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Effect of conventional and power office bleaching with diode laser and led light on enamel microhardness

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Aim: The present study aimed to asses enamel microhardness after office bleaching with diode laser and LED light compared to the conventional bleaching procedure. **Methods:** Thirty-nine human premolar teeth were collected and randomly divided into three groups regarding of the bleaching technique. Group 1: Snow O bleaching gel with LED light-curing unit; Group 2: Snow L bleaching gel with diode laser irradiation; and Group 3: Opalescence Boost bleaching gel with no light source in group 3. Enamel surface changes were evaluated in one tooth in each study group and one intact tooth as a reference under a scanning electron microscope (SEM). In the remaining samples (n=12), enamel microhardness was determined by Vickers microhardness test before and after bleaching. Data were analyzed with repeated-measures ANOVA to compare microhardness changes, followed by post hoc Tukey tests at the 0.05 significance level. **Results:** Enamel microhardness decreased in all the groups after bleaching, with the maximum decrease in microhardness in the Snow O bleaching group with LED light, which was significantly higher than the other groups (P=0.002). The two other groups did not exhibit any significant difference in microhardness decrease (P>0.05). **Conclusion:** Based on the limitations of this study, it can be concluded power bleaching with 980nm diode laser was less time-consuming compare to conventional bleaching procedure and yielded better outcomes in terms of enamel surface microhardness compared to the use of an LED light-curing unit.

Keywords: Lasers, semiconductor. Dental enamel. Hardness. Curing lights, dental. Tooth bleaching.

Introduction

Currently, modern dentistry deals with the ever-increasing esthetic needs of patients in addition to the treatment of dental diseases. Bleaching is considered a conservative and favorable treatment for discolored teeth compared to composite resins and porcelain veneers[1]. Although at-home bleaching is the most commonly suggested method for vital teeth, some patients cannot benefit from this technique due to their inability to use a tray, and some demand a faster therapeutic effect. The in-office technique is associated with swallowing of less material and fewer injuries to soft tissues[2].

Irrespective of the technique or the type of the materials used, bleaching agents exert their effects through a complex oxidation process in association with the release of reactive oxygen species into the enamel prism porosities, reaching the dentin and breaking the organic molecules to produce lighter, smaller, and more translucent compounds[3].

There is controversy, and sometimes contradictory reports, on the effect of bleaching procedures and their byproducts on the tooth hard structures. Some researchers have shown that bleaching does not adversely affect the mechanical properties of tooth hard tissues[4]; however, some studies have shown that bleaching agents can decrease the microhardness and increase the surface roughness of teeth by changing the chemical structure of teeth includes demineralization, denaturing of enamel proteins, decreased mineral agent-to-protein ratio[5,6].

The in-office bleaching procedure can be used in association with different light sources, including plasma arcs, halogen lamps, LED light, and lasers, to further activate or irradiate the bleaching agent and increase the rate of the release of oxygen free radicals. The technique of physically heating hydrogen peroxide with light sources is referred to as power bleaching. Of the light sources mentioned above, LEDs are one of the most commonly used light sources with some advantages, including availability, low cost, and induction of less heat in the pulp chamber[7].

Diode laser is commonly used for in-office bleaching. The chief advantages of the diode laser are its small size, flexibility, and portable optic fibers. Besides, it has attracted dentists' attention due to its low cost and high efficacy. The main difference between laser and other light sources is that lasers emit a well-defined monochromatic beam. Various diode lasers are used for bleaching at 790–980-nm wavelength[8]. The laser wavelength is selected based on the relationship between light and the target tissue. A bleaching gel should absorb light with a particular wavelength; the chemical reaction rate then increases, and the tooth structure is affected minimally[9].

Tooth surface hardness is an important factor in the health of teeth which is used as a parameter to evaluate the demineralization process[10].

There is no consensus about the overall effect of bleaching on tooth surface hardness, especially with laser-activated materials. Several studies have evaluated the effect of laser bleaching on enamel microhardness and reported different results[11,12]. A new type of diode laser with a 980-nm wavelength has a higher absorption rate than 810-nm laser; therefore, it is expected that it might function more conservatively and decrease bleaching time[11].

The bleaching material used in the present study is a new Iranian product with all foreign products' standards. Since no study has been carried out on this material, the present study was undertaken to compare its properties with similar highly efficacious foreign products. The null hypothesis is there is no difference in enamel microhardness after different types of dental bleaching.

Materials and Methods

This study was approved by the ethics committee of Tehran University of Medical Sciences with an ethical code of IR.TUMS.DENTISTRY.REC.1398.134.

In the present in vitro study, 36 human premolar teeth, extracted for periodontal or orthodontic treatment, were used. None of the teeth had any signs of extrinsic staining, caries, enamel hypoplasia, cracks, and other defects.

Sample preparation

The teeth were immersed in 0.1% thymol solution for 24 hours for disinfection and stored in normal saline solution until tested. The teeth were then randomly assigned to different groups and prepared using a similar protocol. The tooth crowns were removed at 2 mm apical to the CEJ with a flat-ended cylindrical diamond bur (Dia Tessin, Switzerland) in a high-speed handpiece. The tooth crowns were embedded in self-cured acrylic resin (Acropars, Marlic Co. Tehran, Iran). The buccal surfaces of the embedded tooth crowns were abraded with 600-grit abrasive paper with a rotary polishing machine (LabPol 21, Struers, Ballerup, Denmark) under water cooling to expose a 3×3-mm^2 enamel surface which was polished with 800-, 1200-, and 4000-grit abrasive paper.

Microhardness Test

Vickers hardness (VH) was measured with a 200-gr force with a 10-second indentation time with a microhardness tester (FM-700, Future-Tech, Tokyo, Japan), three indentations were produced on each sample surface, 50 μm apart. The mean microhardness was considered the baseline microhardness.

Tooth Bleaching

Thirty-six teeth were randomly assigned to three groups (n=12) in terms of the bleaching agent used.

Group 1: Prophylaxis and polishing of the teeth were carried out with glycerin-free agents before the procedural steps. A thin layer of 35% Snow O HP bleaching gel (Novateb Hoding, Tehran, Iran) was placed on the tooth surface and completely spread on the surface to achieve a 1-mm thickness. Then the tooth surface was irradiated with high-intensity red and blue lights at 640-nm wavelength (A=1.5) for 20 minutes, using an LED MONITEX light-curing unit (Whiten MAX-BR800, Monitex, Taiwan). Then the gel removed. The process was repeated and the tooth was thoroughly rinsed.

Group 2: Prophylaxis and polishing were carried out with glycerin-fee agents before the procedural steps. A thin layer of 35% Snow O HP bleaching gel (Novateb Hoding, Tehran, Iran) was placed on the tooth surface and completely spread on the surface to achieve a 1-mm thickness. Three rounds of irradiation were carried out with 980-nm diode laser beams (simpler, doctor smile, Vicenza, Italy) with a specific power for 30 seconds with a 1-minute interval. Then the gel remained on the tooth surface for 7–10 minutes, followed by removal of the gel. This process was repeated; Then the tooth was thoroughly rinsed.

Group 3: Before the procedural steps, prophylaxis and polishing were carried out with glycerin-free agents. A 1-mm layer of 40% Opalescence Boost HP gel (Ultradent Products Inc, South Jordan, UT, USA) was placed on the tooth's labial surface. The gel remained on the tooth surface for 20 minutes each time. Then the gel was removed from the tooth surface with a suction device. Water was not used to prevent gel secretion. The process was repeated twice.

After the bleaching procedures, the teeth were stored in artificial saliva at 37ºC for 24 hours. Three other indentations were then produced, and the mean of the three was considered the mean hardness after bleaching. Finally, microhardness means before and after bleaching procedures were compared to determine surface hardness changes due to bleaching procedures.

SEM Evaluation

One tooth from each study group and an intact tooth that did not undergo a bleaching procedure were evaluated under a scanning electron microscope (SEM) (FEI Nova NanoSEM 450, Sydney, Australia) to determine enamel surface characteristics. The samples were rinsed with distilled water and air-dried for 24 hours. After fixing the samples on aluminum studs, they were gold-sputtered to better reflect rays before placing them in the unit. In terms of morphology and possible damage, the surface characteristics of enamel were evaluated at different magnifications (×2000, ×8000, and ×25000).

Statistical Analysis

The data were analyzed with SPSS 25.0. Since data were distributed normally according to the Kolmogorov-Smirnov test, repeated measure one-way ANOVA was used to compare microhardness changes between the groups. In addition, post hoc Tukey tests were used for two-by-two comparisons of bleaching agents. The acceptable type I error was set at 0.05 in this study ($\alpha=0.05$).

Results

Microhardness

Table 1 presents the means and standard deviations of microhardness changes after bleaching and enamel surface hardness changes in all the three study groups. According to the results enamel surface microhardness decreased in all the groups after bleaching with all the bleaching techniques mentioned previously.

Paired-samples t-test showed that the decrease in microhardness after bleaching was significant in all the three groups.

Table 1. The means and standard deviations of microhardness changes and enamel surface changes after bleaching in all the study groups

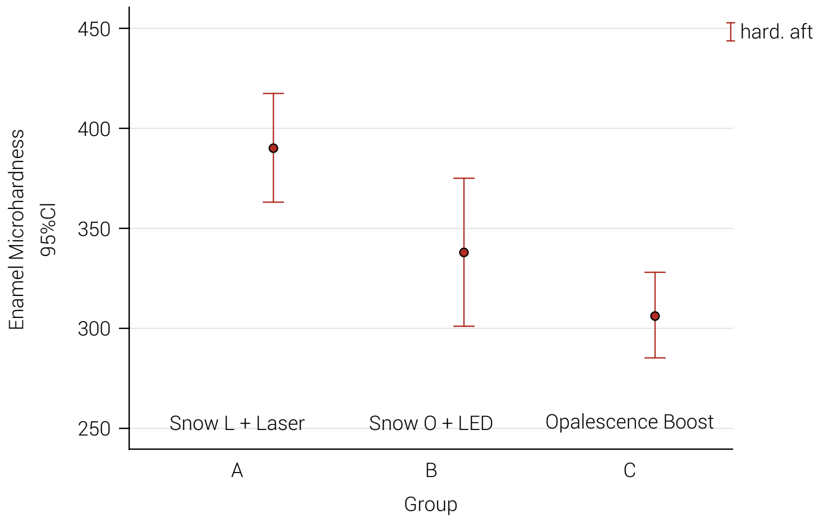
Study groups	Mean ± SD	Sig.
Snow L + Laser	-39.18± 42.70	0.012
Snow O + LED	-85.82 ± 62.63	0.001
Opalescence Boost	-15.64 ± 7.27	0.0001

The highest decrease in enamel microhardness after bleaching was recorded in the Snow O bleaching gel and LED (Monitex) group with 85.81 units, followed by the Snow L bleaching gel plus 980-nm laser group with 39.18 units, and the opalescence Boost HP group with 15.63 units.

A comparison of the three groups' microhardness decreases with repeated-measures ANOVA showed significant differences between the three groups (P=0.003). In other words, there were different changes in enamel microhardness in the study groups. Post hoc Tukey tests were used for two-by-two comparisons of the groups regarding changes in enamel microhardness after bleaching. The results are presented in Table 2, according to which there was no significant difference in enamel microhardness changes between Snow L + laser and Opalescence Boost groups (P=0.431). There was no significant difference in enamel microhardness changes between Snow L + laser and Snow + LED groups (P=0.048). Besides, there was no significant difference in enamel microhardness changes between Snow O + LED and Opalescence Boost groups (P=0.002) after bleaching. In other words, there were significant differences in enamel microhardness changes after bleaching between the Snow O + LED group and the two other groups; however, there were no significant differences between the two other groups. Graph 1 presents the results of comparisons of enamel microhardness after bleaching between the different study groups.

Table 2. Two-by-two comparison of microhardness changes in different study groups

Group	Comparison	Mean ± SD	Sig.
Snow L + Laser	Snow O + LED	46.63± 18.74	0.048
	Opalescence Boost	23.54±18.74	0.431
Snow O + LED	Snow L + Laser	46.63± 63.74	0.048
	Opalescence Boost	70.18±18.74	0.002
Opalescence Boost	Snow L + Laser	23.54±18.74	0.431
	Snow O + LED	70.18±18.74	0.002



Graph 1. Microhardness of different study groups after bleaching.

SEM Evaluations

SEM evaluations revealed minor changes in the study groups compared to the intact enamel. In the tooth enamel without a bleaching procedure, unchanged surfaces were observed in the presence of parallel lines, indicating that the enamel surface was intact (Figure 1). In the Snow L gel + diode laser group, in addition to the parallel lines, mild changes, including fine surface irregularities and wrinkles, were observed (Figure 2). In the Snow O gel + LED group, there were more surface changes than the two other groups, consisting of more depressions and porosities with larger diameters in association with wrinkles on the enamel (Figure 3). In the Opalescence Boost gel group, too, enamel surface changes consisted of porosities, pitting, erosion, and enamel surface dissolution (Figure 4).

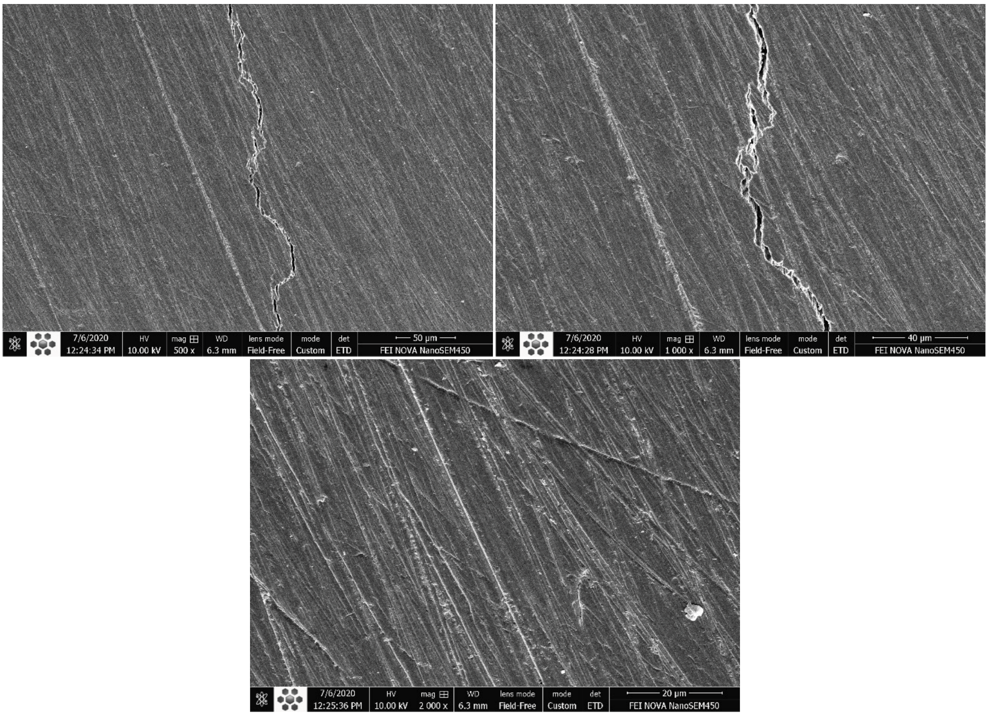


Figure 1. The SEM view of sound and intact enamel without bleaching procedures at ×500, ×1000, and ×2000 magnifications.

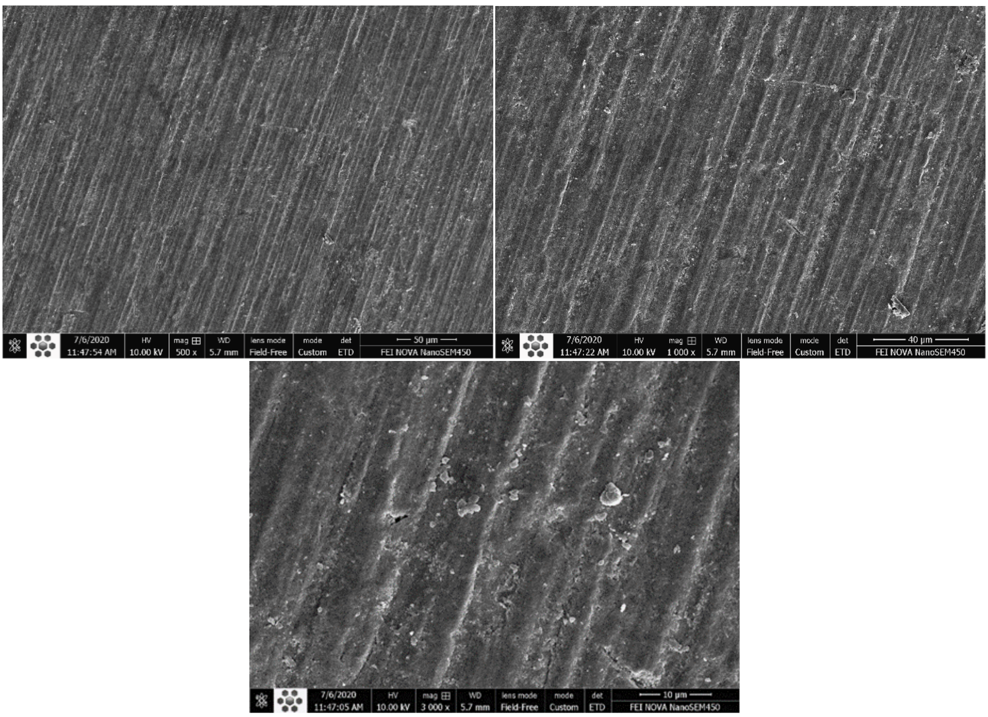


Figure 2. The SEM view of the enamel bleached with Snow L gel and diode laser at ×500, ×1000, and ×2000 magnifications.

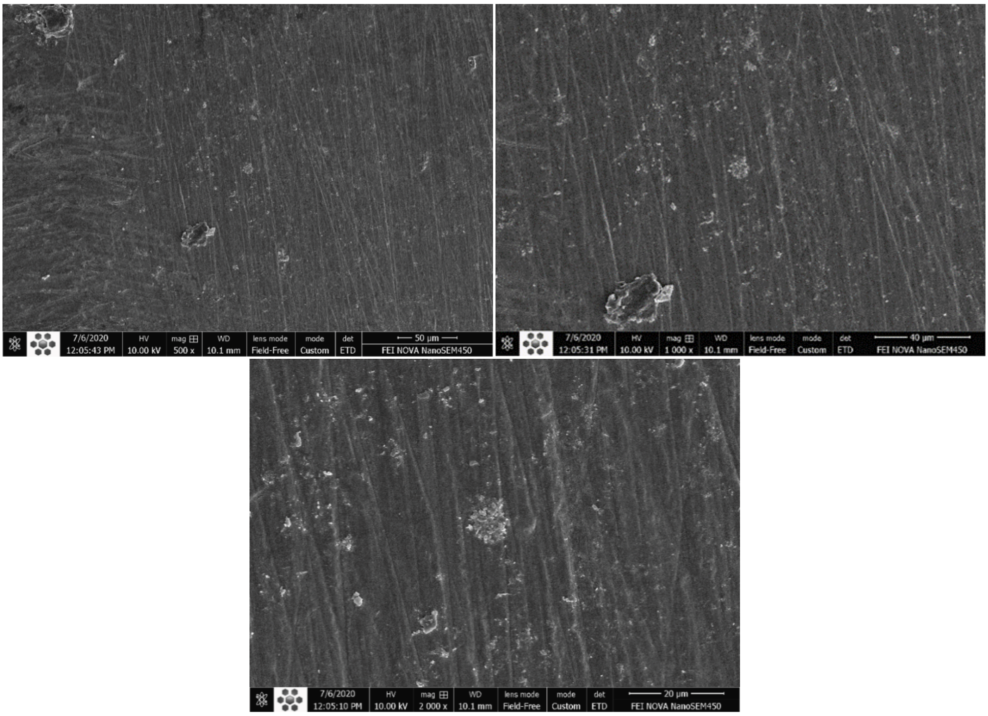


Figure 3. The SEM view of the enamel bleached with Snow O gel and LED at ×500, ×1000, and ×2000 magnifications.

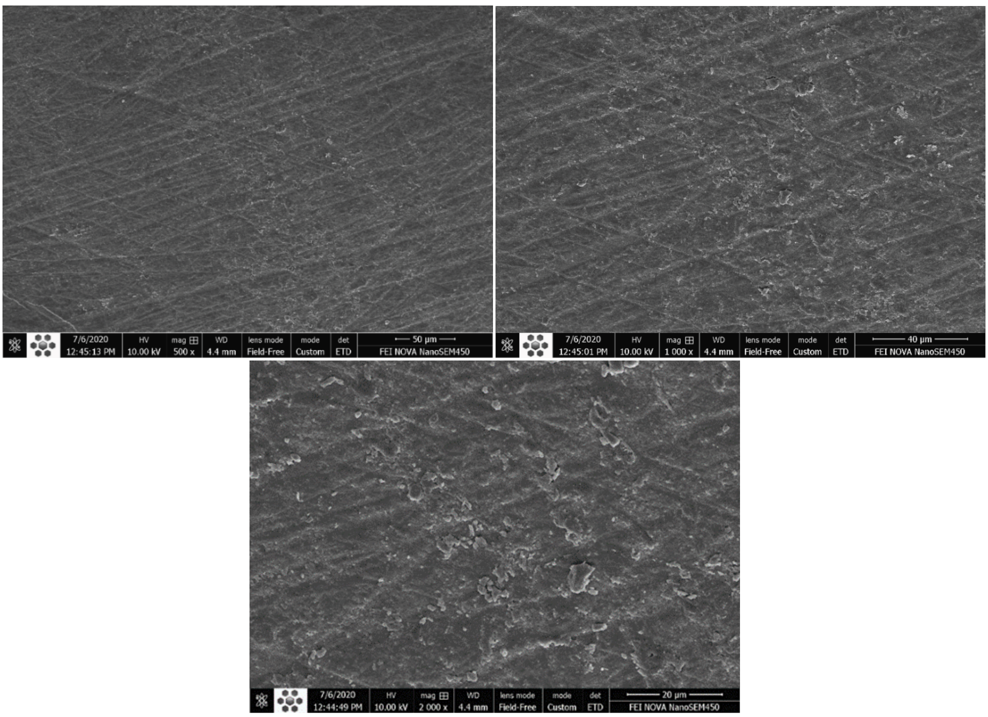


Figure 4. The SEM view of the enamel bleached with Opalescence gel at ×500, ×1000, and ×2000 magnifications.

Discussion

Evaluation of the effect of bleaching procedures on tooth structure, especially enamel microhardness, is one of the most important fields that has been discussed by researchers. Contradictory results are available on the effects of bleaching gels on enamel microhardness[13].

In the present study, enamel surface microhardness decreased after bleaching in all the study groups, consistent with a study by Mondelli et al.[6], in which enamel microhardness decreased after in-office bleaching with gels containing different concentrations of hydrogen peroxide (15%, 25%, and 35%). Saati et al.[11], too, showed a decreased enamel microhardness in samples bleached with 40% hydrogen peroxide alone or in association with a diode laser with 810- and 980-nm wavelengths.

Irrespective of using or not using a light source, the bleaching process leads to important chemical changes in the enamel and dentin. Some of the changes after bleaching are changes in the dental substructure morphology, including pit formation, increased porosity, hardness, and changes in biomechanical properties, including microhardness. Bleaching agents can decrease the enamel mineral content and the number of calcium and phosphorus ions in the structure, similar to microhardness. Besides, hydrogen peroxide's acidic nature can change the matrix and mineral and organic background of enamel by releasing carbonates and proteins of the tooth hard structure[14].

However, some studies, such as that by Sulieman et al.[4], did not report any decrease in enamel microhardness after bleaching with 25% hydrogen peroxide.

Such a discrepancy in the results might be attributed to differences in study designs, including the composition and concentration of bleaching agents or the bleaching techniques (time and the number of applications) or the enamel type (human or animal), the duration of sample storage, the storage material (artificial saliva, human saliva, and remineralizing solutions, the microhardness test used (Knoop or Vickers hardness) and the test conditions (in vivo, in vitro, and in situ). After bleaching, enamel microhardness changes might be related to the exposure time and active factors' concentrations, too[10,13].

Lewinstein and Hirschfield evaluated the effect of 30% HP at different times and reported a significant decrease in enamel and dentin microhardness after 15 minutes, concluding that solubility and penetration increased over time[15]. In the present study. Opalescence Boost was applied for approximately 20 minutes, which might have decreased enamel surface microhardness. The Snow L and Snow O gel were applied for 10 and 20 minutes, respectively, which might explain the differences in enamel microhardness between the study groups.

Another factor affecting enamel microhardness after bleaching procedures is hydrogen peroxide's concentration. Studies have shown that an increase in the concentration of hydrogen peroxide (38%) and carbamide peroxide (30%) significantly decreases enamel and dentin microhardness[15,16].

In the present study, Opalescence Boost resulted in a minor decrease in enamel microhardness, although its hydrogen peroxide concentration was high (40%). According to the manufacturer, the two other gels have used a combination of hydrogen peroxide (35%) and carbamide peroxide. No explanation has been provided about the concentration and amount of carbamide peroxide used in these gels, and conversion of carbamide peroxide to hydrogen peroxide after being placed in the oral cavity environment, and its hydrolysis might lead to an equal or higher concentration of hydrogen peroxide. Therefore, further studies are necessary to learn about the exact concentration of hydrogen peroxide in these gels.

The Opalescence Boost's acidity is 4.3, which is lower than the critical point for enamel, which is 4.5–5.5[17]. Therefore, the enamel might be demineralized by this gel. No data are available about the pH values of the two other gels; however, it appears that its acidic pH is possible by considering the decrease in enamel hardness. Therefore, further studies are recommended on the pH of these bleaching gels.

Even gels with a higher pH, too, can soften the enamel, which might be explained by the saturation rate of gels with different ions in contact with the enamel mineral agents. A low concentration of calcium and phosphate and a high concentration of sodium and chloride in these gels result in under-saturation of hydroxyapatite in bleaching agents, which softens and dissolves enamel, finally leading to a decrease in tooth hardness[17].

The fluoride in the Opalescence Boost gel, too, might be another reason for a lower decrease in tooth enamel microhardness compared to the two other groups. This material contains sodium fluoride and potassium nitrate in one syringe and concentrated hydrogen peroxide in another syringe. When the material is mixed, fluoride appears at 1.1% concentration, and potassium nitrate appears at 3% concentration. This fluoride concentration can prevent a decrease in enamel surface microhardness to some extent[11].

In the present study, the bleaching group's decrease in microhardness without a light source was less than that in the groups bleached with light sources. Therefore, one of the reasons might be the LED light source or diode laser combined with the bleaching agent. Energy sources (including heat, halogen lights, LED lights, diode laser, and other lasers) might serve as catalysts for hydrogen peroxide and used as an accelerator in the bleaching process[18].

With the development of lasers and other light sources used to activate bleaching agents[19], the adverse effects of these sources on tooth hardness have not been reported. There are doubts about the role of these sources in increasing efficiency without damaging the structure of the tooth[20,21].

The laser used in the present study was diode laser with a wavelength of 980 nm, which is the wavelength suggested by the gel's manufacture because, at this wavelength, the diode laser is properly absorbed in the bleaching gel and increases its temperature. Besides, the diode laser with a 1.5-W output has a photothermal effect and increases peroxide precipitation, formation and release of active hydroxyl radicals, and penetration depth of bleaching agents, decreases the time needed, and finally increases the yield of the treatment process[11].

The laser systems' mechanism of action during the bleaching process depends on their wavelength, power, and the radiation's continuous or interrupted nature.

An increase in temperature due to laser irradiation also affects changes in enamel surface microhardness[22]. Since the treatment duration in the laser bleaching technique is about 8–10 minutes, the materials' exposure time, laser irradiation, and temperature rise were lower in this technique.

In the present study, the decrease in enamel microhardness in the Snow L + laser group was higher than that in the Opalescence Boost group; however, the difference was not significant. Currently, the use of conservative bleaching techniques is of great significance, and the use of laser beams is a technique approved by the American Dental Association. Further studies are necessary to find an alternative technique with fewer side effects on the enamel and dentin structure.

Ashnagar et al.[23] reported a decrease in Knoop microhardness after bleaching with the conventional technique with 40% hydrogen peroxide gel alone or with diode or Nd:YAG laser beams. In contrast to the present study, Ahmed et al.[24] did not report any deleterious effects on enamel microhardness after the activation of bleaching agents with different light sources. Such discrepancies might be explained by using different lasers (in terms of different wavelengths), differences in tools or technical properties, differences in settings, and the use of different gels.

In the present study, the most significant decrease in the enamel surface microhardness was observed in the bleaching group with LED light, which was significantly higher than that in the two other groups. It appears that a 20-minute continuous irradiation time increased the heat produced due to the disruption of the bonds in bleaching agents' molecules, causing more structural changes in enamel compared to the two other techniques. Higher energy absorption on the surface has unfavorable effects on the enamel and dentin.

In the present study, SEM evaluations showed the least surface changes compared to the sound enamel in the laser bleaching group, followed by LED and Opalescence Boost gel bleaching groups. Changes in surface and microhardness of enamel were similar except for the Opalescence Boost gel bleaching group. It should be pointed out that studies on SEM evaluations of enamel microhardness changes have yielded different and contradictory results, and it has also reported that there is no relationship between these two[25].

Finally, demineralization after bleaching is in the normal range compared to drinking daily acidic beverages. However, it is important to instruct patients to avoid taking acidic and colorful foods and modify their diet after bleaching procedures because the demineralized enamel is ready to absorb pigments, possibly resulting in unfavorable staining[26].

Moreover, considering the clinical significance of this study, it is suggested that other studies were performed to assess the long-term evaluation of enamel microhardness, at least 7 days. Because the buffering capacity of artificial saliva may not be fully completed After 24 hours. Thus, the long-term evaluation can bring different results in this regard.

Strategies like fluoride therapy, fluoride-containing mouthwashes and bicarbonates without abrasive agents, and refraining from brushing immediately after the bleaching procedure (the effect of salivary remineralization) are important methods to prevent the erosion of enamel after bleaching. Besides, successful attempts have been made to increase microhardness by incorporating fluoride and calcium into bleaching agents[2].

Also, these changes in the oral cavity might be reversible without any clinical significance. It should be noted that if bleaching procedures are carried out correctly according to the manufactures' instructions to ensure their safety and patient health[27].

Based on the results of the present study and under its limitations, it can be concluded that all the three materials and techniques used during in-office bleaching resulted in a significant decrease in enamel microhardness; however, the most significant decrease in microhardness was recorded in the LED bleaching group. Laser Bleaching seems to be a good choice in dental bleaching due to the less chair time and no significant difference with conventional bleaching group regarding enamel microhardness. However, long-term storage in artificial saliva may affect the result.

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Data Availability

Datasets related to this article will be available upon request to the corresponding author.

Conflict of interest

None

Author Contribution

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All authors have read and agreed to the published version of the manuscript.

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