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Original Article

Shear Bond Strength Evaluation of Rebonded Brackets Using Different Composite Removal Techniques

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Abstract

Introduction: The biggest challenge that orthodontist face in the clinical practice is debonding of the brackets. The best way to avoid bond failure is to adhere strictly to the rules of good bonding.

Aims and Objectives: Aims and objectives of the study were to measure shear bond strength of orthodontic brackets which were rebonded using different tooth surface reconditioning methods that are diamond bur and air abrasion with aluminum oxide particles on debonded tooth surfaces and to evaluate the enamel surface topography of reconditioned enamel surface after debonding using scanning electron microscope study.

Materials and Methods: This *in vitro* study consisted of three groups with 25 samples in each group. Metal brackets were pressed with 2 ounce of horizontal pressure. After debonding, reconditioning of the tooth surface was performed by the finishing diamond bur and air abrasion. Rebonding of the reconditioned teeth was again performed. Universal testing machine was used to evaluate the shear bond strength of the orthodontic brackets. Enamel surface topography was evaluated using scanning electron microscope.

Results: Shear bond strength was highest in the air abrasion group (7.68 ± 0.99 megapascal [MPa]) diamond bur group (6.7 ± 1.3 MPa). There was a relationship between surface roughness and the bond strength achieved. The method which created rougher surface achieved the higher shear bond strength.

Conclusions: Air abrasion can be used as preferred method of reconditioning the tooth surface after bond failure to achieve optimal bond strength of rebonded brackets.

Key words: Air abrasion, Scanning electron microscopy, Shear bond strength

INTRODUCTION

The biggest challenge that orthodontist face in the clinical practice is debonding of the brackets. The best way to avoid bond failure is to adhere strictly to the rules of good bonding.[1] According to Reynolds, optimum shear bond strength of 5.9-7.8 megapascal (MPa) is required for orthodontic purpose.[2]

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Rebonding the orthodontic brackets should achieve the bond strength which should be comparable to the optimal bond strength required for orthodontic purposes. To facilitate rebonding, the search for an efficient and safe method of resin removal after debonding has resulted in the introduction of variety of instruments and procedures. These include tungsten carbide burs,[3-5] diamond burs,[6] sandblasting,[3,7] and soflex disc.[8] Studies have recommended different methods for resin removal from the enamel surface, but there is no consensus as to which is the best method to remove composite from the enamel surface providing optimal bond strength and minimal damage to the enamel surface.[3,6,9]

Hence, this study has been conducted to evaluate the shear bond strength of rebonded orthodontic brackets

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with different reconditioning methods of enamel surface along with evaluation of reconditioned enamel surface topography using scanning electron microscope.

MATERIALS AND METHODS

A sample of 75 maxillary first premolar teeth extracted for orthodontic purpose was used and was selected on the basis of following inclusion criteria, i.e., intact enamel, noncarious and nonrestored tooth surface, no enamel hypoplasia, no fluorosis, and no abnormal anatomy.

The teeth collected were stored at room temperature in distilled water. All teeth were mounted on self-cured acrylic resin block in such a way that root were completely embedded into the acrylic up to the cementoenamel junction level leaving the crown exposed.

The buccal surfaces of all teeth were etched with 37% orthophosphoric acid etching gel (3M, ESPE Scotchbond™) for 15 s. A thin layer of primer (3M Unitek, Monrovia CA) was applied followed by the application of the adhesive (3M Unitek, Monrovia CA) over the bracket base using 2 ounce pressure with the help of a force gauge (M3-05, Mark 10 Wagner Instruments; U.S.) (Figure 1), which was mounted onto the table for applying horizontal perpendicular pressure onto the bracket slot (0.022 × 0.028″ slot, American Orthodontics). All samples were light cured with LED curing light at 1200 mW/cm^2 (Mini LED Satelec, India) for 20 s.

The samples were randomly divided into three groups of 25 samples each according to different adhesive removal methods which were as followed:

- Group 1: Control group: Initial bonding followed by debonding with no surface treatment done.
- Group 2: Enamel surface reconditioning with diamond bur (TF-11, ISO 173/014, SS White; USA) using a high-speed handpiece (35000-40000 rpm) with air cooling and gentle pressure.
- Group 3: Enamel surface reconditioning with air abrasion (50 μm aluminum oxide particles). The teeth surfaces were held 5 mm away from the nozzle of microetcher (Sandy Plus GD, Italy) under the air pressure of 150 psi.

Figure 1: Mark 10 force gauge (Wagner Instruments, U.S.)

After every 5 samples, the burs and scalar tip used for reconditioning the enamel surface were replaced with the new one.

For the control group, debonding was carried out with the Universal Testing Machine at the crosshead speed of 5 mm/min. Debonding of Groups 2 and 3 was carried out with debonding plier by placing the beaks of the plier mesiodistally and then peeling type of force was applied. Teeth were stored in distilled water at room temperature after debonding. The composite from the bracket surface was removed with air abrasion with 50 μm aluminum oxide particles until the bracket mesh was cleared from the macroscopically visible residual adhesive for all the groups in which reconditioning was done.

The composite was removed until the enamel surface became glossy without any macroscopically visible composite under the dental lamp's light of Groups 2 and 3.

Rebonding was again carried out of the reconditioned tooth surface with the same method as stated earlier and then debonding was carried out with the Universal Testing Machine for measuring the shear bond strength.

Scanning Electron Microscopy (SEM) Evaluation for Emanel Surface Alteration

All the experimental group samples were checked for enamel surface alteration after first debonding and of the reconditioned enamel surface after second debonding with scanning electron microscope.

From each group, tooth with average bond strength was selected for SEM. For the standardization procedure, all the microphotographs were viewed under 100X, 1.50 KX magnification.

RESULTS

The maximum average score of bond strength was in control group followed by air abrasion group with 50 μm aluminum oxide particles and diamond bur group (Table 1). Shear bond strength showed a significant difference in between different groups (Tables 2 and 3).

SEM microphotographs revealed that more roughness of enamel surface was seen in the diamond bur group followed by air abrasion group. Distinct impression of the bracket

Table 1: Depicting the mean, standard deviation, maximum, minimum and median scores of shear bond strength (MPa) for control and experimental groups with different reconditioning methods

Groups	Control group	Diamond bur	Air abrasion
Mean	9.06	6.75	7.68
SD	0.95	1.33	0.99
Maximum	10.6	8.4	9.14
Minimum	7.06	3.69	6.02
Median	9.048	7.2	7.94

SD: Standard deviation

Table 2: One-way ANOVA – F table for comparing the significant difference in shear bond strength (MPa) among the control and experimental group with different reconditioning methods

Source of variation	SS	df	MS	F	*P* value	F criteria
Between groups	181.92	4	45.48	38.30	0.00 $P<0.05$ (significant)	2.45
Within groups	142.49	120	1.19			
Total	324.41	124				

Table 3: Comparative study for significant difference in shear bond strength between different pair of groups

Pair of groups/materials	Probable values of Mann-Whiteny test scores	Significance
Control and diamond bur	0.0000*	$P<0.05$ (significant)
Control and air abrasion	0.0000*	$P<0.05$ (significant)
Diamond bur and air abrasion	0.0077*	$P<0.05$ (significant)

*Shows a significant difference at 0.05 level of significance i.e., $P<0.05$

was evident in the control group after debonding, depicting bond failure at the bracket - resin interface (Figures 2 and 3).

DISCUSSION

Bond failure during orthodontic treatment is relatively unavoidable and unenviable. Hence, this study was undertaken to evaluate the shear bond strength of rebonded orthodontic brackets using different composite removal techniques.

It has been reported that significant differences exist between bond strengths of different tooth type. Thus, studies of bond strength to enamel surface should ideally take this into account by using one tooth type or equal number of different tooth types in test groups.[10] Therefore, in this study, maxillary first premolars were taken because of relative ease of procuring the sample following therapeutic extraction.

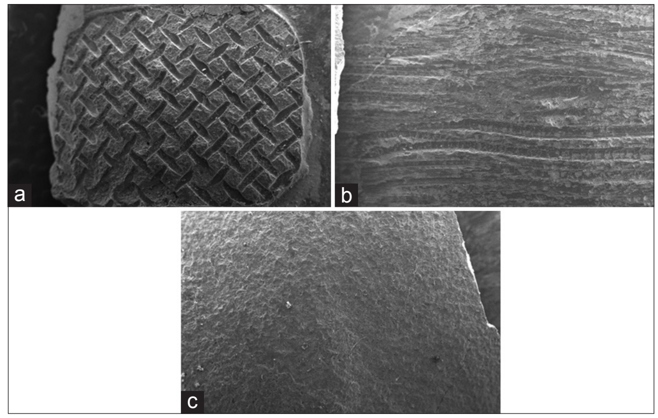

Figure 2: (a) Topographical view of enamel surface after initial debonding, (b) reconditioned enamel surface with diamond bur, (c) reconditioned enamel surface with air abrasion. Viewed at ×100 under scanning electron microscopy

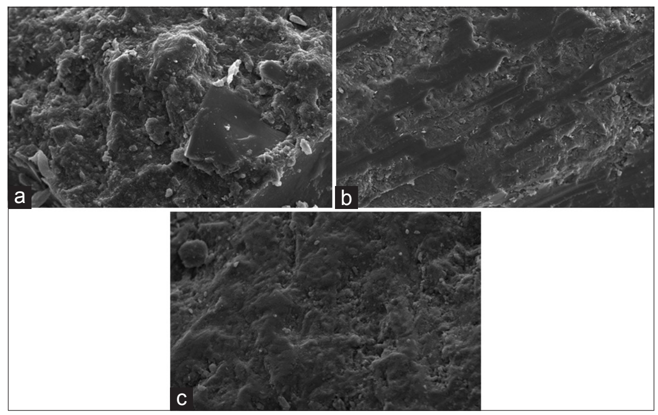

Figure 3: (a) Topographical view of enamel surface after initial debonding, (b) reconditioned enamel surface with diamond bur, (c) reconditioned enamel surface with air abrasion. Viewed at ×1.50 K under scanning electron microscopy

In this study, distilled water was used as a storage media. A similar study conducted by Sachdeva *et al.*[11] attained the shear bond strength which was comparable to clinically acceptable bond strength of 6-8 MPa with isotonic saline and distilled water which was 7.59 and 6.15 MPa, respectively; hence, distilled water can be used as one of the effective storage media for conducting bond strength studies.

MacColl *et al.*[12] in their study observed reduction in bond strength with the reduction of bracket base surface area from 6.82 to 2.38 mm^2. Hence, in this study, all the brackets were taken of the same type. The brackets used were maxillary first premolar metal brackets of 0.22″ slot and the bracket surface area was determined to be 10.83 mm^2 which was similar to the bracket surface area used by Bayram *et al.* (10.88 mm^2).[6]

Etching was done with 37% orthophosphoric acid gel for 15 s since the bond strength achieved with 15 s as compared to 60 s etching was greater than required for orthodontic bonding that is 9.38 ± 4.35 MPa[13] and also surface etched in young permanent teeth with 15 s had greater number of surface irregularity as compared with surface etched with 60 s thereby enhancing the bond strength.[14]

A universal test machine was used for the shear bond test at a crosshead speed of 5 mm/min.[15-18] An occlusogingival vertical shear force was applied to the occlusal sides of bracket wings. The maximum necessary load to debond or initiate the bond fracture was recorded in Newton units and was used to calculate the shear bond strength in MPa units.

Peeling type force which is a combination of shear, tensile, and torsional forces is the most effective in breaking the adhesive bond. It creates peripheral stress concentrations that cause bonded metal brackets to fail at low force values. The bond failure occurs at the adhesive bracket interface, thus leaving adhesive on the enamel surface.[1] As stated by Reisner *et al.*,[16] a bracket is never debonded with a pure shear or pure tensile force, as this would increase the likelihood of tooth fracture. Therefore, in this study, the method used for debonding the bracket was peeling type of force with the aid of debonding plier.

In this study, for the removal of the adhesive from the bracket base air abrasion with 50 μm aluminum oxide particles was used. Various authors[17,19-21] have confirmed that air abrasion with 50 μm aluminum oxide particles is an effective method to remove residual adhesive from the bracket base without compromising the bond strength. The process appears to be both time and cost effective, facilitating the re-use of accidentally debonded attachments.

The bond strength of the orthodontic bracket is influenced by many factors, i.e., tooth type, material, bonding procedure, and the force used for pressing the orthodontic brackets on the tooth surface. One variable which is important for determining the bond strength is the horizontal pressure which is applied while placing the bracket over the tooth surface to remove the adhesive flash but most of the studies on bond strength have not taken this into consideration.

To standardize the pressure, force gauge (Model number: M3-05 (250 g), Mark 10 Wagner Instruments) was used to deliver the constant amount of force to obtain the optimal bond strength of 5.9-7.8 MPa as stated by Reynolds. Optimal force required for applying pressure onto the bracket was checked by conducting a short study in which varying amount of horizontal pressure, i.e., 1.5, 2, 2.5, 3, 3.5 ounce was applied while placing the bracket over the tooth surface using commonly used Transbond XT as adhesive resin for orthodontic bonding. It was observed that with increase in pressure there was increase in bond strength. It was found that 2 ounce of force resulted in mean shear bond strength of 9.49 MPa. Since the bond strength achieved was close to the optimal bond strength therefore in this study 2 ounce of horizontal pressure was applied while pressing the brackets on the tooth surface.

Most of the studies[22,23] have stated that the bond strength of Transbond XT light-cured resin is stronger than that of the self-cured resin of concise. Transbond XT also showed higher bond strength (10.20 ± 3.54) and predominance of score 1 type of failure, which would facilitate the removal of the resin remains from enamel surface after brackets removal.

In this study, the bond strength achieved after debonding in the control group bonded with Transbond XT was 9.06 ± 0.95 MPa which is approximately same by studies done by various authors.[15,23-26]

A variety of techniques has evolved over a period to remove the adhesive from the enamel surface without causing any damage or minimal damage to the enamel surface so as to achieve comparable optimal bond strength. Another method used to remove resin from the tooth surface was the diamond bur (TF-11, SS White, Germany).

In this study, the bond strength achieved after removal of the residual adhesive with TF-11 diamond bur (106-125 μm diamond grit) was 6.7 ± 1.3 MPa which was significantly lesser than the air abrasion group.

Some studies had reported the bond strength which was closer to our study. Demirtas *et al.*[27] achieved the bond strength of 8.12 ± 1.16 MPa after roughening the tooth surface with diamond bur (150 μm; 856/018, Diatech Diamant AG, Hecrbrugg, Switzerland). Ahrari *et al.*[28] stated that shear bond strength acquired was 8.1 ± 1.77 MPa, when a low speed round bur was used to remove the remaining adhesive.

In contrast to our study, Bayram *et al.*[6] stated that the bond strength of 10.61 ± 2.28 MPa was achieved after roughening the surface with diamond bur (150 μm; 856/018, Diatech Diamant AG, Heerbrugg, Switzerland) at a high speed under water cooling. One possible reason of difference in bond strength found may be that their study used composite resin discs was used as the testing samples instead of teeth for bonding of the brackets. Another possible reason for higher bond strength could be the use of super course diamond burs creating more roughness in the above-mentioned studies in comparison to the standard diamond bur (TF-11, 106-125 μm diamond grit) used in our study.

Reconditioning of the tooth surface with 50 μm aluminum oxide particles was also done in this study. It is seen that finer alumina particle causes a smoother surface thereby causing less iatrogenic effect on the enamel therefore 50 μm aluminum oxide particles were used inspite of 90 μm aluminum oxide particles.[15] Therefore, air abrasion with 50 μm aluminum oxide particles was used as one of the techniques for reconditioning the tooth surface in this present study.

In this study, the bond strength achieved with 50 μm aluminum oxide particles was 7.68 ± 0.99 MPa which was higher than the diamond bur group.

Bond strength achieved by Canay *et al.*[29] (6.1 ± 0.43 MPa) and Reisner *et al.*[16] (7.8 ± 2.1 MPa) with air abrasion connate to the present study.

Disparity was seen with the study done by Bayram *et al.*[6] who reported the bond strength of 10.29 ± 1.92 MPa. The credit for achieving high shear bond strength in their study can be given to the use of composite resin disc on which bonding of the brackets was done in place of extracted teeth which was used in this study.

It is evident from the SEM images that air abrasion results in the roughest surface as compared to the other techniques used in this study which is in concordance with Cochrane *et al.*[30] and Khosravanifard *et al.* (Figures 2 and 3).[31]

The success of sandblasting techniques currently used in orthodontics, as well as in other areas of dentistry, suggests that sandblasting enamel directly may be a feasible technique, both for preparing teeth before bonding and for increasing bond strength.

This study was conducted in an attempt to evaluate the shear bond strength using different tooth surface reconditioning methods. It was seen that surface roughness was directly correlated to the bond strength. The more roughness was seen with the air abrasion group as compared to the diamond bur group.

There is a need for further investigation using these methods with the objective that if we use different categories of instrumentation which creates more roughness will it be advantageous or detrimental on the enamel surface and since SEM provided only the qualitative interpretation of enamel surface, profilometry could have been performed to determine the quantitative loss of enamel with different tooth surface reconditioning methods.

CONCLUSIONS

The following conclusions can be drawn from this study:

1. Air abrasion was found to be the best method for reconditioning the tooth surface before rebonding since it resulted in higher bond strength in comparison to the diamond bur group.
2. Reconditioning with diamond bur produced the bond strength which was also in the clinically acceptable limits.
3. Surface roughness can be correlated with the bond strength. Surface roughness of enamel was seen more in air abrasion group and was associated with highest bond strength followed by diamond bur group.

Therefore, our study recommends that air abrasion can be used as preferred method of reconditioning to achieve the optimal bond strength of rebonded brackets.

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