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Original Research Article

Comparison of shear bond strength of orthodontic metal brackets recylced using different methods: An in-vitro study

Waheed Ahmed Shaikh[1], Ajit Kalia[1], Faisal Ayub Mulla[1,*]

[1] *Dept. of Dentistry, M.A. Rangoonwala College of Dental Science & Research Centre, Pune, Maharashtra, India*

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ABSTRACT

Background: The aim of this study was to compare the effect of recycling orthodontic metal brackets by sandblasting with aluminum oxide particles of different sizes and by laser blow method after first and second rebonding /recycling.

Materials and Methods: 120 human premolars extracted for orthodontic purpose were randomly divided into four groups. 40 MBT prescription Orthodontic metallic brackets were bonded on the buccal surface of the samples. Brackets were recycled by sandblasting with 3 different particles size and laser. Debonding of all brackets was performed using a universal testing machine and shear bond strength was determined. Brackets were examined under Field emission scanning electron microscope from each group at each level to compare the surface characteristic of new and rebonded brackets. Data were analyzed with paired test, ANOVA, and post hoc tests.

Results: The shear bond strength of group I (sandblasted with 25μm alumina) was significantly higher at the end of 1st recycling compared to group II(50 μm) and III(100 μm) but it was comparable to group IV(laser) at the end of 1st recycling. Group IV showed clinically significant higher shear bond strength compared to group II and III after 1st and 2nd recycling. The shear bond strength for group II and III (sandblasted with 50 and 110μm alumina) was significantly much lower after 2nd recycling as compared to new i.e., Control (p value<0.001).

Conclusion: 25μm alumina sandblasting and Er-YAG laser blow method obtained better results after three successive recycling. Overall sandblasting emerged as the best method to recycle the orthodontic brackets.

1. Introduction

Newman heralded the onset of direct bonding in orthodontics by combining acid etching with composite resins for improving their mechanical retention along the tooth surface.[1] This led to the development of modern adhesive materials and their widespread use to bond attachments i.e., brackets and molar tubes in fixed orthodontic appliances. Many factors influence the strength of the bond obtained, this includes the nature of enamel surface, enamel conditioning procedures, adhesive material, shape and design of the brackets. And recycling of the bracket is done if the brackets debond itself due poor oral hygiene, poor bonding techniques or if clinicians want to alter the position of brackets during finishing stage.

Estimation of shear bond strength gives us the idea of how well the bracket would resist the debonding under loading forces. According to Reynolds, shear bond strength of 5.9–7.8 MPa is sufficient to withstand masticatory force.[2] Mean bond strength of 10.4 and 11.8 MPa was observed by Bishara et.al, with composite resin and conventional adhesive system.[3] Values above 13MPa may increase the risk of enamel tear out because the enamel structure's cohesion forces may be exceeded.[4] Low shear bond strength

* *Corresponding author*.
E-mail address: faisalm37863.fm@gmail.com (F. A. Mulla).

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can cause bracket bond failure and increase the risk of bracket debonding.

The prevalence of bracket loss or debonding ranges between 6 to 7.2% with a predominance of premolars and molars brackets.[5] The reason for brackets to debond includes incomplete retention pattern, unfavourable enamel morphology and antagonistic unbalanced tooth contacts.[6,7] Improper cleaning of buccal surface or lingual surface and over retained plaque also encourage bond loss. Rebonding of the orthodontic brackets can be done with either new set of brackets or the same brackets can be reused by recycling them.[8] In developing countries with low per capita income, it's always economical and feasible to recycle the brackets. For reuse, brackets have to be recycled, the process of recycling can be direct as in orthodontic clinics or can be done in laboratories wherein they can be recycled using specialized techniques.[9]

Recycling of orthodontic brackets can be immediate that it can be done within the dental office or delayed that it can be done by specialized companies.[10] Different methods for in office recycling are rotatory instruments, Flame Method, Chemical Method, Sandblasting and Laser blow method.

Along with this various auxiliary procedure can be used in recycling of orthodontic brackets to enhance their adhesive capacity such as Ultrasonic Cleaning, Electropolishing and Adhesion Enhancement.

Air abrasion or micro sandblasting or simply sandblasting is another method that was introduced in 1950 and has also been used to recondition debonded brackets.[11–13]

The bracket is held by a bracket holder in such a way that the base of the bracket is at right angle to tip of the sandblaster unit. A foot paddle controls the line pressure. A line pressure of 29 psi, 50 psi, 72.5 psi, 75 and 90 psi has been recommended.[8,14,15]

The time required to remove the adhesive effectively ranges from 7 to 40 seconds. In one study it usually took 15–30 seconds (Sonis, 1996).[16] However, studies found that sandblasting new bracket base for 9 seconds cause distortion of mesh structure. Following points dictate the time required such as site of bond failure, size of the sand particles, type of adhesive and distance between bracket base and blaster tip. The selection of sand particle size is somewhat controversial in literature. In literature usually 50μm, 90μm, 110μm, 120μm and recently in one article the authors used 25μm alumina particle size.[8,14–16]

Sandblasting has been shown in numerous studies to improve the bond strength and survival time of new brackets. The other method which shows promising result is the use of ErYAG or Nd-YAG laser blow method. Another study showed that the Er-YAG laser group was found to have the highest bond strength among the recycled brackets.[17]

In our study we compared the shear bond strength of brackets recycled by means of sandblasting with aluminum oxide particles of different sizes (25μm, 50μm, 110μm) successively along with another method of recycling i.e., laser blow method (Er-YAG). We carried out this comparison so as to determine which is the best and simple way of recycling the orthodontic brackets. Other reason was to evaluate if the recycled bracket has ideal qualities comparable to new brackets and whether they are able to withstand all the shear and tensile forces. Our aim for this study was to device a method which is most efficient and economical for the patients as well as for the orthodontist as we recycled the same bracket 3 consecutive times. This was done in conjunction with the finding of Matasa et al. (1989) who said that a single bracket can be reused up to 5 times.[18]

2. Materials and Methods

The present study was conducted over a period of 18 months after obtaining the ethical clearance. The samples comprised 120 healthy premolars extracted for orthodontic purpose from the patients between the ages 18 to 35 years who needed orthodontic extraction. Extracted premolars were thoroughly cleaned and then placed in a 0.01 percent thymol solution for 24 hours before being stored in an airtight jar with distilled water that was changed every 24 hours until the premolars were used.[19,20]

2.1. Inclusion criteria

1. Good morphology - devoid of any developmental defect
2. No pretreatment with any chemical agent.
3. The absence of cracks/fissures, caries, attrition, abrasion, erosion and abfraction.

2.2. Exclusion criteria

1. Patient is not willing to give consent/assent for the use of their extracted premolars.
2. Teeth treated with chemical agent e.g., hydrogen peroxide.
3. Teeth which were malformed, cracked and showing attrition, erosion, abrasion and abfraction.

Brackets were divided randomly into four groups according to the method of recycling:

Group I was recycled with sandblasting - 25μm aluminum oxide sand, Group II- 50μm, Group III- 110μm, Group IV- Er-YAG laser blow method.

Color tags given to the groups were - Pink for group I, Blue for group II, Green for group III, Orange for group IV.

40 new brackets were bonded to the teeth's buccal surface. For the bonding procedure, 37 percent phosphoric acid (15 seconds), bonding agent (Trans bond XT, 3M Unitek), adhesive (Tranbond XT, 3M Unitek), and LED curing light unit (Ivoclar Bluephase NM with 800mW/cm2) were used. The same operator carried out the procedure. For

24 hours, the samples were immersed in distilled water at 37^0 C. This method was used for all 3 consecutive bonding and every time a fresh set of extracted premolars were used.

Group I: After first debonding, the brackets were sandblasted with 25μm aluminum oxide sand for 20-40 seconds.

Each bracket's bonding and debonding procedures were repeated three times. For each subsequent rebonding, a new tooth was used. The brackets were all bonded using the same procedure as described above, debonded with the customised blade of the upper movable head of the universal testing machine to obtain the shear bond strength in newtons, and then sandblasted twice more using the same procedure. In this way we got the shear bond strength of the brackets after first debonding which was the shear bond strength of new(control) brackets and then successively two more times after sandblasting with 25μm alumina dust.

Group II: Recycling with sandblasting - 50μm aluminum oxide and shear bond strength reading was taken for three successive bonding debonding.

Group III: Recycling with sandblasting - 110μm aluminum oxide and shear bond strength reading was taken again for three successive times.

Group IV: Recycling with Er-YAG laser blow method: Here the brackets were recycled using Er-YAG laser with a wavelength of 2940nm, 250 mJ energy with repetition rate of 12 Hz with an average power of 3 W for 5 seconds. Again, the brackets were recycled for 3 consecutive times with a fresh set of teeth each time and shear bond strength reading were taken.

2.2.1. The universal testing machine

A universal testing machine made in India by Acme Engineers, model UNITEST 10, was used to test the shear bond strength. It runs at a speed of 1mm/min and has a system accuracy of +/—1 percent. The crosshead speed was set to 1mm/min. The shear bond strength force to debond the bracket was recorded in Newtons by the computer.

The surface area of the premolar brackets (American Orthodontics 0.022 MBT) which we used for this study was 10.29mm^2.

2.3. Scanning electron microscopic observation

Brackets from each group at each level were examined using a Field emission scanning electron microscope (FESEM: FEI Nova NanoSEM 450) to compare the surface characteristics of new and rebonded brackets. The brackets were cleaned in an ultrasonic tank with distilled water for 30 minutes before being dried with compressed air. Each specimen was prepared for better resolution by sputtering with gold palladium in a Quorum Q150T ES sputter coater unit. After gold sputtering each specimen was then examined under FESEM (FEI Nova NanoSEM 450) at an operating voltage of 15KV and at a 20 mm distance the images were enlarged and captured to 130X and 250 X.

3. Results

The purpose of this study was to compare the shear bond strength of brackets recycled by means of sandblasting with aluminum oxide particles of different sizes (25μm, 50μm, 110μm) successively along with another promising method of recycling i.e., laser blow method (Er-YAG).

The data on continuous variables is presented as mean and standard deviation (SD). The intergroup statistical comparison of means of continuous variables was done using analysis of variance (ANOVA) with Bonferroni's Post-Hoc test for multiple group comparisons. The pair wise statistical significance of difference in the means of 63 continuous variables was tested using paired test. The underlying normality assumption was tested before subjecting the study variables to ANVOVA and T test. All results are shown in tabular as well as graphical format such as Bar graph to visualize the statistically significant difference clearly.

In the entire study the p values less than 0.05 was considered to be statistically significant. All the hypotheses were formulated using two tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data was statistically analyzed using statistical package for Social Sciences (SPSS ver. 22.0, IBM Corporation, USA) for MS Windows.

4. Result Summary

Overall, the shear bond strength of new brackets (control) and the strength after the first recycling did not differ significantly for all study groups (P value >0.05 for all groups), indicating that there was no significant difference in shear bond strength between new brackets (control) and brackets after the first recycling.

However, the distribution of shear bond strength after the second recycling was significantly lower in all study groups when compared to the mean shear bond strength of new (control) brackets (P value 0.05 for all groups).

The shear bond strength for Group III (sandblasted with 110μm alumina) was significantly lower after the second recycling as compared to the new (Control) (p value 0.001***).

The shear bond strength of groups II (sandblasted with 50μm alumina) and IV (recycled with laser Er-YAG) was significantly lower after the second recycling when compared to new brackets, but they were comparable (P value 0.008** for group II and P value 0.007** for group IV).

Group I (sandblasted with 2μ5m alumina) had significantly higher shear bond strength at the end of the first recycling than groups II and III, but it was comparable to group IV at the end of the first recycling.

Table 1: Inter-group distribution of mean shear bond strength at first and second recycling

	Control		**First Recycling**		**Second Recycling**		**Difference1 Control-First Recycling**		**Difference 2 Control-Second Recycling**	
Group	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Group I (25μ) (n=10)	8.88	2.43	7.12	1.74	6.24	0.95	1.78	0.84	2.61	0.67
Group II (50μ) (n=10)	8.88	2.43	6.88	1.45	6.10	0.96	2.04	0.50	2.79	0.53
Group III (110μ) (n=10)	8.88	2.43	6.64	2.15	5.74	0.87	2.26	0.62	3.16	0.61
Group IV (Laser) (n=10)	8.88	2.43	7.10	1.79	6.16	0.86	1.79	0.81	2.68	0.72
P-value (Inter-group)										
Group I vs Group II	0.999^{NS}		0.812^{NS}		0.999^{NS}		0.048*		0.047*	
Group I vs Group III	0.999^{NS}		0.710^{NS}		0.789^{NS}		0.041*		0.037*	
Group I vs Group IV	0.999^{NS}		0.991^{NS}		0.892^{NS}		0.999^{NS}		0.920^{NS}	
Group II vs Group III	0.999^{NS}		0.943^{NS}		0.992^{NS}		0.842^{NS}		0.086^{NS}	
Group II vs Group IV	0.999^{NS}		0.902^{NS}		0.993^{NS}		0.047*		0.048*	
Group III vs Group IV	0.999^{NS}		0.843^{NS}		0.652^{NS}		0.017*		0.022*	

P-value by ANOVA with Bonferroni's correction for multiple group comparisons. P-value<0.05 is considered to be statistically significant. *P-value< 0.05, NS – Statistically non-significant.

Table 2: Intra-group distribution of mean shear bond strength

	Control		**First Recycling**		**Second Recycling**		**P-values (Inter-group)**		
Group	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Control vs First Recycling**	**Control vs Second Recycling**	**First Recycling vs Second Recycling**
Group I (25μ) (n=10)	8.88	2.43	7.12	1.74	6.24	0.95	0.840^{NS}	0.012*	0.029*
Group II (50μ) (n=10)	8.88	2.43	6.88	1.45	6.10	0.96	0.729^{NS}	0.008**	0.042*
Group III (110μ) (n=10)	8.88	2.43	6.64	2.15	5.74	0.87	0.602^{NS}	0.001***	0.033*
Group IV (Laser) (n=10)	8.88	2.43	7.10	1.79	6.16	0.86	0.819^{NS}	0.007**	0.021*

P-value by repeated measures ANOVA (RMANOVA). P-value<0.05 is considered to be statistically significant. *P-value<0.05, **P-value<0.01, ***P-value<0.001, NS – Statistically non-significant.

After the first and second recyclings, Group IV had clinically significant higher shear bond strength than Groups II and III.

In all groups, the shear bond strength after the second recycling was significantly lower than the mean shear bond strength after the first recycling (P value 0.05 for all).

Overall, compared to the control, group I had numerically higher shear bond strength at the end of the second recycling, while group III had the lowest shear bond strength numerically among all groups.

5. Discussion

Brackets can be recycled in office by mechanical methods like sandblasting, adhesive grinding, laser blow or by manual methods like thermal method or Buchman's method.[9,21–23]

Salama et al. (2018)[21] and other authors, in their studies used 50μm alumina particles for sandblasting and reported shear bond strength of recycled sandblasted brackets was higher than new brackets.

Chung et al. (2000),[24] Basudan et al. (2001),[15] and Wu Hm (2015)[25] found that sandblasted orthodontic brackets had comparable shear bond strength to new brackets. Nadia Lunardi et al. (2008)[26] discovered that repeated sandblasting with 50μm alumina particles had no effect on the shear bond strength of metal brackets.

Another promising method of recycling orthodontic brackets is the Er-YAG or Nd-YAG laser blow method.

According to P. Chacko et al. (2013)[17] and Mirhashmi et al. (2018)[[27], laser recycling is the most efficient method, followed by sandblasting.

N. Devjeee et al. (2015)[27] discovered that for stainless steel brackets, the sandblasting method was superior to the ErYAG laser, as the recycled brackets demonstrated higher shear bond strength.

For recycling, we used aluminium oxide particles with diameters of 25μm, 50μm, and 110μm, as well as the Er-YAG laser blow method.

One of the aims of our study was to evaluate the shear bond strength obtained after recycling and rebonding the same bracket. The results found no significant differences in shear bond strength between the control and four study groups after brackets were recycled for the first time, a finding that agrees with other studies that have evaluated the shear bond strength of new brackets and recycled brackets with sandblasting. However, most studies used 50μm or 90μm alumina for sandblasting, with the exception of a study by Montero MMH et al. (2015),[9] who used different sizes of alumina particles for sandblasting and compared them to industrial recycling methods. Chung et al.,[24] on the other hand, reported that brackets recycled through sandblasting required additional bond booster treatment to achieve shear bond strength comparable to new brackets.

Reynolds[2] reported in 1975 that the required optimal bond strength of 5.9- 7.85 MPa is adequate and acceptable, but in our study, we obtained an average shear bond strength of 8.88 MPa for newly debonded brackets.

After the first recycling, we measured shear bond strengths of 7.12 MPa for group I, 6.88 MPa for group II, and 6.64 MPa for group III on average.

Shear bond strength was significantly reduced after the second recycling (third debonding) for all groups when compared to the control group (first debonding), but it was still well above the level recommended by Reynolds et al.[2] This matched the findings of Eslamian et al. (2015).[28] Regan et al. (1993)[29] discovered no significant reduction in shear bond strength after recycling metal brackets up to five times.

As with laser group recycling, we discovered that it was comparable to sandblasting with 25μm alumina particles, but sandblasted brackets with 25μm alumina showed numerically higher shear bond strength than laser blow method, despite being statistically insignificant. This finding is in agreement to the study carried out by Devjee et al (2015) where the stainless-steel metal brackets recycled with sandblasting showed higher shear bond strength than the brackets recycled with laser blow method (Er-YAG).[27]

This study found comparable shear bond strength between laser group and group I. This is in contrary to the study conducted by P Chacko et al (2013)[17] and Mirhashemi et al. (2018)[30] where they found Er-YAG laser (2940nm) is more efficient then sandblasting. When compared with group II and group III, laser group showed significant better shear bond strength after 1st recycling as well as 2nd recycling. Here this was similar to the studies carried out by P. Chacko et al. (2013)[17] and Mirhashemi et al. (2018).[30]

According to systemic review by Finnema KJ et al. (2010)[31] many studies used distilled water; however, it has been suggested that teeth must be ideally stored in thymol solution and not in water as this may reduce bond strength significantly. We used the method suggested by Mobarak EH et al. and Aydin B et al. for storage medium for the present study. We thoroughly washed and cleaned the extracted premolars before immersing them in 0.01 percent thymol solution for 24 hours and finally storing them in an airtight jar of distilled water that was changed every 24 hours until we used them.[19,20]

According to the findings of this study, the larger the particle size, the greater the loss of shear bond strength during successive rebonding. This could be explained by the events observed under the scanning electron microscope, in which the obliteration of the brackets mesh increased as particle size increased and vice versa.

We found more obliteration of the bracket mesh with 110μm alumina sandblasting then 25μm and 50μm. As far as recycling with laser is concerned it was comparable to

25μm alumina with less obliteration of the mesh structure self-explaining the comparable shear bond strength.

Overall, the main advantage of reusing the recycled brackets is cost-effectiveness, in term of the cost of new brackets as manufactures are selling the single bracket at higher cost.[18]

We must consider the possibility of litigation as a result of using recycled brackets,[32,33] because manufacturers generally labelled them as intended for single use.. But this possibility can be eliminated by recycling the same bracket in the clinic for the same patient. Let's not forget that there are limitations for the in vitro studies. Most reported in vivo shear bond strength might not be as high as those measured using the in vitro studies. The average reported in vivo bond strengths were approximately 40% less than the in vitro studies.

6. Conclusion

1. There was no significant difference in shear bond strength between the new brackets and brackets recycled for 1st time (1st recycling) as agreed with most of the authors that a single recycling has negligible effect on the shear bond strength of the orthodontic brackets.
2. Group I (sandblasted with 25μm alumina) showed higher shear bond strength as compared to group II and group III (sandblasted with 50μm and 110μm alumina) after first recycling.
3. After 2nd recycling, brackets recycled with 25μm alumina again showed significant higher shear bond strength as compared to group II and group III (P but again showed comparable shear bond strength with group IV (Er-YAG laser group) or we can say its statistically insignificant.
4. With sandblasting, as the sizes of the alumina particles increased, shear bond strength decreased with each successive recycling of the orthodontic brackets.
5. Overall, after 2nd recycling shear bond strength reduced significantly in all groups but it was still well above the recommended shear bond strength.
6. 25μm alumina sandblasting and Er-YAG laser blow method obtained better results after three successive recycling. Sandblasting with 25μm alumina particle size should be recommended than the 50μ and 110μm alumina particles.
7. Overall sandblasting emerged as the best method to recycle the orthodontic brackets as it is the most convenient, technically simple, ecological and also the most cost-effective way to recycle the brackets in orthodontic clinical set up.

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None.

8. Conflict of Interest

The authors declare no conflict of interest.

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Author biography

Waheed Ahmed Shaikh, Senior Lecturer

Ajit Kalia, Professor and HOD

Faisal Ayub Mulla, Post Graduate Student https://orcid.org/0000-0002-9705-7809

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