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Effect of mechanical disturbances during and after acid etching on shear bond strength

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ABSTRACT

Objectives: To study the effect of mechanical disturbances during and after acid etching on shear bond strength and their debonding characteristics.

Materials and methods: An in vitro study was performed taking 60 extracted human first premolars divided equally in three groups. Samples in Group A were bonded according to manufacturer instructions; in Group B, they were etched by rubbing a sponge that contained 37% orthophosphoric acid over the enamel for 15 s, and then bonded, and in Group C they were etched for 15 s, washed and air dried. After etching and drying, they were rubbed with a dry sponge for 5 s and then bonded. Shear bond strength testing was performed.

Results: The differences in bond strengths and adhesive remnant index (ARI) scores between the groups were assessed by one-way ANOVA test and Post hoc Tukey test. Both the tests revealed statistically significant differences for bond strengths and ARI scores. Group A shows higher values for bond strength (13.825 MPa) as compared with Group B (12.996 MPa) and Group C (10.146 MPa). Group A shows higher values for ARI (3.89) as compared with Group B (3.55) and Group C (1.8).

Conclusion: Mechanical disturbances during and after acid etching reduce the shear bond strength of composite resin. Etchant and primer should be applied on the tooth surface by dabbing the solutions.

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1. Introduction

The introduction of acid etch bonding technique has changed the practice of orthodontics. Buonocore demonstrated increased adhesion produced by acid pretreatment using 85% phosphoric acid (1955).[1] Newman applied these findings to direct bonding in orthodontics.[2] Since then, the use of resin bonding agents is superior in many ways over banding for the placement of orthodontic brackets.

Acid etch bonding is a multistep process where a variation at any step may affect the ultimate bond strength. The etching of the enamel results in increased porosity, and thus increasing total retentive surface area available for bonding. Practice of orthodontics often requires bonding under difficult conditions of moisture or blood contamination.[3] Another factor like mechanical disturbances may also affect the etched surface.

The overall etch surface pattern depends on the dissolution and reprecipitation of surface enamel. The reprecipitation of

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dissolved materials during the etching process is an important factor in the etch pattern formation, which causes elevation of the enamel prism sheaths and hence improves the quality of the etch surface for retention. However, rubbing/vigorous agitation during acid etching causes a different etched pattern formation. Rubbing the enamel surface during the etching process may disrupt the normal pathway of etching. Consequently, the reprecipitation of the dissolved material, and the elevation of the prism sheaths reported during the static etching condition, may not occur during rubbing.[4]

After drying the etched enamel surface, every effort must be made to apply polymer coatings immediately to secure the maximum effect from a properly conditioned surface. Dennison and Craig observed that a freshly etched enamel surface is extremely sensitive and fragile.[5] The surface structure can be destroyed easily with even a slight abrasive process, so it is important not to disturb etched enamel surface.

Only one study, which evaluates quantitative differences in bond strength under conditions of mechanical disturbances during etching, has been reported in the literatures. This study was designed to investigate the effect of mechanical disturbances, both during and after the acid etching process on shear bond strength of adhesive composite resin.

2. Materials and methods

Sixty sound human first premolars were collected (12–18 yrs), which were extracted for orthodontic purpose. Teeth with restorations, carious lesions, enamel defects, or cracks were excluded. All teeth were stored in 37% formaldehyde for maximum of 6 months to inhibit bacterial growth. Teeth were randomly divided into 3 equal groups.

Retentive groves were placed on the root portion of each tooth. Teeth were mounted in acrylic blocks (Fig. 1). The buccal surfaces were cleaned with pumice and water slurry for 15 s, and washed with water for 5 s. Etching was done with 37% phosphoric acid for 15 s, rinsed with water, and dried with oil free compressor air for 3 s.[6] Metal 0.018 brackets[#] were bonded with adhesive and primer and light cured for 40 s, as per the manufacturer's instructions.

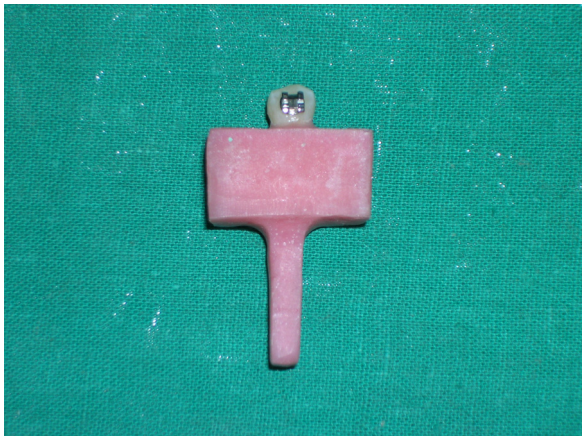


Fig. 1 – Sample being tested. Tooth mounted in acrylic block and bonded.

Group A: The teeth in group A were bonded with adhesive[*] and primer[**], as per the manufacturer's instructions.
Group B: The teeth in group B were etched by rubbing the sponge that contained 37% orthophosphoric acid over the enamel surface for 15 s, rinsed with water, and the teeth were air dried and then bonded with adhesive and primer.
Group C: The teeth in group C were etched for 15 s, rinsed with water, and air dried. After etching they were rubbed with a dry sponge for 5 s; the teeth were then bonded with adhesive and primer.

All teeth were stored in distilled water at room temperature for 24 h.

– Gemini metal brackets; Unitek
* Adhesive – Transbond XT; 3M
** Primer – Transbond MIP; 3M Unitek, Monrovia, CA

2.1. *Determination of shear strength*

After 24 h of bonding and storage in artificial saliva, the acrylic blocks with teeth embedded were removed from water and allowed to dry for 5 min. The testing was done on KMI tensile testing machine (working within accuracy of −1% and +1% and is of Class 1 of IS: 1828 (Pt. I)-1991). The sensitivity range of the testing machine is 0–500 N. The machine consists of 2 crossheads mounted on a frame, one of which moves away from the other. The acrylic block with the tooth sample was fixed on the lower crosshead. A stainless steel tie wire (23 gauges) was attached to the upper head. This tie wire was the one, kept constant for testing each specimen.

The crosshead speed was set to move away from each other at 5 mm/min. As the wire was engaged into the bracket slot and the crossheads allowed to move away from each other at the above-mentioned speed, the wire became firm and gradually became parallel to the bracket slot. The load was applied till the point of fracture, i.e. till the bracket detached from the tooth. The operator recorded load in Newtons and the shear bonding strengths were calculated (megapascals: MPa) using the formula:

$$\text{Shear bond strength (MPa)} = \frac{\text{Breaking load (N)}}{\text{Area of the mesh base (mm}^2\text{)}}$$

2.2. *Adhesive remnant index (ARI)*

In addition, the surfaces of both the tooth and the bracket were examined to assess the ARI, which describes the amount of composite adhesive that remains on the surface of the tooth[7] (Fig. 2). All the data were subjected to statistical analysis by using one-way analysis of variance (ANOVA).

3. Results

Each group was subjected to statistical analysis for mean, standard deviation, and standard error of mean.

The difference in bond strength and ARI score between the groups was assessed by one-way ANOVA test and Post hoc Tukey test. One-way ANOVA test revealed that the different

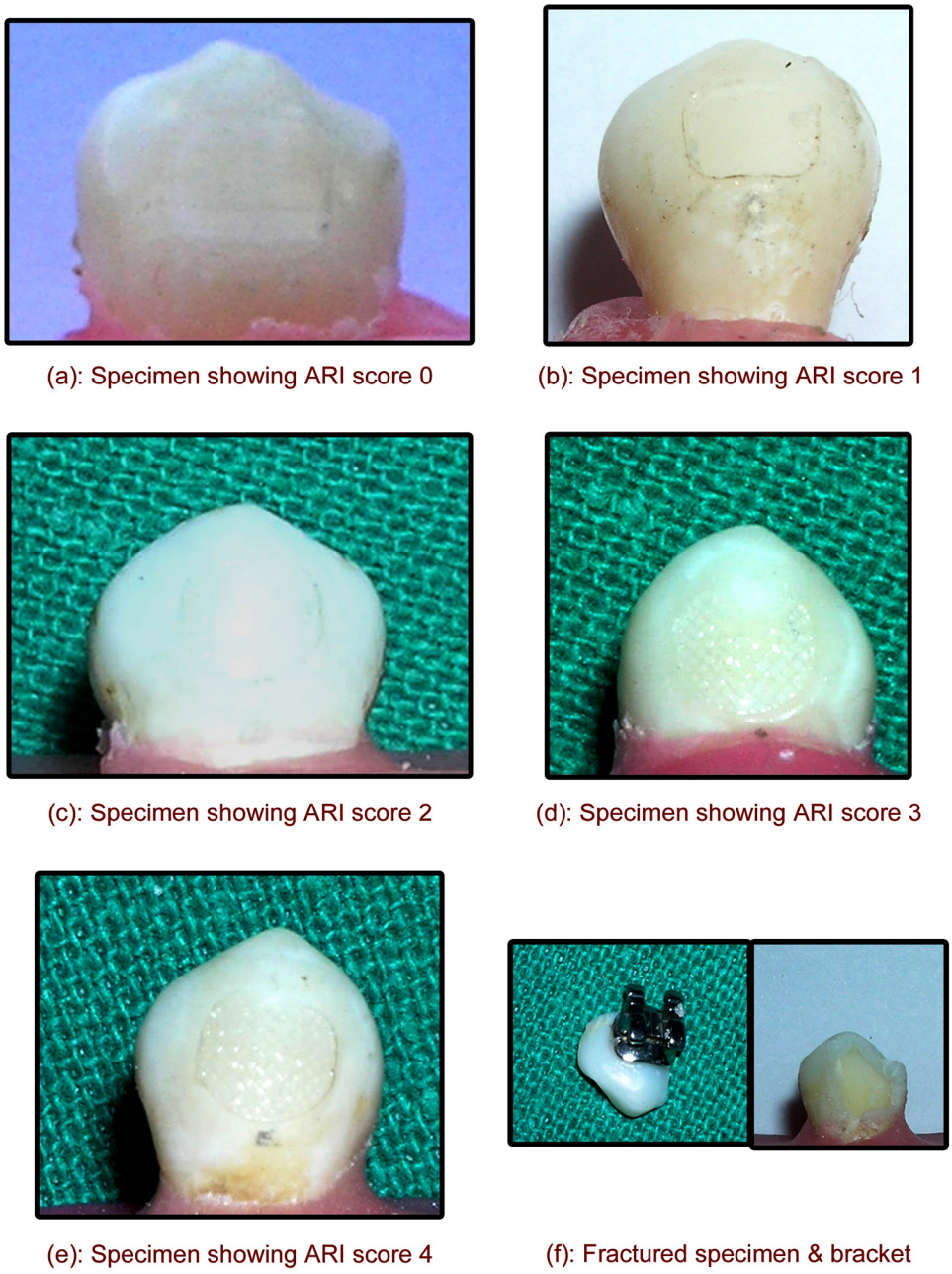


Fig. 2 – Tested samples with AIR score 0–5 and fractured sample.

bonding technique exhibit significant difference in bond strength (Table 1a) and ARI score (Table 2a). Post hoc Tukey test also revealed significant intergroup difference between groups (A-B, B-C and A-C) for bond strength (Table 1b) and ARI score (Table 2b).

Group A shows higher values for bond strength (13.825 MPa) as compared with Group B and Group C. All the groups show significant difference in bond strength. There was a statistically significant difference between the adhesive remaining indices for each group. Group A shows higher

Table 1a – Shear bond strength in megapascals (MPa) of the three groups.

Group tested	N	Mean (MPa)	SD	Range (MPa)
Group A	20	13.825	4.84	12.13–19.87
Group B	20	12.996	2.97	9.41–16.32
Group C	20	10.146	4.82	6.69–14.44

N, no. of samples; SD, standard deviation.

Table 1b – Post hoc Tukey test for shear bond strength.

	Group A	Group D	Group E
Group A		0.000	0.000
Group B	0.000		0.004
Group C	0.000	0.004	

Table 2a – Adhesive remnant index score of the three groups.

Group tested	N	Mean (MPa)	SD
Group A	20	3.89	2.08
Group B	20	3.55	1.98
Group C	20	1.8	1.66

N, no. of samples; SD, standard deviation.

Table 2b – Post hoc Tukey test for adhesive remnant index score.

	Group A	Group D	Group E
Group A		0.014	0.00
Group B	0.014		0.00
Group C	0.00	0.00	

values for ARI (3.89) as compared with Group B (3.55) and Group C (1.8).

4. Discussion

There can be various factors that can reduce the bond strength. One of these may be the mechanical disturbances during and after acid etching. Certainly, disturbance in normal etching affects the formation of retentive elevations. Logically any disturbance to the etched enamel surface during the entire bonding procedure may compromise clinically useful bond strength. This study was formulated to estimate the quantitative effect on bond strength.

In the present study, Group A showed the highest bond strength of 13.82 MPa and is comparable with the study of Hobson et al.[8] (MIP dry field –15.69 MPa), Klocke et al.[9] (MIP dry field – 15.07 MPa), Schaneveldt et al.[10] (MIP dry field – 14.82 MPa), Cacciafesta[11] (MIP dry field – 12.76 MPa), and Grandhi et al.[12] (MIP dry field – 10.14 MPa).

The specimen used in the study of Grandhi et al.[12] was bovine teeth and may provide a different force level compared to human teeth. In addition, the acid preparation of teeth significantly alters the morphologic conditions of enamel and may not resemble the human teeth. Theoretically, studies using human teeth could have different bond values from those using bovine teeth, but the results should show the same trend in different conditions. The study of Zeppieri[13] showed the bond strength of 20.7 MPa. The higher value might be due to dual curing procedure, i.e. first 10 s exposure of light on primer and after application of bonding material.

Littlewood et al.[14] found that the bond strength of hydrophilic primer was significantly lower than with conventional primer; however, the median bond strengths were promising.

The difference in bond strength of control group of different investigators might be due to variability in proper fit between enamel surface and bracket, precisely placing the blade of machine, the bonding procedure, and no parallelism between direction of force and long axis of tooth.

Group B showed the significant difference in bond strength as compared with Group A. The mean bond strength in this group was 12.996 MPa. Hormati et al.[15] studied the effect of rubbing during etching and found the etch pattern created by the rubbing technique is not as sharp as the normal etch pattern and that prism peripheries (prism sheaths) were shorter and more blunt. Each tooth was flattened on the labial surface with a diamond disk and smoothed with a sandpaper disk of medium harshness. However, he did not find any significant difference in bond strength after rubbing the tooth (12 samples) surface for 60 s.

Rubbing the cotton pledget on the enamel surface during the etching process may disrupt the normal pathway of etching. Consequently, the reprecipitation of the dissolved material, and the elevation of the prism sheaths during the static etching condition, may not occur during rubbing.

Group C also shows a significant decrease in bond strength. The bond strength of this group was found to be 10.146 MPa. One reason for this decrease in bond strength may be the deposition of the fractured elevations on the etched surface and thereby preventing the penetration of adhesive. Dennison and Craig[5] observed that a freshly etched enamel surface is extremely sensitive and fragile. The surface structure can be destroyed easily with even a slight abrasive process. The author advised that every effort must be made to apply polymer coating immediately after the etching procedure is completed to secure the maximum effect from properly conditioned surface. Some authors advised wiping etchant with alcohol swab under conditions of moisture and blood contamination while bonding impacted tooth.[16]

4.1. *ARI*

There was a statistically significant difference between the adhesive remaining indices for each group. Group A showed higher values for ARI (3.89) as compared with other groups. The ARI of Group A was followed by Group B (3.55) and Group C (1.8). ARI of Group A (3.89) and Group B (3.55) showed that more of the adhesive remained on the tooth surface after debonding. Adhesive remained after debonding in Group B was less than Group A.

There were two samples with enamel fractures in both Group A and Group B. In both, the groups of teeth with enamel fractures had bond strength greater than 15 MPa. This suggested that bond strength of 15 MPa is excessive for orthodontic use and results in a significantly higher risk of enamel fractures on debonding. Hobson et al.[8] also found that bond strength greater than 17 MPa significantly increased the chances of tooth fractures. According to Lopez,[17] the recommended minimum bond strength for successful clinical bonding is 7 MPa.

ARI of Group C was 1.8 showing slightly less than half of the adhesive, which remained on the tooth surface that might be because of deposition of the fractured elevations on the etched surface porosities thereby preventing the penetration of adhesive. ARI score depends on many factors, including the bracket base design and the adhesive type, and not simply on the bond strength at the interface.

The present study was undertaken to find out the effects of mechanical disturbances detrimental to the bond strength. The research of in vitro testing of bond strength should be interpreted with care because many differences exist between the in vitro and in vivo testing conditions. Considering this, it is suggested to have further clinical studies to evaluate the effect of mechanical disturbances on bond strength of adhesive composite resin, when used as a bonding agent for direct bonding of the orthodontic brackets.

5. Conclusion

Bonding to surface enamel is a multistep process whereby a variation at any of the steps may affect the bond strength. The etched enamel surface is highly sensitive to mechanical disturbances and can lead to compromised bond strength. This study evaluated the effect of mechanical disturbances during and after the etching process. Based on the recorded data and the statistical analysis, the results indicated:

1. Mechanical disturbances during the etching process decrease the shear bond strength of composite resin, so etching must not be performed by rubbing the tooth surface.
2. Mechanical disturbances after the etching process also decrease the shear bond strength of composite resin. It is advisable to dab the primer on to the etched enamel surface.

Etching and application of primer should be performed by dabbing the solutions on the tooth surface and rubbing at any stage of bonding procedure must be avoided, although the bond strength obtained in this study under the conditions of mechanical disturbances seems to be sufficient for clinical use.

Conflicts of interest

The authors have none to declare.

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