DEBONDING OF CERAMIC BRACKETS WITH ER,CR:YSGG LASER

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ABSTRACT:

Introduction: *The purpose of this study was to investigate the effectiveness of debonding ceramic brackets using an Er,CR:YSGG laser.* ***Materials and methods:*** *Sixty Clarity (3M) ceramic brackets were bonded to human premolar teeth which were randomly divided into three equal groups. The first group was debonded without performing previous laser application. The Er,Cr:YSGG laser was used for group 2 at 2.5W and for group 3 at 3.5W. The laser was applied at two points on each bracket for 20 seconds each. Shear bond strengths were measured in megapascals with a universal testing machine and adhesive remnant index scores were recorded.* ***Results:*** *Statistically significant lower shear bond strengths were found in the lased groups compared with non-lased group. The adhesive remnant index scores were statistically significant; the lased groups had scores of 2 or 3.* ***Conclusion:*** *The Er,Cr:YSGG laser was effective for debonding ceramic brackets and significantly decreased debonding force, thus decreased the risk of enamel damage.*

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INTRODUCTION

In the mid-1980s, ceramic bracket was introduced to the market because of patient demands for more esthetic braces, since then; much research has been conducted to evaluate their clinical characteristics and properties. The ceramic brackets currently on the market are made of aluminum oxide and are chemically inert to oral fluids.[1] A disadvantage of inert brackets is their failure to form bonds with acrylic and diacrylic adhesives.[2] As a result, various methods of retention have been developed including chemical, mechanical, and a combination of both. Mechanical retention can be provided by indentations or undercuts in the bracket base. The chemically retained ceramic brackets are retained with a silane coupler as a chemical mediator between the bracket base and the adhesive resin. [3]

Although these brackets offer better esthetics, the removal of these brackets can present problems, including bracket wing fracture, enamel fracture, and toothache.[4] Several debonding techniques have been developed to solve these problems.[5] Increased bond strength usually results in bond failure at the enamel surface, rather than at the bracket-adhesive interface. Consequently, the continuing challenge is to develop a bond between orthodontic attachments and the enamel that is strong enough to accomplish treatment but can be broken for debonding without damage to the enamel surface. [6]

Several methods have been suggested to debond ceramic brackets, including special pliers[7] for mechanical debonding[8] and diamond burs to grind the brackets off the tooth surface.[9] Other debonding techniques including wood-burning pens,[10] warm-air dryers,[11] ultrasonic instruments,[5,8] electrothermal devices,[12] and lasers[13,14] have been used to overcome problems during debonding. With these techniques, debonding is achieved by thermal softening of the adhesive resin by heat conductivity. Studies concerning this issue emphasize laser debonding, which is an effective way that works by controlling the amount of thermal energy delivered.[15-17]

The discovery of optic laser technology began with the intervention of ruby lasers in the early 1960s. [18] Since then, the tremendous advances in the field have led to various applications in medicine, the military, and many manufacturing industries. During the 1980s and early 1990s, the use of lasers was introduced into dentistry as various types were approved by the United States Food and Drug Administration.[19] Since the early 1990s, lasers have been used experimentally for debonding ceramic brackets. Each of the four major dental laser wavelengths (diode, CO_2, Nd:YAG, and Er:YAG) have been utilized to try and help with debonding these brackets and can be effective in significantly lowering the shear bond strength (SBS) of ceramic brackets.[20-23]

Erbium lasers wavelengths are well absorbed in water and hydroxyapatite. Their absorption in these tissues compounds makes it possible to ablate basically anything with water content in it. These laser wavelengths cause rapid expansion of water molecules, leading to microexplosions to occur. Enamel was not affected by the erbium lasers energy, and the pulpal temperature rise was measured to be below the 5.5 °C threshold. Erbium lasers have been shown to safely remove orthodontic brackets without damaging increases in pulpal temperature.[24]

If laser irradiation is effective in debonding ceramic brackets, everyday clinical debonding procedures will be simpler, safer, and patients will have less discomfort. The purpose of this in-vitro study was to develop an effective method for debonding ceramic orthodontic brackets with an (Er,CR:YSGG) laser.

MATERIALS AND METHODS

Sixty non-carious human premolars were used in this study, which had been extracted for orthodontic reasons. Selection criteria included the absence of any visible decalcification or cracking of the enamel surface. The buccal surfaces of all teeth were polished using a rubber cup, thoroughly washed, and dried using a moisture-free air source.

Clarity (3M Unitek, Monrovia, CA, USA), polycrystalline ceramic brackets were bonded to the buccal surfaces of premolars with the conventional etch and rinse adhesive system (Transbond XT, 3M Unitek) according to the manufacturer's instructions. Force was applied until the composite material overflowed from all margins of the brackets and the base of the brackets touched the labial surfaces of the premolars. Excess bonding material was removed with an explorer. All samples were light-cured for 10 seconds through the brackets using Mr. Light (Dr's light, Good Doctors Co., Seoul, Korea), a LED curing system.

After the bonding procedures, the specimens were stored at room temperature, in distilled water that was changed weekly to prevent bacterial growth. The teeth were embedded in an autopolymerizing acrylic resin (Probase Cold, Ivoclar Vivadent Inc., Germany) with the labial surfaces and the brackets exposed. Then the specimens were randomly divided into three equal groups, 20 of each group, to be debonded with and without lasing.

The Er,Cr:YSGG laser (Waterlase iPlus, Biolase Technology, Inc. $ Cromwell, Irvine, CA 92618 USA), which operates at a wavelength of 2,780 nm, was used in this study. Two laser power output settings (2.5W and 3.5W) were applied to laser the brackets. Laser was performed with pulse repetition rates of 25 pulses/second (25Hz). The air and water levels were 70% and 30%, respectively. The laser was applied to two points for 20 seconds each. The laser tip was positioned, as close as possible, mid way between the bracket wings incisally and gingivally (i.e. above and below the stainless steel slot of the Clarity brackets) as shown in figure 1. The three groups were as follows:

***Group 1 (Control group)*:** The brackets were not lased before debonding.

***Group 2*:** The brackets were lased with Er,Cr:YSGG before debonding with 2.5W power output for 40 seconds.

***Group 3*:** The brackets were lased with Er,Cr:YSGG before debonding with 3.5W power output for 40 seconds.

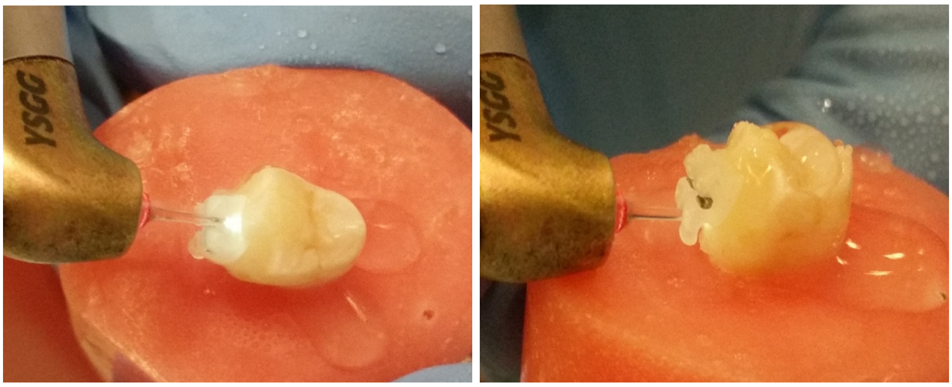

Figure 1: The Er,Cr:YSGG laser tip was positioned, as close as possible, mid way between the bracket wings incisally and gingivally.

After the Er,Cr:YSGG laser was applied, the embedded teeth and ceramic bracket were positioned in a universal testing machine (Comten industries Inc., Florida, USA) so that the bracket slot was parallel to the horizontal. A knife-edged shearing blade was secured to the crosshead with the direction of force parallel to the buccal surface and the bracket base; the brackets were then debonded at a crosshead speed of 1 mm/min. After bond failure, the bracket bases and enamel surfaces were examined with a stereoscopic microscope (Olympus stereomicroscope SZ II Optical Co, Tokyo, Japan) at a magnification of 30x . The adhesive remnant index (ARI)[25] scores were used to assess the amount of adhesive left on the enamel surface. ARI scores ranged from 0 to 3. A score of 0 indicates no adhesive remained on the enamel surface, 1 indicates less than half of the adhesive was left on the tooth, 2 indicates more than half of the adhesive was left on the tooth, and 3 indicates all adhesive was left on the tooth.

STATISTICAL ANALYSIS

The data were analyzed with SPSS software (SPSS for windows, version 20.0 SPSS Inc, Chicago, IL, U.S.A.). The mean, standard deviation and median were evaluated for each group. The one-way analysis of variances (ANOVA) was performed to evaluate the difference in mean SBS between the groups followed by Post Hoc test of Tukey

(LSD). Then, the Kruskal Wallis test was performed to determine the difference in ARI between the groups. Significance for all statistical tests was predetermined at $P < 0.05$.

RESULTS

The results showed statistically significant differences between the lased groups and the non-lased group. The shear test showed significantly lower shear bond strengths in the laser groups. Means and standard deviations of the shear bond strengths of each group are shown in Table 1. The shear strength values were (12.62±0.95) MPa for the control (non-lased) group, (8.12±0.50) MPa for the 2.5W lased group and (6.76±0.54) MPa for the 3.5W lased group. The 2.5W group had a significant decrease in bond strength compared with the control group. The 3.5W lased group, when compared with the control and the 2W laser groups, showed a significant decrease in bond strength (Table 2).

Table (1): Comparison of the shear bond strengths between the three different groups

	Control (n=20)	2.5W Laser (n=20)	3.5W Laser (n=20)	F	p
Shear Bond					
Min. – Max.	11.10 – 14.20	7.20 – 9.10	5.80 – 7.80		
Mean ± SD	12.62 ± 0.95	8.12 ± 0.50	6.76 ± 0.54	3.89.993*	<0.001*
Median	12.65	8.15	6.85		

F: F test (ANOVA)
*: Statistically significant at $p \leq 0.05$

Table (2): Significance of difference between shear bond strengths of pairs of groups

	2.5 W Laser	3.5 W Laser
Control	p <0.001*	p <0.001*
2.5W Laser		p <0.001*

p: value for Post Hoc Test (LSD) for comparing between pairs of groups
*: Statistically significant at $p \leq 0.05$

When the ARI scores were considered, 0 score was not found for the laser groups while the control group had scores of 0 and 1. The results for the laser groups had almost twice as much adhesive, with ARI scores of 2 and 3 (Figure 2). The data in Tables 3 and 4 showed that the difference in ARI scores was statistically significant when comparing control group to 2.5W laser and when comparing control group to 3.5W laser but the difference in ARI scores was statistically insignificant when comparing 2.5W laser and 3.5W groups. A negative correlation was found between bond strengths and ARI scores as the shear bond strengths decreased, the ARI scores increased.

Figure 2: Distribution of ARI Scores for three studied groups

Control	ARI:1	ARI: 0
2.5 W Laser	ARI:3	ARI:2
3.5 W Laser	ARI:3	ARI:2

Figure 2 shows that ARI scores for the control groups were between 0 and 1 scores and for 2.5W Laser and 3.5W Laser specimens were 2 and 3 scores.

Table (3): Comparison of the ARI scores between the three different groups

	Control (n=020)		**2.5 Laser (n=20)**		**3.5 Laser (n=20)**		$^{KW}\chi^2$	**P**
	No.	**No.**	**No.**	**%**	**No.**	**%**		
Scores for ARI							43.843*	<0.001*
0	9	45.0	0	0.0	0	0.0		
1	11	55.0	0	0.0	0	0.0		
2	0	0.0	13	65.0	8	40.0		
3	0	0.0	7	35.0	12	60.0		

KW: Kruskal Wallis test

*: Statistically significant at $p \le 0.05$

Table (4): Significance of difference between pairs of groups according to ARI

	2.5 W Laser	3.5 W Laser
Control	<0.001*	<0.001*
2.5W Laser		=0.118

Sig. bet. groups was done using Mann Whitney test

*: Statistically significant at $p \leq 0.05$

DISCCUSION

During the removal of ceramic brackets, enamel damage has been the subject of concern to many researchers. Some studies evaluated the etching time factor on the enamel surface and the type of adhesive used,[2, 26] others assessed the different types of bracket base retentions.[6, 27] Several studies evaluated the debonding method which would cause less damage to the enamel[8,28] and some tested the methods of adhesive remnant removal and surface polishing.[4, 29]

Since the optimum force to debond a bracket was shown to be 6 to 8 MPa[30], it should be kept in this range to prevent damage to the teeth and periodontal structures. Meanwhile, debonding of ceramic brackets can reach values approaching 20 MPa,[31] which can cause enamel cracks or fractures.[32] To prevent these debonding complications laser-initiated debonding mechanisms were developed that work by degrading the adhesive resin. In previous debonding studies,[13-15,21,28,33,34] lasers were used on ceramic brackets and have shown that lasers can significantly reduce ceramic bracket debonding force.

Tocchio et al [34] described three methods of debonding: thermal softening, thermal ablation, and photo ablation. During thermal softening, decomposition of the adhesive resin is obtained by heat transmitted through the bracket. To avoid loss of the laser energy while passing through the bracket to reach the resin during debonding ceramic brackets, a laser should be chosen that will directly affect the resin without conducting too much heat. In this study, we investigated the effects of using an Er,CR:YSGG laser for ceramic bracket debonding. This type of laser was selected as it would directly influence the resin because it has a lower ceramic absorption level than the carbon dioxide (CO_2) laser and appears to have lesser thermal effect than the Nd:Yag laser.[35]

The laser light of the Er,Cr:YSGG laser can be absorbed by silane and resin that contain water or residual monomer.[36] Therefore, the effect of irradiation with the Er,CR:YSGG laser can result in decomposition of the resin because of the microexplosions of the water or the monomer.The laser used did not produce any of the carbonization-like changes to the remnant resin, or decomposition of the bracket base as reported by Hayakawa [14] when using an Nd: YAG laser.

When comparing the lased groups with the non-lased group, the 2.5W group experienced an apparent decrease in bond strength, and the effect of lasing was significant. While debonding was achieved more effectively in the 3.5W group because of the higher output level which could be attributed to less energy loss during transmission through the brackets, thus the bond surfaces received the laser energy more effectively.

In this study, most of the lased ceramic bracket specimens had bond failure at the bracket-adhesive interface. In almost all samples in laser groups, all or most of the adhesive remained on the tooth, with an imprint of the bracket pad after debonding. On the other hand, the most common site for the bond failure of the non-lased ceramic brackets was at the adhesive-enamel interface, thus entailing damage risks for the enamel surface. They had a mean ARI score of or close to 0. The pattern of bond failure interface observed after removal of non-lased ceramic brackets in this study supports the findings of previous studies.[31, 37] Yet, there were no enamel fractures or cracks found in either the lased or the non-lased groups of our study.

The use of Er,Cr:YSGG laser was effective in significantly lowering the debonding force for the ceramic brackets (Clarity 3M). Both the 2.5W and the 3.5W laser irradiations had significantly lower debonding force than the non-lased group. There was significant difference in debonding force when the two laser power levels (2.5W and 3.5W) were compared. The ARI scores differences were significant between two laser groups and the non-lased group tested.

CONCLUSIONS

Er,Cr:YSGG laser irradiation on ceramic brackets was efficient and significantly decreased the debonding force . It also increased the ARI scores and thus decreased the risk of enamel fracture. As a result, this method might be an effective clinical way to reduce the shear bond strengths of orthodontic ceramic brackets from high values to the desired levels needed for safe removal from the teeth.

RECOMMENDATIONS

Many different ceramic brackets are available today. In this study, we tested only on one type of ceramic brackets (Clarity 3M). Further testing should be done to determine whether there are differences among other brackets. There are other variables that could be studied as the thickness of the bracket base and the thickness of the bracket itself. Brackets with larger profiles would be expected to transmit less laser energy to the bracket base and the underlying layer of adhesive. Also, further studies are necessary to investigate the thermal effects of this method on the pulp tissues.

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