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EFFECT OF ER, CR: YSGG AND ER: YAG LASERS DURING DEBONDING OF ORTHODONTIC CERAMIC BRACKETS: IN VITRO STUDY

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KEYWORDS

ARI, Debonding, ESR, Polycrystalline, YAG, YSGG.

ABSTRACT

Introduction: Ceramic brackets debonding is considered a clinical challenge due to their low fracture toughness and high shear bond strength. The shear bond strength must be reduced to facilitate removal. **Aim:** Debonding polycrystalline ceramic brackets with Er: YAG and Er, Cr: YSGG lasers, and comparing their impacts on adhesive remnant index (ARI) and enamel surface roughness (ESR) to the traditional debonding technique. **Materials & Methods:** 60 polycrystalline ceramic brackets were bonded to 60 extracted premolars and divided into 3 groups: group 1(control group) contained 12 premolars that were debonded conventionally with a debonding plier, group 2: contained 24 premolars that were debonded with Er, Cr: YSGG laser and was divided into two equal subgroups: group 2A: the samples were irradiated with Er, Cr: YSGG laser at power 9 W & group 2B: the samples were irradiated with Er, Cr: YSGG laser at power 6 W, & group 3: contained 24 premolars that were debonded with Er: YAG laser and was divided into two equal subgroups: group 3A: the samples were irradiated with Er: YAG laser at power 9 W & group 3B: the samples were irradiated with Er: YAG laser at power 6 W. The debonded samples were examined using a scanning electron microscope (SEM) at 20x magnification for ARI scoring and at 60x magnification for enamel surface roughness after polishing. **Results:** Regarding ARI, the results showed that group 2A had the highest percentage for score 0 and group 3A for score 2, while regarding ESR, group 2B had the highest percentage for score 2. **Conclusion:** When compared to the traditional procedure, using Er, Cr: YSGG and Er: YAG lasers to debond polycrystalline ceramic brackets may reduce the risk of enamel damage.

INTRODUCTION

Ceramic brackets are aesthetic alternatives for metallic brackets that were introduced in the 1980s that combine both a better appearance for patients and reliable technical performance for orthodontists. Ceramic brackets include polycrystalline alumina, single-crystal alumina, and zirconia, and have lower fracture toughness and higher bond strength compared to metallic brackets. They are brittle and more liable to fracture and can't be peeled away from the enamel tooth surface, unlike ductile metal brackets (1). Pliers can be conventionally used to remove ceramic brackets; however, they may cause enamel fracture and bracket breakage (2). The bond strength must be reduced to facilitate ceramic brackets removal. Reducing bond strength can be done mechanically by lift-off, wrenching, and delamination(3), by ultrasonic(4) or chemically

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changing the bond between bracket and adhesive by using electro-thermal debonding devices (ETD) (5,6), or lasers(2). According to Zach and Cohen(7), one of the main constraints of these approaches is the increase in intra-pulpal temperature, which should never surpass 5.5°C. Many types of lasers have been utilized to debond ceramic brackets to avoid such negative effects. The effect of Erbium Yttrium Scandium Gallium Garnet (Er, Cr: YSGG) and Erbium-doped Yttrium Aluminum Garnet (Er: YAG) lasers on orthodontic ceramic bracket debonding was evaluated in this study using the adhesive remnant index (ARI) and enamel surface roughness (ESR).

MATERIALS AND METHODS

The Sample selection

60 premolars extracted for orthodontic purposes were used in this study and were collected from patients seeking orthodontic treatment at the Department of Orthodontics, Faculty of Dentistry, Suez Canal University after taking their permission.

The effect size was 0.68, using alpha (α) level of 0.05 and Beta (β) level of 0.95, i.e., power = 90%; the estimated minimum sample size (n) was a total of 60 specimens. G*Power version 3.1.9.2, Franz Faul, University Kiel, Germany, was used to calculate sample size. Copyright (c) 1992-2014.

The selection criteria included the following: no caries, which were visually inspected and detected with a sharp explorer, no cracks which were visually inspected by LED curing light, no white spot lesions which were visually inspected and detected by a rounded probe & no damage from extraction forceps.

The teeth were preserved in saline solution at room temperature till the time of bonding & mounted into color-coded acrylic blocks to facilitate their grouping.

Bonding of the ceramic brackets

The 60 extracted premolars were bonded using the following procedure: the middle third of the buccal surface of the clinical crown was etched with 37 percent phosphoric acid for 15 seconds, then washed by compressed water stream for 15 seconds, then air dried with a three-way syringe; the bonding agent was then applied to the etched surface and thinned by light air blow then light-cured for 20 seconds; each bracket with adhesive on its base was placed in middle-middle of the buccal surface; each bracket was pressed against the tooth surface and the excess adhesive around the bracket was removed with a sharp explorer before being light-cured for 40 seconds.

After bonding was completed, the samples were preserved in a distilled water filled container at room temperature for 48 hours to ensure complete polymerization of the adhesive.

Debonding of the ceramic brackets

Group 1: the plier‘s blades were placed at the bracket base/enamel surface interface at opposite corners (inciso-gingival plane) to allow debonding of the brackets.

Group 2 was divided into two equal subgroups:

Group 2A: the samples were irradiated with Er, Cr: YSGG laser (wavelength 2780 nm, at power 9 W, in non-contact mode with the repetition rate 20 Hz, water 80%, and air 60%, using gold hand-piece and MZ10 - 6mm, Zip Tip).

Group 2B: the samples were irradiated with Er, Cr: YSGG laser (wavelength 2780 nm, at power 6 W, in non-contact mode with the repetition rate 15 Hz, water 80%, and air 60%, using gold hand-piece and MZ10 - 6mm, Zip Tip).

Group 3: was divided into two equal subgroups:

Group 3A: the samples were irradiated with Er: YAG laser (wavelength 2940 nm, at power 9 W, in non-contact mode with the repetition rate 20 Hz, water 80%, and air 60%, using BOOST hand-piece and no tip).

Group 3B: the samples were irradiated with Er: YAG laser (wavelength 2940 nm, at power 6 W, in non-contact mode with the repetition rate 15 Hz, water 80%, and air 60%, using BOOST hand-piece and no tip).

Laser energy was applied at a distance of 1 mm from the bracket, parallel to the bracket, guided by the tooth surface, directed between the bracket base and tooth surface, and in a circular motion around the bracket in all samples of the test groups.

Tests and measurements:

a. Adhesive remnant index (ARI)

The debonded samples were evaluated by scanning electron microscope (SEM) at 20x magnification to assess the ARI score. The samples were dried in a hot air oven at 100°C for 2 hours before being inserted into the SEM (Fig.1). The ARI score classification was: **0**, No adhesive remained on the enamel surface, **1**, Less than half of the adhesive remained on the tooth surface, **2**, More than half of the adhesive remained on the tooth surface, **3**, All the adhesive remained on the tooth surface (Fig.2) (8).

b. Enamel surface roughness (ESR)

After removing all the adhesive remnants at the site of debonding in all groups with a tungsten carbide bur at high speed followed by polishing with pumice and polishing brush at low speed, enamel surface roughness was evaluated by SEM* at 60x magnifications. The micrographs were interpreted and classified into the following: - **0**, Enamel surface free from cracks or tear-outs (no damage). - **1**, Enamel surface with cracks. - **2**, Enamel surface with tear-outs. - **3**, Enamel surface with cracks and tear-outs (9).

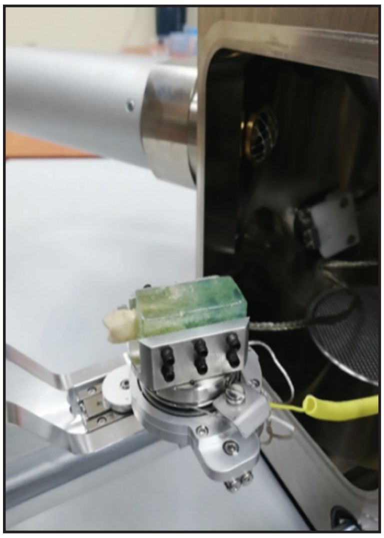

Fig. (1) The sample is inserted into the scanning electron microscope (SEM)

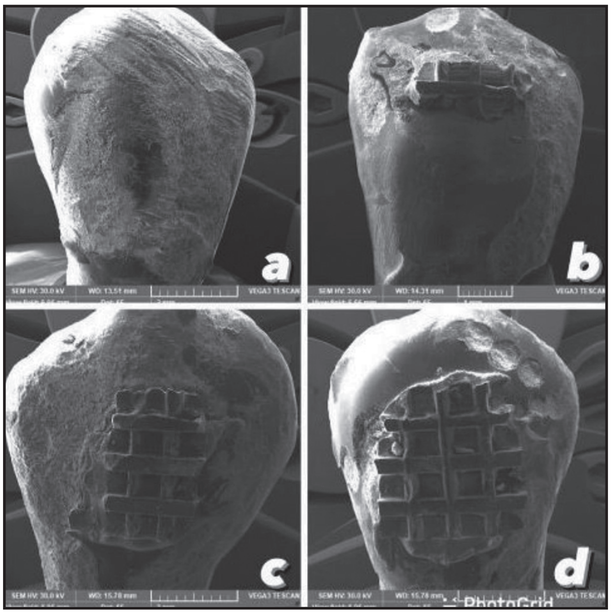

Fig. (2) SEM image at 20x magnification for enamel surface after debonding showing ARI scores: a. score 0, b. score 1, c. score 2, d. score 3

Statistical analysis

The data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data for debonding of orthodontics ceramic brackets showed non-parametric distribution (non-normal).

Frequencies and percentages were calculated for debonding tests following a scoring system in each group were calculated. Friedman test for ordinal variables followed by post hoc Wilcoxon test was used to compare between more than two groups in related samples while Mann Whitney was used to compare between every two groups in non-related samples.

The nonparametric chi-square test was used to evaluate enamel surface after debonding procedure of brackets and compare them within groups following a scoring system.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 19 for Windows.

Table 1 showed that there were statistically significant differences among all groups (P-value < 0.001) where group 2A had the highest percentage for score 0 and group 3A for score 2.

Table 2 showed that there was a statistically significant difference among all groups (P-value <0.05) where group 2B had the highest percentage for score 2.

RESULTS

a. Adhesive remnant index (ARI)

Table (1) *Frequency (N) and percentage (%) for ARI scores in different groups.*

	Debonding (%)										
Score	Group I		Group II				Group III				P-value
			YSGG 9W		YSGG 6W		YAG 9W		YAG 6W		
	N	%	N	%	N	%	N	%	N	%	
Score 0	1	8.3%^{Bb}	5	41.7%^{Aa}	3	25.0%^{Aa}	0	0%^{Bb}	1	8.3%^{Cb}	0.002*
Score 1	8	66.7%^{Aa}	6	50.0%^{Aa}	5	41.7%^{Aa}	6	50%^{Aa}	6	50.0%^{Aa}	1.0 ns
Score 2	1	8.3%^{Bc}	1	8.3%^{Bc}	3	25.0%^{Ab}	6	50%^{Aa}	3	25.0%^{ABb}	0.002*
Score 3	2	16.7%^{Ba}	0	0%^{Ba}	1	8.3%^{Ba}	0	0%^{Ba}	2	16.7%^{Ba}	1.0 ns
Total	12	100%	12	100%	12	100%	12	100%	12	100%	
P-value	0.01*		0.001*		0.001*		0.001*		0.001*		

*Superscripts with different capital letters indicate statistically significant difference within the same column while superscripts with different small letters indicate statistically significant difference within the same row *; significant (p≤ 0.05) ns; non-significant (p>0.05) b. Enamel surface roughness (ESR)*

Table (2) *Frequency (N) and percentage (%) for ESR scores in different groups.*

Score	Control		Er, Cr: YSGG 9W		Er, Cr: YSGG 6W		Er: YAG 9W		Er: YAG 6W	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Score 0	**0**	0	**0**	0%	**0**	0%	**0**	0%	**0**	0%
Score 1	**0**	0	**0**	0%	**0**	0%	**0**	0%	**0**	0%
Score 2	**4**	33.3%	**7**	58.3%	**12**	100%	**5**	41.7%	**8**	66.7%
Score 3	**8**	66.7%	**5**	41.7%	**0**	0%	**7**	58.3%	**4**	33.3%
Total	**12**	**100%**	**12**	**100%**	**12**	**100%**	**12**	**100%**	**12**	**100%**
X^2	**1.33**		**0.333**		**11.33**		**0.333**		**1.33**	
P-value	**0.248 ns**		**0.564 ns**		**<0.001***		**0.564 ns**		**0.248 ns**	

Score 0 *No cracks or tear-outs;* **Score 1:** *enamel surface with cracks;* **Score 2:** *enamel surface with tear-outs*; **Score 3**: *enamel surface with cracks and tear-outs*. **(Fig. 4, 5).** **; significant (p≤ 0.05)*
ns; non-significant (p>0.05)

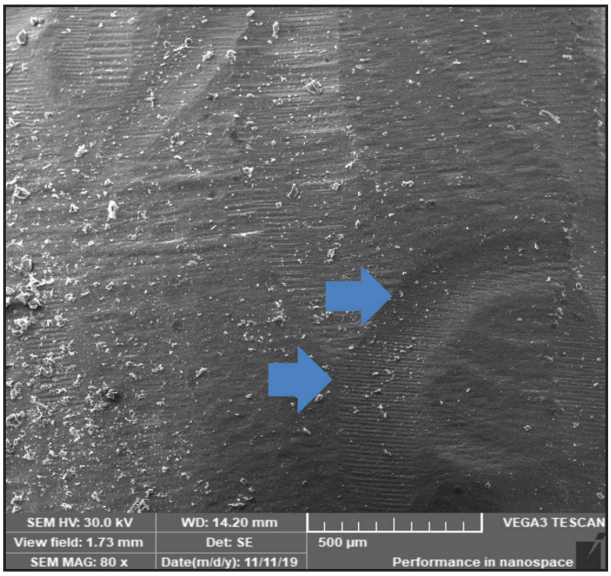

Fig. (4) Score 2, enamel surface with tear-outs (blue arrows)

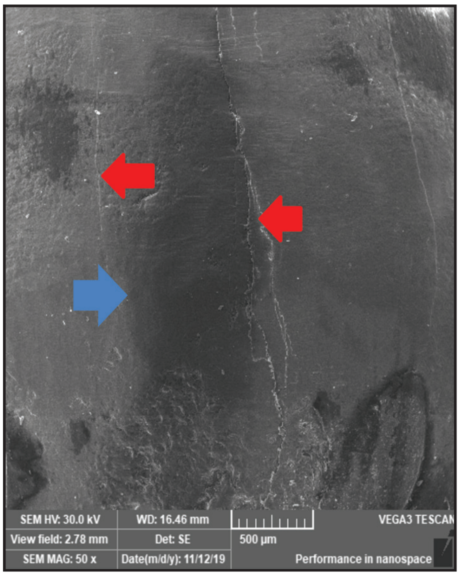

Fig. (5) Score 3, enamel with cracks (red arrows) and tear-outs (blue arrows)

DISCUSSION

Ceramic brackets were introduced in 1986 as an aesthetic alternative to metal brackets and due to their lesser fracture toughness and stronger bond strength than metal brackets, debonding is considered a clinical problem (10).

Pliers can be conventionally used to remove ceramic brackets; however, they may cause enamel fracture and bracket breakage. To facilitate ceramic bracket removal, the shear bond strength must be reduced.

Laser energy decreases the shear bond strength (SBS) by degrading the adhesive resin used to bond the brackets. According to Tocchio et al.(11) the mechanism of laser debonding includes thermal softening, thermal ablation, or photo-ablation. Thermal softening occurs when a laser with low power density irradiates the brackets until the resin softens. The brackets will slide off the tooth surface with gravity. Thermal ablation and photo-ablation vaporize the resin when its temperature is raised quickly by high power density lasers. Therefore, the bracket can be blown off the tooth surface.

In the present study different laser types with different energy powers were used and the results agreed with Tocchio et al.(11), and Hayakawa (12) who used different laser types. According to them, laser light was absorbed by the bracket and indirectly affected the adhesive resin. While direct application of the laser to the resin could enhance the effects of thermal ablation and photoablation, which increase from reaching the laser energy to the resin leading to stronger debonding and thus producing less thermal effects to the pulp. This is considered the advantage of Er: YAG and Er, Cr: YSGG lasers over Nd-YAG or CO2 lasers.

Kilinc et al. (13) reported that the Er, Cr: YSGG laser generates less increase in pulpal heat than Er: YAG laser in ablating enamel and dentin tissue.

Ozer et al. (14) recommended a power output of 2.5–6 W for laser ablation of enamel, which is harder than remnant adhesive.

In the present study, the Er-YAG laser was emitted at 2904 nm, and the Er, Cr: YSGG laser at 2780 nm. Their high wavelengths were the reason for their high absorption by water and hydroxyapatite, thus allowing them to be highly absorbed by the adhesive bonding resin which contains water and residual monomer and directly affects it (15).

Previous studies by Nalbantgil et al.(16), Dostalova et al. (17), Sabuncuoglu et al. (18), and Hibst et al.(19) found that the Er: YAG laser was effective in reducing the shear bond strength of polycrystalline ceramic brackets. Polycrystalline ceramic brackets don't have a uniform crystal structure to enable high transmissibility, which in turn increases the energy loss passing through the bracket to the resin. Therefore, the selected laser should be chosen to directly affect the resin without conducting too much heat.

In the current study Er: YAG and Er, Cr: YSGG with different wavelengths were used for debonding of polycrystalline ceramic brackets, and their effect on adhesive remnant index (ARI) and enamel surface roughness (ESR) were evaluated and compared to the conventional debonding method.

Debonding procedure

Oztoprak et al.(20) studied Er: YAG laser for bracket debonding by using a scanning method. The mechanism of debonding was found to be due to thermal softening of the resin. In the current study, the mechanism of the laser debonding was thermal ablation contradicting the results of the study performed by Oztoprak et al. (20), and by Tozlu et al. (21) who stated that the degradation occurred through thermal softening. Both lasers used in the present study were able to debond the brackets without the need for any additional force to remove the brackets. The brackets just fell or "jumped" off the teeth matching the results of Mundethu et al.(22). Laser energy was applied at a distance of 1 mm from the bracket, parallel to the bracket, guided by the tooth surface, directed between the bracket base and the tooth surface, by circular motion around the bracket, to avoid any iatrogenic enamel damage and focus the laser beam energy on the adhesive until debonding occurred, following the technique in previous studies by Nalbantgil et al.(16), Les'niak et al.(23), and Sedky et al.(24).

Moving in a circular motion around the bracket not applying the laser on just 1 point and applying the laser with water cooling reduced the probability of increasing the intrapulpal temperature during the debonding. According to Zach and Cohen(1), a 5.5°C temperature increase could cause pulp necrosis in 15% of teeth, thus the laser was applied with water-cooling in the present study to reduce the probability of intra-pulpal temperature increase while debonding the ceramic brackets.

Shinkai et al.(25) stated that a spray with 70% water was the most efficient. They also showed that shallow ablation of dentin was optimized with a spray with 70% air. The best conditions for Er, Cr: YSGG laser irradiation proved to be 1.50 W, 75% air, and 65% water and that's how the water and air ratio in the present study were chosen.

Adhesive Remnant Index (ARI)

Bishara et al.(26) stated that the ARI score indicates where the destruction of the bonding occurs (enamel–resin interface, the interior of the resin, or the resin–bracket interface).

Bond failures can be classified into three categories: adhesive failure between the adhesive and the bracket's base, adhesive failure between the adhesive and the enamel, and cohesive failure between the adhesive layer's molecules. The shear bond strength and adhesive remnant index have a negative relationship, meaning that as the shear bond strength falls, the ARI score rises, lowering the chance of enamel damage.

In the present study, there were significant ARI score differences between the control and study (laser) groups. Higher ARI scores were observed for the results of the laser groups with ARI scores 1 and 2 which showed much adhesive remained, in comparison to the control group which means lesser damage to the enamel surface. This finding was consistent with that of other studies by Nalbantgil et al.(16), Oztoprak et al. (20), Tozlu et al. (21), Mundethu et al.(22), and Sedky et al.(24) who concluded that Erbium lasers significantly decreased the force required for debonding of the polycrystalline ceramic brackets.

In the present study Er, Cr: YSGG 6W had higher ARI scores compared to Er, Cr: YSGG 9W this was attributed to that higher laser energy can soften the adhesive resin and decrease the adhesive remained on tooth surface agreeing with Oztoprak et al.(20), and Tozlu et al.(21) also, Er: YAG 9W had higher ARI scores compared to Er: YAG 6W.

Unfortunately, higher ARI scores also mean more post-debond cleanup required thus extending chairside time. Removing all adhesive during laser debonding eliminates the need for post-debond cleanup and thus decreases the chairside time.

Enamel Surface Roughness

Zachrisson et. al.(27) stated that irreversible damage to the enamel surface after fixed orthodontic treatment is inevitable. There are many other factors than the debonding method affecting enamel damage:

- Bracket type: ceramic brackets have higher shear bond strength to enamel than metal brackets, causing more enamel damage when debonded.
- The integrity of the enamel surface before bonding: the presence of caries, cracks, and fillings weaken the enamel surface and increase enamel damage.
- Tooth vitality: non-vital teeth are weaker than vital teeth and more liable to enamel damage.

- Tooth position: incisors, canines, and first molars are the most common teeth to have cracks.
- Post-debond cleanup method: Tungsten carbide bur (TCB), Sof-Lex (SL) discs, ultrasonic tools, pliers (PL), rubbers, or composite burs.

According to Fan et al. (28), all adhesive remnant removal methods changed enamel topography and roughness. According to Eminkahyagil et. al. (29), tungsten carbide bur is a very common and the quickest method for debonding but most hazardous.

Zarrinnia et al (30) recommended the removal of the bulk of the remaining resin with a 12-fluted tungsten carbide finishing bur (TCB), operated at high speed. While the literature is controversial about the most effective method of removing the residual resin.

Zachrisson et al. (27) concluded that a TCB at low speed produced the finest scratch pattern with the least enamel loss of 7.4 μm. Retief (31) recommended the use of TCB at high speed with adequate air cooling, while Campbell (32) suggested water spray instead of air cooling for heating control.

In the present study, post-debond cleanup was done by tungsten carbide bur (TCB) at high speed with water cooling followed by polishing with pumice and polishing brush at low speed as recommended by Tocchio et al. (11), Hibst et al.(19), Zachrisson et al. (27) and Pignatta et al. (33).

The results in the present study showed that the Erbium laser-assisted debonding decreased the severity of enamel damage when compared to the debonding with a debonding plier, which was consistent with the results of Kitahara-Ceia et al.(9), and Eliades et al. (34) .

CONCLUSION

Within the limitations of the current study, the following was concluded:

1. Under the inquired parameters, both Er, Cr: YSGG, and Er: YAG lasers can effectively debond polycrystalline ceramic brackets without using any additional forces.
2. Both Er, Cr: YSGG, and Er: YAG laser debonding may decrease the risk of enamel damage compared to the conventional method.

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