

Effect of Er:YAG and Er,Cr:YSGG Lasers on Ceramic Bracket Debonding from Composite Blocks

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Article Info

Article type:
Original Article

Article History:

Received: 7 July 2018
Accepted: 6 November 2018
Published: 3 July 2019

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ABSTRACT

Objectives: This study aimed to assess the effect of erbium-doped yttrium aluminum garnet (Er:YAG) and erbium, chromium: yttrium, scandium, gallium, garnet (Er,Cr:YSGG) lasers on the shear bond strength (SBS) of ceramic brackets debonding from the surface of composite blocks.

Materials and Methods: Thirty-six composite blocks were fabricated using Filtek Z250 light-cure composite. Block surfaces were etched with 37% phosphoric acid for 30 seconds and then rinsed with water for 20 seconds and dried. Maxillary right central incisor ceramic orthodontic brackets were bonded to the surfaces of composite blocks using Transbond XT adhesive and were cured for 40 seconds. Twelve samples were irradiated with Er:YAG laser, while 12 samples were irradiated with Er,Cr:YSGG laser, and the brackets were then debonded using a universal testing machine. Twelve samples served as controls (debonding using the universal testing machine without using a laser). The adhesive remnant index (ARI) score and bracket or composite cracks were evaluated under a stereomicroscope. One-way analysis of variance (ANOVA) was used for the comparison of the three groups. Kruskal-Wallis test was used to compare the ARI scores.

Results: The mean SBS was 17.01±5.22 MPa with Er:YAG laser, 18.03±6.46 MPa with Er,Cr:YSGG laser, and 16.61±6.73 MPa in the control group; the difference of the three groups was not significant (P=0.835). The difference in the ARI scores and enamel and composite cracks was not significant either (P>0.05).

Conclusion: This study did not show any reduction in the bond strength of ceramic bracket to composite blocks after Er:YAG and Er,Cr:YSGG laser irradiation.

Keywords: Er:YAG Laser; YSGG Lasers; Solid-State Lasers; Ceramics; Orthodontic Brackets; Dental Debonding; Dental Bonding

- **Cite this article as:** Mirhashemi AH, Hossaini SMH, Ardavan Etemadi A, Kharazifard MJ, Bahador A, Souidi A. Effect of Er:YAG and Er,Cr:YSGG Lasers on Ceramic Bracket Debonding from Composite Blocks. *Front Dent.* 2019;16(2):90-97.

INTRODUCTION

Ceramic brackets were first introduced in the mid-1980s [1]. Compared to metal brackets, ceramic brackets have lower fracture toughness and higher bond strength [2]. Debonding may

occur at the bracket-adhesive interface, within the adhesive or at the enamel-adhesive interface. Higher bond strength changes the location of debonding towards the enamel-adhesive interface, and higher pressure is

therefore applied to the enamel surface. Thus, the risk of formation of enamel cracks following debonding increases, which would result in patient discomfort and need for tooth restoration [3]. Also, discoloration of enamel cracks due to food stains and pigments would cause esthetic problems for patients. These problems may occur during and after debonding due to the high strength of ceramic brackets [3].

Several tools are used for bracket debonding such as special pliers for mechanical debonding, electrothermal debonding tools, lasers, and ultrasound. [4] Pliers apply shear and torsional forces for ceramic bracket removal; however, this technique can cause enamel fracture or bracket fracture [4]. Other methods of ceramic bracket debonding (except for laser), such as electrothermal device, transfer about 30 J of energy and soften the adhesive at a temperature higher than the critical temperature (around 150°C to 200°C). However, bracket debonding with laser occurs at a much lower temperature and does not cause patient discomfort or irreversible pulpal inflammation. [5] The electrothermal method has two other shortcomings as well: (I) considering the generated heat in the device, only a limited number of brackets can be debonded at a time, (II) this instrument has been designed for a specific type of bracket [5].

Lasers are available in different types. Erbium-doped yttrium aluminum garnet (Er:YAG) and erbium, chromium: yttrium, scandium, gallium, garnet (Er,Cr:YSGG) lasers are among the solid-state lasers [5].

Er,Cr:YSGG laser can be used for all types of restorations (such as amalgam restoration), on the enamel and dentin and also for enamel surface preparation for bracket bonding and reportedly yields a bond strength similar to that of the acid-etching technique [5].

Er:YAG laser has an insignificant thermal effect, and therefore, is more ideal than neodymium-doped yttrium aluminum garnet (Nd:YAG) and carbon dioxide (CO₂) lasers. It increases the intrapulpal temperature to a lower extent [6]. Moreover, Er:YAG laser can be used for dental etching [7,8] and can eliminate the residual resin after debonding [9].

Er:YAG laser is irradiated at 2904-nm wavelength, which matches the absorption peak of water [10]. Thus, this laser can be highly absorbed by the residual adhesive containing

water or monomer [11].

In several studies on bracket debonding using Nd:YAG laser or CO₂ laser, the debonding force is applied immediately after laser application [12-14]. However, these lasers have a higher thermal effect, and their clinical use is associated with the risk of falling of a hot bracket into the mouth of the patient. Therefore, they require safety features for harmless bracket debonding in the clinical setting. The advantage of using Er:YAG laser for debonding is in that it is similar to the conventional debonding process for the clinician and does not require additional equipment as it has a less thermal effect [12-14].

At present, aesthetic composite restorations are extensively used, and orthodontists encounter a high number of orthodontic patients with composite restorations. Ceramic brackets bonded to a composite restoration surface with a composite material have a risk of fracture because these brackets have low fracture toughness and high bond strength. In case of fracture of a ceramic bracket, it needs to be removed from the surface of the restoration by grinding which is highly time-consuming in the clinical setting and is associated with the risk of thermal and mechanical damage to the tooth structure and restoration surface. If a fracture occurs at the restoration surface, the restoration needs to be repaired or replaced [12-14]. No previous study has evaluated debonding of ceramic brackets from the composite restoration surface by laser. Selection of Er:YAG and Er,Cr:YSGG lasers in this study was due to the fact that Er:YAG laser has an insignificant thermal effect and is highly absorbed by the adhesive layer; thus, it would enhance bracket debonding. No previous study was found on the effect of Er,Cr:YSGG laser on debonding of ceramic brackets. Therefore, this study aimed to assess the effect of Er:YAG and Er,Cr:YSGG lasers on debonding of ceramic brackets from the surface of composite blocks.

MATERIALS AND METHODS

In this in-vitro experimental study, 36 composite blocks measuring 7×7×5 mm³ were fabricated and stored in distilled water for one week. For the purpose of standardization, a custom-made mold with the aforementioned dimensions was used for the fabrication of composite samples (Fig. 1). Before placing the composite resin in the metal mold, the internal

and external surfaces of the mold were lubricated with petroleum jelly for easy retrieval of the samples. Composite blocks were fabricated of Filtek Z250 composite (3M ESPE, St. Paul, MN, USA), and each increment was light-cured for 30 seconds.



Fig. 1. The mold used for fabrication of composite blocks.

Increments were applied until the mold was filled with composite, and then, the blocks were removed from the mold. The surface of the samples was etched with 37% phosphoric acid for 10 seconds, rinsed with water for 20 seconds, and dried with air spray.

Bracket bonding:

Maxillary right central incisor ceramic orthodontic brackets (GAC International. Inc., Islandia, NY, USA) were bonded to composite blocks by one orthodontist using Transbond XT adhesive (3M Unitek, Monrovia, CA, USA). The pressure was applied to the center of the brackets using an explorer to form a thin and homogenous layer of adhesive beneath the bracket. Excess adhesive was gently removed using an explorer. Adhesive curing was performed using a light-emitting diode (LED) light-curing unit (Starlight PRO, Mectron S.p.A., Carasco [GE], Italy) for 40 seconds; the brackets were irradiated for 10 seconds from each of the mesial, distal, occlusal, and gingival surfaces. After 24 hours of immersion of the samples in distilled water at 37°C, they were subjected to 500 thermal cycles between 5-55°C with a dwell time of 30 seconds.

Bracket debonding:

The samples were divided into three groups: two experimental groups and one control group. In the control group, 12 ceramic brackets were debonded from the surface of composite blocks using a universal testing machine (Zwick/Roell, Ulm, Germany).

In Er:YAG laser group, Er:YAG laser system (LightWalker device, Fotana, Ljubljana, Slovenia) was used for surface treatment with a tip diameter of 1 mm. This laser system

produces photons with a frequency of 20 Hz. The output power was 3 W, and the energy density was 22/28 J/cm². Twelve ceramic brackets were treated manually by the operator using the laser with a pulse duration of 100 μs and an exposure time of 10 seconds in the scanning mode and from a 2-mm distance.

The debonding procedure was performed immediately using the universal testing machine [15].

In Er,Cr:YSGG laser group, Er,Cr:YSGG laser system (Biolase Technology Inc., San Clemente, CA, USA) was used with a tip diameter of 800 μm for surface treatment. The laser, with the output power of 3 W, 22/28 J/cm² of energy density, and a pulse duration of 60 μs, was irradiated manually by the operator to 12 ceramic brackets for 10 seconds in the scanning mode and from a 2-mm distance. Debonding procedure was performed immediately using the universal testing machine [16].

The Er:YAG and Er,Cr:YSGG laser parameters were adopted from similar previous studies in order to be able to compare their efficacy for debonding [15,16]. Figure 2 shows a sample ready for bracket debonding using the universal testing machine. For debonding process, the samples were placed in the machine, and a steel piston with a cutting blade applied the load to the adhesive-composite interface such that the cutting surface was perpendicular to the horizon, and the load was applied in an occlusolingival direction.

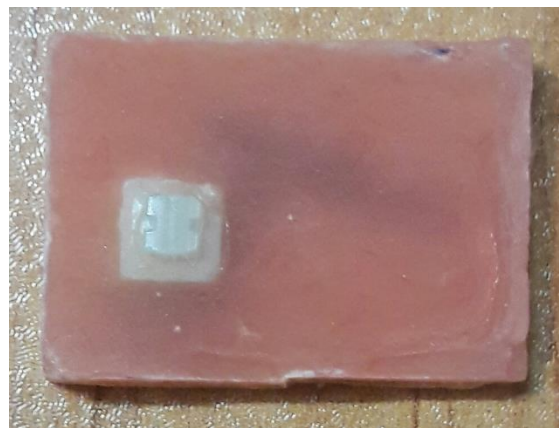


Fig. 2. A mounted sample ready for bracket debonding in the universal testing machine.

To measure the shear bond strength (SBS), the samples were subjected to a shear load at a crosshead speed of 0.5 mm/minute. The load was applied as close as possible to the bracket-

composite interface. The debonded brackets and composite surfaces were evaluated under a stereomicroscope (SMZ800, Nikon, Japan) at $\times 10$ magnification. The amount of residual adhesive was determined using the adhesive remnant index (ARI) score to determine the mode of bond failure as follows [17]:

0: No adhesive remaining on the composite surface

1: Less than half of the bonding surface is covered with adhesive

2: More than half of the bonding surface is covered with adhesive

3: The entire bonding surface is covered with adhesive.

In all three groups, cracks on the surfaces of the brackets and composite were evaluated under the stereomicroscope after debonding.

Statistical analysis:

Since the data regarding the SBS and composite and bracket cracks were normally distributed, one-way analysis of variance (ANOVA) was used for the comparison of the three groups in this regard. Kruskal-Wallis test was used to compare the ARI scores among the three groups.

RESULTS

The results of this study showed that the mean SBS was 17.01 ± 5.22 MPa with Er:YAG laser, 18.03 ± 6.46 MPa with Er,Cr:YSGG laser, and 16.61 ± 6.73 MPa in the control group (Table 1). The difference in this respect was not significant among the three groups ($P=0.835$).

Table 1. Mean shear bond strength (MPa) in the three groups

Group	Min	Max	Mean	SD
Er:YAG	5.27	25.26	17.01	5.22
Er,Cr:YSGG	10.94	33.79	18.03	6.46
Control	3.69	28.74	16.61	6.73

SD: Standard deviation; Er:YAG: Erbium-doped yttrium aluminium garnet Er,Cr:YSGG: Erbium, chromium: yttrium, scandium, gallium, garnet

Figure 3 shows the 95% confidence interval (CI) for the mean SBS in the three groups. Observation of the samples after SBS testing under the stereomicroscope revealed that most samples in the three groups had ARI scores of 1 (Table 2), and no significant difference was

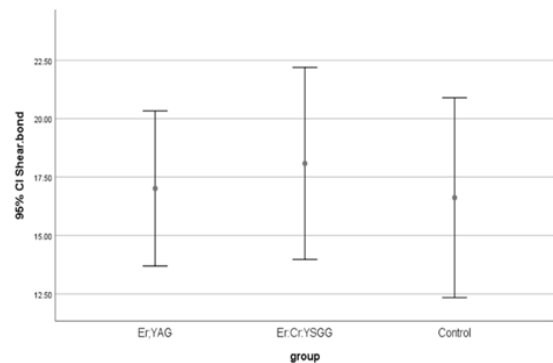


Fig. 3. The 95% confidence interval (CI) for mean shear bond strength (SBS, MPa) in the three group

noted in the ARI scores among the three groups. Similarly, there was no significant difference neither in bracket- ($P=0.649$) nor composite-cracks ($P= 0.128$) among the three groups.

Table 2. Adhesive remnant index (ARI) scores in the three groups.

Groups	ARI scores			
	0	1	2	3
Er:YAG	0 0%	8 66.7%	2 16.7%	2 16.7%
Er,Cr:YSGG	1 8.3%	9 75%	0 0%	2 16.7%
Control	3 25%	6 50%	2 16.7%	1 8.3%

Er:YAG: Erbium-doped yttrium aluminium garnet, Er,Cr:YSGG: Erbium, chromium: yttrium, scandium, gallium, garnet

ARI score of 3 ranked second in terms of frequency in Er:YAG and Er,Cr:YSGG laser groups, but in the control group, ARI score of 0 ranked second in terms of frequency after ARI score of 1; this indicates the higher risk of damage to the composite restoration of teeth during debonding in the control group.

The evaluation of the frequency of bracket cracks and composite cracks after debonding showed that although the percentage of ceramic bracket cracks (33.3%) and composite cracks (75%) was higher in the control group, the difference was not statistically significant. Figure 4 shows ceramic bracket cracks and composite block cracks in debonded samples.

DISCUSSION

In this study, we evaluated the effect of lasers on the bond strength of ceramic brackets to composite blocks in comparison with a control

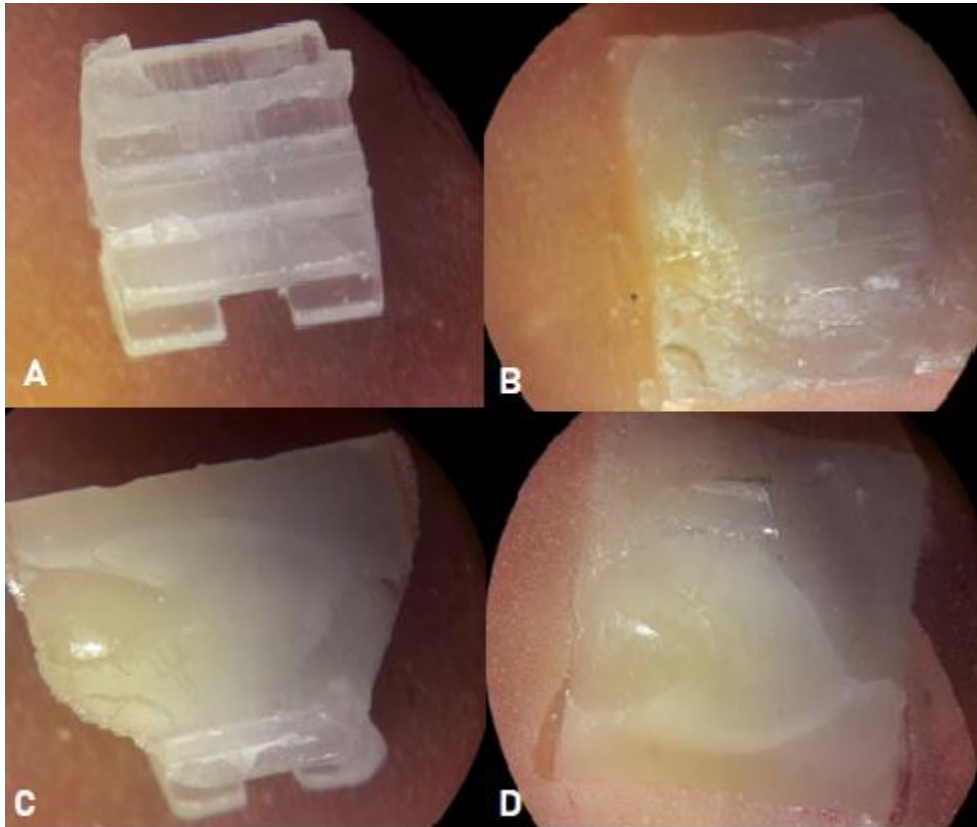


Fig 4: Debonded samples of ceramic brackets (A, B) and composite blocks (C, D) with cracks

group. Our next purpose was to compare the effect of Er,Cr:YSGG laser with that of Er:YAG laser on the bond strength of ceramic brackets to the surface of composite blocks.

Several studies have evaluated the effects of lasers on the bond strength of ceramics to the tooth surface [5,7,8]. However, no previous study has evaluated the effect of lasers on the bond strength of ceramic brackets to the surface of composite restorations.

The present study aimed to evaluate the effect of Er:YAG and Er,Cr:YSGG lasers on the bond strength of ceramic brackets to composite blocks. Our findings did not support the hypothesis stating that laser would decrease the bond strength of ceramic brackets to composite blocks.

The results showed no significant difference in the bond strength of ceramic brackets to composite blocks, ARI scores, bracket cracks or composite cracks among the control group, Er:YAG laser group, and Er,Cr:YSGG laser group. The authors found no previous study on the effect of lasers on the bond strength of ceramic brackets to the surface of composite restorations to compare our results with.

The SBS:

In the present study, the difference in the SBS

between the laser-irradiated groups and the control group was not significant. Articles that have examined the SBS of ceramic brackets to enamel have mostly indicated that laser irradiation reduces the bond strength [1,2,4]. However, Macri et al [18] showed that 5-W and 8-W powers of CO₂ lasers were not effective in reducing the SBS of ceramic brackets to enamel, and 10-W or higher powers of lasers must be used. Thus, in order to be effective in debonding, adjusting the irradiation parameters for each laser is essential.

Ahmad Akhouni et al [19] came to the same results about irradiating metallic brackets with Nd:YAG laser. Also, in the mentioned study, the SBS between enamel and metallic brackets was not significantly different from that of the control group [19].

Feldon et al [20] showed that in reducing the bond strength, the diode laser is not effective on polycrystalline brackets but it is effective on monocrystalline brackets; this might be explained by their uniform crystal structure that enables high transmissibility, thereby limiting energy loss. Moreover, the brackets used in this study had a metallic slot which can prevent the laser from reaching the bracket base and adhesive [20]. We used polycrystalline

brackets in our study. However, since there is no similar study, we are not able to compare our results with those of other studies.

The ARI:

In the present study, the ARI score was not different in the laser-irradiated groups and the control group. According to the studies on dental enamel, there is an inverse relationship between the ARI score and SBS [21-23]. However, some other studies have indicated that the ARI score shows no statistically significant difference between the control group and the laser-irradiated groups although the laser-irradiated groups exhibited a lower SBS [14,20,24-26].

In the evaluation of Er:YAG laser in debonding of ceramic brackets, Dostálová et al [27] showed that in spite of the lower bond strength in the laser-irradiated groups, the ARI was less than that of the control group. Another study came to the same results about diode lasers [28].

Overall, it can be concluded that in case of exact adjustment of irradiation parameters, laser irradiation reduces the SBS between brackets and teeth, while the ARI can show reduction, no change, or increase.

Damage to ceramic brackets and composite surface:

In this study, there was no statistically significant difference regarding damage to ceramic brackets and composite surface in comparison with the control group. However, different results have been observed in studies which assessed ceramic bracket debonding from teeth [22,24,27].

One possible explanation for this difference is that dental enamel has a crystalline structure with very high mineralization rates. Hydroxyapatite crystals account for 90% to 92% per volume of dental enamel. Structurally, enamel is composed of millions of enamel rods and is the hardest substance in the human body [29]. Composite, however, is made of a resin or polymer matrix with inorganic fillers distributed in it. These two components are coupled with the silane coupling agent surrounding the fillers [29]. Composite is not as hard as enamel and does not have a crystalline structure either. Enamel contains water (4% per volume). In contrast, orthodontic adhesives have higher percentages of residual monomer and water [29]. Thus, Er:YAG laser is better absorbed by the adhesive, causing its softening and degradation. Consequently, the bond

strength of a ceramic bracket to enamel decreases, and the bracket is debonded without traumatizing the enamel surface. However, when ceramic brackets are bonded to composite surfaces, the laser is absorbed by both the adhesive and the composite restoration surface and results in the degradation of both of them (compared to destruction of adhesive and no effect on the enamel in bonding of brackets to dental surfaces); as a result, the bond strength does not decrease, and the restoration surface is damaged during debonding.

Another possible explanation for this difference is the lack of adjustment of the laser parameters that are effective in ceramic bracket debonding from the composite surface. In the present study, irradiation parameters were adjusted according to similar previous studies [15,16]. Irradiation parameters might be different for composite and enamel.

It is noteworthy that the loads applied to brackets in the oral environment are different from those in vitro. In the clinical setting, a combination of tensile, shear, and torsional loads are applied to brackets. Moreover, there are different types of stress in the oral environment in addition to thermal changes, moisture, and bacterial plaque, which complicate the generalization of in-vitro results to the clinical setting. Therefore, care must be taken when interpreting the results of in-vitro studies. Despite these limitations, in-vitro testing prior to the application of dental materials and techniques in the clinical setting is currently the most suitable option to ensure their safety and optimal efficacy [29].

Future studies are required to assess the effect of different types and powers of lasers on the bond strength of ceramic brackets to composite restorations. Moreover, the effects of different powers and types of lasers (for easier debonding of ceramic brackets from composite restorations) on intrapulpal temperature during irradiation should be studied.

CONCLUSION

Although this study failed to show any reduction in the bond strength of ceramic brackets to composite blocks following Er:YAG and Er,Cr:YSGG laser irradiation, further studies are required on different types and powers of lasers since no previous study is available on this topic.

ACKNOWLEDGMENTS

This study was part of a DDS thesis supported by Tehran University of Medical Sciences (Grant No. 918T). This study was funded and supported by Tehran University of Medical Sciences (Grant No. 96-02-97-35886).

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