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Laser Effect on Surface Microhardness of Enamel Around Composite Restoration: An In Vitro Study

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ABSTRACT Objectives: The aim of the current study to determine the effectof Er,Cr:YSGGand Diode laser on surface microhardnessof enamel around composite restoration.

Materials and Methods: The total number of teeth in the main study was (48) sound wisdom teeth that were extracted due to impaction. Teeth samples were sorted into three groups at random, with each group containing (12) teeth samples, group A(composite only) (control), group B (composite restoration +Demineralization) (acide) group C (composite restoration+Diode laser +Demineralization) and group D (composite restoration+Er:Cr,YSGG laser +Demineralization).After application of the laser, and in order to avoid dehydration, the samples were kept for 24 hours in distilled water at room temperature. Force of Vickers microhardness was applied at 1 mm distance from the enamel restoration interface, a load of 500 gm was applied to the placements with dwelling time of 15 sec. Data was analyzed by using one way ANOVA at the significant p-value of ($p \leq 0.05$). All samples were immersed in a demineralizing solution

Results: significantly increased the Vickers microhardness value of the of enamel surface around composite restoration after irradiation with Er,Cr:YSGG laser and Diode laser

Conclusion: Within the limitation of this in vitro study, irradiation of enamel around composite restoration with Er,Cr:YSGG laser and Diode laser improves the surface microhardness.

Keywords: Er,Cr:YSGG laser, Diode laser, composite restoration, surfacemicrohardness.

I. INTRODUCTION

Dental caries is a ubiquitous process, defined as the result of partial chemical dissolution of the tooth surface due to the acid produced by the tooth biofilm (plaque) that is frequently exposed to sugar[1]. Clinical studies have shown that secondary caries is one of the main reasons for replacement of restorations [2]. Resin-based composites are becoming more and more popular in direct dental restorations [3].

The tooth structure next to the restoration is prone to secondary caries [4]. Therefore, in order to find ways to prevent secondary caries and increase the durability of clinical dental restorations, different techniques have been introduced and applied in dental clinics.as conventional methods used in caries prevention are costly, time consuming and need sustainability, the use of laser, especially cold lasers (soft of low level lasers), which is characterized by low cost, is portable, not of heavy weight, and provides easy application and handling, can be an alternative [5].

The use of CO_2lasers in the 1970s demonstrated for the first time the possibility of increasing the acid resistance of tooth enamel after laser irradiation [6].

Given that enamel is 85% carbonated hydroxyapatite, with 12% water and 3% protein and lipid by volume, the use of wavelengths highly absorbed by water and hydroxyapatite together is expected to generate thermal changes in the enamel, which may be able to alter its structure chemically and/or morphologically [7].

Various types of lasers were used in previous research. However, it is still unclear which one has the best results. Among these lasers, diode lasers have many unique characteristics, such as low cost, smaller volume compared with other lasers, and easy application in the oral cavity due to the existence of optical fibers. However, only a few studies have investigated the effect of diode lasers on the structure of tooth enamel [8].

The Er,Cr:YSGG (erbium, chromium: yttrium-scandium gallium-garnet) laser has a wavelength of 2.78 μm and for that reason, has been investigated for caries-prevention purposes, even though they are applied to cavity preparation due to the mechanism of ablation[9]. However, in order to prevent dental caries, it is important that the laser does not ablate the treated surface, but changes the enamel morphologically or chemically.

Therefore, in order to avoid ablation of the target tissue, some low energy density studies have been carried out. The decrease in acid solubility of tooth enamel after high-intensity laser irradiation is related to the physical and chemical changes caused by photothermal and photochemical effects [10].

II. MATERIALS AND MEHODS

A total of 48 healthy, non-carious lower wisdom teeth that were extracted due to impaction, and collected from specialized dental centers and private clinics.The teeth were free of apparent caries, macroscopic cracks, and abrasions and staining, as assessed by visual examination [11]. The teeth were polished by using non-fluoridated pumice with disposable rubber cup and slow speed handpiece before cutting of the root for ease of handling during the polishing procedure .the root of cleaned molars were cut by usingusing a section machine diamond disc at the level of cement-enamel junction at low speed[9].

- Group A(composite only) (control): Contains 12 teeth, cavity was prepared in the buccal surface and then restored by composite restoration.
- Group B (composite restoration +Demineralization) (acide):Contains (12) teeth, cavity was prepared in the buccal surface and restored by composite restoration and then immersed in demineralizing solution.
- Group C (composite restoration+Diode laser +Demineralization) (Diode):Contains (12 teeth), cavity was prepared in the buccal surface of teeth and then the border of the cavity has irradiated with diode laser, restored with composite restoration, and then immersed in demineralizing solution.
- Group D (composite restoration+Er:Cr,YSGG laser +Demineralization) (Er:Cr,YSGG):Contains (12 teeth), cavity was prepared in the buccal surface of teeth and then the border of the cavity has irradiated with Er,Cr:YSGG laser, restored with composite restoration, and then immersed in demineralizing solution.
- The experimental test (surface microhardness) was performed for the Group A and was considered as baseline.
- The cavity margins of the slabs of groups C will be irradiated by Diode laser. The energy of the laser was transmitted via the optical fiber delivery system (EZ tips) with (400) micrometer in diameter and (4) mm length, the tip of the laser was positions in non- contact mode with a standard distance of (1) mm from the enamel surface. For standardization of the distance and perpendicularly of the laser tip, this was achieved by fixing a wood stick Indicated at 1 mm to ensure a constant spot size
- This equipment emits pulses at a 980 nm wavelength and was used to irradiate the exposed surface in a non-contact mode (perpendicular to the enamel surface), under the following parameters: 5.0 W, 199.04 J/ cm^2 20 Hz repetition rate [12].
- The cavity margins of the slabs of Group D irradiated with Er,Cr:YSGG under the supervision , The samples of the experimental groups were irradiated immediately after removal from the distilled water in order to prevent drying out of the dental hard substance and any associated corruption of the results.. MZ6 tip (diameter of 600 µm-6 mm long) was placed in the hand piece according to the manufacturer instructions.
- The device was adjusted at the following parameters: emits photons at a wavelength of 2.78 µm. The repetition rate will be fixed at 20 Hz. The pulseduration will be fixed on 140 µs. The beam diameter at the focal area for the handpiece will be 600 µm. The tip will be positioned 1.0 mm from the enamel surface (focused mode).
- For standardization of the distance and perpendicularly of the laser tip, this was achieved by fixing a wood stick Indicated at 1 mm to ensure a constant spot size
- The energy density per pulse used is 125 J/cm^2 0.5 W power output. The Er,Cr:YSGG laser is hydrokinetic energy system. This device allows precise hard tissue treatment by virtue of laser energy interaction with water above and at the tissue interface. It operates at a wavelength of 2,780 at a rate of 20 Hz with pulse duration 60 ms (H- mode). Water and air flow parameters was fixed in all groups, Water and air flow were set to (40%, 60%) respectively [13].
- All cavities have been restored using a resin-based composite (shofuInc, Germany), a dental adhesive Single Bond have been used according to the manufacturer's instructions. Cavities have been restored in one increment and light-polymerized for 40 s [11].

Microhardness test:

Specimen was fixed on the microhardness stage in perpendicular alignment to the indentation head. The diamond pyramid head of Vickers microhardness testing machine (Amsler Otto

Wolpert-Werke GmbH- Ludwigshafen Germany) was applied to surface of enamelat 1 mm distance from the restoration at a force of 0.5 kg for 15 seconds. The length of the two indentation lines was measured at 40× through the built-in scale microscope. The measurements were converted into a micro-hardness value (VHN) using the following equation: HV = 1.854 P/d2, (P= applied load in kg), d= indentations diagonal length in mm) [11], the indentation was applied for each specimen at 1mm distance from the composite restoration. The data were statistically analyzed using one way ANOVA test and Duncan's Multiple Range Test for post hoc comparison.

Statistical Analysis: A software program was used to perform statistical analysis (IBM SPSS version 22). The results of the readings were statistically examined by using (One Way-ANOVA Test) was used to identify the existence or absence of a significant difference between groups, at the 0.01 level of significance, and to establish the significant difference between the groups, Duncan's Multiple Range-Test was performed.

III. RESULTS

According to the statistical analysis, the results revealed that there were a highly statistically significant differences within and in between groups at $p \leq 0.01$ as seen in table (1)**.** The mean microhardness for control group, acid group, Diodelaser group and Er,Cr:YSGG laser group are significantly different from each other at $p \leq 0.01$. Er,Cr:YSGG laser group had surface microhardness around composite restoration significantly higher than other groups, while acid group had the lesser mean as seen in table (2) and figure (1).

IV. DISCUSSION

The microhardness of the enamel surface indicates the mineral content of the enamel. The microhardness measurement has acceptable sensitivity and can be used to evaluate the demineralization resistance of the enamel[8].

Since the surface of the enamel plays a decisive role in the decay process, it is important to evaluate the changes in this area. The calculation of the surface microhardness is a suitable method, which is carried out by the Vickers hardness measurement method. The advantages of this method are high accuracy and strong quantitative measurement capabilities[14].

In this studymicrohardness of tooth enamelwas evaluated and compared in vitro using Vickers Hardness Measuring method after the irradiation of cavity walls by Er,Cr:YSGG and Diode laser around composite restorations submitted to acide challenges.

It is reported that before using the laser, the surface microhardness value obtained in this study was completely in the range of 331.3 kg/mm^2, which is close to the reported microhardness of normal enamel tissue Scope[15].

The present study which was designed with the aim of evaluating effects of two types of laser showed that there was a significant increase in enamel microhardness in both groups while this increase was not observed in the control group.

In case of Er,Cr:YSGG laser the surface microhardness around composite restoration was in the range of 356.9 kg/mm^2 which is more than the control group after acid challenge . The results were reported by de Olivera et al. Show that irradiation with this type of laser alone may maintain the microhardness of tooth enamel after erosion challenges. Irradiation of Er,Cr:YSGG lasers with different power parameters and pulse frequency settings may change the surface and erosity of tooth enamel [16].

Apel et al. (2004) pointed out that the Er,Cr:YSGG laser can increase the microhardness of the enamel surface and give it acid resistance challenges. Apel et al. (2000) discussed that Er,Cr:YSGG laser is more effective than Er:YAG in reducing the solubility of tooth enamel in acid, and explained that this may be due to the greater absorption of Er,Cr:YSGG by hydroxyapatite crystals.

However, a study combining Er,Cr:YSGG laser irradiation and fluoride application found that this combination reduces tooth enamel demineralization better than any treatment using laser or fluoride alone [17] [16].

Erbium lasers (Er:YAG and Er,Cr:YSGG) have been introduced into dentistry and are mainly used for tooth decay preparation and caries removal. Over time, researchers began to consider the possibility of using this wavelength to promote chemical changes on the enamel surface, thereby creating a structure that can resist the caries process. In this way, many in vitro experiments can verify the potential of this wavelength in increasing the acid resistance of tooth enamel[10]. To prevent dental caries, tooth enamel should not be ablated or melted. Therefore, unlike the high parameters used for cavity preparation to promote chemical modification of the irradiated surface, it is necessary to use sub-ablation parameters.

Previous studies showed that the Er,Cr:YSGG laser pro-motes an increase in enamel acid resistance by heating the surface during irradiation, which leads to structural and chemical changes in that dental hard tissue [11, 14, 21]. It is currently not known whether other interactions between light and matter occur, such as photochemical effects or nonlinear interactions, thus leading to changes within the enamel. Thermal changes in dental enamel and the associ-ated effects on acid solubility have already been investigated and also serve to explain the effect of laser radiation.

According to Perhavec and Diaco [22], even at low energy densities, the temperature at the superficial layers of the dental enamel reaches values above 400°C during irradia-tion. This temperature decreases to 250°C 2.5 ms after Er Previous studies have shown that the Er,Cr:YSGG laser promotes the increase in acid resistance of tooth enamel by heating the surface during irradiation, which leads to structural and chemical changes in the hard tissues of the tooth[19] [17] [18].

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The main mechanism that makes the enamel structure less soluble and more resistant to caries is the reduction of carbonate and hydroxyl groups and the decomposition of organic matrix (Holcomb and Young, 1980; Fowler and Kuroda, 1986). Because crystalline carbonateforms an apatite phase, which is less stable and more soluble in acid, the resistance of tooth enamel to demineralization is reduced (Ulusoy et al., 2020). Increasedtemperatures were reported to remove carbonateand hydroxyl groups from the enamel structure[20] [21].Using Er,Cr:YSGG laser irradiation at an energy density of at least 8 J/cm^{2}achieves the temperature and chemical changes required for the enamel surface (Fried et al., 1996). Moreover, Er,Cr:YSGGlaser irradiation with a fluence of 8.5 J/cm^2 was reported toreduce the carbonate content of the human permanent toothenamel substantially [22].

The second type of laser that used in the present study was Diode laser; the surface microhardness around composite restoration was in the range of 322.8 kg/mm^2 after Diode laser irradiation which is more than the control group after acid challenge.

In this study the diode laser produced increased microhardness of enamel structure. This outcome is in agreement with findings of study conducted byPavithra et al. (2016), they concluded that Vickers hardness value after Diode laser irradiation higher than the Vickers hardness value obtained from untreated surface, also they concluded that microhardness of a lased enamel surface is higher following CO_2 laser treatment when compared to Erbium and Diode lasertreatment. However, though diode laser is traditionally viewed as a soft tissue, it has produced a significant increase in the microhardness compared to the control [23].

Another study that in agreement with the result of this study conducted by Mostafa et al.indicating marked increase in hardness due to laser application alone or in combination with fluoride[24].

Saafan et al. reported that diode laser, a traditional soft tissue laser, induces enamel fusion in pits and fissures, and has no harmful effects on dentin and dental pulp. Its low absorption coefficient in tooth enamel leads to a rapid increase in surface temperature, leading to melting and recrystallization of enamel crystals[23].

According to the results of this study, the two lasers used in this study have similar effects in increasing the microhardness of tooth enamel. The erbium laser microhardness test results obtained in this study are higher than the microhardness of diode lasers.

From the report provided by Romanos and Nentwig [25], it can be proved that the use of diode lasers in hard tissue surgery is reasonable. They found the penetration of diode lasers with a wavelength of 980 nm the depth is smaller than that of an erbium laser.A smaller penetration depth increases the energy deposition on the surface and the melting and recrystallization of the enamel structure. In this study, the diode laser increased the microhardness and recrystallization of the enamel structure.

V. CONCLUSION

Within the limits of the current study, there was an increase in surface microhardness of enamel around composite restoration after Er,Cr:YSGG and Diode laser irradiation thus increase the caries inhibition after acide challenge.

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Table (1): ANOVA Test for TBS Mean Values Between The Variables in Each Group:

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	62279.824	2	31139.912	195.051	.000
Within Groups	11015.846	69	159.650		
Total	73295.670	71			

DF: Degree of Freedom. Showed statistically differences

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Table (2): Mean Values, Standard Deviation and Duncan's Multiple Range Test Between Mean Values of TBS for the Teeth in Each Group:

Hardness			
Groups	Mean	N	Std. Deviation
Control	331.3160 a	24	11.09558
Acid	265.1395 c	24	11.13251
Diode	322.8853 b	24	15.22843
Er,Cr:YSGG	356.8076 a	48	13.94216
TOTAL	306.447	72	32.12995

N: Number of the specimens**, Std. Deviation:** Standard Deviation**. Statistically significant differences within the same column (vertically) are shown by different small letters (p≤ 0.01).**

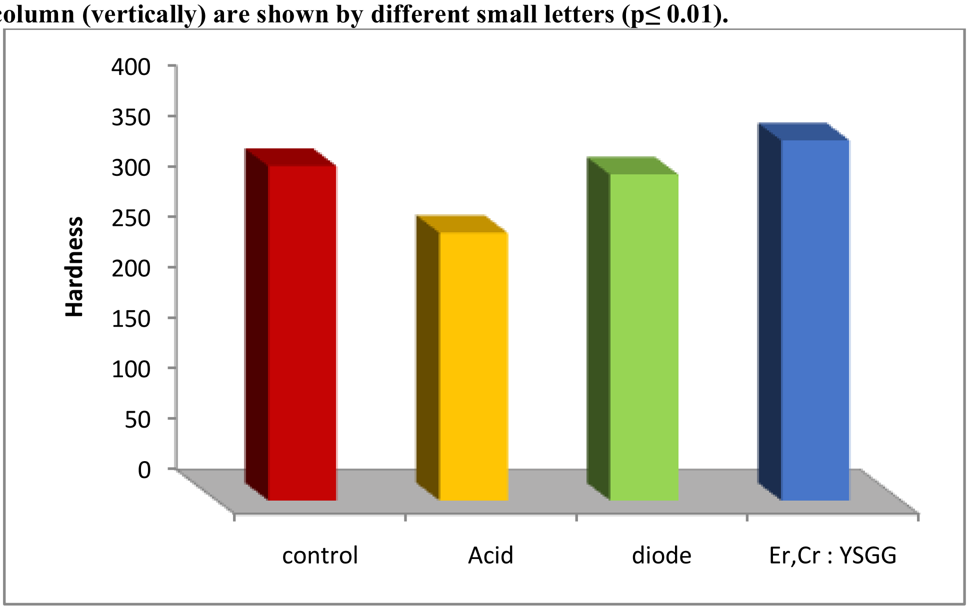

Figure (1): The mean values of microhardness measurements for control group, acid group and Diode laser group and Er,Cr:YSGG laser group.