooth surface for 3 min. After that, the surface of each sample was rinsed for 10 s and dried to remove the bleaching gel completely. The samples were then stored in normal saline.

Surface roughness evaluation

Pre- and post-treatment surface roughness of all samples was evaluated with a profilometer (TR200, Qualitest, USA).

In order to perform the pre- and post-treatment comparison of the surface roughness in each group, repeated measure ANOVA was used. Pre- and post-treatment values were considered as the repeated factor, and the bleaching treatment was used as between-subject comparison. Ra showed the mean surface roughness of enamel, Rmax showed the maximum surface roughness of enamel, and Rz was the mean five highest peaks and five deepest valleys.

Results

As demonstrated in Table 1, Ra value in group A (office bleaching) was 0.02±0.046 before and 0.82±0.43 after treatment. The changes were 0.77±0.44. The same values in group B (laser bleaching) were 0.049±0.02 before and 0.051±0.02 after treatment, with changes of 0.02±0.002. Repeated measure ANOVA test showed that changes in Ra had a significant difference between two groups ($p<0.05$). Ra value did not show any significant difference in group B before and after treatment ($p>0.05$). On the contrary, in group A, Ra value significantly increased following treatment ($p<0.05$). The

Table 1 Mean Ra values in experimental groups before and after treatment (in micrometers)

Experimental groups	Mean±SD of Ra		
	Pretreatment	Post-treatment	Pre- and post-treatment difference
Office bleaching (group A)	0.049±0.025	0.051±0.027	0.002±0.021
Laser bleaching (group B)	0.046±0.02	0.82±0.43	0.77±0.44

same statistical test showed that there was a significant difference between the two groups in Rmax values ($p<0.05$). There was no statistically significant difference between pre- and post-treatment Rmax values in the laser bleaching group; but in the office bleaching group, a significant increase in Rmax was observed ($p<0.05$) (Table 2).

Repeated measure ANOVA test showed a significant difference in Rz values between the two groups ($p<0.05$). The difference between pre- and post-treatment Rz values was not statistically significant in the laser bleaching group ($p>0.05$). On the other hand, there was a significant increase in Rz values after the office bleaching procedure in group A ($p<0.05$) (Table 3).

Discussion

This in vitro study evaluated the effect of 40 % Opalescence Xtra Boost on the surface roughness of enamel in comparison with laser bleaching using JW power bleaching gel (Heydent GmbH). It was shown that both materials increased surface roughness of the enamel, with the laser bleaching group showing a milder increase in comparison with office bleaching.

In the present study, samples should have comprised freshly extracted caries-free teeth which could have been found only in severe periodontally diseased individuals. Due to the extremely low number of individuals having the aforementioned criteria, intact freshly extracted third molars were included instead of anterior teeth, as done by some other investigators [15].

Bleaching is principally a chemical reaction between the oxidizing bleaching agent on enamel and dentin to remove discolorations. Hydrogen peroxide has long been used in dental bleaching procedures. It can penetrate deep through the organic matrix of enamel and dentin due to its extremely low molecular weight.

It is commonly theorized that free radicals react with organic materials to render them chemically stable. This causes other free radicals to react with other unsaturated bonds in organic molecules to change their electron arrangement, thereby changing their energy absorption, which is detectable in enamel. This results in formation of simpler molecules that reflect light less than before. Therefore, the tooth appears brighter. In initial steps of the bleaching procedure, severely stained carbonic rings are opened to form lighter ones. Yellow-colored coordinate carbonic bonds turn into colorless hydroxyl groups. In this stage, bleaching of the teeth becomes stable which is in turn dependent upon the speed of the process [30].

The results of the present study were in line with those of Dominguez et al. [31], Abouassi et al. [32], Vasconcelos et al. [33], and Sasaki et al. [34] who declared that office bleaching caused increased surface roughness of enamel. Also, the results of this study can be corroborated by Canzi Almada and colleagues [35] who revealed that laser bleaching did not increase surface roughness of enamel. The findings of the current study is in contrast with Mondelli et al. [8], Augusto et al. [36], and Borges et al. [37] who concluded that conventional bleaching could not increase surface roughness of enamel. The reason for the difference with study of Mondelli et al. can be attributed to the use of bovine teeth and difference in the light source used. Augusto and colleagues used dental ceramics, and Borges et al. stored their samples in saliva which has a remineralizing effect and can cause discrepancies in the obtained results. In the present investigation, human molars were used, and polishing was carried out using the finest sandpapers (grit 3,000). In the current study, the profilometer was used to evaluate roughness which is currently an accurate method for such evaluation [38, 39].

Evaluation of the Rmax value by the device is a confirmation for the results of Ra evaluation. Considering equal conditions for all samples, an increase in Rmax was found after using the materials. This confirmed postoperative changes in

Table 2 Mean Rmax values in experimental groups before and after treatment (μm)

Experimental groups	Mean±SD of Rmax		
	Pretreatment	Post-treatment	Pre- and post-treatment difference
Office bleaching (group A)	0.66±0.59	0.65±0.45	−0.017±0.29
Laser bleaching (group B)	0.53±0.27	0.82±0.43	0.29±0.49

Table 3 Mean Rz values in experimental groups before and after treatment (in micrometers)

Experimental groups	Mean±SD of Rz		
	Pretreatment	Post-treatment	Pre- and post-treatment difference
Office bleaching (group A)	0.36±0.18	0.40±0.19	0.038±0.12
Laser bleaching (group B)	0.32±0.13	0.54±0.23	0.21±0.22

Ra when compared with the preoperative condition in both groups. Changes in Rmax indicate increased surface roughness of enamel in most of the samples in office bleaching and those in laser bleaching groups. These changes were more pronounced in the office bleaching group. Evaluation of the Rz value shows that an increase in this variable following use in both the office and laser bleaching groups was noted. This also confirms increases in Ra and Rmax values showing increased surface roughness of enamel in both groups. It was also more pronounced in the office bleaching group.

Therefore, all three components evaluated in this investigation are stated to be influential in enhancing surface roughness of enamel in both bleaching groups. This can be attributable to the demineralizing effect of components with a relatively acidic pH (5.2 to 5.8). The optimal pH for hydrogen peroxide to act as a bleaching agent is 9.5 to 10.8 [30], in which hydrogen peroxide is not chemically stable. Therefore, manufacturers tend to reduce its pH in bleaching systems. This can cause surface changes in enamel such as decalcification, increased porosity, and surface roughness [40].

Increased surface roughness of enamel leads to adverse effects such as diminished enamel resistance against pressure, increased permeability, and staining [9, 30], increased plaque (*Streptococcus mutans*) adhesion up to 25 times [41], and eventually caries susceptibility following frequent use of bleaching agents. Enamel surface coverage by bacterial plaque paves the ground for increased accumulation of the bacterial mass leading to caries [5]. Authors believe that dissolution of superficial organic layers of enamel such as enamel cuticle and acquired pellicle as well as disintegration of the superficial prismless layer of enamel can take place following exposure to bleaching agents for a long time. This occurs due to the effect of oxidizing agents on the organic matrix of dental hard tissues (enamel and dentin) [9, 41]. On the other hand, laboratory studies confirmed changes in calcium-to-phosphate ratio to a depth of 10 nm in subsurface enamel when some bleaching techniques were undertaken. This could result in increased inter-rod distance, thereby justifying the resultant increase in surface roughness of enamel [5]. These results limited the use of bleaching agents in dentistry. Nevertheless, according to the previous studies, use of fluoride-containing toothpastes or fluoride therapy after bleaching agents can improve surface characteristics of enamel [42].

Generally, several methods have been proposed to decrease the time and to increase the effectiveness of the bleaching procedure such as elevation of the peroxide gel concentration and alkalinization of the peroxide preparation through incorporation of a ground substance such as sodium hydroxide. Sodium hydroxide destroys peroxide solution and increases peroxide activity, but it decreases shelf life of the material. Bleaching procedure can also happen in a shorter time through temperature rise of the chemicals. This can take place with enhancing the exploration time of the bleaching devices [43]. Each 10° of temperature rise corresponds to a 2.2 times increase in the amount of operating bleaching factor. Therefore, temperature rise enhances bleaching efficacy. There are limits to such temperature rise due to the potential harm to enamel and pulp [11]. Diode laser-assisted bleaching has an in-depth activity, whereas conventional bleaching has a superficial activity and requires more time to be influential on the tooth surface. Since diode laser is absorbed in specific chromophores within the bleaching gel, reactions take place more rapidly, more effectively, and more safely in comparison with the conventional methods. Scanning electron micrographs showed that enamel was intact in laser-bleached samples, whereas demineralization and dissolution were observed in conventionally bleached counterparts [44]. Nevertheless, research is ongoing to find a method with minimal side effects on dental enamel. More extensive investigations are needed to disclose the effects of the bleaching agents on dental hard tissues. On the other hand, it should not be overlooked that the results of in vitro studies cannot be extrapolated to the clinical situations [3]. It should be noted that absorption of the minerals from the saliva in the oral environment results in remission of such effects and remineralization of the enamel surface [45].

Conclusion

Considering the limitations of this study, it can be concluded that microroughness of enamel surfaces following diode laser bleaching using Heydent bleaching gel was significantly less than that observed in conventional technique using 40 %hydrogen peroxide gel. It was also shown that both techniques could increase microroughness of the enamel surface.

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