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Original Research

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Comparison of Shear Bond Strength of Three Self-etching Adhesives: An *In-Vitro* Study

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Abstract:

Background: The aim of the study was to determine and compare the shear bond strength of brackets bonded with Adper Prompt self-etching adhesive (3M ESPE), Xeno III self-etching adhesive (DENSPLY), Transbond plus self-etching adhesive (3M) with that of conventional bonding procedure, and to calculate the adhesive remnant index (ARI).

Materials and Methods: Totally, 60 maxillary premolar teeth were collected, and divided into Group I (Blue): Transbond[™] XT primer, Group II (Purple): Adper[™] Prompt[™] self-etching adhesive, Group III (Orange): Xeno III[®] self-etching adhesive, Group IV (Pink): Transbond[™] Plus self-etching adhesive.

Results: The results of the study showed there was no statistical significance in the shear bond strength according to an analysis of variance ($P = 0.207$) of the four groups. The mean shear bond strength of Groups I, II, III, IV were 14.56 ± 2.97 Megapascals (MPa), 12.62 ± 2.48 MPa, 13.27 ± 3.16 , and 12.64 ± 2.56 , respectively. Chi-square comparison for the ARI indicated that there was a significant difference ($P = 0.003$) between the groups.

Conclusion: All the four self-etching adhesives showed clinically acceptable mean shear bond strength. The ARI score showed a self-etching adhesive the debonding occurred more within the adhesive interface leaving less composite adhesive on the tooth surface making it easy to clean up.

Key Words: Adhesive remnant index score, self-etching adhesives, shear bond strength

Introduction

Efficient orthodontic treatment requires adequate bonding of orthodontic brackets to the enamel surfaces of teeth. The

acid-etch bonding technique was introduced by Buonocore¹ and modified later for bonding composite resins and later this technique were adopted for bonding orthodontic brackets by Newman² in 1968. This method has widened the scope in orthodontics, and bandless treatment was born. With the introduction of direct bonding to orthodontics there is overall improvement in treatment results because of decreased gingival irritation, improved esthetics, easier plaque removal by the patient, the elimination of pretreatment separation, the elimination of band occupying interdental spaces, decreased risk of decalcification of enamel and easier detection, and the treatment of dental caries by the practitioner. Conventional bonding of orthodontic brackets uses an enamel conditioner, a primer, and an adhesive resin. A unique characteristic of some new bonding systems is they combine the conditioning and priming agents into a single acidic primer solution for simultaneous use on both enamel and dentin. These self-etching agents are sixth generation bonding agents that were developed to eliminate the conditioning, rinsing, and drying steps, which may prove to be critical and difficult to standardize in operative conditions because of the instability of demineralized matrix. This single step in bonding results not only in improvement in both time and effectiveness to the clinician but also indirectly to the patient.

Recently, a new self-etching system that incorporates additional modifications to improve bond strengths has been introduced for restorative dentistry, these are sixth generation Type 2 bonding agents, in addition to the improved bond strength they also has the property of fluoride release. They,

1. Adper[™] Prompt[™] (3M ESPE) self-etching adhesive
2. Xeno III[®] (DENSPLY) self-etching adhesive
3. Trans[™] Bond Plus (3M) self-etching adhesive.

The purpose of this *in-vitro* study is to determine and compare the shear bond strength and mode of failure of brackets bonded with Adper Prompt (3M ESPE) self-etching adhesive, Xeno III (DENSPLY) self-etching adhesive, Transbond Plus (3M), self-etching adhesive with that of conventional bonding procedure and to determine the adhesive remnant index (ARI) for the three groups.

Materials and Methods

Sample preparation

Totally, 60 teeth were collected, thoroughly cleaned and stored in formalin at room temperature and they were

randomly assigned to four sub samples with 15 teeth per sub-sample and were color coded (Blue, Purple, and Orange, Pink). Acrylic stubs were used to mount the teeth, and they were oriented in a way to ensure that the buccal contours of the teeth are perpendicular to the bracket base (Figures 1 and 2).

Bonding procedure

Same operator conducted the bonding to eliminate any bonding errors:

1. Group I (Blue): Transbond™ XT primer
Teeth were pumiced and etched with 37% orthophosphoric acid³ for 15 s. The teeth were rinsed for a period of 15 s and dried thoroughly with oil free air until a chalky white appearance on the enamel was noted. The primer (Trans bond XT) was then applied on the tooth surface and light cured the brackets were coated with Trans bond XT resin, the resin were cured for a period of 40 s 10 s proximally 10 s occlusally and gingivally⁴
2. Group II (Purple): Adper™ Prompt™ (3MESP) self-etching adhesive
One drop each of liquid A and B (1:1 ratio) are taken and mixed well with a disposable applicator.⁵ The adhesive is then rubbed on the enamel surface and spread uniformly using air stream. The brackets were bonded similar to Group I with Trans bond XT resin
3. Group III (Orange): Xeno III® (DentsplyCaulk) self-etching adhesive
One drop each of liquid A and B (1:1 ratio) are taken and mixed well with a disposable applicator. The adhesive is then rubbed on the enamel surface and spread uniformly using air stream. The brackets were bonded similar to Group I with Trans bond XT resin
4. Group IV (Pink): Transbond™ Plus (3M Unitec) self-etching adhesive
The two components, i.e. acid and the primer⁵ were squeezed together, and the mix was applied onto the tooth surface. The brackets were bonded similar to Group I with Trans bond XT resin.

All samples after bonding are stored in distilled water at room temperature for 24 h. The specimens were placed in a mounting jig in the Instron universal testing machine in such a way the bracket base was parallel to the debonding force. To avoid errors, all brackets were arranged in the same orientation to the acrylic cylinder, the teeth were suspended on a 0.019" × 0.025" stainless steel wire. A shear debonding force was applied to the bracket base in a gingivo-occlusal direction at a crosshead speed of 1 mm/min.⁵⁻⁷ The force necessary to debond or initiate bracket fracture was calculated in newtons and then converted into Megapascals (MPa) as a ratio of newtons to bracket base surface area. Debonded specimens were randomly examined at ×50 magnification

with an optical microscope to evaluate the mode of bond failure.

Mode of bond failure was determined on the basis of the amount of adhesive remaining on the tooth and bracket pad and was expressed as a percentage of the total bonded area.



Figure 1: Acrylic mounted for the shear test.

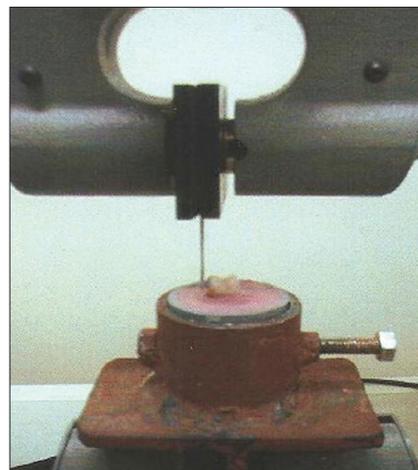


Figure 2: Mounted blocks in the universal testing machine.

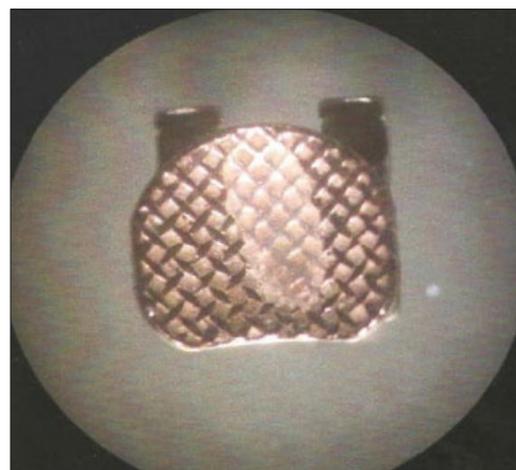


Figure 3: Adhesive remnant index.

ARI⁸ scores were assigned to each specimen (Figure 3).

Statistical analysis

One-way ANOVA^{5,9-12} was used to find the statistical significant difference among groups. This was followed by *post-hoc* Tukey⁵ test to make pairwise comparison between groups. Chi-square test^{5,13} was used to find the statistically significant difference among the ARI scores.

Results

The descriptive statistics comparing the shear bond strength of four groups is shown in Table 1. Analysis of variance for shear bond strength is shown in Table 2 and *post-hoc* Tukey test to make pairwise comparison between groups in Table 3.

Analysis of variance included that the shear bond strength of the four groups was not significantly different ($P = 0.207$) from each other.

The mean shear bond strength of Group I, II, III, IV was 14.56 ± 2.97 MPa, 12.62 ± 2.48 MPa, 13.27 ± 3.16 , and 12.64 ± 2.56 , respectively.

The ARI scores for the four groups are given in Table 4 and Graph 1.

Chi-square comparison for the ARI indicated that there was a significant difference ($P = 0.003$) between the groups.

Discussion

Direct bonding of the orthodontic brackets has changed the way orthodontics is practiced. Orthodontic attachments are now routinely bonded to teeth using the acid etching technique. This technique was first outlined by Bunocore,¹ its use in orthodontics was pioneered by Newman² and latter refined by Miura *et al*.

When bonding orthodontic brackets to enamel current technique involves three steps, application of phosphoric acid to dry tooth enamel for approximately 15-60 s prior to thoroughly washing and drying the enamel. This etching causes dissolution of interprismatic material in the enamel producing an irregular enamel surface facilitating the retention of an orthodontic attachment via its bonding agent.

The composite resin adhesives are viscous, and they cannot penetrate the acid etched microspores. Hence, an unfilled resin in the name of a sealant or primer or a bonding agent is applied after etching. This on polymerization provides the mechanical retention to the adhesive (filled resin) by flowing into the etched undercuts on one side and the other side joins the polymer links of the filled resin adhesive to become an integral part of it thereby aiding retention.

The disadvantages of conventional etching include toxicity of acid to oral tissue, technique sensitivity, and requiring complete

Table 1: Mean bond strength and SD for each group.

Groups	Shear bond strength		P value
	Mean	SD	
Group I	14.56	2.97	0.207
Group II	12.62	2.48	
Group III	13.27	3.16	
Group IV	12.64	2.56	

SD: Standard deviation

Table 2: Analysis of variance for shear bond strength.

Source	DF	Sum of squares	Mean squares	F ratio	F probability
Between groups	3	37.1752	12.3917	1.5703	0.2067
Within groups	56	441.9080	7.8912		
Total	59	479.0841			

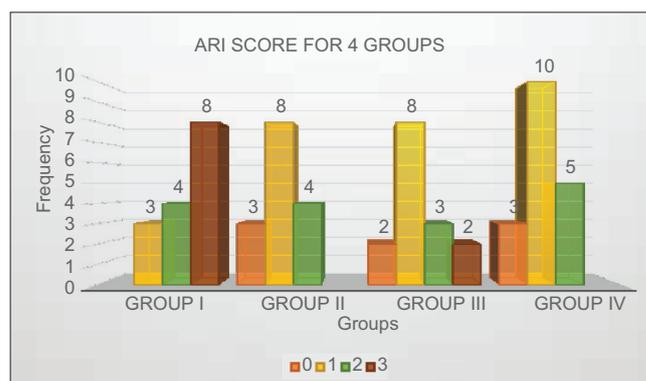
Table 3: Tukey's HSD test.

Group	Group I	Group II	Group III	Group IV
Mean	12.624	12.644	13.271	14.5620

Table 4: Absolute and relative frequency of ARI scores for four groups.

Groups	0 (%)	1 (%)	2 (%)	3 (%)
Group I		3 (20)	4 (26)	8 (54)
Group II	3 (20)	8 (54)	4 (26)	
Group III	2 (13)	8 (54)	3 (20)	2 (13)
Group IV	3 (20)	10 (67)	2 (13)	

ARI: Adhesive remnant index



Graph 1: Adhesive remnant index score for four groups.

dry field without contamination by saliva and gingival fluid.¹⁴ When exposed to saliva for a second or more, the etched enamel is coated with a tenacious surface coating that cannot be removed by simple washing thus reducing the shear bond strength of the adhesive. The decalcification seen on the etched enamel following debonding is attributed to prolonged accumulation and retention of bacterial plaque on the enamel surface.

New bonding systems use a combination of conditioning and priming agents into a single primer solution for use on both enamel and dentin.¹⁵ The single treatment step results in improvement in time and cost-effectiveness for both clinicians and patients.

Active ingredient in self-etching primer (SEP) is methacrylated phosphoric acid ester. The phosphoric acid and the methacrylate group combine into a substance that etches and primes at the same time. The phosphate group on the methacrylated phosphoric acid ester dissolves the calcium and removes it from the hydroxyapatite. The calcium then forms a complex with the phosphate group and gets incorporated into the network when the primer polymerizes.

Continuous rubbing of primer on the tooth surface ensures an uninterrupted flow of fresh primer. Etching and monomer penetration to the exposed enamel rods occur simultaneously. In this manner, the depth of etch is identical to that of the primer penetration.

The aim of the present study was to compare the three new self-etching adhesives to a conventional acid etching technique and to find out whether the new SEPs provide adequate bond strength to be used clinically in orthodontics thereby reducing the steps in bonding.

The results of present study showed that the mean shear bond strength of Group I (conventional acid etching) had the highest bond strength (14.56 ± 2.97 MPa.) when compared with other. Among the self-etching adhesives, Group III (Xeno III) had the highest bond strength (13.27 ± 3.16 MPa) followed by Group IV (Transbond Plus) with a bond strength of 12.64 ± 2.56 MPa. Group II showed the least bond strength (12.62 ± 2.48 MPa). There was no statistical difference between the groups.

There is no universally accepted minimum bond strength. Different authors have proposed different values of bond strengths to produce a clinically efficient orthodontic bond. According to Reynolds,¹⁶ maximum bond strength of 5.9-7.9 MPa (60-80 kg) is adequate. Lopez¹⁷ recommended a value of 7 MPa (75 kg) as the minimum bond strength for successful clinical bonding. According to profit the forces produced by mastication are highly variable with ranges up to 50 kg requiring 4-5 Mpa and the force required for moving a tooth orthodontically range approximately from 15 to 150 g, i.e. <2 MPa. In the oral cavity, bonded brackets are subjected to shear tensile and torsional forces. Normally, orthodontic forces do not surpass 0.45 kg per tooth. Taking all the force into consideration a minimum force of 50 kg is require.¹⁶

This difference in values can be due to the variation in conducting the study. The surface area of the base of the bracket, the number of mesh present on the brackets was different in all the studies, contributing to the variation in bond strength obtained, Maijer and Smith (1982).¹⁷ The methodology employed for curing the material and the light cure system used for curing the material was different.

The ARI⁸ provides an easy method of evaluating adhesive remnants following debond. An ARI score of 0 indicated

that no adhesive was left on the tooth in the bonded area; 1 indicated that less than half of the adhesive was left on the tooth; 2 indicated that more than half was left on the tooth; and 3 indicated that all the adhesive remained on the tooth, with an impression of the bracket mesh.

There was a significant difference in the ARI score for conventional etching procedure when compared with SEPs. In conventional etching, 58% of the teeth scored a score of 3 indicating there was more of bond failure at adhesive bracket interface leaving the entire adhesive on tooth surface making it difficult to clean it.

There was no significant difference in the ARI score among the three self-etching adhesives; score of 1 and 2 are more common indicating there was more of bond failure within the adhesive interface which is more desirable making clean up more easy.⁵

This study revealed that there is no statistically significant difference in the shear bond strength of all brackets bonded with conventional, Adper Prompt, Xeno III, and Trans bond Plus self-etching adhesives. All of them showed clinically acceptable bond strength.

The nature of the forces exerted onto the orthodontic brackets *in-vivo* and the nature of the stress distribution generated within the adhesive is complex and likely to combine shear, tensile and compressive force systems. The results of this *in-vitro* study cannot be extrapolated directly into *in-vivo* conditions. Further clinical investigations are needed for validation.

Summary and Conclusion

The present study was undertaken to analyze and compare the shear bond strength of three different self-etching adhesives (Transbond plus SEP, Adper Prompt self-etching adhesive, and Xeno III self-etching adhesive) with conventional acid etching technique with Transbond XT primer.

Within the limitations of this study, the following conclusions can be made:

1. The shear bond strength of the conventional acid etching was found to be highest (14.56 ± 2.97 MPa) followed by Xeno III self-etching adhesive with a shear bond strength of 13.27 ± 3.16 MPa, Transbond plus (12.64 ± 2.56 MPa), Adper Prompt self-etching adhesive showed the least mean shear bond strength (12.62 ± 2.48 MPa)
2. However, there was no statistically significant difference in mean shear bond strength among the four groups
3. All the three self-etching adhesives showed clinically acceptable mean shear bond strength
4. The ARI score showed a statistically significant difference among the conventional and self-etching adhesives. In self-etching adhesives, the debonding occurred more within the

adhesive interface leaving less composite adhesive on the tooth surface making it easy to clean up.

The mean shear bond strength of Adper prompt, XenoIII, Transbond plus self-etching adhesives was comparable to conventional acid etching with Trans bond XT. Therefore, the use of these self-etching adhesives as a method of pretreatment of enamel for direct bonding purpose, could be beneficial by simplifying the bonding procedure, minimizing the loss of surface enamel, and reducing the cariogenic damage which could develop around attachments during treatment.

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