Er,Cr:YSGG Laser as a Novel Method for Rebonding Failed Ceramic Brackets

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Abstract

Objective: Since there is no standard method for rebonding loose ceramic brackets, the aim of this study was to evaluate the possibility of using Er,Cr:YSGG laser to eliminate the remaining composite materials from the base of ceramic brackets and to compare the bond strength of rebonded brackets with the new ones. **Materials and methods:** Sixty-two extracted human premolars were mounted in acrylic cylinders. Thirty-one ceramic brackets were bonded, and shear bond strength was tested using Hounsfield testing machine. The remnants of the bonding material were removed from the bases of brackets using Er,Cr:YSGG laser. These brackets were rebonded to 31 fresh teeth and again shear bond strength was measured. Pattern of debonding was assessed in both cases under a stereomicroscope and graded according to ARI index. Data were analyzed with independent *t*-test and Fisher's exact test. **Results:** Mean shear bond strength of the bond and rebond groups was 12.29 ± 5.46 and 10.58 ± 5.16 MPa, respectively. There were no significant differences between the two groups ($p=0.21$). Pattern of bond failure was not statistically different between the two groups. **Conclusions:** Er,Cr:YSGG laser was effective in removing the remnants of bonding material from the base of ceramic brackets without any interference with the ceramic base itself, demonstrating that it might be a suitable method for rebonding ceramic brackets.

Introduction

DISLODGE MENT OF ORTHODONTIC brackets is a common occurrence in the course of orthodontic treatment, which prolongs the treatment time and/or increases the costs.^{1–3}

Metal brackets are the most commonly used brackets in orthodontics, and since a study by Sonis showed that shear bond strength of new brackets and rebond strength of air-abraded failed brackets is comparable, the sandblasting technique⁴ is the method of choice for rebonding loose metal brackets.⁵

Nowadays, demands for more esthetic options have resulted in more frequent use of ceramic brackets.^{6,7} Although it has been shown that combined use of sandblasting and silane and also silica coating and silane for rebonding failed ceramic brackets results in comparable shear bond strength to new brackets,⁷ there is no standard method for rebonding failed ceramic brackets.⁵

The main challenge in rebonding brackets is restoring the bracket base to a retentive pattern (original one or comparable) without deteriorating the bracket itself.

Er,Cr:YSGG, a hydrokinetic laser system, was introduced in 1995 and is a member of Erbium laser superfamily, with a wavelength of 2.780 nm in the infrared spectrum.^{8–10} It is

used for conditioning hard tissue surfaces, including those of teeth and bone.¹¹ Due to high absorption of Er,Cr:YSGG in both water and hydroxyapatite, it can be used in both oral soft and hard tissues.¹² Absorption in water makes this laser inert relative to ceramic materials and is used when differential removal of a material from ceramic surfaces is intended.

Therefore, the aim of this study was to evaluate the possibility of using Er,Cr:YSGG laser to eliminate the remaining composite resin from the base of ceramic brackets and to compare the bond strength of rebonded brackets with the new ones.

Materials and Methods

In this *in vitro* study, assuming $\alpha=0.05$, power=80%, and $\delta/d=1$, a sample size of 31 was calculated for each group. Therefore, 31 ceramic brackets were utilized for the study. In addition, 62 human premolars (30 lower and 32 upper), extracted for orthodontic purposes with no caries, no visual cracks, and no restorations, were stored in 0.5% chloramine. The teeth were mounted in acrylic cylinders, exposing their crowns and orienting the middle third of the crown perpendicular to cylinder bases to facilitate

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FIG. 1. The base of the bracket before (A) and after (E) application of laser (A–E) illustrates gradual removal of the adhesive from the base and (F) shows a new bracket before bonding.

paralleling the debonding force with the bracket–enamel interface.¹³

Then, the teeth were polished with fluoride-free pumice and rinsed with water for 10 sec.

Thirty-one ceramic brackets (Fascination II; Dentaaurum) were bonded to teeth with Transbond XT (3M Unitek). Then, the samples were thermocycled between water baths held at 5°C and 55°C for 30-sec cycles for a total of 500 cycles to imitate the heat and humidity of the oral cavity and finally incubated in 37°C distilled water for 24 h.^{1,7}

Then, the shear bond strength was tested using Hounsfield test equipment (HSK-5 Model) and bond strength was calculated in MPa.^{2,9}

In the second part, bracket bases were irradiated with Er,Cr:YSGG laser (Biolase Europe GmbH) using the parameters of 3.5 W, 65% air, and 55% water until visible remnants of bonding material were eliminated from the bases. This took 10–15 sec for different samples. Irradiation was noncontact from a distance of 1–2 mm. The laser parameters

were based on a pilot study. Figure 1 demonstrates gradual removal of the adhesive from the base of the bracket.

After removing the composite, these brackets were rebonded on 31 fresh teeth using the same procedure and were debonded.

In both stages, tooth surfaces were inspected under a stereomicroscope (Nikon) ($\times 10$) and failure patterns were graded according to ARI score: score 0 indicates that no bonding resin remained on the tooth; score 1 indicates that less than half of the bonding resin remained on the tooth; score 2 indicates that more than half of the bonding resin remained on the tooth; and score 3 indicates that all bonding resin remained on the tooth.⁹

Statistical analysis

Descriptive statistics, including the mean, standard deviation (SD), and minimum and maximum values, were calculated for each session of bonding. The Kolmogorov–Smirnov test was used for testing the distribution of data.

TABLE 1. DESCRIPTIVE STATISTICS AND COMPARISONS FOR TWO GROUPS

Groups	n	Statistic for Kolmogorov–Smirnov test	p Value of Kolmogorov–Smirnov test	Range	Bond strength (MPa)			p
					Mean	SD	SEM	
Bond	31	0.14	0.15	5.52–29.01	12.29	5.46	0.98	0.21
Rebond	31	0.14	0.07	2.66–22.30	10.59	5.16	0.93	

SD, standard deviation; SEM, standard error of the mean.

TABLE 2. RESIDUAL ADHESIVE REMNANT RATINGS ACCORDING TO ARI FOR TWO SESSIONS OF BONDING

Groups	ARI			
	0	1	2	3
Bond	2	0	3	26
Rebond	1	1	4	25

ARI, adhesive remnant index.

Comparisons of means were made with independent samples *t*-test. Chi-square and Fisher's exact tests were also used to determine any significant differences in the ARI scores between the two groups (SPSS for Windows, Release 17).

Results

Mean shear bond strength values were 12.29 ± 5.46 MPa for bond and 10.59 ± 5.16 MPa for rebond groups. The Kolmogorov-Smirnov test showed normal distribution of data in both groups (Table 1). Comparison of the groups revealed no statistically significant differences between groups ($t=1.26$, $df=60$, $p_{two\ sided}=0.21$).

Pattern of bond failure in both groups was compared (Table 2). Due to blank cells in the distribution table, requirements of chi-squared test were violated; therefore, the cells of grades 0 and 1 and grades 2 and 3 were combined to make the comparison feasible (Table 3). Fisher's exact test showed no significant differences between the two groups (Fisher's exact test = 0.00, $p=1.00$).

Discussion

In this study, bond strength in the bond group was in the similar range of reported values of bond strength in previous studies.^{3,7} The bond strength values recorded in the bond group were not significantly different from the ones in the rebond group, but if the sample size of the study had increased, the *p*-value would have approached the significance level, although it can be predicted that this difference would not have been clinically relevant. This similarity of bond strength values of two groups could be attributed to the fact that Er,Cr:YSGG laser was capable of eliminating the remaining composite material selectively from the base of ceramic brackets, without significantly deteriorating the retentive features built in the base (Fig. 1).

TABLE 3. RESIDUAL ADHESIVE REMNANT RATINGS ACCORDING TO MODIFIED ARI FOR TWO SESSIONS OF BONDING

Groups	Mainly on bracket ^a	Mainly on enamel ^b
Bond	2	29
Rebond	2	29

^aCombined ARI scores of 0 and 1.

^bCombined ARI scores of 2 and 3.

It is known that pulsed infrared lasers are effective in removing orthodontic bonding materials¹⁴ and the use of these lasers (i.e., Er:YAG, Nd:YAG, XeCl, KrF...) results in fusion, evaporation, and elimination of composite materials.¹⁴⁻¹⁷ Studies evaluating the effect of Er:YAG laser on ablation of composite resins have shown that during ablation, the composite resin surface becomes porous. It is supposed that ablation of composite resins by Er,Cr:YSGG laser occurs through the same mechanism as Er,Cr:YSGG and Er:YAG lasers interact with hard tissues.¹⁸ Since ceramic materials do not have water in their structure, it has been shown that they are insensitive to hydrokinetic Er,Cr:YSGG laser irradiation,¹⁹ and this eliminates concerns regarding any deterioration in the shape and dimension of brackets.

Differences between the bond and rebond groups, although nonsignificant, might be attributed to the fact that after removing composite resin remnants, small nonvisual remnants can remain because of low irradiation on some specific marginal areas, which might decrease the bondable surface and also prevent exact adaptability.

Chung et al. studied the rebond strength of ceramic brackets with mechanical retention and reported that rebond + sandblast + silane showed results comparable with new brackets.³ Silane coupling agent, as a bond promoter (enhancer), has been used successfully, although the results are not conclusive. Harris et al. showed that silanizing the debonded ceramic brackets resulted in a rebond strength of 1.8 MPa,²⁰ which was lower than the minimum values required for clinical success.²¹ Toroglu and Yaylali reported that although the combination of silane and sandblasting was not successful, combining silane and silica coating was successful in conditioning the ceramic bracket bases (mean: 12.7 MPa) compared with new ones. That study showed that combination of silane and silica coating was successful in rebonding ceramic brackets, although maximum tensile rebond strength exceeded that of the new bracket group (19.6 and 18.5 MPa, respectively); in addition, there was a noticeable shift in ARI scores of the silane and silica coating group to lower score, indicating that there was greater chance in this group for debonding to occur at the tooth-bonding interface. However, high bond strength values in combination with lower ARI scores can increase the possibility of enamel cracks and/or tear-outs at the end of treatment when the appliances are removed.⁷

Air abrasion has been evaluated as a solution for failed ceramic brackets, but was not successful, which might be attributed to the nonselective effect of sandblasting on ceramic base and composite remnants, resulting in the elimination of retentive features of bracket base and possibly leaving some parts of composite materials intact.

In this study, the failure pattern was not different between the bond and rebond groups; failure occurred at the interface of base and bonding material, which was consistent with the results of other studies evaluating new ceramic brackets.^{3,7} Unsuccessful groups in a study by Toroglu and Yaylali had failure patterns similar to the failures of the present study and also similar to new brackets; however, in the combination of silane and silica coating, which was the successful group of that study, this pattern shifted to the interface of enamel and adhesive, which can deteriorate enamel by cracks and/or tear-outs.

Shortcomings and implications for research

Full-term clinical studies are required to confirm the results of this *in vitro* study by evaluating failure rate and/or survival rate of failed ceramic brackets bonded utilizing this method individually and/or in comparison with other known methods.

Authors continue to research other Er superfamily lasers in order, using them for rebonding failed ceramic brackets.

Conclusions

Since there is no standardized well-accepted method for rebonding failed ceramic brackets and using a new bracket is the only well-accepted method,⁵ it seems that Er,Cr:YSGG laser can be used as a safe method for rebonding failed ceramic brackets.

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Author Disclosure Statement

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References

- Montasser MA, Drummond JL, Evans CA. Rebonding of orthodontic brackets. Part I, a laboratory and clinical study. *Angle Orthod* 2008;78:531–536.
- Mui B, Rossouw PE, Kulkarni GV. Optimization of a procedure for rebonding dislodged orthodontic brackets. *Angle Orthod* 1999;69:276–281.
- Chung CH, Friedman SD, Mante FK. Shear bond strength of rebonded mechanically retentive ceramic brackets. *Am J Orthod Dentofacial Orthop* 2002;122:282–287.
- Sonis AL. Air abrasion of failed bonded metal brackets: a study of shear bond strength and surface characteristics as determined by scanning electron microscopy. *Am J Orthod Dentofacial Orthop* 1996;110:96–98.
- Zachrisson BU, Buyukyilmaz T. Bonding in orthodontics. In: *Orthodontics: Current Principles Techniques*. LW Graber, RL Vanarsdall, KW Vig (eds.). St. Louis: Elsevier Mosby, 2012; p. 748.
- Azzeh E, Feldon PJ. Laser debonding of ceramic brackets: a comprehensive review. *Am J Orthod Dentofacial Orthop* 2003;123:79–83.
- Toroglu MS, Yaylali S. Effects of sandblasting and silica coating on the bond strength of rebonded mechanically retentive ceramic brackets. *Am J Orthod Dentofacial Orthop* 2008;134:181e1–181e7.
- Abad-Gallegos M, Arnabat-Dominguez J, Espana-Tost A, Berini-Ayres L, Gay-Escoda C. In vitro evaluation of the temperature increment at the external root surface after Er,Cr:YSGG laser irradiation of the root canal. *Med Oral Patol Oral Cir Bucal* 2009;14:e658–e662.
- Al Shamsi A, Cunningham JL, Lamey PJ, Lynch E. Shear bond strength and residual adhesive after orthodontic bracket debonding. *Angle Orthod* 2006;76:694–699.
- Mir M, Meister J, Franzen R, Sabounchi SS, Lampert F, Gutknecht N. Influence of water-layer thickness on Er:YAG laser ablation of enamel of bovine anterior teeth. *Lasers Med Sci* 2008;23:451–457.
- Obeidi A, Liu PR, Ramp LC, Beck P, Gutknecht N. Acid-etch interval and shear bond strength of Er,Cr:YSGG laser-prepared enamel and dentin. *Lasers Med Sci* 2010;25:363–369.
- Berk N, Basaran G, Ozer T. Comparison of sandblasting, laser irradiation, and conventional acid etching for orthodontic bonding of molar tubes. *Eur J Orthod* 2008;30:183–189.
- Meguro D, Hayakawa T, Kawasaki M, Kasai K. Shear bond strength of calcium phosphate ceramic brackets to human enamel. *Angle Orthod* 2006;76:301–305.
- Dumore T, Fried D. Selective ablation of orthodontic composite by using sub-microsecond IR laser pulses with optical feedback. *Lasers Surg Med* 2000;27:103–110.
- Sherk HH, Lane G, Rhodes A, Black J. Carbon dioxide laser removal of polymethylmethacrylate. *Clin Orthop Relat Res* 1995;67–71.
- Thomas BW, Hook CR, Draughn RA. Laser-aided degradation of composite resin. *Angle Orthod* 1996;66:281–286.
- Tocchio RM, Williams PT, Mayer FJ, Standing KG. Laser debonding of ceramic orthodontic brackets. *Am J Orthod Dentofacial Orthop* 1993;103:155–162.
- Kimyai S, Mohammadi N, Navimipour EJ, Rikhtegaran S. Comparison of the effect of three mechanical surface treatments on the repair bond strength of a laboratory composite. *Photomed Laser Surg* 2010;28 Suppl 2:S25–S30.
- Keller U, Hibit R. Er:YAG laser effects on oral hard and soft tissues. In: *Lasers in Dentistry*. LJ Miserendino, RM Pick (eds.). Berlin: Quintessence Publishers, 1995; p. 165.
- Harris AM, Josef VP, Rossouw PE. Shear peel bond strengths of esthetic orthodontic brackets. *Am J Orthod Dentofacial Orthop* 1992;102:215–219.
- Elaut J, Wehrbein H. The effects of argon laser curing of a resin adhesive on bracket retention and enamel decalcification: a prospective clinical trial. *Eur J Orthod* 2004;26:553–560.

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