

Comparative Evaluation of Shear Bond Strength of Recycled Brackets using Different Methods: An *In vitro* Study

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Abstract:

Background: Debonding of brackets commonly occurs during orthodontic treatment. Due to increase in costs replacement of a damaged bracket is not liked by the dentist. This study is done to assess the shear bond strength of recycled brackets using different methods.

Materials and Methods: This study was conducted using five groups of orthodontic brackets (0.022" × 0.028", MBT prescription) bonded on the premolars mounted in cubes. Other materials required were cubical trays, bonding material, light cure unit, universal testing machine, digital camera and sandblasting unit.

Results: From the result of ANOVA test we observed the test is significant ($F = 20.79$, $P < 0.01$) and the test is rejected. When the Tukey's *t*-test result was applied it was seen that the mean shear bond strength of all groups of brackets is as follows: Group I (5.31 Megapascals [Mpa]) < Group II (7.37 Mpa) < Group III (8.96 Mpa) < Group IV (5.56 Mpa) < Control group (9.24 Mpa). Alternatively we can say that shear bond strength of following bracket groups can be arranged as Group I < Group IV < Group II < Group III.

Conclusion: From this study we conclude that Group III, which was recycled with an ultrasonic cleaner with electropolisher and silane coupling agent in place of primer, showed the highest shear bond strength.

Key Words: Recycling, shear strength, stainless steel

Introduction

The debonding of brackets is common among orthodontic patients. It may be due to bond failure or as the need for repositioning. Typically practitioners will discard dislodged brackets and replace it with a new bracket.¹ As more complex and precise brackets are manufactured, their cost is also increasing so it is necessary to rebond an existing recycled bracket rather than going for a new bracket.

The main goal of recycling process is to remove the adhesive from the bracket completely without damaging or weakening the delicate bracket base meshwork or distorting the dimensions of the bracket slot. Reusing a debonded bracket traditionally requires burning off the residual adhesive with a flame and then cleaning the bracket and restoring its shine with a micro etcher. A simple, quick and inexpensive way to clean a bracket after the adhesive has been burnt off is to submerge the bracket for 5-15 s in a solution of 32% hydrochloric acid and 55% nitric acid mixed in a 1:4 ratio. Commercial processes use heat (about 450° centigrade) to burn off the resin, followed by electropolishing to remove the oxide buildup at the bracket base. Some recycling companies advocate bicarbonate bath to neutralize remaining residual electrolytes from the base of the bracket after electropolishing. The advantages of recycling a bracket includes smoother, more corrosion resistant bracket after electropolishing. The disadvantages of recycling may include a reduction in bracket quality, loss of identification marks, lack of sterility and increased risk of cross-infection.²

Many investigators have compared initial bond strengths with rebonded bond strength and reached differing conclusions. Initial and rebond bond strengths were equivalent. Initial bond strengths were higher than rebond bond strengths.

Egan *et al.* reported that initial bond strengths were equivalent to those of one rebond sample but were higher than those for the remaining three rebond samples.²

Materials and Methods

The present study was undertaken in the Department of Orthodontics and Dentofacial Orthopaedics of Teerthanker Mahaveer Dental College and Research Centre, Moradabad. A study was performed to determine the shear bond strength of metal brackets with different recycling methods to assess the best method of recycling.

Sample

A total of 50 extracted maxillary and mandibular premolars were used for this study. The criteria for tooth selection were as follow:

- The crown has to be grossly perfect with no defect or any evident surface deformities.
- No history of any chemical insult with agents like hydrogen peroxide or formalin.
- No history of trauma or any structural alteration caused by mechanical procedures.

Brackets

A total of 50 metal brackets (premolar) manufactured by Ormco(orthos) with a slot configuration of 0.022” × 0.028”, MBT prescription were used. All samples were divided into five groups (10 samples each). Each group was further divided into two groups which were the control group and experimental group. Experimental group was subdivided into four groups namely Group I, Group II, Group III, and Group IV respectively (Figure 1).

The samples were grouped as:

- Group I: This comprised of 10 brackets manufactured by Ormco and recycled by flaming the base of the bracket and dipping the bracket into the electropolisher.
- Group II: This group comprised of 10 brackets manufactured by Ormco and recycled by flaming of base and sandblasting the base of the bracket.
- Group III: This group comprised of 10 brackets manufactured by Ormco and recycled flaming the base, cleaning

the base with ultrasonic cleaner then dipping the bracket into the electropolisher and using silane coupling agent in place of primer.

- Group IV: This group comprised of 10 brackets manufactured by Ormco and recycled by flaming and removing the remaining composite by ultrasonic cleaning.

Ice cube plastic trays were poured by sandstone and teeth were embedded in them.

After surface preparation, the enamel surface was treated with an acid etchant to improve wettability and surface area. A 37% phosphoric acid gel (3M etchant) was applied to the buccal surface of each tooth for 15 s. The teeth then rinsed with a continuous water spray for 30 s and dried with an air-spray until the buccal surface of the etched teeth appeared to be chalky white in colour.⁴

After etching the primer (Transbond XT Primer, 3M Unitek) was applied on the enamel photo-polymerized for 10 s. A small layer of adhesive (Transbond XT, 3M Unitek) was applied to the bracket base and positioned on the pretreated crowns. After some time, brackets were debonded using the bracket debonding plier.

Curing of light cure resin material was done with light emitting diode (Dentaurum Australia Private Limited, 18 Bertram St., Mortlake, Australia) having intensity of 440-480 nw/cm².

Sand blasting was done with portable sandblasting unit manufactured by Samit Dental Equipment’s, Delhi using 50 micron aluminum oxide abrasive powder.

Flaming was done with non-luminous zone of the flame of the gas torch manufactured by Libral Traders, Delhi.

The shear bond strength was measured using a Universal Testing Machine manufactured by Banbros Machines, Delhi. The test for shear bond strength was conducted at ITS Engineering College, Greater Noida. All photographs were taken using Nikon L 310, 13.5 megapixels camera.

Results

The present study was undertaken in the Department of Orthodontics and Dentofacial Orthopedics of Teerthanker Mahaveer Dental College and Research Centre with the objective of determining the shear bond strength of metal brackets debonded and recycled with various recycling methods available in the department.

Shear bond strength (± standard deviation [SD]) in Megapascals (Mpa) for brackets recycled by four methods of recycling and represented individually were determined. They were found to be as follows:

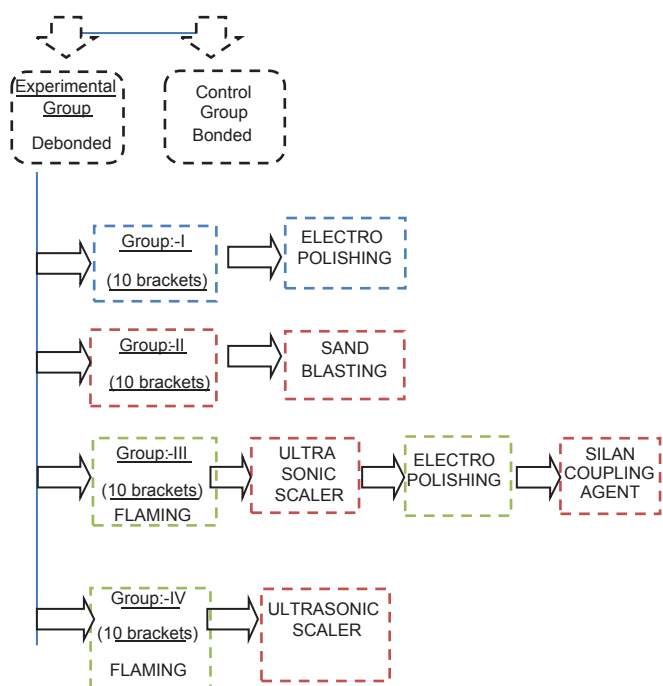


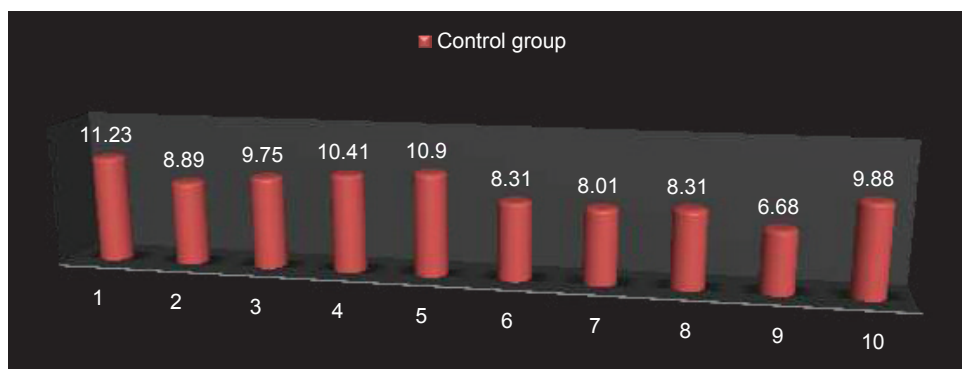
Figure 1: The study design with distribution of the control and test groups.

- Shear bond strength of the control group was higher than that of the four test groups (Table 1). The mean shear bond strength of the control group was found to be 9.24 Mpa with SD 1.24 Mpa (Graphs 1 and 2).
- The mean shear bond strength of experimental groups were as follows: In Group I = 5.31 Mpa (Graphs 2 and 3), Group II = 7.37 Mpa (Graphs 2 and 4), Group III = 8.96 Mpa (Graphs 2 and 5) and Group IV = 5.56 Mpa (Graphs 2 and 6) and Standard deviation in Group I = 1.47 Mpa, Group II = 1.01 Mpa, Group III = 1.20 Mpa, Group IV = 0.92 Mpa.

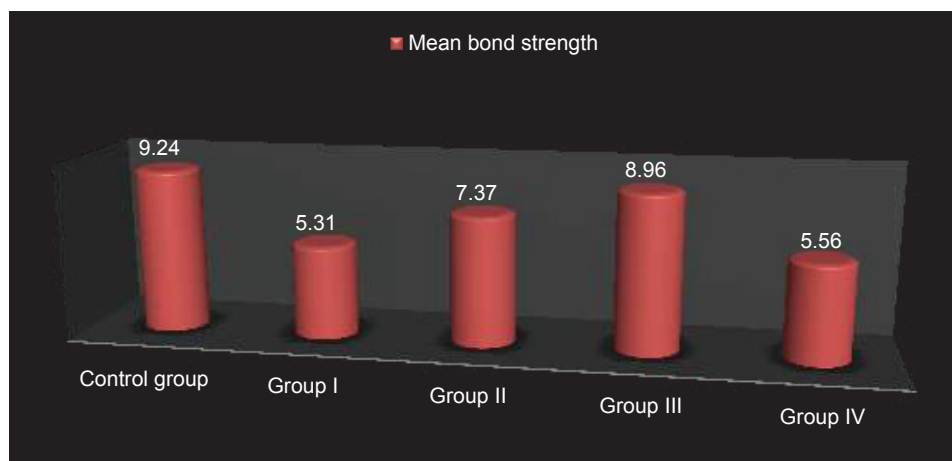
Brackets recycled with flaming and electropolishing were having the least shear bond strength (Graph 7).

It was found that, the ANOVA test for the comparison of mean of different groups yielded a significant result i.e. the ANOVA test is rejected with $P < 0.01$. As such we can say that the different groups cannot be considered to have the same mean.

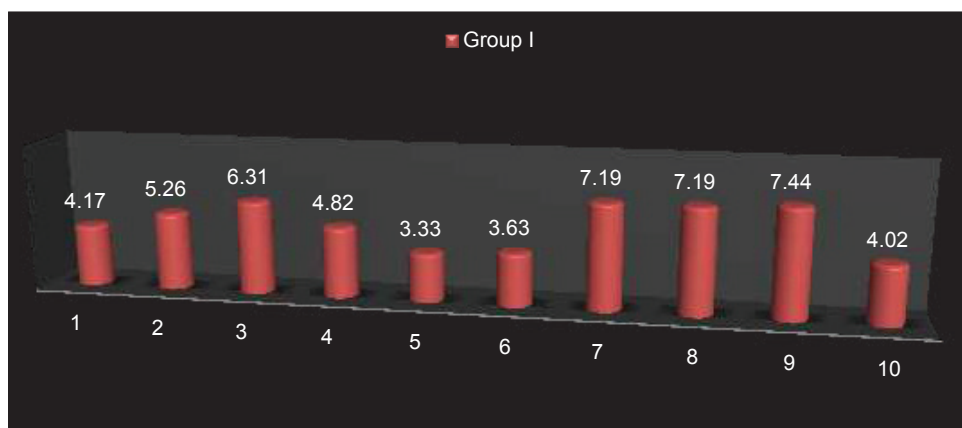
The Tukey's test analysis to identify those groups that had lead to the rejection of the ANOVA was applied. The F value was significant. Hence, shear bond strength differed significantly



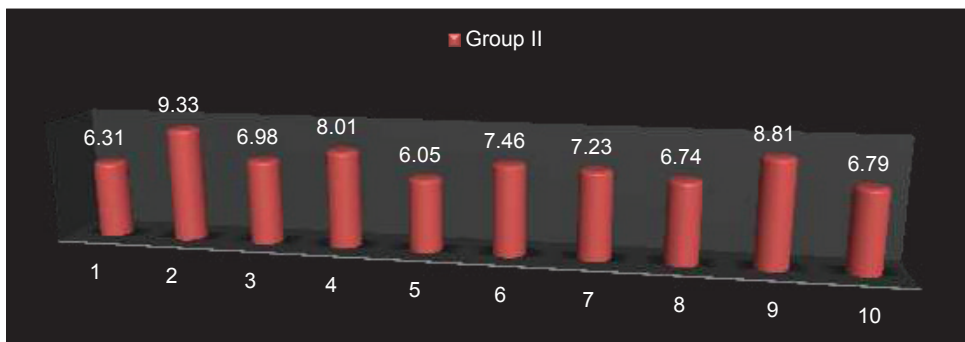
Graph 1: Shear bond strength of 10 samples of the control group.



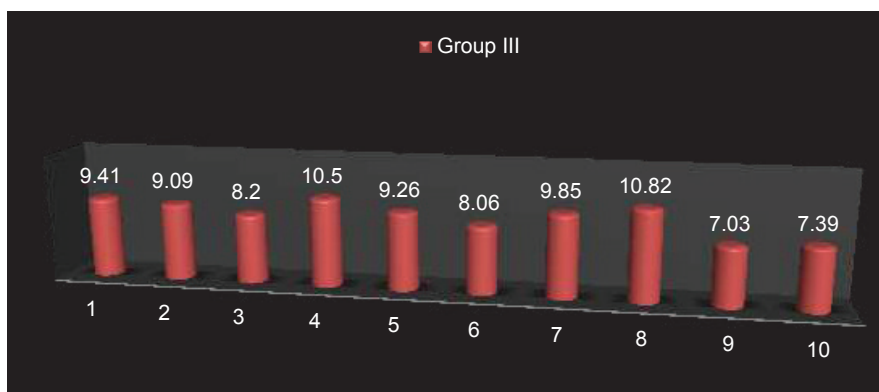
Graph 2: Mean shear bond strength of control and experimental group.



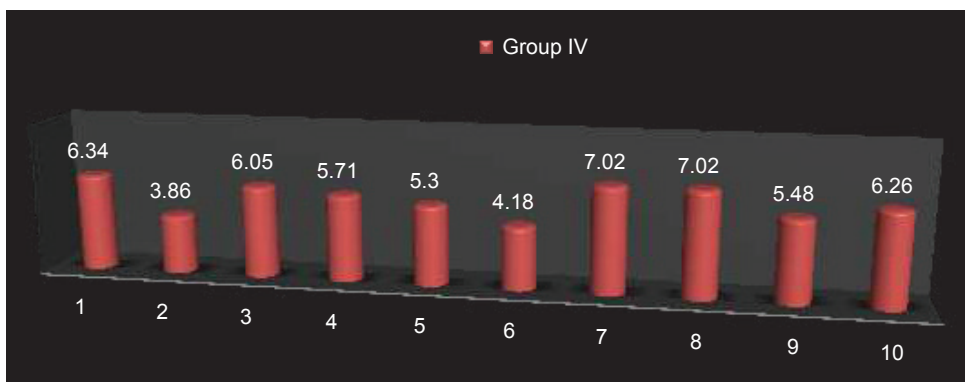
Graph 3: Shear bond strength of 10 samples of Group I.



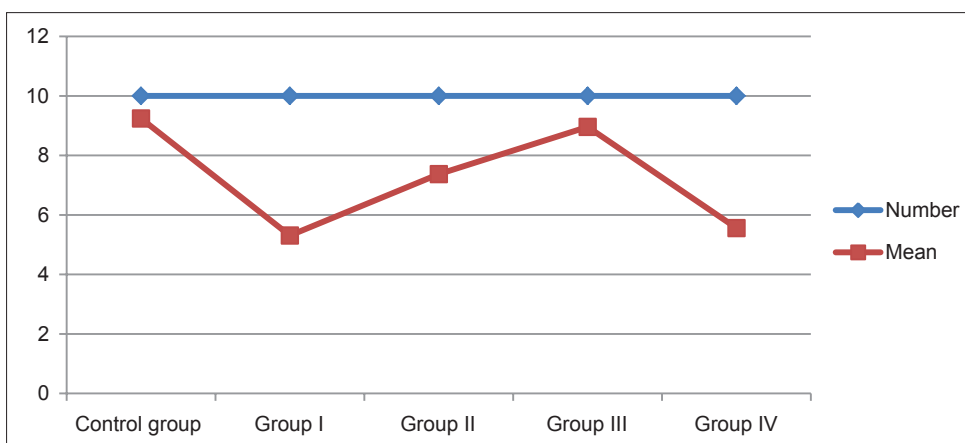
Graph 4: Shear bond strength of 10 samples of Group II.



Graph 5: Shear bond strength of 10 samples of Group III.



Graph 6: Shear bond strength of 10 samples of Group IV.



Graph 7: Comparison of shear bond strength of the control group and all four subgroups of the experimental group.

in different groups. Shear bond strength was found maximum in the control group (Table 2).

Shear bond strength of the control group was found to be maximum among all recycled groups.

From Table 3 we understand that, the ANOVA test for the comparison of mean of different groups yielded a significant result i.e. the ANOVA test is rejected with $P < 0.01$. As such we can say that the different groups cannot be considered to have the same mean.

Shear bond strength of recycled brackets bonded with silane coupling agent (Group III) and recycled with flaming, electropolishing, sandblasting and ultrasonic cleaning was equivalent to the control group. Multiple comparisons are displayed in Table 4.

Brackets recycled with flaming and sandblasting had less shear bond strength as compared to Control group.

Hence, the result summary for highest shear bond strength is as follows:

Control Group = Silane coupling Agent > Flaming + Sandblasting > Flaming + Ultrasonic Cleaning > Flaming + Electropolishing

Table 1: Shear bond strength of the control group and experimental group comprise of four groups of 10 brackets in each group with surface area of 6 mm² in Megapascals (Surface area - 6 mm²).

Sl. no	Control group	Group I	Group II	Group III	Group IV
1	11.23	4.17	6.31	9.41	6.34
2	8.89	5.26	9.33	9.09	3.86
3	9.75	6.31	6.98	8.20	6.05
4	10.41	4.82	8.01	10.50	5.71
5	10.90	3.33	6.05	9.26	5.30
6	8.31	3.63	7.46	8.06	4.18
7	8.01	7.19	7.23	9.85	7.02
8	8.31	7.19	6.74	10.82	7.02
9	6.68	7.44	8.81	7.03	5.48
10	9.88	4.02	6.79	7.39	6.26

Table 2: Mean (Megapascals) and standard deviation (Megapascals) of shear bond strength of the control group and experimental group.

	Control group	Group I	Group II	Group III	Group IV
Number	10	10	10	10	10
Mean	9.24	5.31	7.37	8.96	5.56
Standard deviation	1.24	1.47	1.01	1.20	0.92

Table 3: Analysis of variance of shear bond strength in the control group and experimental group.

Source of variation	Sum of square	Degree of freedom	Mean sum of square	Variance ratio "F"	P value	F
Between groups	135.187	4.000	33.797	20.779	9.31E-10	2.579
Within groups	73.190	45.000	1.626			
Total	208.377	49.000				

Discussion

The invention of Etching Technique by Bunocore (1955) and its eventual application in our discipline for directly bonding brackets to the surface of teeth, largely simplified the time consuming procedure of fixed orthodontic treatment. The ease of bonding improved patient acceptance and assured its widescale application by orthodontists.

The discussion of our results will be dealt with under the following headings:

- Comparative discussion of shear bond strength of recycled brackets.
- Recycled method with maximum shear bond strength.

Comparison of shear bond strength of recycled brackets

The result of our study showed that shear bond strength for brackets recycled with flaming, electropolishing, sandblasting, ultrasonic cleaning and those bonded with silane coupling agent was significantly equivalent to control the group when shear bond strength measured after 24 h.⁵

This increase in bond strength of Group III brackets is in agreement with the result of wright and powers, 1985. According to them, there is an increase in bond strength which was treated with silane and had been flamed and ultrasonically cleaned. According to Quick *et al.*,⁶ sandblasting for a period of 15 s using 50 µm aluminum oxide granules at a pressure of 4.5 bar was adequate to remove the residual composite without compromising the bond strength.

Comparison of new and recycled brackets

Recycling consist of the removal of remnant bonding agent on the bracket bases, without causing damage to the retention mesh and preserving retentive characteristics.⁷ Several techniques are available for recycling brackets:

- Mechanical methods:
 - Sand blasting (Aluminum oxide blasting -50 µm, 90 µm particles etc.)
 - Ultra sonic scaling.
- Thermal methods:
 - Direct flaming
 - Heating in a furnace.
- Chemical methods:
 - Use of chemical solvents to dissolve the bonding agent in combination with high frequency vibrations.
- Combination of mechanical and thermal methods:
 - Buchman method (Heat application to burn the bonding agent followed by electrolytic polishing for oxide removal).

Debonded brackets were recycled using the following techniques.⁸

- In Group, I base of the brackets were flamed in the non-luminous layer of the flame and residual composite is removed after placing in the electropolisher.
- In Group II base of the brackets were flamed in the

Table 4: Multiple comparisons.

Tukey test						
(I) Group	(J) Group	Mean difference (I-J)	Standard error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Control group	Flame+Ultrasonic	3.67700*	0.57034	0.000	2.0564	5.2976
	Silane	0.27600	0.57034	0.988	-1.3446	1.8966
	Flame+Sandblast	1.86600*	0.57034	0.017	0.2454	3.4866
	Flame+E. Polishing	3.93100*	0.57034	0.000	2.3104	5.5516
Flame+Ultrasonic	Silane	-3.40100*	0.57034	0.000	-5.0216	-1.7804
	Flame+Sandblast	-1.81100*	0.57034	0.022	-3.4316	-0.1904
	Flame+E. Polishing	0.25400	0.57034	0.992	-1.3666	1.8746
Silane	Flame+Ultrasonic	3.40100*	0.57034	0.000	1.7804	5.0216
	Flame+Sandblast	1.59000	0.57034	0.057	-0.0306	3.2106
	Flame+E. Polishing	3.65500*	0.57034	0.000	2.0344	5.2756
Flame+Sandblast	Flame+Ultrasonic	1.81100*	0.57034	0.022	0.1904	3.4316
	Silane	-1.59000	0.57034	0.057	-3.2106	0.0306
	Flame+E. Polishing	2.06500*	0.57034	0.006	0.4444	3.6856
Flame+E. Polishing	Flame+Ultrasonic	-0.25400	0.57034	0.992	-1.8746	1.3666
	Silane	-3.65500*	0.57034	0.000	-5.2756	-2.0344
	Flame+Sandblast	-2.06500*	0.57034	0.006	-3.6856	-0.4444

*The mean difference is significant at the 0.05 level. DV: Dependent variable, E. Polishing: Electropolishing

non-luminous layer of the flame and residual composite is removed by treating them in sandblaster using 50 micron alumina oxide abrasive powder.

- In Group III base of the brackets were flamed in the non-luminous layer of the flame, cleaned with an ultrasonic scaler, cleaned in electropolisher than treated with silane coupling agent.
- In Group IV base of the brackets were flamed and cleaned with an ultrasonic scaler.

After recycling of the bracket, brackets were rebonded on the teeth, and shear bond strength is measured with Universal Testing Machine.

Mean shear bond strength of all groups in decreasing order were as follows:

1. Control Group = Group III (Flaming + Ultra Sonic Cleaning + Electropolishing + Silane Coupling Agent).
2. Group II (Flaming + Sand blasting).
3. Group I (Flaming + Electropolishing).
4. Group IV (Flaming + Ultrasonic cleaning).

These methods have been subjected to several investigations to prove their efficacy. Marked reduction in the bracket bond strength was reported after grinding the adhesive with a green stone to the surface of the mesh base.⁹ In addition, a study by Egan *et al.* (1993) revealed that the Buchman method also causes a decrease in bond strength.

On the other hand "Sandblasting" with aluminum oxide particles (90 micron) for 15-30 s at a distance of 10 mm from the bracket bases is efficient and technically simple.

It also enhances bracket bonding to tooth structure by producing micromechanical retention on the base surface due

to an increase in the area of composite interlocking, which is essentially mechanical due to the micro pores of the bracket mesh.

These reasons positively guided us to choose sandblasting with aluminum oxide to be a method of choice for recycling in the present study.¹⁰

Factors which affect shear bond strength on sandblasting include:

- The mesh size and configuration of the bracket base.
- Particle size of both resin and the sand blasting material.
- Complete removal of resin.
- Damages caused by sand blasting to the base.

Conclusion

The following summary is drawn from the present study:

- Brackets recycled with flaming, ultra sonic scaling, electropolishing and treated with silane coupling agent is recorded with highest shear bond strength.
- Sand blasting of metal brackets to remove composite residue, has an insignificant effect on the shear bond strength. Hence, sandblasting should be considered as viable, time saving and convenient method of recycling.
- The order for shear bond strength of new and recycled brackets are as follows:
 - Control group
 - Flaming + Ultrasonic scaling + Electropolishing + Silane coupling agent
 - Flaming + Sand blasting
 - Flaming + Ultra sonic scaling
 - Flaming + Electropolishing.

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