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Microhardness of Enamel Surface Irradiated with Nd:Yag Laser

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ABSTRACT

Aims of the study: To measure the microhardness of enamel surface irradiated with Nd:YAG laser with or without the presence of photo absorber (Black ink).

Materials and Methods: The buccal enamel surface of twenty human permanent upper premolars was made flat and the microhardness measured before treatment as control. Then, the teeth were divided into two groups: Group 1: received laser irradiation alone and in group two a black ink was applied on the enamel surface before laser treatment. All the surfaces were subjected to irradiation with Nd:YAG laser using the following parameters: 160mJ, 35 hertz and 5.6Watts.Then the microhardness was measured for the two groups after laser irradiation.

Results: statistical analysis revealed significant reduction in enamel surface microhardness in both groups, with Group 1, recording the least mean value.

Conclusion: Enamel surface microhardness was reduced significantly after Nd:YAG laser irradiation with or without the presence of photo absorber.

Keywords: Dye, Enamel, Laser, Microhardness,

INTRODUCTION

The use of laser in dentistry has been increasing since Stern and Sognnaes (1)firstly reported the effect of ruby laser on dental hard tissues. Although their results were discouraging, many types of lasers have been used since then in an effort to replace the currently used dental Handpiece that causes patients' discomfort and pain due to noise, vibration and heat production as well as the need for anesthesia (2).Lasers used may be of continuous wave such as: CO_2, Nd:YAG and Argon laser, or of pulsed type such as: Er:YAG, Er, Cr:YSGG, ArFexcimer, CO_2, and the Nd:YAG laser(3-8).

The Nd:YAG laser has been used in dentistry since 1990 (9). Soft tissue clinical applications of the Nd:YAG laser include gingivectomies, gingivoplasties, operculectomies, biopsies, incising and draining procedures, frenectomies and treatment of aphthousulcers; while hard tissue clinical applications include vaporizing decay, desensitizing exposed root structure, creating temporary analgesia, and etching of enamel and dentin (10). It generates 1064nm wavelength which is poorly absorbed by dental hard tissues(enamel and dentin)(11), but is capable of producing shallow craters with numerous micropores, when used in conjunction with a nontoxic dye solution (12).The use of photo absorbing dye (i.e. black ink) in conjunction with Nd:YAG causes laser energy to be confined to small volume with resultant increase in ablation efficiency as well as decrease in thermal build up (13).

However, during laser irradiation, ultra structural changes occur as a result of melting and resolidifying of enamel surface due to surface temperature increase. Water is lost in enamel between 80-120°C; organic substance decomposition at 350°C; initial loss of carbonate hydroxyapatite between 400-660°C; and melting of enamel at more than 800-1000°C (14).The melted enamel then recrystallizes to form larger hydroxyapatites than the original ones (14) which leads to a reduction in permeability, a lower acid penetration and prominent chemical and mineral content change (15).

One of the factors to be considered during these changes is enamel microhardness. The mineral content of enamel contributes to its microhardness (16) and plays a role in demineralization inhibition (17) and erosion inhibition

(18).Conflicting results are presents in the literature regarding the effect of Nd:YAG laser on enamel microhardness that may be due to different experimental conditions and laser parameters used. Jennet *et al*.(13), Tagomori and Iwase(15) and Kuramoto *et al*. (19)demonstrated a decrease in enamel microhardness after irradiation of the enamel with Nd:YAG laser. On the other hand, Marquez *et al*.(20) showed an increase in enamel microhardness when it was exposed to Nd:YAG laser. Shimizu(21)reported no significant differences of microhardness between lased and non-lased enamel. Bedini and colleagues (22)tested the microhardness of enamel irradiated by Nd:YAG laser using different parameters: 60mj and 10Hz; 120mj and 10Hz; 160mj and 15Hz. They reported no significant differences between the test groups and the control group(no laser treatment). However, they suggested the use of laser with lower energy levels to increase enamel resistance to acid and caries attack as the surface produced was glazed with no microcracks when studied under SEM, while higher levels can be used for conservative dentistry(e.g etching), since it created retentive surface suitable for sealants and composites anchorage.

The aim of this study is to compare enamel surface microhardness when it is etched with Nd:YAG laser alone or preceded by black ink application.

MATERIALS AND METHODS

Twenty human permanent upper premolars extracted for orthodontic reasons and free from caries and cracks were used in the study. The buccal enamel surface of the teeth was made flat by grinding with coarse, medium and fine grits diamond discs under running tab water for a total of 15 seconds (5 seconds for each grit). The treatment area was defined by adhering a white tape that has a punch of 2mm diameter circular area to the buccal enamel surface. Then, each of these flat surfaces of all twenty teeth was subjected to 4 indentations within the treatment area to determine enamel microhardness before treatment using a Vicker microhardness tester MHT-10 (Axioskop 40, Carl Ziess, Göttingen, Germany). The amount of force used was 200gf (gram force) applied for 10 seconds. The average of the 4 tested Vickers hardness number (HV) was recorded for each tooth(as a control). The teeth were stored in physiological saline solution (20) at 37°C and were divided randomly into two groups (n=10)according to the type of treatment as follow:

Group 1: Nd:YAG laser etching alone,

Group 2: Black ink (Rotring, Germany)coating of enamel surface+ Nd:YAG laser etching. The control teeth for groups 1 and 2 (n=10/ each group) were named as control 1 and control 2 respectively.

For both groups, laser irradiation of the treatment area was performed using Nd:YAG laser (Pulse Master 600 IQ, American Dental Technologies, Corpus Christi, TX, Texas) for 15 seconds with a fiber optic delivery system of320µm tip diameter. The laser parameters used were 160mJ (milliJoul), 35 hertz and 5.6Watts. The laser tip was held perpendicular by the aid of an articulating holder and about 1mm from the enamel surface Fig (1).

Figure (1): A: Articulating holder used to hold laser tip. B; Laser tip perpendicular and1mm from tooth surface.

Irradiation was carried out in horizontal motions (mesial to distal) starting from the occlusal toward cervical portion of the circular area to ensure complete irradiation of the area. In group 2, the treatment area was covered by black ink as a photo absorber by the aid of small head brush before laser exposure Fig (2)

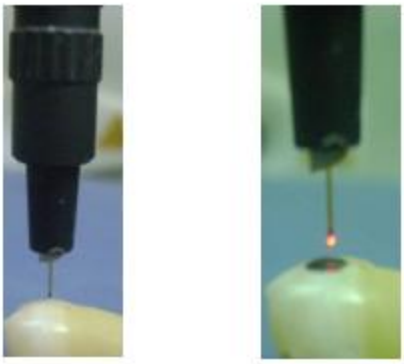

Figure (2): Black ink applied on the treatment area for laser irradiation.

After laser irradiation in both groups, the surface of each tooth was submitted to another 4 indentations within the treatment area. The mean values of the same surface before and after treatment were compared to obtain more accurate results.

STATISTICAL ANALYSIS:

The data collected were analyzed using one way analysis ANOVA and Least Significant Difference (LSD) post hoc test to compare between groups at p≤ 0.05.

RESULTS

Descriptive statistics of the results are shown in (Table 1). One way analysis ANOVA showed significant differences among the groups (Table 2). There was a significant decreased in enamel microhardness values in groups 1 and 2 compared to their controls (Table 3).Although group 1,recordedlower microhardness value(71.7690 HV) than group 2 (96.3980 HV), no significant difference existed between them(Table 3).No significant difference was found between the mean microhardness values of the control groups 1 and 2.

Table (1): Descriptive statistics

Groups	N	Mean HV*	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control 1	10	270.3720	32.01046	10.12260	247.4731	293.2709	227.85	324.20
Group 1	10	71.7690	27.74925	8.77508	51.9184	91.6196	25.53	104.50
Control 2	10	279.7230	42.13020	13.32274	249.5849	309.8611	225.91	365.03
Group 2	10	96.3980	15.95059	5.04402	84.9876	107.8084	72.76	119.60
Total	40	179.5655	101.59740	16.06396	147.0731	212.0579	25.53	365.03

*: Vickers hardness number

Table (2): One way ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	368142.637	3	122714.212	128.360	.000
Within Groups	34416.589	36	956.016		
Total	402559.227	39			

Table (3): LSD Multiple Comparisons

Comparison between groups		Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control 1	Group 1	198.60300*	13.82763	.000	170.5593	226.6467
	Control 2	-9.35100-	13.82763	.503	-37.3947-	18.6927
Group 1	Control 1	-198.60300-*	13.82763	.000	-226.6467-	-170.5593-
	Group 2	-24.62900-	13.82763	.083	-52.6727-	3.4147
Control 2	Control 1	9.35100	13.82763	.503	-18.6927-	37.3947
	Group 2	183.32500*	13.82763	.000	155.2813	211.3687
Group 2	Group 1	24.62900	13.82763	.083	-3.4147-	52.6727
	Control 2	-183.32500-*	13.82763	.000	-211.3687-	-155.2813-

*: The mean difference is significant at the 0.05 level.

DISCUSSION

Nd:YAG laser was used in this study for enamel etching, it was reported by many studies that it can produce surface irregularities which may be beneficial for bonding procedure (23,24, 25). Additionally, the results regarding its effect on enamel microhardness are inconsistent. Therefore, more studies are required to investigate this effect.

The laser parameters used (160mj, 35Hz, 5.6 Watts) were based on previous studies that preferred the use of high energies for enamel etching (22, 26, 27).

The time adopted (15seconds) was originally based on studies conducted by von Fraunhofer *et al*.(26), who suggested that a minimum time of 12seconds was required to remove all traces of carbon based initiator and this time (15seconds) is comparable to that minimum required for acid etching.

The significant reduction in enamel microhardness for both groups found in this study coincides with other studies (15, 19)and may be attributed to temperature rise associated with laser irradiation. The Nd:YAG laser energy can induce structural, phase and physicochemical changes in calcified tissues. These interactions are characterized by a thermal mechanism, which is largely dependent on wavelength specificity, the energy density, the interaction time and the organic and mineral composition of the calcified tissue (28,29). It has been shown by previous studies (22, 30,31)that Nd:YAG laser irradiation of enamel caused surface cracks. Those cracks can be explained by stresses in enamel due to expansion and contraction through localized heating and cooling associated with the pulsed beam interaction with the tooth (32). Those cracks can weaken the enamel (13) with subsequent reduction in the microhardness.

However, in group 2, less reduction in microhardness was observed compared to that in group 1. This could be due to that the application of black ink in group 2 resulted in more absorption of laser beam by the ink which confined laser energy to the surface area and reduced thermal build up (11, 13,33). Consequently, less cracks or cracks depth may be formed compared to group 1 leading to less amount of reduction in the microhardness.

Meanwhile, in group 1 when no black ink was applied and since Nd:YAG laser is poorly absorbed by tooth enamel (23), this leads to penetration of laser beam instead of its absorption. This can cause subsurface heating with deeper cracks depth than group 2 resulting in more reduction of microhardness. Further studies are required to measure enamel cracks' depth after laser irradiation with or without black ink application, in addition to scanning electron microscopic studies to determine enamel surface changes.

CONCLUSION

It can be concluded that within the parameters used in this study, the Nd:YAG laser adversely affected enamel microhardness with or without black ink application although the latter resulted in more reduction in microhardness.

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