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EVALUATING THE SHEAR BOND STRENGTH OF REBONDED CERAMIC BRACKETS AFTER USING THREE DIFFERENT TECHNIQUES FOR ADHESIVE REMOVAL: AN IN-VITRO STUDY

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Abstract

Objective: *The main purpose of the study was to compare the shear bond strength of the rebonded ceramic bracket after using different techniques for removal of the adhesive from the debonded brackets base to find the most favorable method for recycling ceramic brackets. The Research Question of the study was that In recycling of ceramic brackets, would removal of the adhesive from the debonded brackets base using Er,Cr:YSGG laser versus using carbide bur and sandblasting, enhance the shear bond strength of the rebonded ceramic bracket?*

Materials and Methods: *Sixty premolar teeth were randomly divided into 4 equal groups (n = 15) then embedded in resin blocks with their crowns exposed. Sixty upper premolar ceramic orthodontic brackets were used in this study and were divided into 4 equal groups (n = 15) according to different adhesive resin removal protocols; Control Group (New brackets), Laser Group, Sandblast Group, and Handpiece Group. Then ceramic brackets were rebonded and the shear bond strength of the rebonded brackets was evaluated using a universal testing machine. All collected data were statistically analyzed.*

Results: The highest statistically significant shear bond strength mean value was revealed between control group (13.2302MPa) and handpiece (carbide bur) as it has showed the smallest mean (6.1863MPa). While there was no statistically significant difference between Control group vs Laser group and Sandblast group.

Conclusion*: Er,Cr:YSGG laser and Sandblasting were efficient for reconditioning of mechanically retentive ceramic brackets.*

Keywords*:*

Rebonded Ceramic brackets, Er,Cr:YSGG laser, Sandblasting, Tungsten carbide bur

Introduction:

Ceramic brackets, which have been in use for quite some time, are produced to combine the aesthetics and durability of metallic brackets. Ceramic brackets have a shear bond strength that is at least as strong as metallic brackets. Ceramic brackets are more aesthetically pleasing than metallic ones, but debonding them offers a number of difficulties, including bracket tie wing breakage, enamel fracture, and discomfort for the patient [1].

The need to rebond the dislodged bracket or even bond a new bracket may result from bracket failures and debonding caused by either the patient improperly exerting too much

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force on the bracket or the operator using poor bonding technique. Since the early 1990s, different methods for debonding ceramic brackets have been introduced. Numerous studies have been carried out in order to remove the residual adhesive resin from debonded ceramic brackets [2].

There are several methods for removing the remaining adhesive from orthodontic brackets. Some of these methods include air abrasion, wear with carbide burs, microetching, lasers, and industrial recycling procedures. Each method should provide adequate bonding strength, have fewer undesirable side effects, be straightforward to use, and consume less time [3].

Recycling is carried out to completely remove any remaining adhesives from the bracket base without endangering any property or modifying the dimensions of the bracket slot [4].

Another method frequently used to etch enamel, roughen resin composites, and even remove adhesive residue from orthodontic bracket bases is sandblasting. By enhancing the micromechanical retention at the base, sandblasting significantly enhances the bond between the brackets and the tooth structure [5].

Innovative dental in-office approaches are becoming possible for the reuse of dislodged orthodontic brackets in response to the rising desire for a quick and more effective manner to reuse these debonded brackets. Although it is thought that using tungsten carbide stones to remove resin composite is an efficient and simple process, many studies have noted negative effects on bond strength [6].

Recently, composite removal has become easier and more common with the use of lasers. Additionally, ceramic brackets have been experimentally debonded using lasers [7].

Therefore, this study was conducted to evaluate the most efficient technique for removal of remaining adhesive resin from ceramic base and the shear bond strength of ceramic bracket was measured after rebonding to determine the most effective technique as an economic solution for recycling of ceramic brackets if debonded.

Materials and Methods:

Sample size calculation:

The sample size (n = 15/each group/shear bond strength) was assessed with a power analysis to provide a statistical significance of alpha (α) = 0.05 at 80% power. The post hoc power percentage (98.87%) indicated that the power of sample size was adequate.

• G*Power to determine sample size: n = ($Z\alpha/2+Z\beta$) 2 ´ 2 ´ $\sigma 2$ / d2

Where $Z\alpha/2$ is the critical value of the Normal distribution at $\alpha/2$ (e.g. for a confidence level of 95%, α is 0.05 and the critical value is 1.96), $Z\beta$ is the critical value of the Normal distribution at β (e.g. for a power of 80%, β is 0.2 and the critical value is 0.84), $\sigma 2$ is the population variance, and d is the difference you would like to detect.

The sample size of 60 as minimum (n=15/each group/ Shear bond strength) was assessed with a power analysis to provide a statistical significance of alpha (α) =0.05 at 80°1° power.

The post-hoc power percentage (98.87°1°) indicated that the power of sample size was adequate.

Study design:

Selection of Teeth:

This study was conducted on a total of sixty human first premolars that were extracted as a part of orthodontic treatment. The selected teeth were sound with intact buccal enamel surface, Absence of decalcification, hypoplasia or caries, Absence of cracks, fractures and absence of restorations, gross irregularities, and were not pretreated with chemical agents (eg. Hydrogen peroxide).

The sixty premolar teeth were randomly divided into 4 equal groups (n = 15) then embedded in resin blocks with their crowns exposed. Four different colors for resin blocks were used according to different adhesive resin removal protocols.

Sample Grouping:

Sixty upper premolar ceramic orthodontic brackets (0.022-inch slot, Symetri clear, Ormco, USA) were used in this study and were randomly divided into 4 equal groups (n = 15) as the following:

1. Control Group (New untreated brackets)

2. Laser Group (Experimental Group treated by Er,Cr: YSGG)

3. Sandblast Group (Experimental Group treated by sandblaster)

4. Handpiece Group (Experimental Group treated by Carbide bur)

1. Control Group (New untreated brackets)

In the control group, Fifteen ceramic brackets were bonded to fifteen premolars according to manfacturer's insructions. All the teeth were etched with a 37% ortho- phoshphoric acid solution (Ormco Corporations, USA) approximately 30 seconds per tooth then rinsed thoroughly for a minimum of 15 seconds per tooth then air-dried for another 15 s. A very thin coat of Ortho Solo bond (Ormco Corporations, USA) was applied to the prepared teeth. A Small amount of Blugloo adhesive paste was applied onto the bracket pad then immediately placed, accurately positioned to the tooth surface then pressed firmly and the excess adhesive was removed then Elipar™ S10 LED light cure (3M, ESPE, USA) was applied for 20 s.

In the three experimental groups, Blugloo light cure composite (Ormco Corporations, USA) was firstly bonded to the base of the new symmetri clear ceramic brackets and then light cured for 20s with LED dental curing light to mimic debonded brackets.

2. Laser Group (Experimental Group treated by Er,Cr: YSGG)

Removal of the adhesive resin composite was done using Er,Cr:YSGG laser (Waterlase, Iplus, Biolase technology, CA, USA) emitting a wavelength of 2780 nm, with average power of 4 W; repetition rate, 30 Hz; pulse duration, 60 μs; energy, 250 mJ; energy density, 49.7 J/cm^2; water, 80%; air, 60% in non-contact mode (2 mm away); and sweeping motion

(Figure 1). Tip used was 800 μm in diameter (MZ8) until resin composite was completely removed from the fifteen brackets [8].

Figure (1): Er,Cr:YSGG laser (Waterlase, Iplus, Biolase technology, CA, USA)

3. Sandblast Group (Experimental Group treated by sandblaster)

Removal of the adhesive resin composite was done using the sandblasting machine (Eurocem s.r, k, Milanese, Italy) (Figure 2). The bracket bases were subjected to 50 μm aluminum oxide particles, with a 5 mm distance away from the sandblasting handpiece. Each bracket was sandblasted for 40 s until resin composite was completely removed from the fifteen brackets [8].

Figure (2): Eurocem sandblasting machine

4.Handpiece (Carbide bur) Group

Removal of the adhesive resin composite was done using a tungsten carbide bur 8 flutes in a high-speed T3 racer (Sirona Dental Systems LLC Germany), contra angle handpiece (250, 000 rpm) until resin composite was completely removed from the fifteen brackets.

Rebonding procedure:

After removal of the adhesive resin composite from the ceramic brackets. Assessment of the brackets surfaces and bases was done to ensure it is not broken and all the adhesive resin composite is removed from the bracket bases. Each bracket base was sprayed with water then air-dried.

The enamel surface of each tooth was polished with pumice and rubber cup for 10s, sprayed with water and then air-dried. Each tooth was embedded in resin block using a standard size stamp (2x1.5x 1.5 cm).

Every group had resin blocks with color different from the color of the other groups. The colored blocks were as following: White (Control group), Green (Laser group), Yellow (Sandblast group) and Blue (Handpiece carbide bur group).

Enamel surface was treated with 37% phosphoric acid for 30 s, rinsed thoroughly for 15 s, and then air-dried for another 15 s. Then Orthosolo bond (Ormco, USA) was applied to the enamel surface. Premolar brackets were bonded using Blugloo light cure composite (Ormco, USA) to the treated enamel surfaces following manufacturer's instructions. The brackets were positioned and seated on the buccal enamel surface, and any excess resin composite was removed before curing using a dental probe. The resin composite was then cured for 20 s with LED dental curing light (Elipar S10 LED Curing Light 3 M ESPE Dental Products St. Paul, MN, USA)

Testing of Shear Bond Strength (SBS) for Rebonded Ceramic Brackets:

Blocks with bonded ceramic brackets were separately placed in a holding ring positioned in the lower jaw of the universal testing machine (**TIRA test 2805, Tirs GmbH, Eisfelderstrabe 23/25 D-928, Schalkau, Germany) (Figure 3)**. The SBS test was carried out with a universal testing instrument. Each sample was secured in the lower part of the machine so that the shear force could be applied parallel to the bracket base. The samples were stressed in an occluso-gingival direction with a crosshead speed of 1 mm per minute (mm/min). The blade reached the tooth bracket interface and stopped as soon as debonding occurred.

The fracture / breakage measurements were recorded on the TIRA machine in Newtons (N). The Bond Strength, in megapascal was calculated by dividing the debonding force (N) by the bracket base surface area (mm2). (MPa = N/mm2).

Figure (3): TIRA test 2805 shear bond testing machine

Statistical analysis:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov– Smirnov and Shapiro Wilk tests). Data showed non-normal (non-parametric) distribution. Data were presented as median, range, mean, and standard deviation (SD) values.

Kruskal–Wallis test was used to compare between the four groups.

Mann-Whitney test was used for pair-wise comparisons when Kruskal–Wallis test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Results:

In terms of descriptive statistics, the control group had a mean shear bond strength ±SD of 13.2302±5.02074 MPa, while the laser group had a mean shear bond strength ±SD of 11.8348±5.66587 MPa, the sandblast group had a mean shear bond strength ±SD of 11.0537±6.60254 MPa, and the handpiece (Carbide bur) group had a mean shear bond strength±SD of 6.1863±4.65379 MPa (Table 1).

Table (1): The descriptive statistics (mean & SD & median) of the shear bond strength among four groups:

Ceramic Brackets (MPa)	Control=15	Laser=15	Sandblast=12	Handpiece (Carbide bur) =13
Mean	13.2302	11.8348	11.0537	6.1863
±SD	±5.02074	±5.66587	±6.60254	±4.65379
Median	13.7201	10.1508	8.2508	4.5762

Three brackets were broken upon loading in the universal testing machine among the Sandblast group and two brackets among the Handpiece (Carbide bur) group. There are no broken brackets in the control or laser groups (Figure 4).

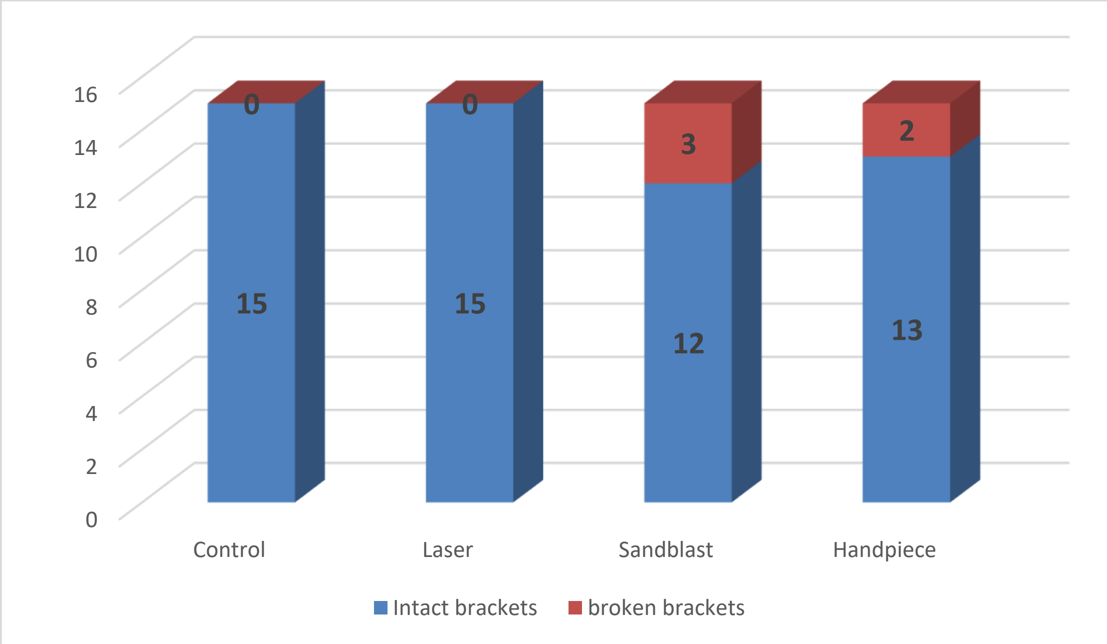

Figure (4): Bar-chart showing the frequency distribution of intact and broken Brackets

There was a statistically significant difference between shear bond strength of the four groups (P-value=0.006) (Table 2 & Figure 5).

Pair wise comparison between four groups revealed highest mean (13.2302MPa) shear bond strength with statistically significant difference between control group and handpiece (carbide bur) as it has showed the smallest mean (6.1863MPa) (P-value=0.002).

While there are no statistically significant difference between Control group vs Laser group (P-value=0.254) and Sandblast group (P-value=0.188).

Table (2): Comparison between shear bond strength among four groups using Kruskal-Wallis test

Ceramic Brackets (MPa)	Control= 15	Laser=15	Sandblast=12	Handpiece (Carbide bur) =13	P-value
Mean	13.2302^{A}	11.8348^{A}	11.0537^{A}	6.1863^{B}	0.006*
±SD	±5.0207	±5.6658	±6.6025	±4.6537	
Median	13.7201	10.1508	8.2508	4.5762	
Minimum	2.51	4.47	5.24	1.56	
Maximum	20.93	23.55	25.55	17.32	

***P value <0.05 is statistically significant difference, Different superscripts in the same column indicate statistically significant differences according to Mann-Whitney test**

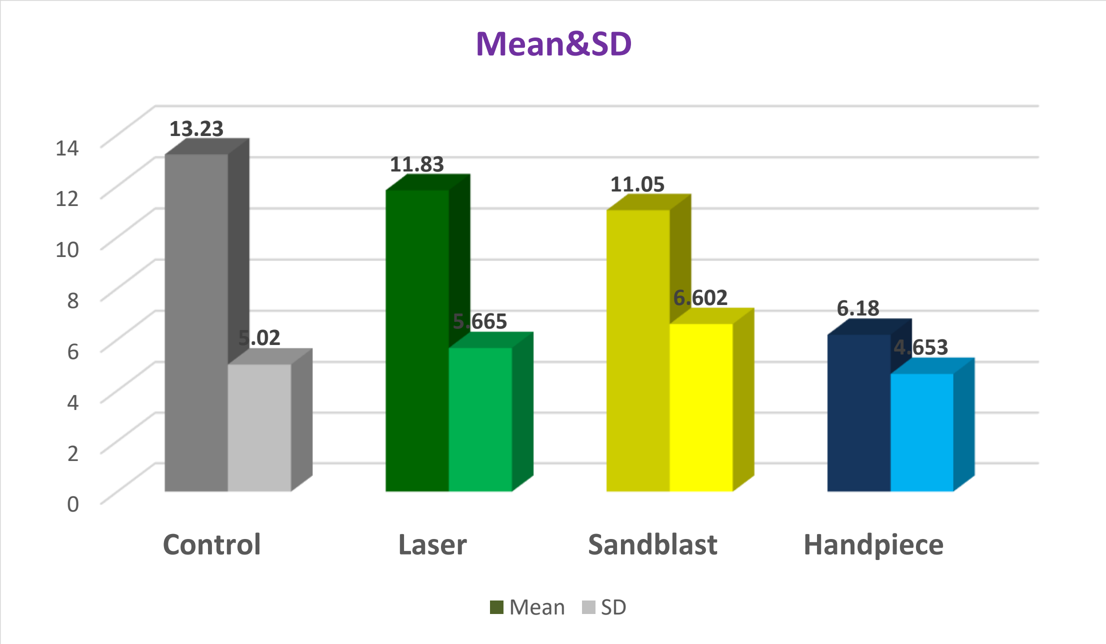

Figure (5): Bar-chart showing the descriptive statistics (mean & SD) of the shear bond strength ceramic brackets among four groups

Discussion

With the increasing popularity and clinical use of ceramic brackets, there is a need for an efficient way to recycle these expensive brackets [9].

Debonding of brackets is still a common visit issue for most orthodontists, despite all the recent advancements and successes in adhesion of orthodontic brackets to tooth surface [10].

Bracket debonding may be caused by severe masticatory pressures or an ineffective bonding technique; however, intentional bracket detachment may be done by the dentist to relocate misplaced brackets and to position teeth properly [11].

Numerous approaches have been proposed in the literature to address the bracket debonding and failure issue; more recently, laser devices have been developed [12].

Although dental laser technology is quite expensive, it has been utilised in various dental disciplines that aims to deliver treatment outcomes that are superior to those achieved by conventional approaches [8].

Several techniques are used for recycling of orthodontic brackets to remove the remaining adhesives. These methods include air abrasion, wear by silicon carbide bur, microetching, lasers and industrial recycling procedures. Each method should provide acceptable bond strength, create less destructive side effects, be easy to use and less time consuming. The purpose of recycling is to remove the remaining adhesives completely from the bracket base without causing any damage or change the bracket slot dimensions.

Although the required bond strength for clinical work has not been determined specifically and previous studies have reported different values, this parameter should be high enough for the bonded bracket to resist chewing forces. On the other hand, the bond strength should allow easy debonding of the bonded brackets without damaging the tooth enamel [13].

In the course of daily practice, recycling orthodontic brackets is a routine procedure. Our goal was to identify an intervention method that, when compared to other widely-used methods, can deliver the best results. So, this study was designed to evaluate and compare the shear bond strength of recycled mechanically retentive ceramic brackets by Er,Cr:YSGG laser, sandblasting and tungsten carbide bur with new brackets.

The results of the current study showed that there was a statistically significant difference between shear bond strength of the four groups (P-value=0.006).

The control group had the highest mean shear bond strength (13.2302 MPa) followed by Er,Cr:YSGG laser group with a mean shear bond strength (11.8348 MPa), followed by the Sandblast group that showed a mean shear bond strength (11.0537 MPa), While the adhesive removal method by handpiece with carbide bur showed the lowest shear bond strength (6.1863 Mpa).

Pair wise comparison between four groups revealed statistically significant difference between control group and handpiece (carbide bur) (P-value=0.002), While there are no statistically significant difference between Control group and Laser group (P-value=0.254) and Sandblast group (P-value=0.188).

These results stated that application of Er,Cr:YSGG laser showed significantly higher bond strength than tungsten carbide bur group but with comparable results to the sandblast group, yet it is still considered to be the closest to the control group. These results are due to the significantly higher absorption of the Er,Cr:YSGG laser in the resin composites, which facilitates the selective removal of the resin adhesive from the base of debonded brackets.

These results can be in agreement with other previous studies, which stated that Er,Cr:YSGG laser has shown effective results in adhesive removal from bases of orthodontic brackets, with acceptable bond strength values such as Ishida K et al [14] who conducted a study to measure Shear Bond Strength of debonded ceramic brackets that were recycled by Er,Cr:YSGG and sandblasting and it was concluded that Er,Cr:YSGG laser certainly could serve the purpose of promoting the use of recycled orthodontic brackets.

The sandblasting group showed lower shear bond strength results than laser group. It is also important to mention that three brackets were debonded from teeth upon loading to the universal testing machine. This lower bond strength mean values in the current study could be contributed to the destruction of the brackets base by sandblasting, as supported by few studies as Yassaei S et al [15] who noted remarkable micro-roughening of the base of the bracket was apparent after adhesive removal by sandblast although they concluded that sandblasting was efficient to mechanically recondition retentive ceramic brackets.

Regarding the adhesive removal by handpiece and carbide bur group, the current study showed lowest bond strength mean values in comparison to the control group, Er,Cr:YSGG laser group and sandblast group. Also, two brackets were debonded from teeth upon loading to the universal testing machine. This could be related to the significant reduction in the retentive areas of the brackets base, because of the incomplete removal of the adhesive, in addition to the distortion of the mesh structure.

Other previous studies have reported the same findings as Aksu M and Kocadereli I. [16] study found that the shear bond strength of rebonded brackets after sandblasting was not significantly different from that of new brackets while the bond strength of rebonded brackets after carbide bur cleaning group significantly decreased.

Although removing resin adhesives from the bases of the brackets using a tungsten carbide bur is quick, easy, and simple, the meshwork structure is damaged and lost in the process. All of this helps to lower the bond strength values [17].

There were some limitations during this study which included the difficulty in collecting the freshly extracted teeth for orthodontic reasons, checking the tip of the laser for any damages after each bracket recycling process, checking the integrity of the bracket base meshwork after adhesive removal, the debonding of some brackets upon loading and handling.

The findings of the current study encourage the usage of erbium laser in recycling of debonded ceramic orthodontic brackets.

Conclusion

Based on the results of this study the following conclusions were produced:

• Er,Cr:YSGG laser and Sandblasting were efficient for reconditioning of mechanically retentive ceramic brackets.

• The shear bond strength of brackets recycled with Er,Cr:YSGG laser and new brackets were not statistically different which make it the most efficient protocol for orthodontic brackets recycling.

• The mean Shear Bond Strength of brackets recycled by adhesive removal by tungsten carbide bur produced the lowest among all groups. Adhesive grinding methods showed very low shear bond strength compared to laser and sandblast constraining their use.

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