TO EVALUATE THE EFFECT OF RECYCLING ON SHEAR BOND STRENGTH OF STAINLESS STEEL BRACKETS AND CERAMIC BRACKETS: AN IN VITRO STUDY

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Abstract-

Objectives of study:

Rebonding of isolated brackets is an economic option that can be conducted using available in-office or commercial recycling methods. Thermal, sandblasting, tungsten carbide bur, and lasers are known as an efficient modality for composite removal.

Material and Method:

Two hundred samples of extracted premolar teeth bonded to stainless steel brackets and ceramic brackets were tested for rebonded shear bond strength after recycling by four methods and compared with a initial group of samples. These 200 samples were randomized into four groups which were recycled by four methods, namely, sandblasting, thermal method, adhesive grinding by tungsten carbide bur, and Er: YAG laser method.

Result:

Stainless steel brackets (group A) and ceramic brackets (group B) showed that the initial mean Shear bond strength of stainless steel brackets and ceramic brackets shows there is no significant difference in bond strength. After recycling highest mean shear bond strength of stainless steel brackets seen in laser recycling A4 (15.18MPa) and least in tungsten carbide bur recycling A3 (5.89MPa) and highest mean shear bond strength of ceramic brackets seen in laser recycling B4 (17.57Mpa) and least in tungsten carbide bur recycling B3 (8.87MPa).

Conclusion:
Er: YAG laser (2940 nm) was found to be the most efficient method for recycling, followed by the sandblasting, thermal, and the tungsten carbide methods, which had the least shear bond strength value and is not fit for clinical usage.

Key words-

INTRODUCTION

Bracket debonding is not unusual during orthodontic treatment and is mainly due to bite forces and low bond strength. In addition, improper placement of bracket may necessitate bracket repositioning. There is a tendency to simplify technical methods in orthodontics to reduce treatment costs, like other fields of dentistry. Thus, bracket rebonding is considered as a cost effective option and it has considerable advantages for clinical work. It seems logical to recycle brackets instead of using new ones, which can lead to decrease costs. The main purpose of the recycling process is to remove adhesives from the bracket base without damaging it or changing the bracket slot dimensions.

MATERIALS AND METHODS

Total 200 extracted premolar teeth were collected from the Department of Oral Surgery, Inderprastha dental college and hospital, Sahibabad, Ghaziabad India. The teeth collected were extracted for orthodontic purposes.

Inclusion criteria for the extracted teeth in study is :-

1.Teeth used in this study should be extracted over the course of 6 months.

2.Teeth should be sound and non-carious.

3.No visible enamel deformity should be present in the surface of tooth.

Exclusion criteria for the extracted teeth in study is:

1.Carious teeth.

2.Hypocalcified and hypercalcified teeth.

3.Fluorosis

4.Teeth should not be pre treated with chemical.

MATERIAL:

- Extracted premolar teeth
- Stainless Steel brackets – Mini Twin; Ormco , Glendora, California, 0.022 slot
- Ceramic bracket - ICE clear brackets; Ormco Glendora, California , 0.022 slot
- 37٪ phosphoric acid - Scotchbond ™ (3M Unitek)
- LED curing unit - Ivoclar Vivadent LEDition. Austria
- Transbond XT Light cure adhesive paste - 3M Unitek , Monrovia , California USA.
- Sandblaster – (SR-922 R Sirio, USA). Sandblaster with aluminium oxide of particle size 50 um and at a speed of 67-70 for 10 min.

- Carbide bur – Tungsten carbide bur DENTSPLY Limited
- Laser – Er,Cr:YSGG (Biolase , Waterlase Millenium dental laser system Unicorn denmart) intensity 3W.

METHOD:

200 premolars with intact buccal enamel surface, extracted for Orthodontic reason were collected. Following extraction, residual on the teeth was removed and washed away with tap water. They were then stored in distilled water to prevent dehydration and water was changed weekly to minimize bacterial growth.

To mount the teeth on universal testing machine, they were fixed in a self-cure acrylic blocks with dimension by 9mm×9mm×35mm.The teeth were mounted on acrylic block such that roots were completely embedded into the acrylic up to the cemento-enamel junction leaving the crown exposed.

The blocks were colour coded for easy identification. Prior to the bonding procedure, enamel surface was cleaned with scaler, rinsed and dried with an air syringe. The mounted teeth were randomly divided into two groups Metal (A) and Ceramic brackets (B). The mean area of Metal bracket was (9.63 mm^2) and mean area of ceramic bracket was (11.5mm^2) Group A and group B were subdivided into four subgroups consisting of 25 teeth each Subgroup.

FIGURE : Collected 200 extracted teeth were fixed in a self-cure acrylic blocks with dimension by 9mm×9mm×35mm

The procedure for bonding metal brackets to the tooth surface is as follows.

S.NO.	SAMPLE SIZE	COLOUR
		CODING
1.	n=25	Red
2.	n=25	Black
3.	n=25	Green
4.	n=25	Blue

The procedure for bonding ceramic brackets to the tooth surface is as follows.

S.NO.	SAMPLE SIZE
1.	n=25
2.	n=25
3.	n=25
4.	n=25

Bonding procedure:

The bonding would be done according to manufacturer's instructions. All 200 premolar teeth was bonded [Transbond XT(3M Unitek)]. The procedure included acid etching with a 37% phosphoric acid gel (Scotchbond^{TM}, 3M Unitek) for 30 seconds followed by thorough washing and air drying for 20 seconds. The sealant was placed on the tooth, and the brackets was bonded with the adhesive and light cured for 20 seconds. Before light curing the adhesive, the brackets will be pressed on the tooth with and excess adhesive was removed with a sharp scaler.

DEBONDING PROCEDURE – A wire was attached to the crosshead of universal machine looped around the bracket. A gingivo-occlusal load was applied to the bracket , producing a shear force at the bracket tooth interface until the bracket is detached the result of each test was recorded by a computer that is connected to the universal testing machine . The machine records the result from each test in megapascals (Mpa) at a crosshead speed of 1 mm/minute.

RECYCLING METHODS - Following bracket debonding, four different recycling methods was done on the experimental groups to remove the resin layer to the bracket base prior to rebonding.

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Group A (stainless steel brackets) further sub divided into 4 subgroups consisting of 25 teeth in each subgroup.

Subgroup A1: 25 samples were recycled with direct flaming (600-800°C) which were colour coded with red. Group A Metal bracket (Mini Twin ; Ormco , Glendora, Calif.)

Subgroup A2: 25 samples were recycled with Sandblasting with aluminium oxide abrasion of particle size 50µm for 15-30 seconds (depending upon the residual bonding agent) which were colour coded with black. Group A Metal bracket (Mini Twin ; Ormco , Glendora, Calif.).

Subgroup A3: 25 samples were recycled with mechanical - composite bases roughened with a silicon carbide bur which were colour coded with green. Group A Metal bracket (Mini Twin ; Ormco , Glendora, Calif.).

Subgroup A4: 25 samples were recycling with Laser Er : YAG laser (Biolase, Waterlase ,Millenium Dental laser system Unicorn denmart) intensity 3W which were colour coded with blue. Group A Metal bracket (Mini Twin ; Ormco , Glendora, Calif.)

Group B (Ceramic brackets) was further sub divided into 4 subgroups consisting of 25 teeth in each subgroup.

Subgroup B1: 25 samples were recycling with direct flaming (600-800°C) which were colour coded with red. Group B(ICE clear brackets Ormco , Glendora, Calif).

Subgroup B2: 25 samples were recycling with Sandblasting with aluminium oxide abrasion of particle size 50µm for 15-30 seconds (depending upon the residual bonding agent) which were colour coded with black. Group B(ICE clear brackets Ormco , Glendora, Calif).

Subgroup B3: 25 samples were recycling with mechanical - composite bases roughened with a silicon carbide bur which were colour coded with green. Group B(ICE clear brackets Ormco , Glendora, Calif).

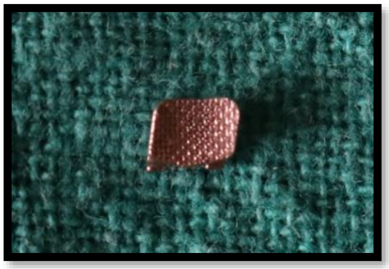
Subgroup B4: 25 samples were recycling with Laser Er : YAG laser (Biolase, Waterlase ,Millenium Dental laser system Unicorn denmart) intensity 3W which were colour coded with blue. Group B(ICE clear brackets Ormco , Glendora, Calif).

FIGURE: Recycling with Micro torch

FIGURE : Recycling with Sandblaster

FIGURE : Recycling with TC bur

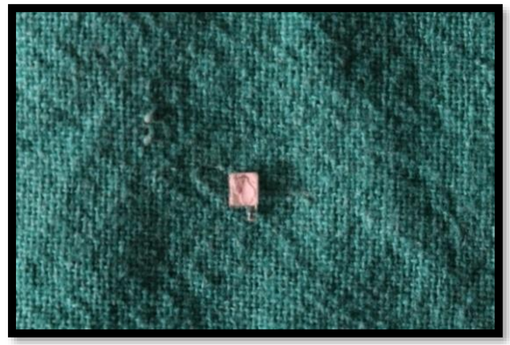
FIGURE : Recycling with Er YAG Laser.

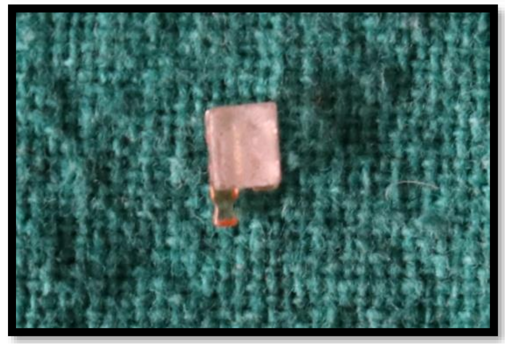


Bracket after direct flaming Bracket after sandblasting

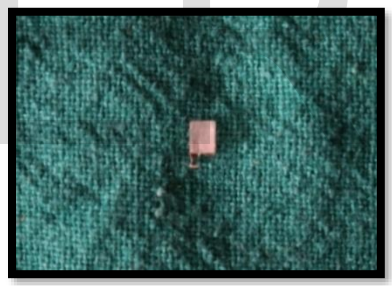
Bracket after roughening with tungsten Bracket after laser

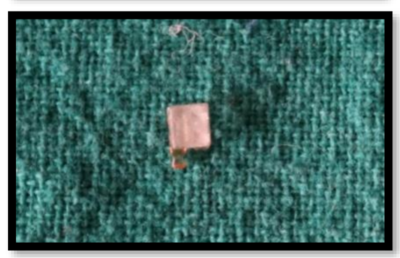
carbide bur





Bracket after direct flaming Bracket after sandblasting





Bracket after roughening with tungsten Bracket after laser

carbide bur

REBONDING - Rebonding of the recycled brackets was done using bonding procedure as described earlier.

DEBONDING AGAIN – After 24 hours data value recorded and then compared to the previously recorded and statistical analysis test was done.

Bond strength:

The bond strength study in this research was conducted in 2 parts:

i. Bond strength of new Stainless Steel Brackets and Ceramic Brackets tested in ,as received form
ii. Bond strength of Stainless Steel Brackets and Ceramic Brackets tested post recycling.

Shear bond strength was measured with universal testing machine (Instron Corporation, Canton, MA, USA) at a crosshead speed of 1 mm/min using a chisel shaped nib. The specimen mounted in acrylic block was secured to the lower grip of the machine. To maintain a consistent debonding force, a custom made blade was fixed in upper grip connected to the load cell. Nib was positioned in such a way that it touched the bracket .Computer recorded the force to debond the bracket in Newtons. Bond strength was calculated in megapascals using formula.

Bond strength MPa = Force in Newtons /surface area of brackets in mm^2.The mean area of Metal bracket was (9.63 mm^2) and mean area of ceramic bracket was (11.5 mm^2). The statistical analysis of the data was done and the standard deviation and mean were calculated. The Anova test, T test, Bonferroni test, Weibull analysis were used to compare the shear bond strengths of the four groups or Compare bonding strength between the two bracket system, the ceramic and the metal brackets.

RESULTS

Stainless steel brackets (group A) and ceramic brackets (group B) showed that the initial mean Shear bond strength of stainless steel brackets and ceramic brackets shows there is no significant difference in bond strength. After recycling highest mean shear bond strength of stainless steel brackets seen in laser recycling A4 (15.18MPa) and least in tungsten carbide bur recycling A3 (5.89MPa) and highest mean shear bond strength of ceramic brackets seen in laser recycling B4 (17.57Mpa) and least in tungsten carbide bur recycling B3 (8.87MPa).

Table 1: Comparison of initial mean Shear bond strength of stainless steel brackets in four groups (Group A)

Groups	N	Mean	S.D.
Subgroup A1	25	15.41	0.91
Subgroup A2	25	15.10	0.67
Subgroup A3	25	15.50	0.84
Subgroup A4	25	15.63	0.56

ANOVA test applied, *p-value significant at $p<0.05$

Table 2: Comparison of initial mean Shear bond strength of ceramic brackets in four groups (Group B)

Groups	N	Mean	S.D.
Subgroup B1	25	21.45	1.14
Subgroup B2	25	21.69	0.86
Subgroup B3	25	21.77	0.78
Subgroup B4	25	21.84	0.82

ANOVA test applied, *p-value significant at $p<0.05$

Table 3: Comparison of mean Shear bond strength of stainless steel brackets post recycling in four groups (Group A)

Groups	N	Mean	S.D.
Subgroup A1	25	8.36	1.56
Subgroup A2	25	12.05	1.52

Subgroup A3	25	5.89	1.18
Subgroup A4	25	15.18	0.93

ANOVA test applied, *p-value significant at p<0.05

		4	4

Post hoc bonferroni applied applied, *p-value significant at p<0.05

Table 4: Comparison of mean Shear bond strength of ceramic brackets post recycling in four groups (Group B)

Groups	N	Mean	S.D.	F	p-value
Subgroup B1	25	12.39	1.16	222.047	0.0001*
Subgroup B2	25	14.94	1.18		
Subgroup B3	25	8.87	1.41		
Subgroup B4	25	17.57	1.21		

ANOVA test applied, *p-value significant at p<0.05

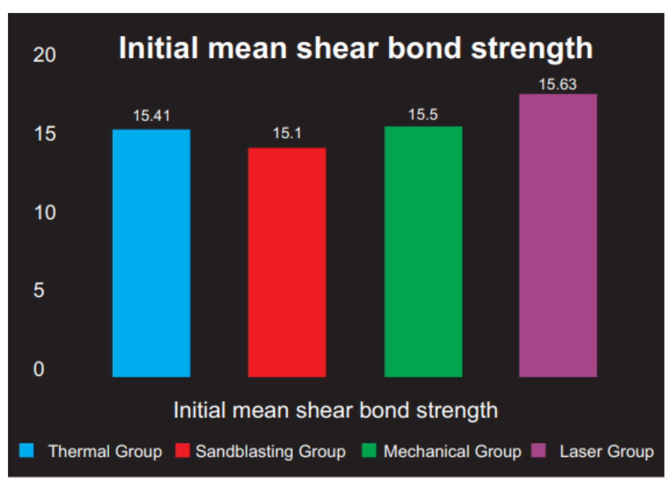
Table 5: Intergroup comparison among the stainless steel brackets post recycling using four methods (Group A)

Group (I)	Group (J)	Mean difference	p-value	Confidence interval	
				Lower	Upper
Subgroup A1	Subgroup A2	-3.684	0.001	-4.694	-2.674
	Subgroup A3	2.468	0.001	1.458	3.478
	Subgroup A4	-6.815	0.001	-7.825	-5.805
Subgroup A2		6.153	0.001	5.143	7.163
	Subgroup A4	-3.130	0.001	-4.14	-2.121
Subgroup A3	Subgroup A4	-9.284	0.001	-10.29	-8.27

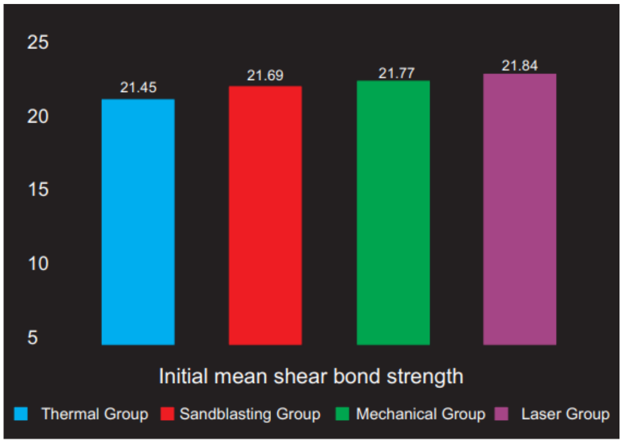
Table 6: Intergroup comparison among the ceramic brackets post recycling using four methods (Group B)

Group (I)	Group (J)	Mean difference	p-value	Confidence interval	
				Lower	Upper
Subgroup B1	Subgroup B2	-2.546	0.001	-3.494	-1.597
	Subgroup B3	3.522	0.001	2.573	4.471
	Subgroup B4	-5.182	0.001	-6.130	-4.233
Subgroup B2	Subgroup B3	6.068	0.001	5.119	7.017
	Subgroup B4	-2.635	0.001	-3.584	-1.686
Subgroup B3	Subgroup B4	-8.704	0.001	-9.652	-7.755

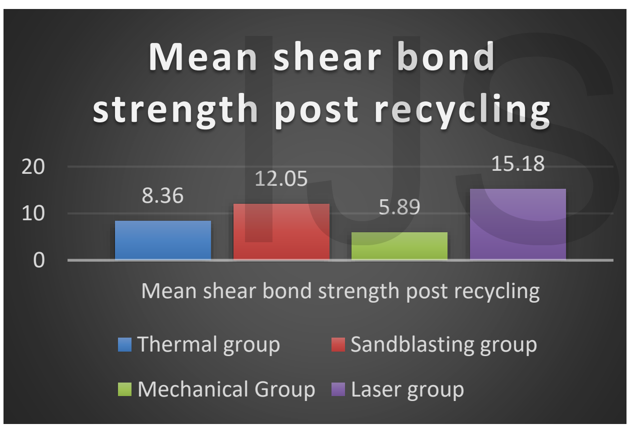
Post hoc bonferroni applied applied, *p-value significant at p<0.05



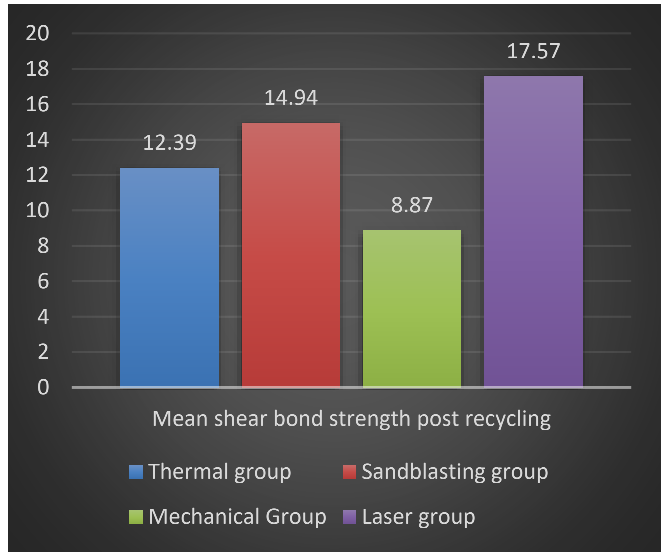
Graph: 1 Initial shear bond strength of Metal bracket (group A)



Graph: 2 Initial shear bond strength of Ceramic bracket(group B)



Graph: 3 Mean shear bond strength post recycling of Metal brackets.



Graph: 4 Mean shear bond strength post recycling of ceramic brackets .

Discussion

Matasa stated that a bracket can be used for up to five times. Considering the increasing popularity and clinical use of brackets, there is a need for an effective way to recycle the brackets. Thus, this study was conducted to evaluate and compare the SBS of ceramic brackets with mechanical retention recovered by different methods. The SBS of new and recycled brackets is an interesting topic in orthodontic research. Removal of the remaining resin and reuse of debonded brackets are less costly than the use of new brackets. In this study, the mean SBS of brackets in the initial group was 21.45 Mpa. No significant difference was found between the groups, which is consistent with the results of **Ishida et al** . In the study by **Reynolds** and **von Fraunhofer** the SBS of 5.9 to 7.8 Mpa was introduced as the minimum required values for clinical practice. However, **Mizrahi** and **Smith** concluded that bond strength in the range of 2.8 to 10 Mpa is sufficient for clinical purposes. The present study indicated that the bond strength of all groups was higher than the minimum range due to the anatomical diversity of the buccal surfaces of the teeth. This range can be affected by accurate placement of the machined blade. Most studies reported a wide range of diversity for bond strength.

Er:YAG laser technique has the highest recycled SBS and is significantly greater when compared to the other methods. The increased shear bond values could be due to the lower penetration energy of Er:YAG laser and the selective absorption of the laser toward composites. An increase in penetration would have caused surface alteration of the metal, thereby reducing the bond strength. Selective absorption property of Er: YAG laser toward composites led to the complete removal of resins from the brackets, which was directly proportional to the bond strength achieved.

The sandblasting method has the second highest recycled SBS. The increase in SBS values can be attributed to the micro-roughness created by the alumina particles, which therefore creates an increased bonding surface area that is essential for retention.

The mean recycled values of the thermal and electropolishing method were much below the normal range and require long exposure to heat. Complete pyrolysis of the resin occurs only at temperatures around 770°C, and during this phase of pyrolysis of resins, it forms acids which are a possible source of inter-granular attack. According to Buchman, heat influences stainless steel at temperatures of 400-900°C, which would definitely lead to sensitization of the metal.

The adhesive grinding method using tungsten carbide bur recorded the least SBS well below the accepted limit and not fit for clinical usage. The grinding of the base using a tungsten carbide bur appears quick, simple, and easy to perform, but the grinding leaves behind a smooth surface with much of the mesh being scraped off. This in turn leads to low bond strength values. This study showed that the resulting bond strength after recycling with Er:YAG laser was the least affected and was above the recommended range. However, a limitation of the study is that the assessment of adhesive remnants was done subjectively and future studies can use the Adhesive Remnant Indices (ARI) to more accurately assess the effectiveness of different recycling methods on the amount of adhesive remnants on bracket surfaces.

CONCLUSIONS

Following conclusion can be drawn as.

1. Er:YAG laser was the most efficient method for recycling.

2. Sandblasting method is the second most effective method of recycling, owing to the increased surface area, which creates better bonding.

3. Direct flaming followed by electropolishing led to significant decrease in shear bond strength as compared to sandblasting and initial bond strength, but within the clinical acceptable range.

4. Grinding the bracket base with tungsten carbide bur led to highly significant lower shear bond strength than control, sandblasting and direct flaming method.

All reconditioning methods tested in the present study were efficient. However, grinding the adhesive attached to the bracket bases with silicon carbide bur seems to be the least efficient method.

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