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Original Research Article

To evaluate the effect of different enamel conditioning procedures on the shear bond strength of new metal bracket on previously debonded tooth surface - An in-vitro study

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ABSTRACT

Objective: To evaluate the efficacy of different enamel conditioning methods while bonding a new bracket on a previously de-bonded site, and assess the difference in shear bond strength and ARI score if any.

Materials and Methods: 125 human-extracted premolars were selected. 250 premolar brackets were procured. 125 brackets were bonded on the buccal surface of the premolars using different enamel conditioning methods (bonding sequence 1) and was followed by debonding using the Instron Universal testing machine (Debonding procedure I).

The remaining 125 brackets were bonded (Bonding sequence II) on the same teeth after the removal of residual adhesive. Bonding sequence II was followed by debonding (Debonding procedure II), shear bond strength calculation, and ARI score calculation.

Results: There was a significant difference in SBS between the 5 groups after initial debonding. SEP group (group 4) showed the highest SBS followed by acid etching groups (groups 3, 2, and 1). The sandblasting group (group 5) had the lowest shear bond strength value. After the second debonding, SBS was found to be highest in Group 3 {37% o-phosphoric acid (Bonding I) sandblasting (Bonding II)} followed by Group 4 {SEP (Bonding I and Bonding II)}, group 2 {acid etching (Bonding I) SEP (Bonding II)}, and group 1 (acid etching in both bonding sequences). Group 5 (sandblasting in both sequences) had the least SBS. Non-significant differences were found in ARI score of the five groups.

Conclusion: Self-etching primer group had highest SBS and sandblasting group had least SBS after first debond. The SBS of new brackets after two debonding procedures significantly decreased but was still found to be above the required bond strength. SEP and sandblasting can be used as a substitute to acid etching technique in second time bonding of brackets as these groups had higher SBS after second debond.

1. Introduction

During orthodontic corrective mechanics, bracket bonding is of great importance in achieving a satisfactory outcome since the desired dental movement depends on it. In routine clinical practice, an Orthodontist frequently encounters debonding of brackets which usually occurs due to many factors such as inappropriate bonding technique or disturbance of bracket during polymerization (cohesive failure), contamination of tooth during bonding, patient applying excessive masticatory forces, increased overbite, increased resin thickness under the bracket, a degradative process in the oral cavity or less frequently, due to archwire engagement and cinching of wire distal to molar tubes. In either case, it may be decided to reuse the same bracket,

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enamel conditioning method, and adhesive for the re-bonding process or bond a new one using different etching and adhesive combinations.[1–3]

Orthodontic literature provides contradictory findings about the shear bond strength of re-bonded attachments. Jassem et al.,[4] Harris et al.,[5] and Cua et al.[6] reported that the initial bond strengths and re-bond strength were equivalent. Wright and Powers,[7] and Regan et al,[8] reported that initial bond strength was higher than re-bond strengths. In contrast, Leas and Hondrum,[9] and Demas et al[10,11] reported that initial bond strengths were lower than re-bond strength.

Similarly, various in-vitro studies have also concluded that the bracket/resin interface is the site of usual failure and is the weakest point in orthodontic bonding.[12–14] Various qualitative and quantitative indices have been introduced in the specialty to evaluate the site of bond failure (cohesive or adhesive) and the amount of resin remaining on the tooth structure. Årtun and Berglund (1984)[15] proposed the Adhesive Remnant Index (ARI) describing the resin remnants. A score of 0 represents a complete resin/enamel separation, a score of 3 is a resin/bracket failure, and scores of 1 and 2 are intermediate.

The surface layer of enamel lost during etching varies between 10-30 μm, whereas the depth of penetration of resin tags reaches up to 50μm. In addition, the cleanup procedure of residual adhesive after debonding may remove up to 55μm of surface enamel. Most of these resin sealant tags remain embedded in the enamel after debonding. During rebonding, the conditioning solution may flow underneath the resin patches and dissolve the enamel prisms that support the bonding agent. The resin extension tags are exposed after the acid dissolves the enamel support, giving rise to a mushroom-like appearance. The enamel surface is re-etched in rebonding, some enamel is dissolved from around the adhesive tags, which will consequently protrude from the surface. These remnants can provide some mechanical retention for secondary bonding.

In recent years new alternatives to acid etching to achieve enamel conditioning have been introduced. Among these are self-etching primer and sandblasting. Self-etching primers (SEPs) combine the conditioning and priming agents into a single solution for simultaneous use on both enamel and dentin, therefore, separate acid-etching, and rinsing with water and air spray are not required, thus reducing chair side time. The active ingredient of SEPs is methacrylate phosphoric acid ester that dissolves calcium from hydroxyapatite. Rather than being rinsed away, the removed calcium forms a complex and is incorporated into the network when primer polymerizes. This minimizes the amount of enamel lost during etching and combining conditioning and priming into one step may improve cost-effectiveness.

On rebond procedures, in which the enamel surface is covered with invisible resin patches, intraoral sandblasting or air abrasion is an effective method of surface treatment after adhesive removal. Air abrasion generates a microretentive topography and increases the surface area. This augments the adhesive strength of bonded brackets. Air abrasion appears to offer clinicians a viable method to reuse previously failed bonded brackets. Additionally, loss of enamel surface is minimized when using sandblasting as a conditioning procedure.

The purpose of the present study was firstly, to evaluate and compare the efficacy of different enamel conditioning methods, i.e., self-etching, sandblasting, and acid etching while bonding a new bracket on a previously de-bonded site, assess the difference in shear bond strength and ARI score if any and secondly, to determine if sandblasted enamel may be viable alternative to acid etching for rebonding the brackets.

2. Materials and Methods

The study was done as per Institutional protocol and guidelines and was initiated only after clearance from the institutional ethical committee (Reference No. JCDV/DC/19/1742). Informed written consent was taken from all the subjects.

125 human extracted premolars were selected based on the following inclusion and exclusion criteria:

2.1. *Inclusion criteria*

1. Intact teeth
2. No caries on the buccal surface.

2.2. *Exclusion criteria*

1. Subjected to any pre-treatment chemical agents
2. Hypocalcified and hypercalcified teeth
3. Fluorosed teeth
4. Cracks on the enamel surface due to the extraction process.

Selected premolars were washed with distilled water to remove any traces of blood and then placed in a 0.1% thymol solution. The teeth were randomly distributed and assigned to 5 groups according to the enamel conditioning method used. The sample was prepared by embedding them in the middle of the color-coded self-cure acrylic blocks up to the level of cementoenamel junction (CEJ). The long axis of each tooth was kept perpendicular to the base of the block. Before bonding, these acrylic blocks were later stored in distilled water at room temperature.

250 premolar brackets (022-inch slot, Mini Diamond 2000, Ormco, USA) were procured, of which 125 brackets were bonded on the buccal surface of the selected premolars using different enamel conditioning methods with the

same adhesive (Bonding sequence I) and was followed by debonding using Instron Universal testing machine (Debonding procedure I).

The remaining 125 brackets were bonded (Bonding sequence II) on the same teeth after the residual adhesive was removed from their enamel surface. Bonding sequence II was then followed by debonding (Debonding procedure II) and shear bond strength calculation. The detailed procedure is as follows:

2.2.1. Bonding sequence I

The buccal surface of the extracted premolars allocated in groups 1, 2, and 3 were etched with 37% ortho-phosphoric acid (Scotchbond^{TM} 3M Unitek, Monrovia, California USA) for 30 seconds, then each tooth was rinsed thoroughly using the oil-free, air-water spray for 15 seconds. The teeth were then air-dried gently until the appearance of a dull, white frosty enamel surface. After that, a thin layer of primer (Orthosolo, Ormco, USA) was applied to the buccal surface of each tooth.

Teeth assigned to group 4 were etched with Self-etch primer (Transbond plus, 3M Unitek, Monrovia, California USA). The liquid component was squeezed from the reservoir towards the disposable applicator and the resultant mix was applied directly on the enamel surface followed by gentle rubbing onto the enamel with the disposable applicator for 3-5 seconds and each tooth was then gently air-dried.

Teeth allocated to group 5 were surface-treated with an intra-oral sandblaster (Bio-art Microjato microblaster). Sandblasting was done at 65 to 70 psi for 3 seconds from 1mm with the aluminum oxide(particle size of 50μm). The samples were then washed with water and gently air-dried.

After the etching of 125 teeth from all the five groups and primer application, adhesive (Enlight light cure adhesive, Ormco, USA) was applied to the individual brackets and then each bracket was pressed firmly onto the etched tooth surface. The excess adhesive was removed around the base of the brackets. The composite was then light-cured for 40 seconds (10 seconds on each side of the bracket) with the curing light (Bluephase N, Ivoclar Vivadent, Austria).

2.2.2. Debonding procedure I

After initial bonding, the shear bond strength was measured with an Instron Universal testing machine. An occluso-gingival load was applied at the tooth/bracket interface with standard knife-edge attachment of the Instron Universal testing machine (Instron 4482, UK) with a 100 KN load cell at a crosshead speed of 0.5 mm/min. The force, that produced bond failure, was recorded on the computer.

2.2.3. Bonding sequence II

After initial debonding, the residual adhesive was removed from the enamel surfaces of all the teeth with a low-speed tungsten carbide bur. The teeth allocated to groups 1, 2, and 3 were re-etched with 37% ortho-phosphoric acid, Transbond plus Self-Etch primer, and sandblasting, respectively. Extracted teeth that were etched with SEP in group 4 were re-conditioned with SEP and teeth that were etched with sandblaster in group 5 were re-treated with sandblaster (Table 1). A new bracket was used on each tooth for repeated bonding and bonding was done as per manufacturer's instructions.

2.2.4. Debonding procedure II

After the repeated bonding, shear bond strength was measured with an Instron Universal testing machine, and the force required to debond each bracket was registered in Newtons (N). It was converted into megapascals (MPa) as follows:

Bond strength calculation

Bond strength (MPa)= Debonding force values (N)/ Surface area of premolar brackets (mm2).

ARI

After the first and second debonding, the site of the bond failure and the amount of adhesive remaining on the enamel surface were scored for each tooth based on the following categories (Årtun and Berglund):

0: No adhesive remaining on the tooth surface

1: less than half the adhesive remaining

2: more than half the adhesive remaining

3: all the adhesive remaining

2.3. Statistical analysis

The sample size for the study was estimated using Epi Info (TM) Software. The power of the test was 0.80 or 80% based on which the sample size was decided i.e., 25 teeth in each group. Data obtained from the study were tabulated and analyzed using Statistical Package for Social Sciences (SPSS) version 22.0. Student's t-test and Analysis of Variance (ANOVA) test were used to determine the inter-group and intra-group shear bond strength differences. The level of significance was set at $p < 0.05$.

3. Results

Descriptive statistics of the SBS test conducted after the first debonding procedure are presented in Table 2. In all the groups, the mean value of SBS was higher than 6.0-8.0 MPa, which is in the ideal range for bonding orthodontic brackets to the teeth. The results of the one-way ANOVA test indicated that there was a significant difference in SBS between the five groups after initial debonding. SEP group (group 4) showed the highest SBS followed by acid etching groups (groups 3, 2, and 1). The sandblasting group (group 5) had the least shear bond strength value among all the groups.

Measurements of the SBS test of the study groups and their statistical analysis after debonding sequence II are shown in Table 4. Mean SBS was found to be highest in Group 3{37% o-phosphoric acid (Bonding I) sandblasting (Bonding II)} This was followed by group 4 {SEP (Bonding I and Bonding II)}, group 2 {acid etching (Bonding I) SEP (Bonding II)}, and group 1 (acid etching in both bonding sequence). Group 5 (sandblasting in both sequences) had the least SBS after the second debonding. Intergroup comparison of SBS values of various first debonding and repeated debonding sequence combinations are shown in Table 5. Statistically significant differences in values were found by comparing Group 1 with Groups 3 and 4; Group 2 with Groups 3 and 5; Group 3 with Group 5; and Group 4 with Group 5, respectively.

The intra-group comparison of values of shear bond strength after the first and second debonding is shown in Table 6. Overall SBS values showed a general reduction, but the values were still above the ideal range for bonding brackets to teeth, which is 6.0-8.0 MPa. A paired t-test was carried out for the comparison of shear and repeated shear bond strength among the five groups. Results revealed statistically significant differences ($p<0.05$) in all the groups except group 5 which showed almost the same bond strength after the first and second debonding (Table 6).

Table 1: Teeth were reconditioned as follows

Groups	Initial Conditioning (Bonding sequence I)	Re-conditioning (Bonding sequence II)
Group 1	37% o-phosphoric acid	37% o-phosphoric acid
Group 2	37% o-phosphoric acid	SEP
Group 3	37% o-phosphoric acid	Sandblasting
Group 4	SEP	SEP
Group 5	Sandblasting	Sandblasting

4. Discussion

Rapid strides in material science over the years have produced progressively advanced materials making the direct bonding procedure more precise, comfortable, and time-effective. Although acid etching is the most used enamel conditioner for bonding and repeated bonding of the orthodontic brackets in clinical practice, and it provides good shear bond strength, one of the potential disadvantages is the demineralization of the most superficial layer of enamel (up to 50-100μm), and another is that the higher strength may cause enamel cracks on debonding.[16] Several studies have evaluated the efficacy of Self-etch primer (Buyukyilmaz T et al., 2003, Montasser MA et al., 2008, Nicolas AI et al., 2010 Turloz C, Ulusoy C et al., 2012)[17–19] and Sandblasting (Olsen ME et al., 1997, Hogervost et al., 2000), and have reported that sandblasting alone should not be used as a substitute for acid etching because of the low SBS.[20,21] Therefore, this study was undertaken to evaluate and compare the shear bond strength of self-etch primer, sandblasting, and conventional acid etching technique after first debonding sequence, and also to assess shear bond strength on a previously debonded site with a new bracket after second debonding sequence (Table 1).

In the first debonding sequence, self-etch primers had the highest shear bond strength (14.28±2.38MPa) which was in concordance with that of the study conducted by Buyukyilmaz T et al.[17] It might be speculated that the high bond strength noted with Trans bond plus was due to nano-retentive interlocking between enamel crystallites and adhesives. Self-etching primer penetrates the entire depth of the etch, ensuring an excellent mechanical interlock. Also, combining conditioning and priming into a single step result in improvement in both time and cost-effectiveness for clinicians as well as for patients. Our study was discordant with the studies conducted by Hitmi et al. (2000)[22] and Bilal R (2021)[23] who reported that the SBS of the acid-etched group was greater than the self-etch group. The lowest shear bond strength was recorded in group 5 (sandblasting) in the first debonding sequence, but it was 7.89±1.01MPa and more than 6 MPa (Reynolds 1975)[24] which is the minimum requirement for clinical use. The advantage of the sandblasting technique is that it is a quick way of conditioning enamel, and the enamel loss can be controlled by reducing the exposure time and by blasting the aluminum oxide particles at low pressure. One of the disadvantages of sandblasting is that the aluminum oxide-containing aerosol used may be swallowed or inhaled by the patient or doctor. Hence, it can be used as an enamel conditioner routinely, but the operator should handle the machine carefully. ARI scores assessed after first debonding sequence did not show significant differences between the groups. All, or at least, more than half, of the bonding area in all samples remained covered with composite (ARI score 2 and 3). Group 3 (acid etching followed by sandblasting) and Group 4 (self-etching followed by self-etching) had comparable re-bond strength and highest re-bond strength amongst all groups while Group 1 (acid etching followed by acid etching) and Group 5 (sandblasting followed by sandblasting) had similar and least re-bond strength (Table 4). ARI scores did not reveal any significant difference among the five groups. A maximum number of the teeth were in Group 2 or 3 with most of the adhesive remaining on the tooth after debonding. In this study, regardless of adhesive systems and bonding/debonding sequences used, all shear bond strengths of three adhesive systems at every debonding exceeded 6 MPa, which is a minimum requirement for clinical use. A general decrease in shear bond strength in repetition was seen. The observed decrease in the shear bond strength could be due to the partial destruction of the etching pattern and weaker retentive enamel morphology. There was a significant decrease in

Table 2: Measurements of shear bond strength in the study groups after initial debonding (MPa)

Group	Minimum	Maximum	Mean	Sd	
Group 1	9.00	10.90	9.94	1.32	
Group 2	9.3	11.1	10.02	1.03	
Group 3	9.1	11.2	10.11	1.09	
Group 4	11.00	16.10	14 .28	2.38	
Group 5	7.60	8.20	7.89	1.01	
		Anova Analysis			
Source of variation	**Sum of Squares**	**d.f.**	**Variance**	**Anova Test**	**p value**
Between Groups	544.58	4	136.14		
With in groups	256.22	120	2.14	63.76	<0.01*
Total	800.79	124			

Table 3: Intergroup analysis of shear bond strength after initial debonding

Group	Mean difference	95% CI	P value
Group 1 vs group 2	0.08	-1.07 to 1.23	0.99
Group 1 vs group 3	0.17	-0.98 to 1.32	0.99
Group 1 vs group 4	4.34	3.19 to 5.49	<0.01*
Group 1 vs group 5	-0.25	-3.19 to -0.91	<0.01*
Group 2 vs group 3	0.09	-1.06 to 1.24	0.99
Group 2 vs group 4	4.26	3.12 to 5.41	<0.01*
Group 2 vs group 5	-2.13	-3.28 to -0.99	<0.01*
Group 3 vs group 4	4.17	3.03 to 5.32	<0.01*
Group 3 vs group 5	-2.22	-3.37 to -1.08	<0.01*
Group 4 vs group 5	-6.39	-7.54 to -5.25	<0.01*

Table 4: Measurements of shear bond strength in the study groups after second debonding (MPa)

Group	Minimum	Maximum	Mean	SD	
Group 1	5.80	8.10	7.43	.50	
Group 2	7.4	9.4	8.06	1.14	
Group 3	8.8	9.9	9.07	.77	
Group 4	7.9	11	8.82	1.64	
Group 5	6.00	7.5	7.17	.78	
		Anova Analysis			
Source of Variation	**Sum of Squares**	**d.f.**	**Variance**	**Anova Test**	**p value**
Between Groups	69.36	4	17.34		
With in Groups	130.57	120	1.09	15.94	<0.01*
Total	199.93	124			

Table 5: Intergroup analysis of shear bond strength after second debonding

Group	Mean difference	95% CI	P value
Group 1 vs group 2	0.63	-0.1871 to 1.45	0.21
Group 1 vs group 3	1.64	0.8229 to 2.46	<0.01*
Group 1 vs group 4	1.39	0.5729 to 2.21	0.0001*
Group 1 vs group 5	-0.26	-1.0771 to 0.56	0.90
Group 2 vs group 3	1.01	0.1929 to 1.83	0.007*
Group 2 vs group 4	0.76	-0.0571 to 1.58	0.08
Group 2 vs group 5	-0.89	1.7071 to -0.07	0.03*
Group 3 vs group 4	-0.25	-1.0671 to 0.57	0.92
Group 3 vs group 5	-1.90	-2.7171 to -1.08	<0.01*
Group 4 vs group 5	-1.65	-2.4671 to -0.83	<0.01*

Table 6: Intra-group comparison of shear bond strength in the study groups after first and second debonding (MPa)

Group	Shear strength		Rebond strength		Paired t test	P value
	Mean	SD	Mean	SD		
Group 1	9.94	1.32	7.43	.50	4.89	0.021*
Group 2	10.02	1.03	8.06	1.14	3.62	0.038*
Group 3	10.11	1.09	9.07	.77	3.01	0.043*
Group 4	14.28	2.38	8.82	1.64	10.19	0.01*
Group 5	7.89	1.01	7.17	.78	2.83	0.07

Group 4 in which Transbond plus SEP was used both in the first and second de-bond sequence. The results were in contrast with Montasser MA, Drummond JL, and Evans CA (2008)[25] who reported increased SBS in the second debond. Numerous sources of variability in the bonding protocol can affect the bond strength within individual specimens including premolar/molar crown contour variations, the quantitative aspects of adhesive and force utilization during bonding, the distance of the point of force application from the bracket base surface, the method of adhesive removal, and interfacial characteristics of the bracket adhesive complex sequence.

Alavi S and Ehteshami A (2019)[26] found no significant differences between first and second debonding sequences when self-etching primer was used as an enamel conditioning agent whereas in our present study, there was a significant decrease in the SBS after repeated debonding sequence.

5. Conclusion

Bracket bond failures are a frequent occurrence in orthodontic practice. It is jeopardizing as it results in increased treatment time and operating costs. When faced with the need to rebond metal brackets, several options are available like rebonding the same bracket or using a new one. Although acid etching is the main method of enamel preparation in orthodontic bonding, other substitutes are also available namely air abrasion and sandblasting. The study was undertaken to evaluate and compare the shear bond strength of self etch primer, sandblasting, and conventional acid etch technique and also to assess shear bond strength on a previously debonded site with a new bracket. After the first debonding sequence, SEP group had higher shear bond strength when compared with groups 1, 2, and 3 which used acid etching as the conditioning technique. The sandblasting group had lower SBS values when compared to conventional acid etching groups, though the bond strength was higher than required. After the second debonding sequence, group 3 using acid etching in the first sequence and sandblasting in the second sequence as an enamel conditioning agent, had the highest SBS. Even group 4 using SEPs in both sequences had comparable SBS values with group 3. Thus, SEPs and sandblasting can be used as a substitute for conventional acid etching technique.

The following conclusions were drawn

5.1. Shear bond strength after the first debonding sequence

1. Self-etching primer group (Group 4) had the highest (14.28±2.38MPa) shear bond strength when compared to conventional acid etching groups, i.e., group 1 (9.94 + 1.32MPa), group 2 (10.02+ 1.03MPa) and group 3 (10.11+ 1.09MPa).
2. The sandblasting group (Group 5) had least (7.89±1.01MPa) shear bond strength.

5.2. Shear bond strength after the second debond sequence

1. The SBS of new brackets after two debonding procedures significantly decreased but was still found to be above the required bond strength.
2. The use of acid etching in the first sequence and sandblasting in the second sequence as an enamel conditioning agent (Group 3- 9.07±0.77MPa) had the highest shear bond strength.
3. Application of self-etching primer in both sequences (Group 4- 8.82±1.64) had comparable shear bond strength with Group 3.
4. Self-etching primer and sandblasting technique can be used as a substitute to conventional acid etching technique in second-time bonding of brackets.

Though the results of the study were very encouraging, in-vitro studies allow for evaluating a specific bonding or conditioning system under more standardized testing conditions. Unfortunately, in-vitro studies have been unsuccessful in predicting in-vivo effectiveness as exact simulation of intraoral conditions is impossible. There is scope for assessing the effectiveness of various conditioning methods in vivo conditions for future research.

6. Source of Funding

None.

7. Conflict of Interest

None.

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