

The Effects of Various In-Office Reconditioning Methods on Shear Bond Strength, Morphology of Slots and Bases of Stainless Brackets: An *in vitro* Study

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ABSTRACT

Aim: The aim of the present study was to evaluate and compare the effects of six in-office reconditioning methods (direct flaming, sandblasting, modified BigJane machine method, direct flaming followed by sandblasting, flaming followed by electropolishing, Buchman method) on standard edgewise metallic brackets.

Materials and methods: One hundred and five brackets were divided into seven groups. The six experimental brackets were reconditioned using six different reconditioning methods. The brackets were rebonded on human premolar teeth and were tested for shear bond strength, slot dimensions and bracket base appearance.

Results: Significant differences in the shear bond strength and slot dimensions were seen between the control and the experimental groups.

Conclusion: This study suggests sandblasting as the simplest, most efficient manner of immediately recycling debonded brackets.

Keywords: In-office reconditioning, Morphology of bases, Shear bond strength, Slot dimensions.

How to cite this article: Bansal N, Valiathan A, Bansal K. The Effects of Various In-Office Reconditioning Methods on Shear Bond Strength, Morphology of Slots and Bases of Stainless Brackets: An *in vitro* Study. J Ind Orthod Soc 2011;45(4):175-182.

INTRODUCTION

Direct bonding in modern day orthodontic clinical practice owes thanks to the pioneering work of Buonocore¹ on the acid etch technique as well as the introduction of a chemically cured composite resin to dentistry by Bowen. This resulted in the introduction of the bracket-bonding technique by Newman² later. Efforts to improve the bond strength have resulted in the development of resins with novel composition³ as well as improvements in acid etching of enamel and also the design and composition of the bracket systems.

Accidental dislodgment of an orthodontic bracket, due to occlusal trauma or intentional removal of a bracket in order to

reposition it to achieve ideal occlusion goals, are common occurrences in orthodontic treatment. The orthodontists are faced with the decision of what to do with the used brackets, suggesting an alternative to the 'disposable' bracket practices, in order to reduce the waste and cost, for both orthodontist and the patient.

Orthodontic bracket recycling, which is often referred to as bracket processing or bracket reworking,⁵ as brackets are not reshaped but only separated from stains and adhesive remnants using heat and chemical agents, followed by cleaning and polishing, results in brackets that reach standards of quality comparable to those shown by unused brackets and are able to withstand the same draw-off strengths.⁶

The two main commercial processes for recycling orthodontic brackets use either heat or chemical method to remove the resin.^{5-7,9,10} While there are several commercial recycling methods available, they are impractical to perform at the chairside. As a result, several in-office bracket reconditioning methods have been introduced.⁷ These include a variety of mechanical methods (e.g. hand pieces with rotary burs), thermal methods (e.g. direct flaming, heating in a furnace) and a combination of both mechanical and thermal methods (e.g. the Buchman method).

The potential effects of reconditioning a bracket are dependent upon the type of procedure used, the type of steel from which the bracket is constructed and the nature of the bracket base mesh diameter.^{11,12}

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Received on: 21/11/11

Accepted after Revision: 22/11/11

According to Buchman,¹⁵ metal will anneal and thus soften at temperatures of 400 to 900°C. Electropolishing reduces surface roughness and oxide layer that is formed by the heat. Sandblasting techniques using a high-speed stream of aluminum oxide particles propelled by compressed air were evaluated by Sonis¹³ and MacColl et al.¹⁴ Although recycling of stainless steel orthodontic brackets reduces the initial cost and waste of providing fixed appliance therapy, this advantage is lost if the bonds are then liable to failure during treatment.¹⁵

The aim of the present study was to evaluate and compare the effects of six in-office reconditioning methods (direct flaming, sandblasting, modified BigJane machine method, direct flaming followed by sandblasting, flaming followed by electropolishing, Buchman method) of standard edgewise metallic brackets on: The shear bond strength, bracket slot width, depth and interwing gap dimensions and bracket base appearance.

MATERIALS AND METHODS

The sample consisted of 105 intact non-hypoplastic and non-carious human premolar teeth extracted for orthodontic purposes and stored in distilled water. The teeth were embedded in acrylic placed in blocks. A total of 105 new stainless steel premolar brackets (standard edgewise twin bracket, 0.022 inch slot with conventional foil base) were selected. The brackets were divided into seven groups, each group consisting of 15 samples; one control (Group I) and six experimental groups (Group II to VII).

Experimental brackets were initially bonded to the mounted teeth using a light-cured orthodontic adhesive Transbond XT 3M in accordance with the manufacturer's instructions. The teeth were cleaned and then polished with non-fluoridated pumice and rubber prophylactic cups for 10 seconds. The procedure included acid etching with a 37% phosphoric acid gel for 15 seconds followed by thorough washing and drying.

The adhesive was applied to the bracket base and was then positioned on the facial surface of teeth and seated under force. Before curing, the brackets were pressed on the tooth and the excess resin flash around the base was removed with a dental explorer. Light was then applied for 10 seconds on each of the proximal sides of the bracket to cure the adhesive using halogen bulb light curing unit.

The brackets were debonded using tweezers to either the mesial or distal tie wings. The brackets were removed within 30 minutes after bonding to simulate the clinical condition at which a newly bonded bracket was tied to the archwire. Following bracket debonding, six different reconditioning methods were applied on the experimental groups to remove the resin layer attached to the bracket base prior to rebonding. The control group was neither bonded initially nor reconditioned.

Group I: Control—new unconditioned brackets.

Group II: Direct flaming—the flame tip of the hydrosolder torch was pointed at the bracket base for 5 seconds during which adhesive starts to ignite and burn out. Then the bracket was quenched immediately at room temperature and dried in an air stream.

Group III: Sandblasting—each bracket base was sandblasted using Microetcher ERC™ (Danville Engineering Inc, San Ramo) (alumina particles 50 µm) for 15 to 20 seconds at a distance of 10 mm under 9 bars of line pressure until all visible bonding agent is removed.

Group IV: Modified BigJane machine method—the brackets were heated in a furnace preset at the temperature of 450°C for 60 minutes. Immediately after heating the brackets were quenched at room temperature water. This was followed by the ultrasonic cleaning for 15 minutes then rinsed and dried. This was followed by electropolishing by using electropolishing unit.

Group V: Direct flaming followed by sandblasting.

Group VI: Flaming followed by electropolishing.

Group VII: Buchman method—brackets were heated in reducing zone of Bunsen burner flame for 5 to 10 seconds until the bonding agent started to ignite and burn, then was quenched in water at room temperature. Then each bracket is subjected to sandblasting, for 5 seconds followed by electropolishing.

After the brackets have been reconditioned, measurements were done to know the possible changes in bracket dimension. The bracket slot width, interwing gap and bracket slot depth of the control and experimental groups were measured using photomicroscope at magnification of ×10. A graduated eyepiece was used together with a micrometer attached to the microscope stage which permitted direct linear measurements to be taken.

The measurement of bracket base was done using digital Vernier caliper. For each variable, two readings were taken and average of two was done. The average surface area of the bracket base was determined to be 10.9 mm². Three representative brackets from each group were examined under stereomicroscope at ×10 magnifications.

Control and experimental brackets were bonded to the same teeth (Figs 1 and 2) as described.^{19,20} For rebonding, the residual composite resin on all the teeth was removed from the enamel using carbide finishing bur in a high-speed dental handpiece.



Fig. 1: Group I: New and unconditioned brackets bonded for the first time



Fig. 2: Groups II to VII: Reconditioned brackets were rebonded on the same teeth

The specimens were then stored in distilled water until bond strength was evaluated.

After 24 hours, both control and experimental groups were tested for bond strength using universal testing machine. An occlusogingival load at 0.5 mm/minute crosshead speed was applied at the bracket adhesive interface (Fig. 3) and shear/peel stress was recorded in megapascals (MPa).

STATISTICAL ANALYSIS

Descriptive data that included arithmetic mean, standard deviation values, were calculated for each variable as well as

for each group and were used for analysis. Shear bond strength, interwing gap, slot width and slot depth variables were tested among the groups using ANOVA followed by post-hoc Tukey’s HSD test using SPSS version 14. The cut-off level for statistical significance was taken at < 0.05.

RESULTS

The mean shear bond strength for the new brackets was 28.48 ± 8.24 MPa (Table 1). The experimental groups showed a significant difference (p < 0.001) in the shear bond strength.



Fig. 3: Bond strength was tested using Instron Universal Testing Machine (Instron model 3366)

Post-hoc analysis shows that the mean bond strength of the group of brackets, prepared by flaming, followed by electropolishing (Group VI), is significantly different from all the other groups. Mean shear bond strength of flaming and sandblasting group (Group V) was highest in the experimental group.

Overall comparison of the mean slot depth among the various methods tested showed a significant difference (Table 2,

$p < 0.010$). The least changes in the slot depth were seen in the sandblasting group alone (Group III). Post-hoc analysis showed that the BigJane (Group IV) group showed significantly lower slot depth when compared to the control and sandblasting groups.

There was a significant difference in slot width measurements between the groups ($p < 0.001$). Modified BigJane (Group IV) showed significantly highest mean slot width changes among the six groups (Table 3).

No significant differences were found between the mean interwiring gap values among the groups (Table 4).

Examination of the bases with stereomicroscope revealed that the control brackets had a smooth base with a multistranded wire structure and clean retentive areas in between the wire strands (Fig. 4). Group II brackets had most of their retentive areas filled with the adhesives (Fig. 5). In Group IV in majority of samples, the wire mesh were disrupted. The retentive areas are larger in size than that of controls indicating loss of metal during electropolishing (Fig. 6). In Group V, bracket base had clean retentive areas and intact wire mesh (Fig. 7). In Group VI, bases were filled with adhesive and had marked disruption of multistranded framework (Fig. 8). None of the Buchman group brackets had any adhesive remnants when viewed. The bases were intact and had clean retentive areas (Figs 9 to 12).

DISCUSSION

The experimental groups showed significant reduction in the shear bond strength. The possibility of incomplete adhesive removal, direct loss of material from the bracket surface during

Table 1: Mean shear bond strength (MPa) (ANOVA with post-hoc Tukey's test)

Parameter	Groups	N	Mean	SD	p-value	Post-hoc test
Shear bond strength	Control (I)	15	28.48	8.24	< 0.001	1 > 2 (< 0.001)
	Flaming group (II)	15	14.30	3.25		1 > 4 (< 0.001)
	Sandblasting group (III)	15	22.64	5.44		1 > 6 (< 0.001)
	Modified BigJane (IV)	15	16.39	5.20		1 > 7 (0.013)
	Flaming and sandblasting group (V)	15	26.94	6.35		3 > 2 (0.001)
	Flaming and polisher group (VI)	15	12.58	2.41		3 > 4 (0.027)
	Buchman method (VII)	15	21.73	4.01		3 > 6 (< 0.001)
					5 > 2 (< 0.001)	
					5 > 4 (< 0.001)	
					5 > 6 (< 0.001)	
					7 > 2 (0.004)	
					7 > 6 (< 0.001)	

Table 2: Mean slot depth (in mm) (ANOVA with post-hoc Tukey's test)

Parameter	Groups	N	Mean	SD	p-value	Post-hoc test
Slot depth	Control (I)	15	0.70	0.03	<0.010	1 > 4 (0.015)
	Flaming group (II)	15	0.68	0.03		3 > 4 (0.021)
	Sandblasting group (III)	15	0.70	0.03		
	Modified BigJane (IV)	15	0.66	0.03		
	Flaming and sandblasting group (V)	15	0.68	0.03		
	Flaming and polisher group (VI)	15	0.67	0.03		
	Buchman method (VII)	15	0.68	0.03		

p-value: Statistical significance < 0.050

Table 3: Mean slot width (in mm) (ANOVA with post-hoc Tukey's test)

Parameter	Groups	N	Mean	SD	p-value	Post-hoc test
Slot width	Control (I)	15	0.61	0.03	< 0.001	4 > 1 (< 0.001)
	Flaming group (II)	15	0.63	0.02		4 > 2 (0.024)
	Sandblasting group (III)	15	0.61	0.02		4 > 3 (< 0.001)
	Modified BigJane (IV)	15	0.65	0.01		4 > 5 (0.012)
	Flaming and sandblasting group (V)	15	0.62	0.02		6 > 1 (0.001)
	Flaming and polisher group (VI)	15	0.65	0.02		6 > 3 (< 0.001)
	Buchman method (VII)	15	0.65	0.02		7 > 1 (0.001) 7 > 3 (< 0.001)

Table 4: Mean interwing gap (in mm) (ANOVA with post-hoc Tukey's test)

Parameter	Groups	N	Mean	SD	p-value	Post-hoc test
Interwing gap	Control (I)	15	1.76	0.13	0.442	—
	Flaming group (II)	15	1.85	0.11		
	Sandblasting group (III)	15	1.82	0.09		
	Modified BigJane (IV)	15	1.82	0.12		
	Flaming and sandblasting group (V)	15	1.83	0.09		
	Flaming and polisher group (VI)	15	1.82	0.11		
	Buchman method (VII)	15	1.81	0.10		

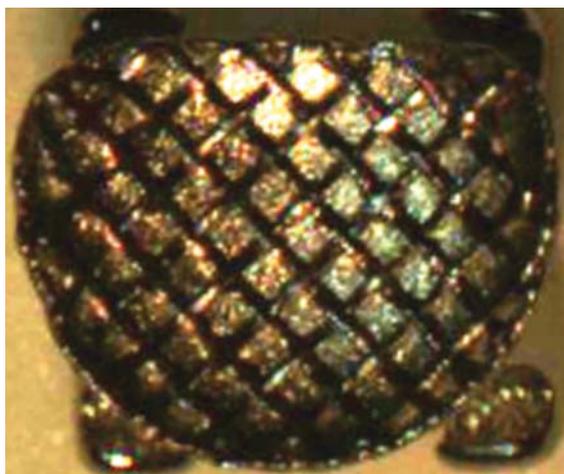


Fig. 4: Group I: Bracket base appearance with intact multi-stranded structure and clean retentive areas

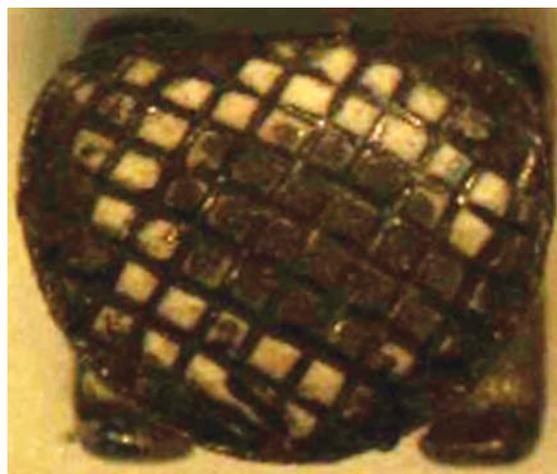


Fig. 5: Group II: Bracket base appearance after flaming showing adhesive filled undercuts and slight discontinuity in the strands' network

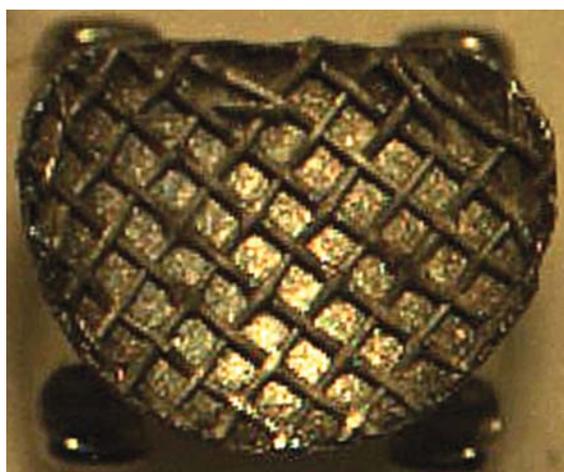


Fig. 6: Group IV: Bracket base appearance after reconditioning appeared very similar to controls with clean retentive areas; however, in majority of samples, the wiremesh were disrupted. The retentive areas are larger in size than that of controls indicating loss of metal during electropolishing

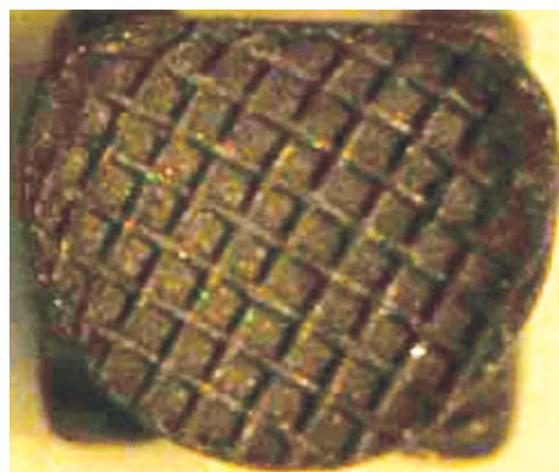


Fig. 7: Group V: Bracket base appearance after reconditioning appeared very similar to controls with clean retentive areas and intact wiremesh

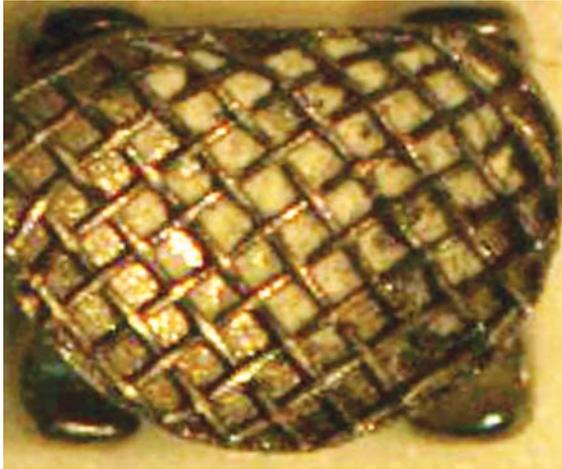


Fig. 8: Group VI: Some of brackets were similar to the controls, while others were filled with adhesive and all had marked disruption of multistranded framework

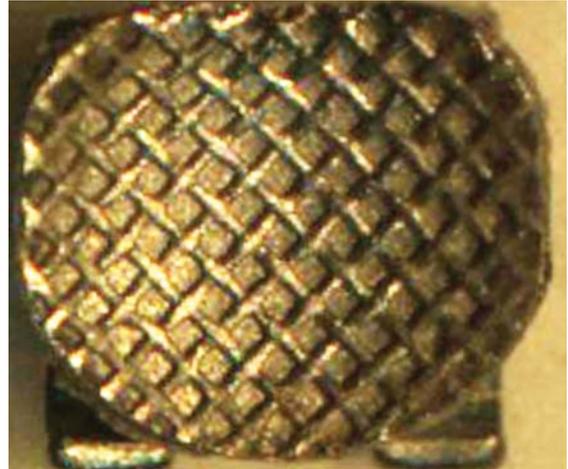


Fig. 9: Group VII: None of the Buchman group brackets had any adhesive remnants when viewed. The bases were intact and had clean retentive areas

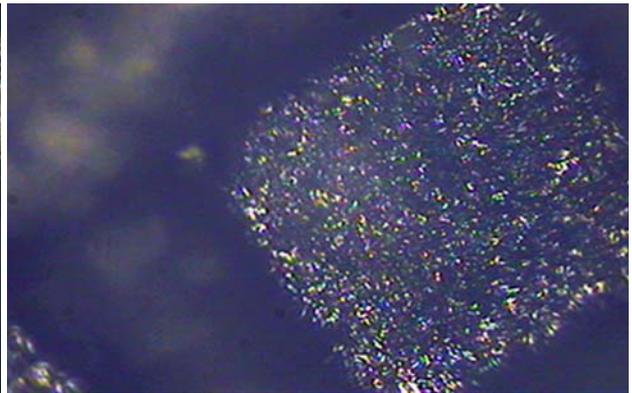
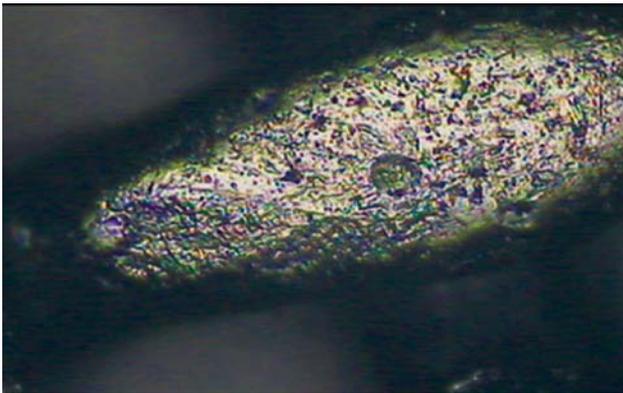


Fig. 10: Group I: Bracket base appearance of control samples before recycling shows smooth wiremesh and retentive areas. Note the lack of roughness

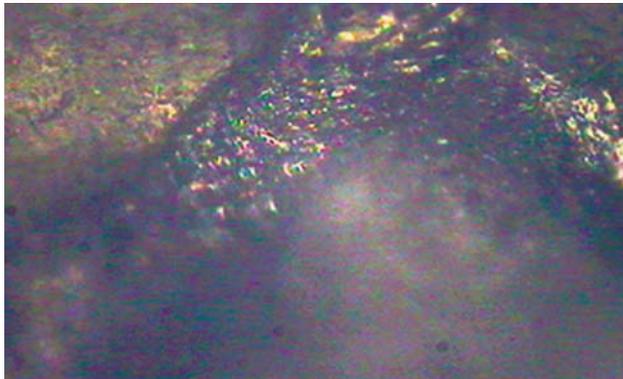
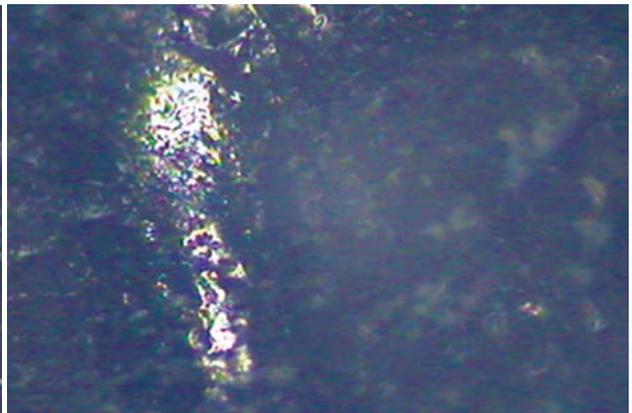
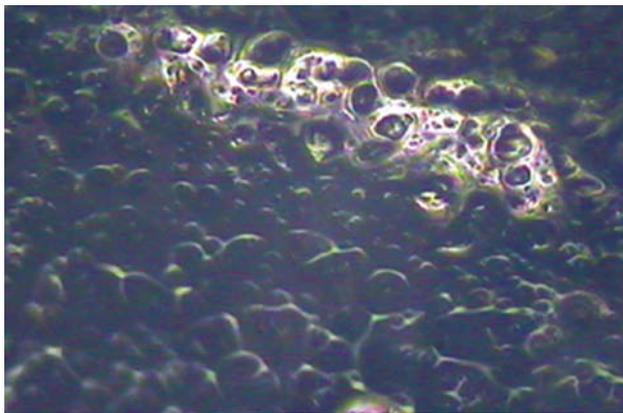


Fig. 11: Group III: Bracket base appearance after sandblasting shows roughened mesh similar to an etch pattern thereby increasing the surface area

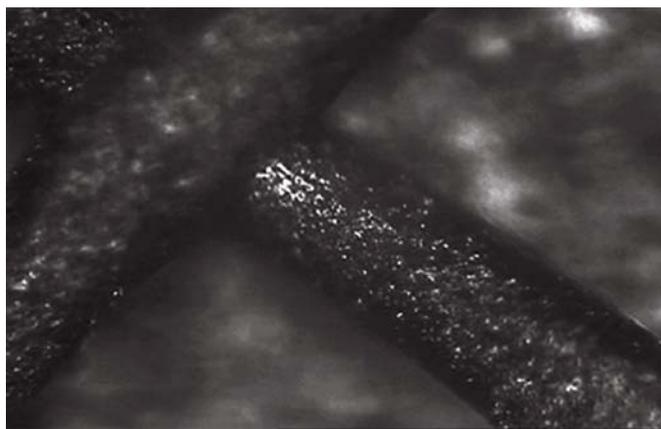


Fig. 12: Group IV: Mesh strand appears thinner and smoother than control samples

recycling and electropolishing procedures, which could reduce the size and effectiveness of the retentive elements of the base, thereby affecting the bond strength of the bracket, could attribute for the reduction of the bond strength.^{7,9,16} The reduction in shear bond strength of the experimental groups, in this study, seems to confirm the findings of various studies.^{5,9,10} However, the values of this study do not correlate with that of other studies reported in the literature. This could be attributed to type of bracket, the adhesive used and the variations in the standardization of procedures.

Lower bond strengths were seen in groups where reconditioning was done by flaming. It was probably because of the incomplete removal of the adhesive (indicating that flaming for 5 seconds was insufficient to combust all the composite), as most of the brackets in Group II, VI, when viewed in stereomicroscopy, had their retentive areas filled with adhesive resin. Electropolishing may affect brackets with an undercut base by opening up the retentive undercuts and smoothing the base, leading to a decrease in retention.

The findings of this study show comparable shear bond strengths between new brackets and failed brackets that were subsequently air abraded. This is in correlation with findings of other studies.^{4,13,18,19} Air abrasion removes residual bonding material from the failed bracket base (resulting in a roughened and irregular surface of the mesh); thinning the oxide layer of stainless steel and it has been suggested as a way of improving the bond at the bracket base. This probably results in increased mechanical retention of the previously failed bracket.²⁰ The findings of this study differ from those of Regan et al,⁵ who found that debonded, cleaned, photoetched brackets had significantly lower bond strengths compared with new brackets when bonded to previously bonded teeth. The microetcher did not remove all the resin attached to the bonding pads, but the retained resin did not appear to significantly affect bond strength.

The disadvantage of burning off the composite is that the bracket discolors, unless it is electropolished afterwards. Furthermore, the metal is softened by the heating process; also, it influences the microstructure of brackets and is more vulnerable to masticatory damage.^{18,19,21} If temperature is

maintained above 400°C, a chromium carbide precipitate is formed and as a result, a partial disintegration of alloy occurs, leading to general weakening of the bracket.¹⁰ Electropolishing may affect brackets with an undercut base by opening up the retentive undercuts and smoothing the base, leading to a decrease in retention.

Reynolds¹⁷ reported (1) the average biting force to be 70 kg with a 10 to 100 kg range (2); the average force transmitted to the bracket during mastication is about 4.5 to 12 kg. This translates into a need of no more than 0.6 to 0.80 kg/mm² of tensile bond strength.²² Hence, if we correlate the shear strength values of the recycled brackets of this study with the above mentioned contemporary orthodontic force prescription, then, the use of this single microetching method, without compromising on the retention or mechanical precision will be adequate enough to resist the forces exerted during the entire orthodontic treatment procedures.

The mean slot width of new brackets is 0.6131 mm (~0.61 mm) which exceeds the manufacturer reported nominal size 0.022 inches (0.5688 mm) and mean depth of new brackets is 0.6976 mm (~0.70 mm) shows decreased value to manufacturer reported nominal value (0.7112 mm). The orthodontic brackets are made in large batches either manually or automatically using machines.²³

There was a significant difference in slot width measurements between the groups ($p < 0.001$). Modified BigJane (Group IV) showed significantly higher mean slot width than other groups.

There are two conflicting views in the literature, one group reported, significant change in bracket dimensions,²⁴ while the other group claimed slight change in the bracket dimensions, which may be statistically significant but clinically insignificant.^{7,10,15}

Our results showed an increase in slot width of 40 μ m, when BigJane method was used; similar to findings of Postlethwaite⁸ who claimed that approximately 50 μ m of metal was removed from the bracket. Jones²⁴ used commercial reconditioning company reported that after first recycling; width increased by 20.7 μ m which was statistically significant. Most of the studies show changes in the slot dimension after the first recycling cycle.^{7,15}

No significant changes were noted for interwing gap measurements between the experimental groups and the control group, though Groups II and IV showed higher values than other groups. This is in contrast to the finding of Basudan⁷ et al, who reported significant change for the Buchmann group; although it was clinically insignificant.

Comparison of the mean slot depth among the various methods tested showed a significant difference. The least changes in the slot depth were seen in the sandblasting group alone. This is in accordance with many studies.^{7,24} The possible explanation for decrease in the slot depth is that, during electropolishing, maximum metal loss occurred from the surfaces and protuberances and thus slot will be last part to alter.^{18,19,23}

Jones²⁴ reported decrease in slot depth by 0.0317 mm (31.7 μm) after first recycling of the brackets using chemical solvent. However, the present study shows a greater reduction in slot depth (120 μm). This could be due to different methods of reconditioning employed which primarily involve use of heat.²³

Widening of the insertion area of the slot not only reduces the depth but also increases friction. When the elastomeric modules are used, the widening of the slot's insertion area drags the module into the gap between the bracket and archwire, generating friction and tearing the module. This makes it difficult to correlate friction with the bracket design, causing random jumps instead of predictable curves.²³

The sandblasted brackets showed roughened meshwire framework that probably increased the rebond strength and gave values comparable to the control samples. The time taken to sandblast the flamed mesh is shorter than other methods.

CONCLUSION

1. Shear bond strength of new direct bonding brackets is greater than that obtained after reconditioning.
2. Debonded brackets cleaned of resin by microetching had shear bond strengths comparable to new brackets when bonded to previously bonded teeth.
3. Buchman and modified BigJane reconditioning methods are time consuming and have most deleterious effects on the bracket without any added benefit of increase in bond strength.
4. Considerable damage to the multistranded structure of the bracket base was seen when heat or electropolishing method were used.

Sandblasting for a period of 15 seconds using 50 μm aluminum oxide granules at a pressure of approximately 9 bars was adequate to remove the residual composite without compromising bond strength. This study suggests sandblasting as the simplest, most efficient manner of immediately recycling debonded brackets.

REFERENCES

1. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J Dent Res* 1955;34:849-53.
2. Newman GV. Epoxy adhesives for orthodontic attachments: Progress report. *Am J Orthod* 1965;51:901-12.
3. Valiathan Ashima, Pal SN, Kallyana Krishnan Miramohanty, Lal AV, Rathimam K, Jayabalan. Development and evaluation of BIS-GMA based composite dental restorative material. *J Ind Orthod Soc* 1992;23:1-9.
4. Agarwal Sachin, Valiathan Ashima. The effect of sandblasting on the retention of metallic brackets bonded with resin modified glass ionomer cement. An in vitro study. Thesis submitted to Manipal University 2009.
5. Regan R, LeMasney B, Noort VA. The tensile bond strength of new and rebounded stainless steel orthodontic brackets. *Euro J Orthod* 1993;15:125-35.
6. Mascia VE, Chen SR. Shearing strength of recycled direct bonding brackets. *Am J Orthod Dentofacial Orthop* 1982;82:211-16.
7. Basudan AM, AL-Emran SE. The effect of In-office reconditioning on the morphology of slots and bases of stainless steel brackets and on the shear/peel-bond strength. *J Orthod* 2001;28:231-33.
8. Postlethwaite KM. Recycling band and brackets. *Br J Orthod* 1992;19:157-63.
9. Wheeler JJ, Ackerman RJ. Bond strength of thermally recycled metal brackets. *Am J Orthod* 1982;83:181-86.
10. Buchman DJ. Effects of recycling on metallic direct bond strength orthodontics brackets. *Am J Orthod Dentofacial Orthop* 1980;77:654-68.
11. Smith NR, Reynold IR. A comparison of three bracket bases: An in vitro study. *Br J Orthod* 1991;18:29-35.62.
12. Smith WA, Rock WP. Bracket recycling—who does what? *Br J Orthod* 1997;24:192-73.
13. Sonis. Air abrasion of failed bonded metal brackets: A study of shear bond strength and surface characteristics as determined by scanning electron microscopy. *Am J Orthod Dentofacial Orthop* 1996;110:96-98.
14. McColl GA, Regan D, O'Keeffe, Van Noort R. The effects of recycling on tensile bond strength of new and clinically used stainless steel orthodontic brackets: An in-vitro study. *Br J Orthod* 1990;17:137-45.
15. Hixson ME, Brantley WA, Pincsak JJ, Conover JP. Changes in bracket slot tolerance following recycling of direct-bond metallic orthodontic appliances. *Am J Orthod Dentofacial Orthop* 1982;81:447-54.
16. Matasa CG. Pros and cons of re-use of direct-bonded appliances. *Am J Orthod Dentofacial Orthop* 1989;96:72-76.
17. Reynolds JR. A review of direct orthodontic bonding. *Br J Orthod* 1975;2:171-80.
18. MacColl GA, Rossouw PE, Titley KC, Yamin C. The relationship between bond strength and orthodontic bracket base surface area with conventional and microetched foil-mesh bases. *Am J Orthod Dentofacial Orthop* 1998;113:276-81.
19. Grabouski James K, Staley Robert N, Jakobsen Jane R. The effect of microetching on the bond strength of metal brackets when bonded to previously bonded teeth: An in vitro study. *Am J Orthod Dentofacial Orthop* 1998;113:452-60.
20. Mui B, Rossouw PE, Kulkarni GV. Optimization of a procedure for rebonding dislodged orthodontic brackets. *Angle Orthod* 1999;69:276-81.
21. Quick AN, Harris AMP, Joseph VP. Office reconditioning of stainless steel orthodontic attachments. *Eur J Orthod* 2005;27:231-36.
22. Sharma-Sayal SK, Rossouw PE, Kulkarni GV, Titley KC. The influence of orthodontic bracket base design on shear bond strength. *Am J Orthod Dentofacial Orthop* 2003;124:74-82.
23. Claude G Matasa. Orthodontic recycling at the crossroads. *J Clin Orthod* 2003;133-39.
24. Jones SP, Davies EH. The effect of reconditioning on the slot dimension and static friction resistance of stainless steel brackets. *Eur J Orthod* 2002;24:183-90.