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EVALUATING THE EFFICIENCY OF ER, CR:YSGG LASER IN REMOVING ADHESIVE REMNANTS FROM TOOTH STRUCTURE AFTER ORTHODONTIC BRACKETS DEBONDING.

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Abstract:

Objective: *This study aims to evaluate the efficiency of the Er,Cr:YSGG laser compared to tungsten carbide bur in removing adhesive remnants from the enamel surface after orthodontic treatment.* ***Materials and Methods:*** *Stainless steel orthodontic brackets were bonded to freshly extracted 30 human premolars. Teeth were divided into three groups; group I used the tungsten carbide bur 6 fluted with a high-speed contra, group II used the Er,Cr:YSGG 2780 nm using 2 W, 15 Hz, H mode (60 µs), 133 m J, and group III used the Er,Cr:YSGG 2780 nm using 2.5 W, 30 Hz, S mode (700 µs), 166 m J. After the debonding process, enamel damage was tested by the enamel damage index (EDI) under a stereomicroscope.* ***Results:*** *There was a statistically significant difference between median EDI scores in the three groups (P-value <0.001, effect size = 0.66). Pair-wise comparisons between groups revealed that there was no statistically significant difference between Groups I and III; both showed statistically significantly higher median EDI scores than Group II. Samples of groups I, and III show a score of 2, while group II showed a score of 1.* ***Conclusion:*** *The Er,Cr:YSGG laser with parameters: 2 W, 15 Hz, H mode (60 µs), 133 mJ showed better enamel surface appearance. and the Er,Cr:YSGG laser can be used as an alternative to the tungsten carbide bur in adhesive remnant removal after orthodontic bracket debonding.*

Keywords: *Er,Cr:YSGG laser, debonding, tungsten carbide bur.*

Introduction

Acquiring a beautiful smile is the main target of all aesthetic dental treatments. In the end, it is the charm of the smile that will show the difference between a satisfying aesthetic dental treatment and a fair aesthetic dental treatment [1]. Removing remnants of the adhesive from the tooth structure following orthodontic brackets debonding, in a minimally invasive way towards the tooth structure has always been a concern [2]. The concern of adhesive remnant removal is not only after finishing the orthodontic treatment and debonding the brackets but also when the patient returns with a broken bracket or even when repositioning a bracket. All these procedures require the removal of adhesive remnants, and a tooth can undergo several bonding and debonding processes during the treatment, all of which could adversely affect the dental enamel surface [3].

While orthodontic treatment can cause damage to the tooth enamel surface while removing the leftover adhesive, damage can also be caused by the abrasives used to clean

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the enamel surface, and the damage caused by the acid etch and the reattaching of broken or failed brackets [2]. While removing the adhesive remnants from the enamel surface, there could be removal or chipping of the outer layer of enamel, which contains minerals and fluoride. As a result, the enamel prisms will be exposed to the bacteria in the oral cavity, resulting in a decalcified lesion on the tooth structure [4].

Several methods have been introduced by researchers for the safe and effective eradication of adhesive remnants from dental enamel surfaces after the debonding process [5]. These include a range of different instruments; manual methods, various shapes of tungsten carbide bur with different handpiece speeds, several ways for finishing and cleaning systems of composite such as Sof-Lex discs and fiber-reinforced composite bur, ultrasonic instruments, pliers, air abrasion techniques and the use of lasers such as CO_2 laser, Nd:YAG laser, Er:YAG laser and Er,Cr: YSGG laser [4,5]. The aim of this study was to evaluate the efficiency of the Er,Cr:YSGG laser at 2.78 μm in the removal of composite remnants from the dental enamel surface, after stainless steel bracket debonding.

Materials and Methods:

Study Settings

This study took place at the Dental Laser Center of the Faculty of Dentistry, Misr International University (MIU). Thirty freshly extracted human premolars were used. They were extracted as a part of orthodontic treatment. Teeth showing any decalcifications, restorations, or hypoplasia were excluded. All selected teeth were then disinfected at the Disinfection Center, Faculty of Dentistry, MIU.

Selection of the Samples

Random sequence generation was obtained through Excel software, where a list was created with each specimen allocated to one of the groups. The list was generated and concealed by an assistant away from the principal investigator. Immediately before working with each tooth, the assistant informed the principal investigator about the group that this tooth belonged to. The principal investigator could not be blinded due to the study methodology. However, the outcome assessor and statistician were blind to the groups.

Grouping

Stainless steel orthodontic brackets were attached to the buccal surface of the teeth and were then divided into 3 groups (n = 10) according to the method used in the removal of the adhesive remnant.

Group I: used the tungsten carbide bur 6 fluted with a high-speed contra.

Group II: used the Er,Cr:YSGG (erbium, chromium-doped yttrium, scandium, gallium and garnet) 2.78 μm wavelength with 2 W average power, 15 Hz repetition rate, 60 μs pulse duration, 133 m J pulse energy.

Group III: used the Er,Cr:YSGG (erbium, chromium-doped yttrium, scandium, gallium and garnet) 2.78 μm wavelength with 2.5 W average power, 30 Hz repetition rate, 700 μs pulse duration and 166 m J pulse energy.

Samples Preparation

1. Bonding of the stainless-steel orthodontic brackets:

All teeth were dried with an air tip, then the etch was applied for 30 seconds (s) with a 37 % phosphoric acid etching gel (3M ESPE, USA). The teeth were then rinsed with the air-water tip for 15 s and then dried. Ortho solo bond (Ortho Solo Universal Sealant and Bond Enhancer, Ormco Corp. Glendora, USA) was applied to all teeth in the three groups. After that the Grengloo adhesive resin (Ormco Grengloo is a two-way color change adhesive for metal brackets) was applied to all brackets and the brackets were attached to all teeth in the three groups. Finally, all teeth were light-cured after removing the excess composite.

2. Debonding of the stainless-steel orthodontic brackets and grouping according to the removal of adhesive remnants from the dental enamel surface:

After attaching brackets to teeth, all brackets were then debonded using an orthodontic bracket remover plier (ICE-Mocar 346). Group I used the tungsten carbide bur 6 fluted (Mani burs, Tochigi, Japan), with high-speed contra (NSK Nakanishi INC., Tochigi, Japan) to remove the adhesive resin remnants. For group II and III, Er,Cr:YSGG laser at 2.78 µm (Biolase, Tooth: (Ranch, CA, USA) was used with specific laser parameters listed in (Table 1). The tip of the laser handpiece was placed parallel to the tooth surface, in a non-contact mode, to decrease the risk of surface roughness. Increasing the tip angle increases the surface roughness, while less surface roughness is obtained when the angle is decreased due to the limited removal of tooth structure [6].

Table 1: Laser parameter Group II and III

	Group II	**Group III**
Wavelength	2.78 µm	2.78 µm
Mode of operation	Free running pulse	Free running pulse
Average Power	2 W	2.5 W
Repetition rate	15 Hz	30 Hz
Water	80%	80%
Air	60%	60%
Hand piece	Gold hand piece	Gold hand piece
Tip	MZ8 (800 µm)	MZ8 (800 µm)
Mode	Non-contact mode	Non-contact mode
Pulse duration	H mode (60 µs)	S mode (700 µs)
Energy of pulse	133 mJ	166 mJ

Peak power	2216 W	237 W
Power Density	397.89 W/cm²	497.36 W/cm²
Energy Density	26.5 J/cm²	33.6 J/cm²

After removing the adhesive remnants from the three groups, all teeth were polished using rubber cups from (one gloss kit, Shofu Inc., Japan) and examined under a stereoscopic microscope (Carl Zeiss, Manaus, AM, Brazil) with a magnification of 9x for measuring the surface roughness using the enamel damage index (EDI) for qualitative assessment. The EDI is a grading system that is described as follows [6-8]:

Grade 0: Smooth non-scratched enamel surface.

Grade 1: The enamel surface has scattered scratches.

Grade 2: Several scratches and a few grooves on the enamel surface.

Grade 3: The enamel surface has deep, rough scratches and wide grooves that can be seen by the naked eye.

Statistical Analysis:

Enamel Damage Index (EDI) score data were presented as median, range, mean and standard deviation (SD) values. The Kruskal-Wallis test was used to compare between the three groups. Dunn's test was used for pair-wise comparisons when the Kruskal-Wallis test is significant. Inter-observer agreement was assessed using Cronbach's alpha reliability coefficient and Intra-Class correlation coefficient (ICC). Closer values of these coefficients to one indicate better inter-observer agreement. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Results:

Enamel surface roughness was evaluated using the EDI (Enamel Damage Index) scoring system and all the samples were examined under a stereomicroscope. Samples of all groups examined under the stereoscopic microscope before polishing (Fig. 1) and after polishing (Fig. 2). The results of the EDI scoring system were plotted depending on the stereoscopic microscope images after teeth polishing as shown in (Fig. 3).

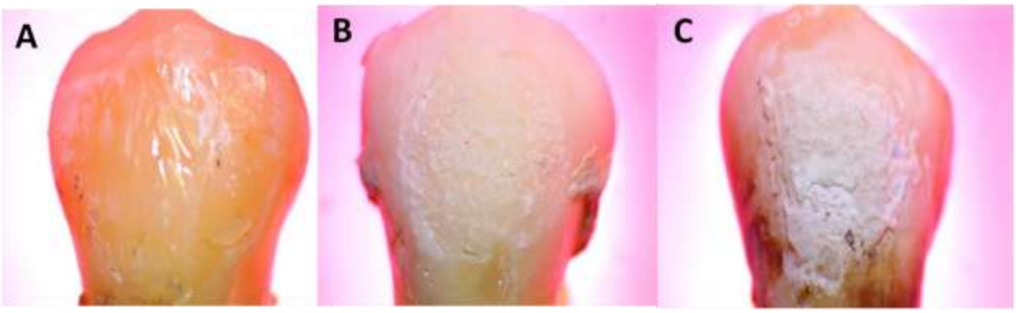

Fig. 1- Teeth samples examined under stereomicroscope before polishing with magnification X9. A: (Group I) used the tungsten carbide bur 6 fluted with a high-speed contra, B: (Group

Fig. 2-Teeth samples examined under stereomicroscope after polishing with magnification X9. A: (Group I) used the tungsten carbide bur 6 fluted with a high-speed contra, B: (Group II) used the

Results showed that the median and range of the Damage Index (EDI) are 2 (2-3), 1 (1-2) and 2 (2-3) for Groups I, II and III respectively with a statistically significant difference between the median (EDI) scores in the three groups (*P*-value<0.001, effect size = 0.66) (Table 2).

Table 2: Descriptive statistics and results of Kruskal-Wallis test for comparison between Enamel Damage Index (EDI) scores in the three groups

Group I (n = 10)		**Group II (n = 10)**		**Group III (n = 10)**		**P-value**	**Effect size (Eta squared)**
Median (Range)	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
2 (2-3) ^{A}	2.3 (0.48)	1 (1-2) ^{B}	1.1 (0.32)	2 (2-3) ^{A}	2.4 (0.52)	<0.001*	0.66

Significant at P ≤ 0.05, Different superscripts indicate statistically significant difference.

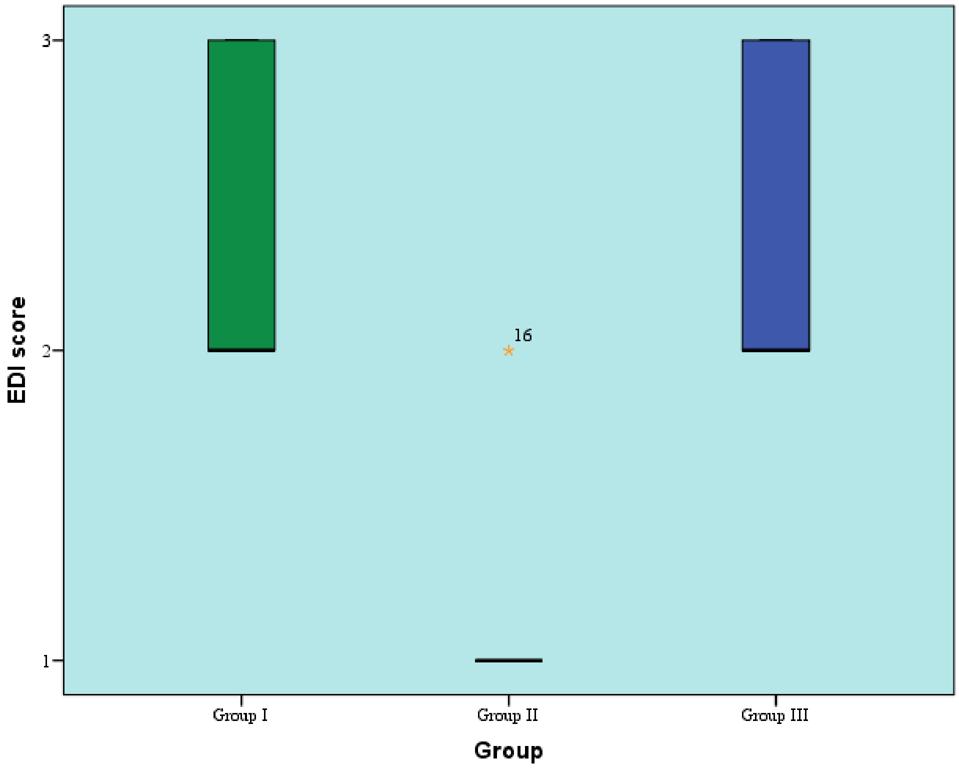

Fig. 3-Box plot representing median and range values for Enamel Damage Index

Pair-wise comparisons between groups revealed that there was no statistically significant difference between Groups I and III; both showed statistically significantly higher median EDI scores than Group II. Results also showed a very good inter-observer agreement in groups I and III, (Cronbach's alpha = 0.889, ICC = 0.8) and (Cronbach's alpha = 0.851, ICC = 0.741), respectively. While group II showed good inter-observer agreement (Cronbach's alpha = 0.667, ICC = 0.5) (Table 3).

Table 3. Results of Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC) to assess inter-examiner agreement

Group I (n = 10)		**Group II (n = 10)**		**Group III (n = 10)**	
Cronbach's alpha	ICC	Cronbach's alpha	ICC	Cronbach's alpha	ICC
0.889	0.8	0.667	0.5	0.851	0.741

Discussion:

Patients seek orthodontic treatment for the better appearance of their teeth. Orthodontic treatment should therefore have minimal side effects and maintain the enamel surface. Nevertheless, it is well known that several steps in orthodontic treatment could cause physical damage to the dental enamel surface. Adhesive remnants removed from the dental enamel surface after orthodontic brackets debonding can cause physical damage to the enamel. As a result, several methods were developed to eliminate and solve this problem [2]. One widely used instrument with great results for adhesive resin remnant removal with minimal damage to the enamel surface is the tungsten carbide bur. Despite the great success of the tungsten carbide bur, it also showed enamel roughness [4]. As a result, it was suggested that after using the tungsten carbide bur, the enamel surface has to be polished [7].

However, these negative drawbacks provoked the researchers to introduce different laser wavelengths with different parameters for adhesive remnant removal, aiming for better results [4]. There is one research study about the Er,Cr:YSGG laser removal of adhesive resin remnants from the dental enamel surface after orthodontic bracket debonding [7].

The aim of that study was to evaluate the efficiency of the Er,Cr:YSGG laser in removing the adhesive remnants from the tooth surface after orthodontic brackets debonding. A comparison between Er,Cr:YSGG laser 2.78 μm and tungsten carbide bur 18 fluted, showed that both methods had the same roughness on the dental enamel surface [7].

Perhavec, T. et al. in 2008, evaluated the efficiency of the Er,Cr:YSGG laser at 2.78 μm in the removal of composite remnants after orthodontic stainless steel bracket debonding [9]. The reason behind choosing the erbium lasers is that they have the highest absorption in water; therefore, they are the better laser to use with hard tissue. This showed that the change in laser wavelength plays an important role in tissue ablation. The Er,Cr:YSGG laser is absorbed by water and other ingredients in the adhesive resin, which leads to thermomechanical ablation of the adhesive resin from the enamel surface [10].

There are not enough studies evaluating the effect of the Er,Cr:YSGG lasers [7]. In this research study, the Er,Cr:YSGG laser was evaluated for its effect on the removal of adhesive remnants from the dental enamel surface, in comparison with conventional methods. The MZ8 tip was used parallel to the tooth structure to decrease the surface roughness, as when the tip angle is lowered, less tooth structure is removed [7,11]. It was proved that when the laser output power is ≤ 1 W, then adhesive resin will not be completely ablated [10].

On the other hand, according to the studies on cavity preparation, the average output power that is used is ≥ 3 W [6,10,12]. For this reason, the power used in this study was 2 W and 2.5 W trying to be minimally invasive, as to remove the adhesive resin and not the enamel surface. In the study by Najaf et al. in 2021, in one group 2 W, 30 Hz, H mode (60µs) was used, and in another group 3 W, 20 Hz, H mode (60µs) was used. They concluded that 2 W, 30 Hz had less surface roughness [10]. Therefore, in our study, we justified the use of 2 W, 15 Hz in one group, and 2.5 W at 30 Hz in another group, however, each laser group used a different pulse duration to compare the enamel surface damage and appearance in both laser groups with different peak powers.

Nevertheless, in the current research study, the findings proved that group II, which used Er,Cr:YSGG with 2 W, 15 Hz, H mode (60 µs), 133 mJ showed less damage and a better appearance to the enamel surface compared with group III, which used Er,Cr:YSGG with 2.5 W, 30 Hz, S mode (700 µs), 166 mJ. This is because a shorter pulse duration increases the peak power, so there is more effective ablation of the remaining adhesive.

Group II also showed less damage and a better appearance to the enamel surface than Group I, which used the tungsten carbide bur. Group III, however, took a very long time to remove the adhesive resin remnants compared to group II, which resulted in the melting of the adhesive resin on the dental enamel surface due to the thermal effect. Yet when comparing all three groups to each other, group II showed a statistically significant difference and there was no statistically significant difference between groups I and III.

When comparing the EDI (Enamel Dame Index) in group I that used the conventional method to group II in the current study, group I EDI score was between 2 and 3, where the median score was 2 (several scratches and a few grooves on the enamel surface), and group II EDI score was between 1 and 2, where the median score was 1 (the enamel surface has scattered scratches), which proved that there is a significant difference between both groups. The EDI of group III is between 2 and 3, where the median score is 2 (several scratches and a few grooves on the enamel surface), which states that groups I and III showed enamel surface damage and the worst surface appearance. To recapitulate, the surface appearance in group II is smoother than that in groups I and III. Group II showed that the Er,Cr:YSGG laser can be used as a method of adhesive remnant removal as the tungsten carbide bur, which agrees with the finding of Najafi et al [7].

Also, stainless steel orthodontic brackets were used as they cause the least damage and demineralization to the tooth surface than ceramic brackets [13]. Moreover, the ceramic brackets have higher shear bond strength than that of stainless-steel brackets, so it requires more effort in removal and could end up in enamel surface chipping or fracture, especially if the tooth is already weak due to the presence of cracks, fillings that are causing stresses on the tooth and root canal treatment [14]. As a result, we used stainless steel brackets. In the current study, the control group used the tungsten carbide bur (Group I), as it was stated that it is one of the best methods and the gold standard for adhesive remnant removal. Tungsten carbide bur is minimally invasive and causes the least enamel surface damage [4,7].

The enamel damage index (EDI) was used for qualitative evaluation of the surface roughness of all teeth in the study [6,7,8]. The EDI was inserted and interpreted by Schuler Van Vaes into research in 2003, as well as the SRI (surface roughness index), and these scoring systems are used for evaluating the images of the dental enamel surface under several magnifications.

The same scoring system was used in the current study [15]. For the evaluation and assessment of the enamel surface using the enamel damage index (EDI), all teeth of the three groups were examined under the stereoscopic microscope to evaluate and compare the appearance of all teeth after the removal of adhesive remnants with different methods [8,16]. For this reason, in the current study, the stereoscopic microscope was used to obtain the EDI. Originally, the enamel damage index (EDI) scoring system was interpreted and introduced in 1990 by Howell and Weekes [16].

Most studies in the literature had only assessed the effect of the Er:YAG laser in the removal of adhesive resin remnants with different parameters after bracket debonding. In these studies the Er:YAG laser was found to not only remove the adhesive resin but also removed the enamel surface. Moreover, in compression to rotary instruments the Er:YAG induces a rougher surface. In conclusion, the Er:YAG laser cannot selectively remove the adhesive resin remnants [3,4,7,17,18,19]. Future investigations on clinical work using the Er,Cr:YSGG laser are needed. The Er,Cr:YAGG laser has to be tested with different tip angulations, parameters, and adhesives as each step has an influence on enamel surface roughness. Er,Cr:YSGG laser, should also be compared to other new conventional methods in the adhesive resin remnants removal in orthodontics to find the most minimally invasive method [7,20]. Moreover, different systems for evaluating the enamel surface roughness have to be used [21].

Conclusion:

Within the limitations of this study, Er,Cr:YSGG; 2.78 μm wavelength using 2 W average power, 15 Hz repetition rate, 60 µs pulse duration, 133 m J pulse energy (Group II) showed better results in the enamel appearance and surface roughness than 6 fluted tungsten carbide bur (Group I) and Er,Cr:YSGG; 2.78 μm wavelength using 2.5 W average power, 30 Hz repetition rate, 700 µs pulse duration and 166 m J pulse energy (Group III) proving that it can be used as an alternative to the tungsten carbide bur in adhesive remnants removal after orthodontic bracket debonding.

Conflict of interest: The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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Figures legends:

Fig. 1: Teeth samples examined under stereomicroscope before polishing with magnification X9. A: (Group I) used the tungsten carbide bur 6 fluted with a high-speed contra, B: (Group II) used the Er,Cr:YSGG 2.78 µm using 2 W, 15 Hz, repetitive rate, pulse duration (60 µs), 133 m J pulse energy, and C: (Group III) used the Er,Cr:YSGG 2.78 µm using 2.5 W, 30 Hz, repetitive rate, pulse duration (700 µs), 166 m J.

Fig. 2: Teeth samples examined under stereomicroscope after polishing with magnification X9. A: (Group I) used the tungsten carbide bur 6 fluted with a high-speed contra, B: (Group II) used the Er,Cr:YSGG 2.78 µm using 2 W, 15 Hz, repetitive rate, pulse duration (60 µs), 133 m J pulse energy, and C: (Group III) used the Er,Cr:YSGG 2.78 µm using 2.5 W, 30 Hz, repetitive rate, pulse duration (700 µs), 166 m J.

Fig. 3: Box plot representing median and range values for Enamel Damage Index (EDI) scores in the three groups (Star represents outlier).