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Effect of Er, Cr:YSGG and Diode lasers on surface roughness 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:YSGG and Diode laser on surfaceroughnessof 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.Enamel surface roughness was measured and compared using non-contact profilometer. Data was analyzed by using one way ANOVA at the significant p-value of ($p \leq 0.01$). All samples were immersed in a demineralizing solution
Results: the results displayed that there was highly statistically significant differences at $p \leq 0.01$ between and within groups.
Conclusion: Within the limitation of this in vitro study, irradiation of enamel around composite restoration with Er,Cr:YSGG laser and Diode laser decrease the effect of demineralization solution.
Keywords: Er,Cr:YSGG laser, Diode laser, composite restoration, profilometer, enamel, surface roughness.

I. INTRODUCTION

Dental caries is one of the oldest and most common diseases discovered by humans, although efforts have been made to reduce its prevalence, it is still widespread, especially in the lower socioeconomic class[1].It's common to lose teeth due to trauma, brushing habits or tooth decay, etc.,this requires the restoration of teeth with materials that have the required characteristics of dental materials.Today, different dental materials have been developed, such as glass ionomer cement (GIC)[2], silicates[3], resin based composites [4]etc.,among these dental restorative materials, resin matrix composites have been widely used in restorative dental materialsbecause they can withstand high compression forces in the mouth and good aesthetic properties[5].
According to reports, dentists spend 60% to 75% of their their working time on replacement restorations, this will result in high personal and social costs. The replacement of restorations is mainly related to the occurrence of secondary caries [6]. Secondary caries might be considered primary lesions around restorations and they can be also known as "dental caries" near to restorations[7]. The main locations are areas of biofilm stagnation, such as the cervical margins of restorations. Secondary caries may appear as a wall lesion or a superficial lesion adjacent or next to a restoration [8].

The tooth structure next to the restoration is prone to secondary caries[9] [10], due to imperfect adaptation of the restorative material and subsequent micro-leakage.Other factors, such as the chemical composition of theenamel and dentin in the cavity wall, and the characteristics of the restoration materials used, will affect the progression of this type of caries[11] [10]. Therefore, in order to determine ways to prevent secondary caries and improve the durability of clinical dental restorations, different techniques have been introduced and applied in dental clinics. Prevention of dental caries is a complex multi-factor disease that requires dental clinics to adopt appropriate prevention methods and appropriate oral hygiene education[12] [13]. Preventive modalities include use of fluoride, reduction of dietary cariogenic refined carbohydrates, removal of plaque, and use of oral hygiene techniques and antimicrobials. A relatively simple and noninvasive caries preventive regimen is treating primary and permanent tooth enamel with low- level laser

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irradiation, either alone or in combination with topical fluoride treatment. This treatment will reduce the solubility and disolution of tooth enamel[13] [14].

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 (Klein, 2005). 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 using a section machine diamond disc at the level of cement-enamel junction at low speed(Geraldo-Martins et al., 2012).

- 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 (surfaceroughness) 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[10].
- 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 operate 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 [17].
- All cavities have been restored using a resin-based composite (shofu Inc, 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 [10].

Surface roughness test:

Non-contact optical profilometry was used to analyze the surface profile in the center of the delineated area. For each enamel sample, one reading was taken at 1 mm distance from the composite restoration. Although perfect repositioning accuracy is impossible at the micron level, the sample was roughly in the same position for every measurement. The roughness parameter analyzed was the average roughness (Ra), which is the arithmetic mean of the height of peaks and depth of valleys from a mean line in the measuring length[18].The data were statistically analyzed using one way ANOVA test and Duncan's Multiple Range Test for 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)**.** Multiple range test shows that the mean surface roughness for control group, acid group, Diode laser group and Er,Cr:YSGG laser group are significantly different from each other at $p \leq 0.01$. Acid group had surface roughness significantly higher than other groups, while control group had the lesser meanas seen in table (2) and figure (1).

IV. DISCUSSION

Roughness is considered to be the predisposing factor for bacterial adhesion and exogenous staining. According to reports, it plays a significant role in the development of oral bacterial biofilms[19].

Indirectly proves the surface change of the enamelbyResearch proves that the physical properties of tooth enamel are reduced, among which surface roughness changes and enamel surface microhardness were reported [20] [21]. This study analyzes the surface roughness because the changes in tooth structure can be quantitatively evaluated, which indicates the loss or increase of minerals in the tooth tissue[22].

In the present study, roughness measurements were performed using profilometry, becauseits advantage is that it can accurately and precisely measure surface roughness without the need for additional measurements. The profilometric method was considered by many studies as an effective quantitative evaluation[23] [19].

Some previous studies have studied the effect of laser on surface roughness. The current study is the first to compare the effect of two types of laser on enamel roughness by using a noncontact optical profilometer. The results of this study showed significant differences in the surface roughness data among the groups tested. Therefore,the null hypothesis that there is no difference in surface roughness between groups must be rejected. All tested surface treatment methods demonstrated significantly greater values in surface roughness parameters than in intact enamel surfaces.

In the current research, the average enamel surface roughness of the control group (intact enamel) was in the range of 0.467 µmwhich is in agreement with a study conducted by Sugsompian et al., 2020 who found that the surface roughness of an enamel was 0.40 µm but different to the result obtained in other studies such as 1.45 (2.58) µm[25].

In the present study the surface roughness value of enamel after Er,Cr,YSGG laser treatment was 0.858 µm this result was in agreement with the study of Hossain et al., 2002 who found an increase in the surface roughness after Er,Cr,YSGG irradiation.

This value was higher than the control group (0.467)µmbut smaller than the acid group (1.033) µm, this means that Er,Cr,YSGG laser treatment of the enamel around composite restoration make enamel more resistant to demineralization after acid challenge.

However with previous study conducted by Nogueira et al., 2017 the irradiation without 5% NaF presence did not change the surface roughness of enamel. The bacterial adhesion was also higher on the enamel surface irradiated in presence of 5% NaF varnish.

A previous study showed that low-energy density Er,Cr:YSGG lasers are used to irradiate tooth enamel(8.5 J/cm^2), can create a slight cavity,typical of microablation areas with fissures and conical craters, with sharp enamel projections[27]. Enamel and dentin surfaces etched with Er,Cr:YSGG laser show micro irregularities and no smear layer[28].laser etching can inhibit dental caries, which can be very important in orthodontics[10]. Laser etching of enamel creates micro cracks that are ideal for resin penetration[29]. Ozer reported that irradiation with a 1.50 w laser produces sufficient orthodontic bonding, but irradiation with 0.75 w laser did not [30].Thesurface produced by laser irradiation is also acid resistant. Laser irradiation of enamel changes the calcium-phosphate ratio and leads to the formation of more stable and less acid-soluble compounds, thus reducing susceptibility to dental caries attack[31] [32]. The discrepant results could be explained by the differences in laser parameters and irradiation protocols.It is difficult to correlate past findings with those of the present study, as methodological differences exist.

High intensity lasers have been used to prohibitenamel demineralization by increasing the surface temperature of the irradiated tissue, which reduces the hydroxyapatite solubility and blocks the interprismatic spaces due to the melting and recrystallization of the surface[15] [33] [10]. The thermal effects are based on the strong absorption of erbium lasers radiation by water and hydroxyapatite from enamel. Higher absorption of laser energy on the enamel surface may lead to changes in the crystallographic structure of enamel and it depends on the applied energy density, which is directly proportional to the increase intemperature generated on the tissue surface [15] [16].

A similar explanation may be used to describe the results obtained when the Diode laser was used, the surface roughness mean value of the enamel around composite restoration treated by Diode laser was 0.697 µm this value was greater than the control group (intact enamel) but smaller than the acid group (1.033 µm), this mean that enamel treated with Diode laser became more resistant to demineralization after acid challenge.

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 ErPrevious 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.

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V. CONCLUSION

Within the limits of the current study, irradiation of enamel around composite restoration with Er,Cr:YSGG laser and Diode laser decrease the effect of demineralization solution .

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Table (1): Anova test of surface roughness test among tested groups at $p \leq 0.01$.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.758	3	1.253	107.276	.000
Within Groups	1.074	92	.012		
Total	4.832	95			

DF: Degree of Freedom. Showed statistically differences

Table (2): Duncan's multiple range test for surface roughness test of control group, acid group, Diode laser group and Er,Cr:YSGG laser group.

Groups	Mean	N	Std. Deviation
Control	.4975 d	24	0.0458
Acid	1.0333 a	24	0.15788
Diode	.6979 c	24	0.01719
Er,Cr:YSGG	.8583 b	24	0.13924
Total	0.7718	96	0.22554

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

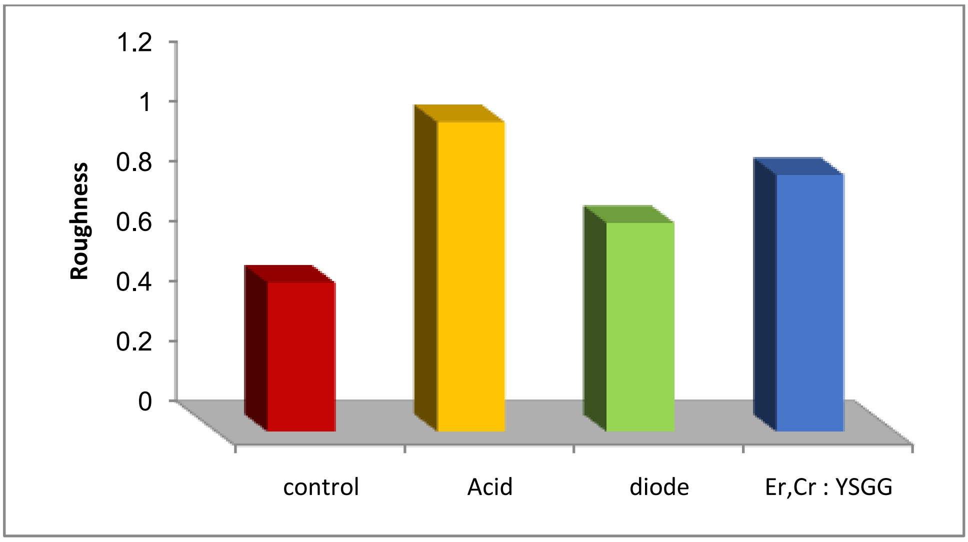

Figure (1): The mean values of surface roughness measurements for control group, acid group and Diode laser group and Er:Cr,YSGG LASER GROUP.