The effect of diode laser in preventing enamel demineralization in permanent dentition (an in-vitro study)

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Abstract Objective: The current study tested the ability of a low power (1 watt) diode laser of wavelength (940 nm) to prevent enamel white spot lesions (WSL).

Materials and Methods: A total of 30 sound natural human premolars were used and were divided into three groups (10 teeth in each group); Group 1 (control group) without any applications, Group 2 coated with fluoride varnish, and Group 3 treated with a diode laser. Samples were then subjected to a cariogenic solution for 1 week. The labial surfaces for each group were evaluated under a scanning electron microscope (SEM) to evaluate the morphological changes that occurred on all enamel surfaces.

Results: The collected data were subjected to One-Way ANOVA followed by Tukey‘s honestly significant difference test, and the results revealed a significant difference in the average mean intensity between the control group (Group 1) and the laser-treated group (Group 3), as well as between the control group and the fluoride-treated group (Group 2), while the least statistically significant result was recorded for Group 1 (control group).

Conclusions: According to the SEM images, preventive effect of Fluoride for WSLs on enamel surface remains better than that of the diode laser (940 nm).

Keywords:

Demineralization, Diode LASER, Fluoride varnish, White spot lesions

Introduction:

White spot lesions (WSLs) development on the enamel surface is associated with orthodontic treatment involving multi-brackets appliances and are a well-known clinical problem for dental specialists representing a significant challenge for achieving an excellent esthetic outcome [1-3].

The presence of bonded attachments affects proper oral hygiene maintenance and provides a greater surface area for the adherence of plaque. These problems can make it more likely that caries will start on surfaces of the teeth that are not usually affected by caries [3].

The use of fluorides is one of the most efficient methods of caries prevention. Twenty years ago, the effects of topical fluoride seemed to have been highly effective in preventing caries incidence [4]. Lasers have been investigated as an alternative to fluoride

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to enhance the quality of tooth enamel and increase its resistance to demineralization.

Additionally, rather than ablating the enamel surface, lasers boost enamel resistance by altering the morphology, chemical structure, or solubility of enamel [5]. So, lasers have been advocated as an addition to traditional preventative therapy [6]. However, there are controversies over how various laser types affect the ultrastructure of the enamel, and the ideal result is still uncertain [7,8].

Based on the current literature, there is an observed lack of evidence evaluating the effect of pre-treatment of the enamel surface with a diode laser in preventing enamel demineralization in permanent dentition. As a result, this study was designed to focus on the acid resistance of low-level diode laser application compared to fluoride varnish application in the prevention of white spot lesion development on the enamel surface of permanent dentition.

Materials and Methods:

Selection of Teeth:

A total of 30 natural human premolars were selected. The teeth were extracted for orthodontic reasons from teenagers or adolescents who were totally sound and free from de-mineralization. Teeth were placed in a 6% sodium hypochlorite solution for 24 hours to remove all soft tissues, stains, and plaque. The teeth were cleaned and polished using a polishing cup with non-fluoridated pumice and a dental brush. They were rinsed with high-pressure water. Under a scanning electron microscope (SEM), all of the teeth were mounted rigidly on a specimen holder or stub using a conductive adhesive and looked at both on a large and small scale to rule out samples with caries, stains, enamel hypoplasia, cracks, microcracks, or any other defects. Until the day of the experiment, all of the samples were kept in normal saline at room temperature (20–25°C).

Study Design:

Grouping and Specimen Preparation

Samples were divided into three groups (10 teeth per group) according to the intervention: no intervention, fluoride varnish-containing agents, and diode laser. Group 1 (n = 10) received no intervention. Fluoro-Dose® 5% sodium fluoride varnish was applied to Group 2 (n = 10). Using a Benda brush applicator, one drop of Fluoro-Dose was put directly on the labial surface of each sample. This was done for 10 seconds, and then each sample was light-cured for 20 seconds. Samples subjected to the diode laser in group 3 (n = 10) received laser treatment using the Epic™Diode Laser, (Biolase Inc., Foothill Ranch, CA, USA). The handpiece, with a single-use irradiation fiber tip, was held perpendicularly to the labial surface of each premolar and moved in a circular motion pattern in non-contact mode with a standard distance of 2 mm (940 nm, 1 watt, CW mode, 400 micrometers, non-initiated fiber for 60 secs). All samples were then subjected to an artificial demineralization challenge after treatment application.

Creation of Artificial Demineralization:

All specimens (n = 30) were subjected for 7 days to a cariogenic challenge to create artificial carious enamel lesions. The demineralizing solution was prepared using 0.1 mm lactic acid, 3 mm calcium chloride, 3 mm potassium dihydrogen phosphate, and 0.2 guar gum at 37 °C. The solution was revived after 48 hours. After 7 days, each tooth sample was rinsed with deionized water for 20 seconds, and then the samples were evaluated for demineralization under a scanning electron microscope (SEM) using field emission electron microscopy. The buccal surface of each sample was parallel to the slide base of the SEM. The samples were analyzed at 15 kV at various magnifications.

Data collection:

SEM images per treatment group were fed to the image J software for image intensity measurements. The average +/- standard deviation of images per selection area was selected and saved locally in CSV format for downstream analysis.

Statistical analysis:

The R programming language was used to do the statistical analysis (R version 4.1.2 (2021-11-01), in which the average pixel intensities per group of each of the above three classes were grouped into respectful matrices, then averaged with +/- standard deviation. This step was conducted to prepare the data for inferential analysis. The analysis included Analysis of Variance and Tukey's HSD (honestly significant difference). This was to pinpoint differences between pairs of classes. The collected data were subjected to One-Way ANOVA followed by Tukey’s HSD Test.

Results:

Scanning Electron Microscope (SEM) Images Results:

The SEM analysis showed irregularities in the surface, roughness, cracks, and pores at any magnification in all specimens of Group 1 (control group) after being subjected to immersion in the cariogenic solution Figure 1. On the other hand, the SEM analysis of group 2 specimens (light curable fluoride varnish-treated group) showed that surface alterations were slighter; the enamel surface had less roughness and fewer cracks and surface irregularities Figure 2. Whereas group 3 (The Epic ™ Diode Laser, Biolase) SEM analysis showed more surface roughness and irregularities as compared to the fluoride varnish treated surfaces Figure 3.

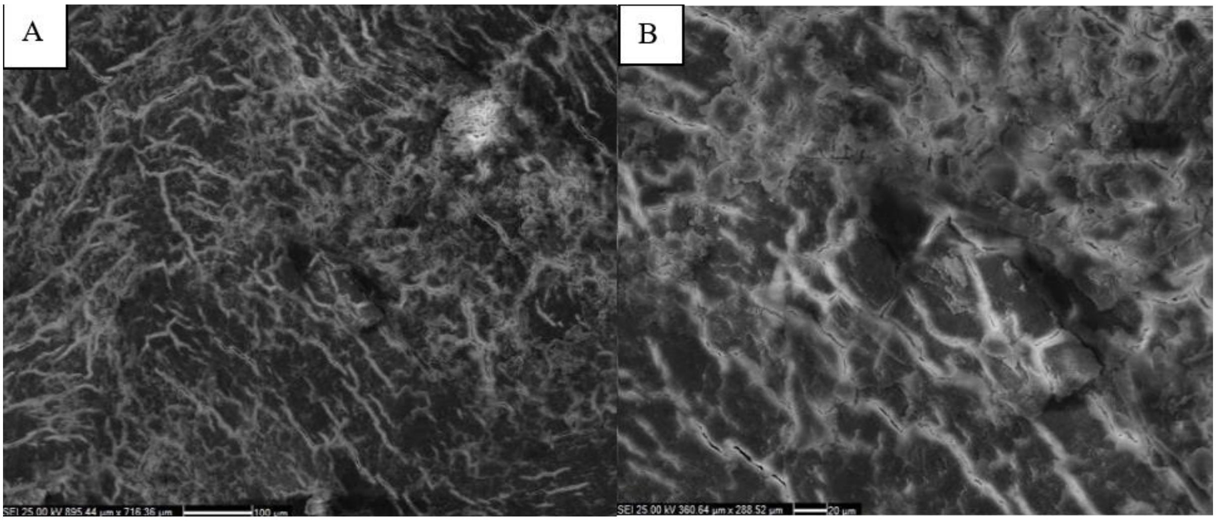

Figure 1: Scanning Electron Microscope Images of control group using magnification A: 100 µm and B: 20 µm.

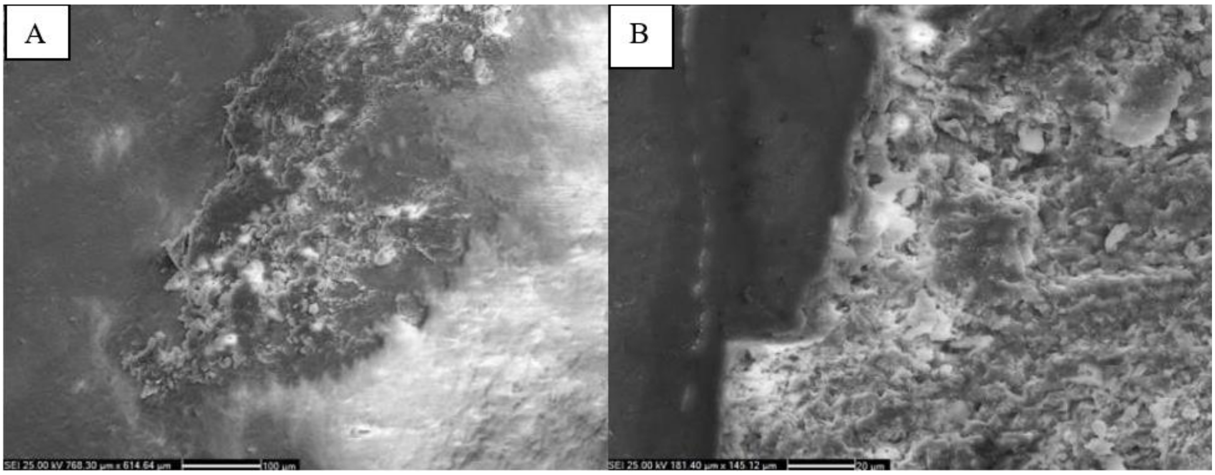

Figure 2: Scanning Electron Microscope Images of the Fluoride group using magnification A: 100 µm and B: 20 µm.

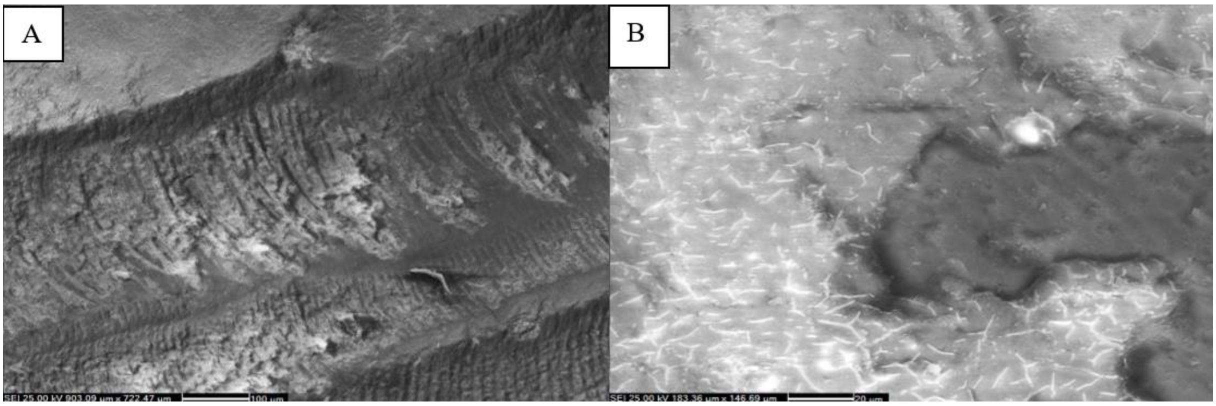

Figure 3: Scanning Electron Microscope Images of the group of the Epic ™ Diode Laser, Biolase using magnification A: 100 µm and B: 20 µm.

Images intensity Results:

Statistical analysis, Table 1 and Table 2, showed that there was a statistically significant difference among the three studied groups ($p = 0.019$). There is a significant difference in the average mean intensity between the control group (Group 1) and the laser group (Group 3), as well as between the control group and the fluoride treated group (Group 2). The least statistically significant difference was recorded for group 1 (control group). Results also revealed a higher effect on the enamel surface for group 2 (Fluoro Dose® 5% Sodium Fluoride Varnish) in comparison to group 3 (Diode), with a statistically significant difference between them.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Groups	2	2910	1455	4.517	0.019*
Residuals	31	9986	322.1		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1					

Table 1: One- way ANOVA of all tested variables.

	diff	lwr	upr	p adj
Fluorinated → Control+Saline	19.13436	0.695353	37.57337	0.0406*
Laser →Control+Saline	19.57673	1.137717	38.01574	0.0355*
Laser →Fluorinated	0.442364	-18.3932	19.27796	0.9982

Table 2: Tukey HSD (honestly significant difference).

Discussion

As far as we know, there is not much evidence that the diode laser can stop enamel from becoming less mineralized in permanent teeth [9-11]. The outcomes of the current study showed a significant difference in the average mean intensity between group 1 (control group) and the rest of the groups. Also, there is a statistically significant higher effect on the enamel surface for group 2 (Fluoro Dose® 5% Sodium Fluoride Varnish) in comparison to group 3 (Epic ™ Diode Laser, Biolase).

This could be explained by the fact that topical fluorides reduce the solubility of enamel, either through CaF_2 or fluoridated hydroxyapatite production. Since the topical fluoride employed in this investigation has a low pH (3.9), calcium is released from the enamel and reacts with fluoride to create CaF_2 on the enamel surface.

When exposed to acid, CaF_2 will release fluoride to create fluoridated hydroxyapatite and promote enamel remineralization. By raising the fluoride concentration and the time of interaction with the enamel, fluoride penetration into the enamel and the production of fluor-hydroxyapatite and CaF_2 are increased [12]. The observation that the detected fluoride precipitations on the enamel surface may lessen the enamel's permeability to acids is further supported by the SEM images in [Figure 2].

Moreover, it has been hypothesized that the primary or probably the only preventative mechanism of topical fluoridation is the production of CaF_2 [13]. Nevertheless, fluoridated apatite has been discovered up to 20 µm below the enamel surface, below the CaF_2 layer. After making a surface coating layer, CaF_2 can block the mineral diffusion channels around the prisms of enamel. This makes enamel less permeable [14,15].

Our findings are consistent with a study by Santaella et al., who used polarized light microscopy to measure the depth of the lesion after pH cycling and compared the ability of the diode laser (809 nm wavelength, 50 Hz, 600 µm fibre, contact mode, absorber, 1 min and 140 mJ pulse energy) to prevent caries against topical fluoride on primary enamel teeth. In comparison to fluoride, they discovered that laser application had a reduced potential for prevention [16].

It was found that materials involving fluoride, calcium, and phosphate were more effective than diode laser and that the use of diode laser alone did not prevent lesions [10]. Their study evaluated caries prevention in primary teeth using only duraphat 5% fluoride varnish or diode laser application for 1 minute followed by fluoride varnish application. According to their results, topical fluoride was more effective than diode laser in caries prevention [16].

Ana PA et al. also found that the diode laser alone could not make enamel less soluble [17]. According to Kato et al. study on the effects of a 960 nm laser diode on the solubility of calcium in tooth enamel, calcium can change the enamel surface on its own but does not increase acid resistance, making the dental surface less susceptible to demineralization unless fluoride is added [10].

Our results contradict those of a study that concluded that the application of a diode laser alone or after fluoride varnish application is more effective for caries prevention than fluoride varnish application alone, after assessing the effectiveness of the 425 nm diode laser when used alone or when applied after topical fluoride varnish in inhibiting the formation of artificial caries lesions [18].

Moreover, studies done by Stern et al. and Lenz et al. both using scanning electron microscopy, attributed the decrease in subsurface demineralization rate to decreased permeability because of the fusion and sealing of the tooth enamel surface layer along with its pores and natural irregularities by the laser irradiance [19-21].

Similarly, other studies also explained the decline in permeability, yet they postulated that the organic matter had altered, depending on polarized light microscopic, X-ray diffractometric, and electron spin resonance spectroscopic data [19,20,22].

Additionally, studies have examined the effects of combining fluoride with laser therapy to identify whether the laser can optimize the fluoride's impact on enamel structure and boost the tooth structure's resistance to acid demineralization [23]. Topical fluoride administration along with diode laser irradiation at 940 nm wavelength and an average power of 2 W for 60 s considerably enhanced the aesthetic appearance of white spot lesions (WSL) in comparison to control and fluoride-only groups [24].

The production of the very insoluble hydroxy-fluorapatites is shown by some studies to be facilitated by greater absorption and penetration of topically administered Fluoride as well as a simultaneous further reduction in both dissolving and subsurface demineralization rates when irradiated by a laser [19,20,25-27].

Conclusion

Diode lasers were less effective than topical fluoride in caries prevention. However, the application of a diode laser increased the hardness of the enamel as well.

Limitations

Within the limitations of this study, it seems that the application of a diode laser at wavelengths of 940 nm might reduce the extent of enamel surface alteration that manifests as white spot lesions and that happens during the demineralization process and as a side effect of the placement of fixed orthodontic appliances. This phenomenon was observed not only in the case of the laser-irradiated enamel but also in the case of the conventional fluoride varnish application.

Conflict of interest: no conflict of interest between authors and other organization either personally or financially.

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