Diode Laser De-Bonding of Pre-Coated Ceramic Brackets.

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ABSTRACT: Objective: The purpose of this In vitro study was to investigate the effects of diode laser de-bonding on the shear bond strength and adhesive remnant index of pre-coated ceramic brackets bonded to extracted human premolars. **Materials and Methods**: Eighty freshly extracted upper premolars were used. The teeth were divided into two groups according to the pre-coated ceramic brackets applied (APC II and APC plus). Each group was subdivided into two subgroups according to the method of de-bonding, either by laser diode (study groups) or without laser application (control groups) (N=20). The shear bond test was performed after the laser pulse had been applied, and the adhesive remnant index (ARI) scores were assigned to each specimen. Random samples from each group were selected for SEM observation. Statistical analysis was performed via a one-way ANOVA analysis and Chi-square test. **Results**: Significantly ($p < 0.001$) lower shear bond strengths were found in the laser groups compared with the control groups. Similarly, the adhesive remnant index scores were significantly different ($p < 0.001$); the laser group had nearly twice as much adhesive, with ARI scores of 2 or 3. **Conclusion:** The application of the diode laser is effective in de-bonding pre-coated ceramic brackets.

[Mohammad Almohaimeed and Sahar Abd El Halim. **Diode Laser De-Bonding of Pre-Coated Ceramic Brackets**. *J Am Sci* 2013;9(5s):177-181]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 28

Key words: In vitro study, shear bond strength, adhesive remnant index, adhesive, orthodontic, pre-coated ceramic brackets.

1.INTRODUCTION

The new generation of pre-coated orthodontic brackets is designed to reduce chair time and thereby increase work efficiency. Pre-coated brackets provide a more uniform adhesive thickness and reduce the number of bonding procedures (Bishara et al., 2002a). The properties of pre-coated brackets have improved. The recently introduced APC Plus system (3M Unitek Dental Products) has exhibited greater tolerance to humidity than its predecessors, and the adhesive also releases fluoride (Brennan et al., 2004). The use of self-etching primers together with pre-coated brackets might provide an important decrease in chair time by reducing the number of intermediate steps in bracket bonding procedures (Hasan, 2010).

The advantages of APC brackets over conventional light cured systems include a) consistent quality and quantity of adhesive; b) reduced waste during bonding; c) easier clean-up following bonding; and d) improved asepsis. The ingredients in the adhesive applied to the pre-coated brackets are the same as those in the Transbond XT adhesive (Cooper et al., 1992).

Various methods have been developed to aid in de-bonding ceramic brackets. These methods use special pliers (Swartz et al., 1988) for mechanical de-bonding and degrading the bonding resin with electro-thermal de-bonding devices (Sernetz and Kraut, 1991; Brouns et al., 1993) and lasers (Tocchio et al., 1993; Hayakawa, 2005). There are four major types of lasers. They are classified mostly by their lasing mediums, which are defined by their state, such as a gas, liquid, solid, and semiconductor (or laser diode).

The goal of bracket de-bonding is to degrade the adhesive resin strength connecting the tooth and bracket. This can be performed by laser radiation, which can penetrate through the bracket to the adhesive resin and influence the strength of its bond to enamel (Dostálováa et al., 2009).

Laser de-bonding is an effective method that works by controlling the amount of thermal energy delivered (Xianglong et al., 2008). The efficacy of lasers on de-bonding has been evaluated in several studies with many variables and techniques, types of lasers (Strobl et al., 1992) with the same and different energy levels, brackets, resins (Hayakawa, 2005) and magnitudes of applied stresses (Rickabaugh et al., 1993).

The objective of this in vitro study was to evaluate the shear bond strength to enamel and the adhesive remnant index (ARI) of both pre-coated ceramic brackets after de-bonding by using a diode laser.

2.MATERIALS AND METHODS

2.1.Materials:

2.1.1.Samples:

Eighty freshly extracted human upper premolars were used; the teeth had been extracted for orthodontic reasons and were collected and stored in a solution of 0.1% (wt/vol) thymol.

* *Criteria for tooth selection :*

- Intact buccal enamel not subjected to pretreatment with chemical agents, such as hydrogen peroxide or enamel conditioner, with no cracks from the use of extraction forceps, and with no caries.
-The teeth were mounted vertically in a self-cure acrylic (Rapid Repair, Detrey Dentsply Ltd, Surrey, U.K.) cylinder.
-The long axis of each tooth was aligned vertically to the base of the cylinder.

The teeth were divided into two groups according to the pre-coated ceramic brackets applied (APC II and APC plus). Each group was subdivided into two subgroups according to the method of de-bonding, either by laser diode (study group) or without laser application (control group, N=20).

2.2. Methods:

2.2.1. De-bonding, by laser diode :

Buccal surfaces of selected upper premolars were polished for 10 s with a rubber prophylaxis cup and fluoride-free pumice and water, rinsed for 15 s with distilled water, and air dried for 5 s.

The enamel surfaces were conditioned with Trans-bond Plus SEP (Self-Etching Primer - 3M Unitek, Miami, FL, USA) for 5s according to the manufacturer's instructions and gently air dried. APCII and APC Plus Adhesive Pre-Coated Ceramic upper premolar brackets (Clarity- 3M Unitek, Monrovia, CA 91016USA) were placed on the bonding surfaces by one operator. Excess adhesive was removed with a sharp explorer, and the samples were light-cured using the Ortholux™ LED Curing Light (App. 1000 mW/cm^2) (3M Unitek Dental Products) for 10 s through the bracket according to the manufacturer's recommendations. After 48 h, all samples were divided into two groups of 40 brackets to be de-bonded with and without lasing. A diode laser (Unata system Italy, 980 nm, maximum energy 25 nm, pulse duration cw) was used at a power of 3 W with a wavelength of 980 nm. The laser energy was applied for 3 s.

2.2.2.The shear test :

It was performed 24 h after the laser pulse had been applied. These tests were performed using NEXYGEN from Lloyd Instruments. Each sample was mounted on the lower fixed compartment of a computer-controlled materials testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) with a load cell of 5 kN, and data were recorded using computer software (Nexygen-MT; Lloyd Instruments). Then, the samples were subjected to compressive loading in the occluso-gingival direction at a crosshead speed of 0.5 mm/min via a mono-beveled chisel-edged rod attached to the upper movable compartment of the testing machine. The chisel tip was positioned to only touch the base of the bracket. The maximum failure load was recorded in N. Failure was manifested by the displacement of bracket and confirmed by sudden drop along the load-deflection curve recorded by computer software (Nexygen-MT; Lloyd Instruments Ltd). To express the bond strength in MPa, the maximum failure load was divided by the bracket base area provided by the manufacturer. The bracket bases and enamel surfaces were examined under a light stereomicroscope at 20x magnification, and the adhesive remnant index (ARI) scores were assigned to each specimen (Artun and Bergland, 1984). The scores were assessed as follows: 0 indicated that no adhesive was left on the tooth in the bonding area; 1 indicated that less than half of the adhesive was left on the tooth; 2 indicated that more than half was left on the tooth; and 3 indicated that all adhesive was still on the tooth, with a distinct impression of the bracket mesh on the remaining adhesive surface. Random samples from each group were selected for SEM observation.

2.2.3.Statistical analysis

Statistical analysis was conducted using SPSS. The SBS data were compared with a one-way ANOVA and post-hoc Scheffe tests. Statistical significance for both tests was defined as $p < 0.05$. The distributions of ARI scores were compared with a Chi-squared test

3.RESULTS

The mean SBS values and standard deviations are given in Table I. The results showed statistically significant differences between the control and study groups ($p < 0.001$) (Fig 1). The shear test demonstrated the presence of significantly lower shear bond strengths in the laser group. The shear strength values for APC II were 29.711 MPa for the control group and 13.706 MPa for the study group. The shear strength values for APC plus were 33.493 MPa for the control group and 16.253 MPa for the study group.

However, the difference in the means of the laser groups was not statistically significant ($p < 0.001$), and the statistical analysis also revealed insignificant differences between the control groups ($p < 0.001$).

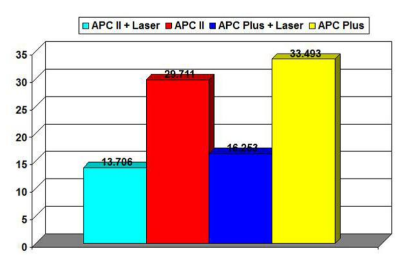


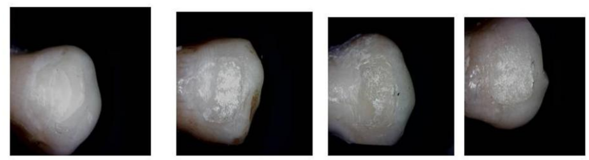
Fig. (1): Mean shear bond strength (MPa) of different treatments.

Table (I): Descriptive statistics and tests of significance for the effect of group and material on shear bond strength (MPa).

Material	Group				*p1*
	Laser de-bonding		Control		
	Mean	S.D.	Mean	S.D.	
APC II	13.706	0.344	29.711	5.114	< 0.001 ***
APC Plus	16.253	3.163	33.493	4.853	< 0.001 ***
p2	0.002 **		0.021 *		

Chi-square analyses determined that the ARI scores were significantly different between the control and study groups ($p < 0.001$). When the ARI scores were considered for the APC plus control group, a 0 score was found in two samples, 16 samples had a score of 1, and two samples had a score of 2. For APCII, a 0 score was not found, 16 samples had a score of 1, and four samples had a score of 2. The laser group exhibited nearly twice as much adhesive, with ARI scores of 2 and 3. A negative correlation was found between bond strengths and ARI scores ($p < 0.001$); The ARI scores increased as the shear bond strengths decreased.

Figures 2 and 3 show photographic and SEM evaluations of representative examples of the enamel surface after de-bonding with the different residual adhesive patterns observed.



a) b) c) d)

Fig.2 Photograph: Showing Tooth Surface After De-bonding of brackets. a) score 0, b) score1, c) score2 and d)score3

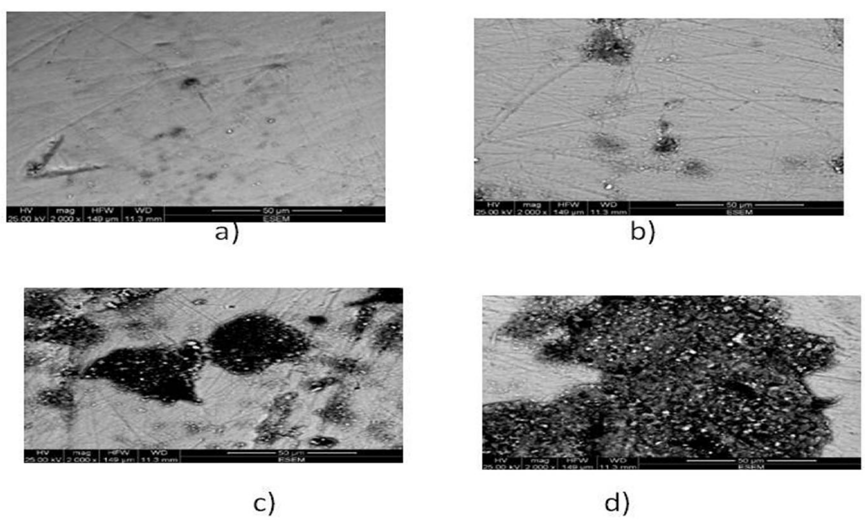


Fig.3 ESEM Images of enamel surface After De-bonding of brackets. a) score 0, b) score1, c) score2 and d)score3

4. DISCUSSION

The current study determined the shear bond strength (SBS) and adhesive remnant index (ARI) for pre-coated ceramic brackets after de-bonding with a diode laser.

Standardization of the thickness of the composite material is an important factor in studies that examine shear bond strengths. In previous studies, there was no specific method for the exact standardization of the composite material (Azzeh and Feldon, 2003; Xianglong et al., 2008).

The use of APC brackets in the present study displayed some advantages, such as a standard quantity of adhesive, easy removal of excess, better asepsis, and the reduction of occasional loss of material (Bishara, 2002, 2003; Cal-Neto et al., 2006). APC brackets were used because they had a less sensitive technique and limited procedural errors (Hasan, 2010).

Many studies have used lasers to reduce ceramic bracket de-bonding forces and prevent enamel cracks or tear-outs (Hayakawa, 2005). The increased bond strength in the attachment of ceramic brackets to enamel might increase the potential for enamel damage or bracket fractures upon de-bonding (Karamouzos et al., 1997; Viazis et al., 1990; Gibbs, 1992).

The shear test revealed significantly lower shear bond strengths in the laser groups. This may be explained by the fact that a diode laser is a semiconductor device that produces coherent radiation (in which the waves are all at the same frequency and phase) in the visible or infrared spectrum when current passes through it. Laser diodes differ from other laser types in several important ways: they are small in size and have low weight, current, voltage, intensity, and power requirements (Feldon et al., 2010). Laser-initiated de-bonding works by degrading or thermally softening the adhesive resin (Ma et al., 1997; Mimura et al., 1995).

However, the use of the diode laser was effective in significantly lowering the required de-bonding force when monocrystalline brackets were tested. Both the 3-W and 5-W per square centimeter laser protocols yielded significantly lower de-bonding forces than the non-lased control group (Feldon et al., 2010).

This finding is in agreement with other studies that concluded that the diode laser de-bonding protocol used did not produce any explosive ''blow-offs,'' noticeable carbonization-like changes to the remnant resin, or decomposition of the bracket base, as was reported by Hayakawa (2005) when using an Nd:YAG laser. It appears that the effect of the diode laser was to provide thermal softening of the adhesive.

The results of our investigation generally agree with previous studies, substantiating the fact that lasers can be used effectively to thermally soften the adhesive resin for the removal of ceramic brackets (Rickabaugh et al., 1993). Our investigation showed that it is possible to use laser radiation to facilitate bracket removal. The applied radiation must exhibit a wavelength that promotes maximal absorption in the bracket and bonding agent material and minimal absorption in the tooth. If these criteria are fulfilled, the radiation is an efficient helper in de-bonding, and no thermal damage to the tooth appears after the procedure (Rechmann and Fried et al., 2008).

However, when laser light was used at wavelengths of 248, 308, and 1060 nm and at power densities between 3 and 33 W per square centimeter to de-bond two types of ceramic brackets with externally applied stress of either 0 or 0.8 MPa, no enamel or bracket damage was reported (Tocchio et al., 1993). According to the investigators, laser energy can degrade the adhesive resin by thermal softening, thermal ablation, or photo-ablation. Thermal softening happens when the bonding agent is heated until it softens. As a result of thermal softening, the bracket slides off the tooth surface. If the heating is fast enough to raise the temperature of the resin into its vaporization range before thermal softening occurs, thermal ablation takes place. The bracket blows off the tooth surface as the result of thermal ablation. The bracket also blows off the tooth from photo-ablation, which occurs when the energy level of the bonds between the bonding-resin atoms rapidly rises above their dissociation energy levels, resulting in the decomposition of the material.

Therefore, in most previous studies, carbon dioxide lasers that have wavelengths that are more easily absorbed by the ceramic brackets have been preferred for de-bonding (Strobl et al., 1992; Rickabaugh et al, 1993). For the de-bonding of ceramic brackets, a laser should be chosen that will directly affect the resin without conducting excessive heat (Oztoprak et al., 2010).

A negative correlation was found between bond strengths and ARI scores as the shear bond strengths decreased and ARI scores increased; there were also significant ARI score differences between the control and study (laser) groups. This result was consistent with the incoming electron microscope results. This finding is in agreement with other studies that concluded that the diode laser significantly decreased the de-bonding force required for monocrystalline brackets (Feldon et al., 2010).

Moreover, laser-aided de-bonding was efficient for de-bonding ceramic brackets without enamel tear-outs or bracket fractures. Er:YAG lasers increased the ARI scores and thus decreased the risk of enamel fracture, and they are thus effective in reducing the shear bond strengths of orthodontic polycrystalline ceramic brackets from high values to levels for safe removal from the teeth (Oztoprak et al., 2010). Additionally, the ARI scores were almost within the secure range, similar to previous studies (Strobl et al., 1992; Mimura et al., 1995).

CONCLUSIONS

Within the limitations of the current study, the following conclusions can be made:

1- Diode lasers are effective in reducing the shear bond strengths for pre-coated ceramic brackets because they were efficient in de-bonding ceramic brackets without enamel tear-outs or bracket fractures.
2- Diode lasers increased the ARI scores and thus decreased the risk of enamel fracture.

ACKNOWLEDGMENT

The authors received no financial support and declare no potential conflicts of interests with respect to the authorship and/or publication of this article.

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5/21/2013