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Comparison of Shear Bond Strength of Occlusal Pad Debonding Pliers Before and After Er-YAG Laser Application: An *In vitro* Study

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ABSTRACT

Background: *Er-YAG laser showed to be effective in debonding ceramic bracket from the enamel surface. Until lately, no previous study was conducted to assess the outcome of the laser in debonding ceramic brackets from tooth surface comparing it with conventional occlusal pad debonding pliers.* ***Materials and methods:*** *Total 60 ceramic brackets were bonded on the tooth surface which was divided randomly into 2 groups. One was assigned as a control non-lased group and the other was experimental lased groups. Er-YAG laser irradiated the experimental groups at the power of 5 W for 10 seconds with swiping motion and 50% air-water cooling. In the lased experimental group, the laser was applied at energy of 250 mJ, 20 Hz frequency, and pulse duration of 100 µs.* ***Results:*** *Shear bond strengths and adhesive remnant index scores were statistically calculated. A highly significant difference of SBS between the non-lased control group and the lased experimental group was observed (p<0.000). A non-significant difference in ARI scores was observed when the non-lased control group was compared with the lased experimental group.* ***Conclusion:*** *It could be concluded that Er-YAG laser is effective in ceramic bracket debonding. This protocol promotes debonding without bracket fracture or enamel surface cracks or damage.*

Keywords: Dental debonding, Ceramic bracket, Er-YAG laser, Shear bond strength, Adhesive remnant index

INTRODUCTION

The interest in esthetic orthodontic braces is increased in last decades which therefore inspire manufacturers to supply acceptable esthetic orthodontic appliance, such as the ceramic brackets which then became an esthetic alternative to the stainless steel brackets [1]. Primarily ceramic brackets are divided into, monocrystalline and polycrystalline, both of these categories comprise aluminum oxide which enhances the bracket to be very rigid and too brittle simultaneously [2]. In spite of the chief advantage of ceramic brackets which is their esthetically pleasing appearance, these brackets are present with unwanted side effects on orthodontic treatment due to their roughness, hardness, and reduced fracture toughness [3]. Although increased bond strength of ceramic bracket is an advantage; it creates difficulties in brackets debonding stage at the end of orthodontic treatment, bracket failure, and enamel surface cracks were encountered during ceramic bracket debonding procedure [4]. Different debonding procedures have been tested for ceramic brackets debonding from enamel surface with few complications. Using ultrasonic debonding procedure, it may reduce enamel surface damage and fracture of the bracket, but this procedure is time-consuming and requires moderate force [5]. Laser-aided debonding of the ceramic brackets has been carried out to reduce complications encountered with other debonding techniques. The need for lasers in the field of orthodontics has increased over the last years. Laser with multiple wave lengths, energies, pulse duration and frequencies for ceramic brackets debonding became an impressive issue. Studies showed that laser irradiation could significantly reduce the force needed for brackets debonding. There are 3 mechanisms for laser debonding. The first mechanism is the thermal softening of adhesive, so the bracket will be dislodged or could be removed with low force magnitude and minimum complications, but the disadvantage of this technique is the rise in temperature that may cause pulpal damage. The second mechanism is the thermal ablation that occurs when the heat is high enough to induce vaporization of adhesive before debonding occurs. The third mechanism is the photo-ablation that results when laser pulse energies cause decomposition of the adhesive material.

Thermal ablation and photo-ablation are rapid procedures and do not cause high-temperature diffusion, which makes them safer than thermal softening [6].

PATIENTS AND METHODS

Teeth

Total 60 upper premolars that were freshly extracted (because of a lack of space) and preserved in 0.1% thymol solution at 20°C were used in this study. Teeth excluded from the study were with enamel damage (fractures, demineralization, or decay), as inspected using a 10X magnifier. Informed consent was taken from the patients or their guardians for a donation of the extracted teeth for study purposes.

Bonding Procedure

Bonding starts by using ceramic brackets of a maxillary first premolar with -7° torque, 0° angulations, and 0.022 × 0.030 slot size. The bonding base has 3 dove tail grooves and the surface area of the bracket base is 16.95 mm^2 (Reflections™/Ortho Technology Co., U.S.A). The teeth were cleaned and dried then etched with 37% phosphoric acid for 30 sec. After that, it was washed with water and dried again, and then the brackets were fitted precisely to the buccal surface of the teeth. The adhesive was cured for 10 seconds from each of the 4 sides of the bracket a total of 40 seconds for each sample (Woodpecker, iLED, USA light output: 2040 mW/cm^2). Teeth were embedded in acrylic blocks (Duracryl® Plus, SpofaDental A Kerr company Markova, Czech Republic) after bonding procedure.

Debonding Procedure

The samples were divided into 2 groups randomly. In Group 1 which is the control group, no process was applied prior to the debonding test (SBS: Shear Bond Strength test) (n=30). While in Group 2, Er-YAG laser (Pluser, Lambda SpA, Italy) was applied prior to the SBS test, scanning was made on the enamel surface (n=30) with the following parameters: 2940 nm wavelength, pulsation width: 100 microseconds (µs), pulsation frequency: 20 Hertz (Hz), power: 5W. The equipment used cooling system: 50% air-water spray, with 250 mJ (millijoule) pulsation energy, 2 mm away from the bracket surface by a single researcher for 10 sec. The scanning was made by swiping motion (Figure 1).

Figure 1 Laser application

Shear Bond Strength Test

Each bracket was tested to a compression test by universal testing machine with a crosshead speed of 0.5mm/minute of a Zwick test machine. The value at the moment of separation of the bracket from the teeth surface was calculated in Newton (N) unit and it was converted to megapascal (MPa) ($MPa=N/mm^2 \times 0.980665$). Each specimen was fixed in the constructed debonding apparatus which in turn was attached to the base of the Zwick machine being parallel to the horizontal plane (Figure 2). The upper arm of the Zwick machine applied a downward force on the movable plier's arm to create a gingiva-occlusal peel/shear force at the bracket-tooth interface for standardization. All measurements were performed by the same operator.

Figure 2 Constructed debonding apparatus

Estimation of the Adhesive Remnant Index

After debonding, the enamel surface of each tooth was assessed with the adhesive remnant index (ARI) in which the debonded bracket and the enamel surface of each tooth were inspected under a stereomicroscope (magnification 20X) to determine the predominant site of bond failure [7]. The site of bond failure is scored as follow:

- Score 0: No adhesive on the tooth surface
- Score 1: Less than half of the adhesive on the tooth surface
- Score 2: More than half of the adhesive on the tooth surface
- Score 3: All adhesive remaining on the tooth surface

Statistical Analysis

Data were analyzed using the Statistical Package of Social Science (SPSS) software version 24 for windows 10. Normality of the distribution was evaluated with the Shapiro-Wilk test. Mean, standard deviation, minimum and maximum values were calculated as a part of the descriptive analysis. Statistical significance was measured using T-test to discover the differences in the shear bond strength between the groups. And Chi-square was used to test the differences between the groups regarding the bond failure site (ARI).

RESULTS

Mean shear bond strength (SBS), standard diviation (SD), maximum (Max), and Minimum (Min) values are summarized in Table 1.

Table 1 Descriptive statistics of the shear bond strength (MPa) in different groups

Groups	N	Mean	S.D.	Min.	Max.
Group 1	30	11.850	2.158	8.130	15.060
Group 2	30	7.333	2.382	3.440	10.530

The highest value of the mean shear bond strength was in Group 1 (11.85 ± 2.15 Mpa), while Group 2 had a lower value of mean shear bond strength (7.33 ± 2.38 Mpa). T-test showed that Group 1 to have significantly higher SBS values than Group 2 ($p<0.001$) as shown in Table 2.

Table 2 Comparing shear bond strength between the groups using T-test

Groups	S.D.	p-value
Group 1 vs Group 2	4.444	0.000 (HS)

Adhesive Remnant index

The sites of bond failure of the test groups are shown in Table 3.

Table 3 Frequency and distribution of the ARI scores in the groups

Groups	0	1	2	3
Group 1	3	3	4	0
Group 2	1	1	4	4
0: no residual adhesive remaining on the enamel; 1: less than 50% of the adhesive remaining; 2: more than 50% of the adhesive remaining; 3: all of the adhesive remaining, with a distinct impression of the bracket base				

Statistically, the Chi-square test showed that there are no significant differences in the amount of the adhesive remaining on the tooth surface between the groups (Table 4).

Table 4 Comparison of ARI scores among the groups

Groups	χ^2	d.f	p-value
Group 1 vs Group 2	6	3	0.054 (NS)

DISCUSSION

Shear Bond Strength

The increasing demand for adults who seek orthodontic treatment existed some difficulties to the orthodontist. Adult orthodontic treatment frequently requires bonding aesthetic brackets on teeth with the development in cosmetic dentistry, these aesthetic types of brackets are used over a great extent to provide beautiful esthetic orthodontic treatment, nevertheless the orthodontic treatment for such patients faced some difficulties in debonding ceramic brackets to enamel surface, since enamel surface may be damaged during the process of debonding [7].

Lately, it has been proposed that Er-YAG laser is more preferred in ceramic bracket debonding when compared with CO_2 and Nd-YAG laser [8,9]. The result in the current study showed a reduction of shear bond strength of lased groups when compared with non-lased control group. A non-lased group where bracket removing pliers (occlusal pad type) group scored 11.85 while the lased group using the same plier's scores mean SBS of 7.33 Mpa. The results were in agreement with those of previous studies which showed that the lasers are effective in debonding of ceramic brackets by decreasing debonding force as well as enamel damage [9,10], this could be attributed to thermal softening of adhesive resin during laser irradiation reducing the bond strength of the bracket to enamel surface and this comes in agreement with Tocchio, et al., who proposed that laser irradiation induce bracket debonding by thermal softening [11].

In the current study, ARI scores were shown to be higher in the lased group samples where Er-YAG laser scanning was applied. In the laser applied group samples, owing to the low SBS values, brackets were removed easily and on the other hand, ARI scores were found to be high and our results come in agreement with Fidan, et al., [12]. This meant that there was more adhesive left at the enamel surface and this indicates the cleaning of teeth surface to be more cautious. Nalbantgil, et al., and Mundethu, et al., using Er-YAG for debonding showed a decreased risk of enamel damage via ARI measurements [13,14].

Smith, et al., found that tooth surface-adhesive interface failure score (0) is advantageous, because the difficulty of residual adhesive removal is not encountered [15,16], while Harari, et al., and Sarac, et al., reported that, cohesive failure within the adhesive layer itself (score II) is desirable to avoid tooth surface damage during debonding which clinically leads to the long-term integrity of the tooth surface, but this kind of residual adhesive may require additional treatment to remove it from the tooth surface, a procedure that could cause unwanted damage to the tooth surface unless care is taken and this coincides with the finding of Trakyalı, et al., [17,18].

CONCLUSION

The current study demonstrated that Er-YAG laser irradiation of a ceramic bracket that bonded on a tooth surface produced the following effect:

- Er-YAG laser irradiation is effective in ceramic bracket debonding by reducing shear bond strength
- ARI score of Er-YAG laser irradiated groups exhibited that debonding happened at the bracket-adhesive interface, which implies that debonding did not destruct tooth surface integrity

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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