Original Article

Optimization of a procedure for rebonding dislodged orthodontic brackets

B. Mui, BSc, DDS; P.E. Rossouw, BSc, BChD, BChD(hons), MChD, PhD;
G.V. Kulkarni, BDS, LLB, MSc, Dip Paedo, PhD

Abstract: The purpose of this study was to compare shear bond strength (SBS) of bonded and rebonded orthodontic brackets following a variety of commonly used conditioning treatments and using both light-cured and self-cured composite resin systems. Brackets debonded during the initial determination of SBS were rebonded after the removal of residual resin from enamel surfaces using five different treatments: (1) Remove residual resin using a tungsten carbide bur, re-etch enamel surface, then bond a new bracket; (2) Remove resin from the base mesh with micro-etching then rebond the same bracket, (3) Remove residual resin from the enamel surface using resin-removing pliers, recondition the enamel with an air-powder polisher, then bond a new bracket; (4) Remove residual resin using a rubber cup and pumice, then bond a new bracket; (5) Remove residual resin using pliers alone, then bond a new bracket. The results revealed that the light-cured system produced higher shear bond strength in the initial bond than the self-cured system ($p<0.005$). Reconditioning the enamel surfaces using a tungsten carbide bur and acid-etching gave the highest SBS (difference 5.8 MPa; $p<0.01$) and clinically favorable fracture characteristics. The data suggest that the optimal procedure for rebonding dislodged orthodontic brackets is to resurface the enamel using a tungsten carbide bur, acid-etch the enamel, and use a new or re-use an old bracket after microetching.

Key Words: Shear bond strength, Rebond strength, Reconditioning, Self-cured, Light-cured

Accidental dislodgment of an orthodontic bracket due to occlusal trauma or intentional removal of a bracket in order to reposition it to achieve ideal occlusal goals are common occurrences in orthodontic treatment. Before rebonding an orthodontic bracket, the following elements should be considered: reconditioning of the enamel surfaces, the use of new brackets or the original brackets, and the bonding system to be used. The bond strength of a rebonded bracket (rebond strength, RBS) has been reported to exceed the minimum force requirement of 6 to 8 MPa.[1-4] However, there is no consensus on how rebond strength compares with original bond strength. Some authors have reported that rebond strength is lower,[2,5] while others have reported that it is either comparable to[1,3] or greater [6,7] than that of the original bond. The differences can be attributed to differences among bonding systems and bracket types used[8] or the method of reconditioning of enamel surface and bracket base.

Failure type is of clinical importance. When the fracture occurs mainly at the resin-enamel (R/E) interface, it allows for easy removal of excess resin. This is preferable from the practitioner's standpoint, as the optimum bonding system is one that results in sufficient bond strength to retain the bracket during active orthodontic tooth movement while allowing speedy removal of brackets and complete removal of residual resin from tooth surfaces at the end of treatment.

The objectives of the present study were: (1) to investigate the effect of different reconditioning techniques on shear bond strength (SBS), (2) to compare SBS of light-cured and self-cured systems that both use enamel sealants, (3) to examine the effect of different types of bonding systems and reconditioning methods on fracture sites, and (4) to describe a procedure that results in optimum SBS and fracture characteristics.

Materials and methods

SBS and RBS of light-cured and self-cured bonding systems were com-

Author Address
Dr. P.E. Rossouw
Department of Orthodontics
124 Edward Street
Faculty of Dentistry
University of Toronto
Toronto, Canada M5G 1G6
B. Mui, Department of Orthodontics, University of Toronto.
P.E. Rossouw, head, Department of Orthodontics, University of Toronto.
G.V. Kulkarni, Department of Paediatric Dentistry, University of Toronto.
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pared using new and debonded brackets. One hundred four bovine teeth were embedded in acrylic blocks with only the labial surface exposed. The specimens were randomly divided into two sets of 52 teeth for light-cured and self-cured resin bonding. Various enamel surface preparations were included, and the experimental groups were tested according to the methodology described in Figure 1.

Initial bond (group 0)
Light-cured resin

The enamel was etched with 37% orthophosphoric acid for 60 seconds and rinsed with water for 30 seconds. A thin layer of light-cured sealant (3M Unitek Transbond XT, Monrovia, Calif) was applied to the etched enamel surface and light-cured for 10 seconds. Metal orthodontic brackets (American Orthodontics, Sheboygan, Wisc) were then bonded onto the treated enamel surfaces with the light-cured composite. A standard force was used to secure the bracket on each tooth, using a method described by MacColl.[9] This process ensured a constant thickness of the composite layer. The composite was light-cured for 40 seconds (10 seconds on each side of the bracket). All samples were stored in distilled water at 37°C for 7 days before testing to failure in an Universal Testing Machine (Instron 4301, Instron Corp, Canton, Mass) at a crosshead speed of 1 mm/min.

Self-cured resin

Teeth were prepared as described above, but bonding was completed using an autopolymerizing sealant and resin (Concise 3M Dental Products Division, St. Paul, Minn).

Rebond (subgroups 1 to 6)

After debonding with the Universal Testing Machine, the teeth and brackets were further divided into six subgroups for different reconditioning treatments as described in Figure 1.

While samples were randomly assigned into the six subgroups, those

Teeth polished and acid-etched
(n=104)

Light-cured	Debond	Self-cured
Group 0 (n=52)		Group 0 (n=52)
Subgroup 1 (n=8)	Controls: Enamel reconditioned with tungsten carbide bur (#7901, Beavers Dental, Ontario), cleaned with rubber cup and pumice, and acid-etched as in initial bond. Rebonded with new brackets.	Subgroup 1 (n=8)
Subgroup 2 (n=8)	Enamel reconditioned as in control group. B/R fractured brackets reconditioned with micro-etching (sandblasting; MicroEtcher, Danville Engineering, Inc, Danville, Calif).	Subgroup 2 (n=8)
Subgroup 3 (n=8)	Enamel reconditioned with composite-removing pliers and air-powder polisher (Dentsply/York Division, York). Rebonded with new brackets as in control group.	Subgroup 3 (n=8)
Subgroup 4 (n=8)	Enamel reconditioned with composite removing pliers alone. Rebonded with new brackets as in control group.	Subgroup 4 (n=8)
Subgroup 5 (n=8)	Enamel reconditioned with composite removing pliers and polished with prophy cup and pumice. Rebonded with new brackets as in control group.	Subgroup 5 (n=8)
Subgroup 6 (n=4)	Enamel reconditioned as in control group. R/E fractured brackets reconditioned with micro-etching	Subgroup 6 (n=8)

Figure 1
Distribution of samples reflecting enamel and bracket conditioning methods

Table 1
Bond strength (MPa) under various conditions

	mean SBS	SD	mean RBS	SD
Light-cured group				
Group 0 (n=52)	16.21	4.63		
Subgroup 1 (n=8)	15.39	4.47	17.28	4.55
Subgroup 2 (n=8)	15.82	3.49	17.15	5.29
Subgroup 3 (n=8)	15.37	4.52	9.23	3.74
Subgroup 4 (n=8)	14.98	5.55	5.07	3.05
Subgroup 5 (n=8)	15.22	4.30	11.40	4.51
Subgroup 6 (n=4)	20.52	2.32	18.24	5.64
Self-cured group				
Group 0 (n=52)	13.50	3.88		
Subgroup 1 (n=8)	13.79	3.78	18.73	4.97
Subgroup 2 (n=8)	15.78	4.74	21.75	6.27
Subgroup 3 (n=8)	14.19	1.84	12.32	4.18
Subgroup 4 (n=8)	13.73	3.98	6.70	4.54
Subgroup 5 (n=8)	14.31	3.42	11.53	3.59
Subgroup 6 (n=8)	11.33	2.13	18.22	6.27

in subgroups 2 and 6 were also selected according to the fracture site location as follows:

Subgroup 1—control group: The enamel was reconditioned using a tungsten carbide bur (#7901, Beavers Dental, Ontario, Canada), cleaned with rubber cup and pumice, and acid-etched as in initial bond. Rebonding was completed using new brackets.

Subgroup 2—experimental group: The enamel was reconditioned as in the control group and rebonding completed with brackets that failed at the bracket-resin (B/R) interface. Before rebonding, brackets were reconditioned with microetching (sandblasting) (MicroEtcher, Danville Engineering, Inc, Danville, Calif).

Subgroup 3—experimental group: The enamel was reconditioned using composite-removing pliers and air-powder polisher (Dentsply/Equipment Division, New York). The enamel was not etched and rebonding was completed using new brackets.

Subgroup 4—experimental group: The enamel was reconditioned with composite-removing pliers alone; no enamel etching was performed. Rebonding was completed with new brackets.

Subgroup 5—experimental group: The enamel was reconditioned with composite-removing pliers then polished with a prophy-cup and pumice. The enamel surface was not etched and rebonding was completed with new brackets.

Subgroup 6—experimental group: The enamel was reconditioned as in the control group. Rebonding was completed with brackets that failed at the resin-enamel (R/E) interface. Before rebonding, brackets were reconditioned with microetching, as in group 2.

All samples were examined under a low-power microscope to determine the amount of resin left on the enamel surface. The adhesive remnant index (ARI)[10] was used to determine the nature of bond failure (see definition). In addition, in selected samples, tooth surface conditioning immediately prior to bonding and rebonding and immediately after debonding was viewed using scanning electron microscopy (SEM).

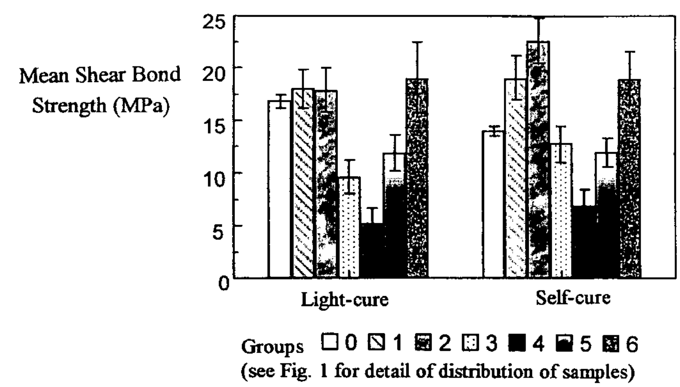

Figure 2
Comparison of mean shear bond strength (MPa) among different groups tested

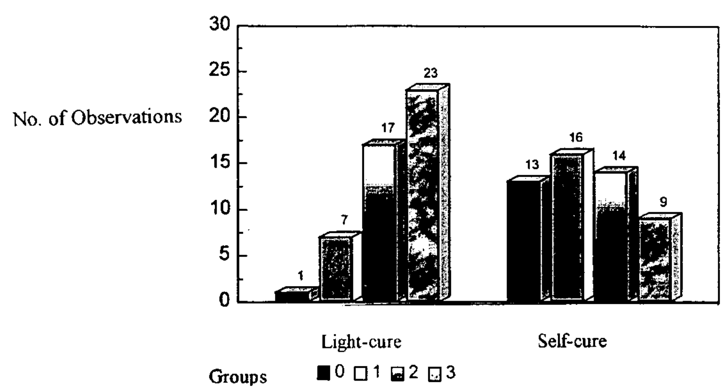

Figure 3
Distribution of bond fracture sites. Note predominance of bracket/resin fracture in light-cured group compared with even distribution over four ARI scores in self-cured group

Definition of grading of ARI

ARI scores were assigned according to the following criteria.

0—No resin left on tooth surface, implying that bond fracture occurred purely at the resin/enamel interface

1—Less than half the resin left on tooth, implying that bond fracture occurred predominantly at the resin/enamel interface

2—More than half the resin left on tooth, implying that bond fracture occurred predominantly at the bracket/resin interface

3—All resin left on tooth, with a distinct impression of the bracket, implying that bond fracture occurred purely at the bracket/resin interface

Statistical analysis

The SBS measurements were analyzed using a two-way ANOVA with group and bond as the two factors and group × bond as the interaction term. Multiple pairwise comparisons were performed using Duncan's multiple range test (SAS 6.04, Cary, NC; significance level was set at 5%). Differences in site of failure were assessed using Chi-square tests.

Results

Mean and standard deviations for initial (SBS) and rebond (RBS) for

Table 2
Pairwise comparisons of mean bond strengths under different conditions

		LSMean number
Light	Group 0	1
	Subgroup 1	2
	Subgroup 2	3
	Subgroup 3	4
	Subgroup 4	5
	Subgroup 5	6
	Subgroup 6	7
Self	Group 0	8
	Subgroup 1	9
	Subgroup 2	10
	Subgroup 3	11
	Subgroup 4	12
	Subgroup 5	13
	Subgroup 6	14

Pr> ITI HO: LSMean (i)= LSMean(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-	0.552	0.603	1E-04	1E-04	0.009	0.408	0.004	0.255	0.002	0.031	1E-04	0.01	0.264
2		-	0.955	8E-04	1E-04	0.015	0.74	0.036	0.679	0.061	0.037	1E-04	0.016	0.69
3			-	0.001	1E-04	0.017	0.705	0.043	0.639	0.054	0.042	1E-04	0.018	0.649
4				-	0.09	0.347	0.002	0.018	2E-04	1E-04	0.193	0.285	0.331	2E-04
5					-	0.01	1E-04	1E-04	1E-04	1E-04	0.003	0.504	0.009	1E-04
6						-	0.02	0.257	0.005	1E-04	0.717	0.045	0.098	0.005
7							-	0.054	0.996	0.23	0.042	1E-04	0.021	0.995
8								-	0.009	1E-04	0.511	2E-04	0.275	0.009
9									-	0.144	0.013	1E-04	0.005	0.988
10										-	1E-04	1E-04	1E-04	0.14
11											-	0.018	0.74	0.013
12												-	0.042	1E-04
13													-	0.005
14														-

various groups and subgroups within the light- and self-cured resin groups are shown in Table 1. Comparisons of mean SBS for the six subgroups within each of the light- and self-cured resin groups prior to rebonding yielded no significant differences, validating the random assignment procedure. Pairwise comparisons of the mean bond strengths measured under the different conditions are shown in Table 2.

Initial bond (Table 1, Figures 2 and 3)

Mean SBS of the light-cured system was significantly higher compared with that obtained using a self-cured system (group 0 of light-cured vs. group 0 of self-cured: difference=2.7 MPa or 20%; $p<0.01$; Table 2 and Figure 2).

Initial bond failure occurred mainly at the bracket/resin interface (ARI 2 and 3) in 83% of the samples in the light-cured system and in 44% of the sample in the self-cured system ($p<0.01$, Figure 3).

Four enamel fractures were found among the light-cured samples, but none occurred in the self-cured group.

Rebond (Table 2, Figure 2)

The RBS of both light-cured and self-cured systems was significantly higher when enamel surfaces were cleaned with tungsten carbide rotary instruments and acid-etched prior to rebonding (subgroup 1 vs. subgroups 3, 4, and 5: difference>5.4 MPa; $p<0.01$) when compared with enamel surfaces that were reconditioned with less aggressive reconditioning methods.

Higher RBS compared with initial SBS was achieved using the self-cured system. This observation was true only when enamel reconditioning methods described for subgroup 1 were used. However, this was valid whether new brackets or reconditioned brackets were used and whether the initial fracture occurred at the B/R or R/E interface (subgroups 1, 2, and 6 vs. subgroup 0 of self-cured: difference>4.7 MPa; $p<0.01$).

In contrast, no significant difference between initial SBS and RBS (group 0 vs. groups 1, 2, and 6 of light-cured) was shown in the light-cured system under the same reconditioning method.

Microetched brackets provided RBSs either comparable to or higher than those achieved using new brackets (subgroups 2 and 6 vs. subgroup 1).

The RBSs of light-cured and self-cured systems using new brackets were not significantly different com-

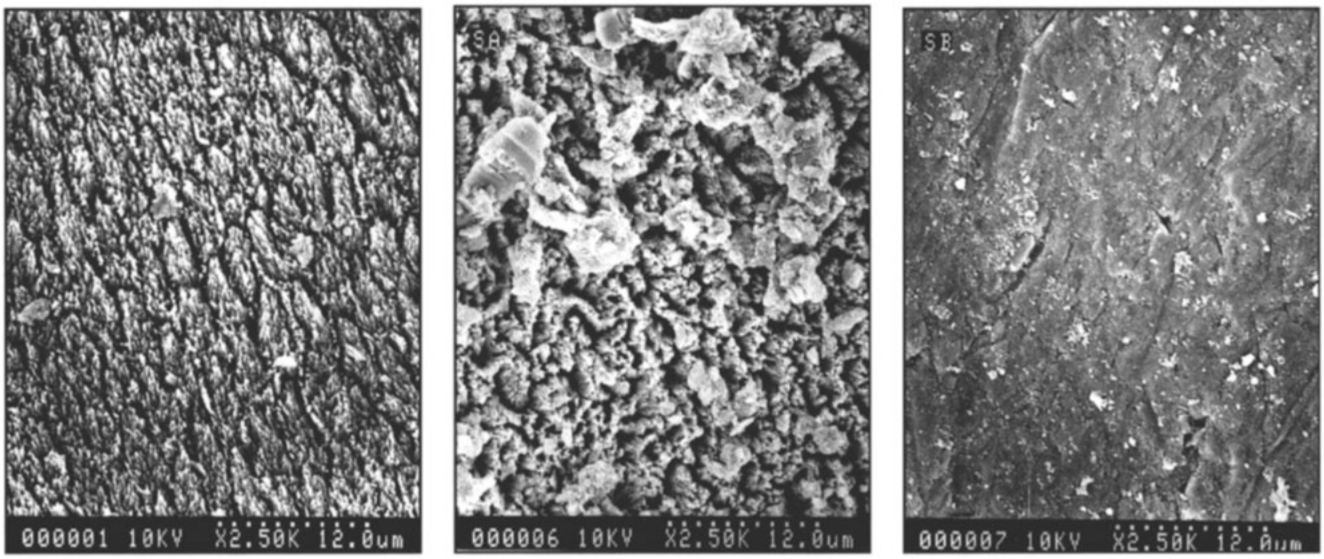

Figure 4A
Figure 4B
Figure 4C

Figure 4
A: Topographical view of etched enamel prepared for initial bonding. B: Reconditioned enamel prepared with tungsten carbide bur and acid etching. C: Reconditioned tooth surface prepared with other, less aggressive methods. These methods failed to remove composite from the enamel.

pared with those of reconditioned brackets (subgroup 1 vs. subgroups 2 and 6, both light- and self-cured; $p>0.01$).

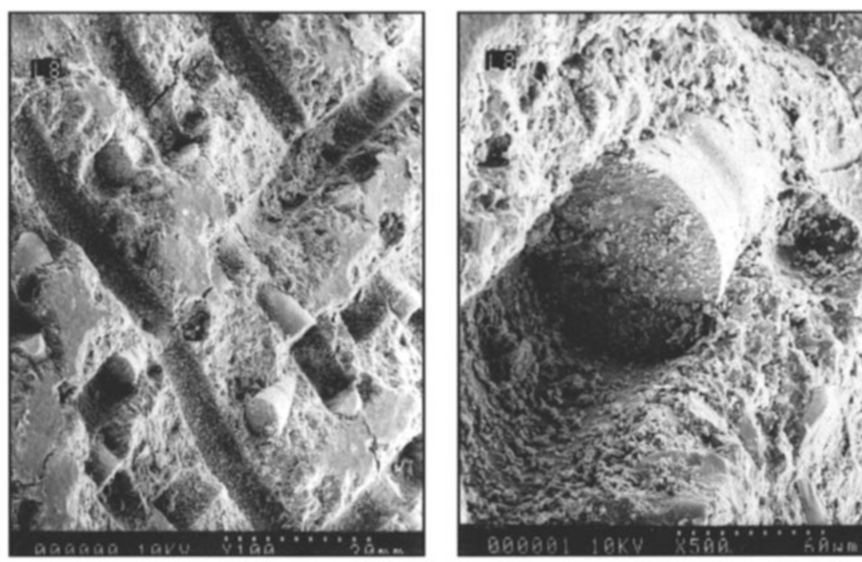

Figure 5A
Figure 5B

Figure 5
A: Topographical view (100x) of the resin surface after debonding. B: Higher power view (500X) of the same sample. Note the metal fragment locked in the resin.

Discussion

Reconditioning the enamel using a tungsten carbide bur followed by acid-etching not only provided RBSs comparable to that of the initial SBS values (the light-cured system), but also provided higher RBS values than initial SBS when using the self-cured (autopolymerizing) system. Meanwhile, reconditioning with rotary instruments and acid-etching also resulted in higher RBS compared with reconditioning the enamel using less aggressive methods. It can thus be inferred that repeating the acid-etching procedure on the enamel surface produces the same kind of roughened surface through demineralization as in the initial bonding (Figure 4).[11,12] However, this still failed to explain the increase in SBS when rebonding in the self-cured system. Since SBS increased whether new or reconditioned brackets were used, the reason may lie between the R/E resin interface where, upon rebonding, the reconditioned enamel became even more favorable for a self-cured resin. These data are similar to those of Leas and Hondrum,[7] who found increases in SBS with self-cured no-mix bonding systems on rebonding. Further study of the microscopic configuration of the R/E interface would be required to investigate this phenomena.

In the case of bracket-resin (B/R) fracture in both self- and light-cured systems, metal fragments were found on the resin that remained on the teeth (Figure 5). Mechanical bonding between bracket mesh and resin was sufficient to damage the macroscopic structure of the bracket base, and when R/E-fractured brackets were reconditioned with microetching, there was also a change in their microscopic structure. No significant difference in RBS was achieved using either new or recycled brackets. This indicates that changes in the macroscopic structure caused by the debonding process and changes in the microscopic structure caused by microetching of the bracket base did not detrimentally affect the RBS.

The light-cured system provided higher initial SBS than the self-cured system. This is contrary to the findings of Andreasen et al.,[13] who found that self-cured systems and adequately cured light-cured systems have comparable SBSs. It was recently shown that a new generation light-cured glass ionomer cement also reaches a tensile bond strength equal to that of conventional self-cured resin adhesive systems and is thus suitable for bonding or rebonding orthodontic brackets.[14] Enamel fractures were noted in the latter study. The present study used a new, improved light-cured system that ensured a standardized, controlled curing process compared with the self-cured system. The sealant of the light-cured system was also polymerized by a controlled method, which plays a part in the SBS. It was shown by Joseph et al.[15,16] that self-cured sealants do not seal adequately, and this may explain the difference in the SBS between the two different curing systems. Moreover, the distinctive types of fracture patterns can be explained by the different natures in curing. The site of failure occurred mostly at the B/R interface in the light-cured system and evenly at the R/E and B/R interfaces in the self-cured system. More bond failures occurred at the R/E interface in the self-cured system, which may be an indication of the inhibition of polymerization of the self-cured sealant by oxygen creating a weak link at the bonding site on the enamel surface.[15,16] Furthermore, in four samples in the light-cured group, strong bonds resulted in enamel fracture. The higher SBS of the light-cured systems carries a risk of damaging the enamel during debonding. Orthodontic bonding resin should have a bond strength high enough to sustain the bracket throughout the treatment period, yet allow debonding to occur without damaging enamel. It is imperative to execute the debonding process meticulously.

The best reconditioning method following debonding appears to be: (1) remove residual composite from the enamel surface using a 12-fluted tungsten carbide bur, (2) acid-etch the enamel for 60 seconds using 30% H_3PO_4, and (3) rebond using a self- or light-cured system. Rebonding should be done using new brackets. Moreover, if brackets are to be reused in the same position following debonding (intentional or unintentional) it is recommended that the base be microetched.

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