

Comparison of Shear Bond Strength of Two Self-etch Primer/Adhesive Systems

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Abstract: Orthodontic brackets adhesive systems use three different agents, an enamel conditioner, a primer solution, and an adhesive resin. A unique characteristic of some new bonding systems is that they combine the conditioning, priming, and adhesive agents into a single application. The purpose of this study was to assess and compare the effects of using one-step and two-step self-etch primer/adhesive systems on the shear bond strength of orthodontic brackets. The brackets were bonded to extracted human molars according to one of two protocols. Group I (control): a two-step self-etch acidic primer/adhesive system was used, Transbond Plus was applied to the enamel surface as suggested by the manufacturer. The brackets were bonded with Transbond XT and light cured for 20 seconds. Group II: a one-step self-etch, self-adhesive resin cement system, Maxcem, was applied directly to the bracket. The self-etch primer/adhesive is made of two components that mix automatically during application. The brackets were then light cured for 20 seconds. The mean shear bond strength of the two-step acid-etch primer/adhesive was 5.9 ± 2.7 Mpa and the mean for the one-step system was 3.1 ± 1.7 MPa. The in vitro findings of this study indicated that the shear bond strengths ($t = 3.79$) of the two adhesive systems were significantly different ($P = .001$). One-step adhesive systems could potentially be advantageous for orthodontic purposes if their bond strength can be improved. (*Angle Orthod* 2006;76:123–126.)

Key Words: Self-etch primer/adhesive; Shear strength; Bonding brackets

INTRODUCTION

Conventional adhesive systems use three different agents, an enamel conditioner, a primer solution, and an adhesive resin in the process of bonding orthodontic brackets to enamel. A unique characteristic of some new bonding systems in operative dentistry is that they combine the conditioning and priming agents into a single acidic primer solution for simultaneous use on both enamel and dentin.^{1,2} Combining conditioning and

priming into a single treatment step results in improvement in bonding time and cost-effectiveness directly to the clinician and indirectly to the patient.

These relatively new systems were used originally on dentin.^{1,3} Essentially, the acidic part of the primer dissolves the smear layer and incorporates it into the mixture. Acidic primer solutions also demineralize the dentin and encapsulate the collagen fibers and hydroxyapatite crystals.² This simultaneous conditioning and priming allows penetration of the monomer into the dentin. The adhesive resin component will then diffuse into the primed dentin producing a “hybrid layer.”³ These new systems were found to be effective also when bonding to enamel.⁴

Orthodontists use the acid-etch bonding technique as a means of attaching brackets to the enamel surface. Maintaining a sound, unblemished enamel surface after debonding orthodontic brackets is a primary concern to the clinician. As a result, bond failure at the bracket-adhesive interface or within the adhesive is more desirable (safer) than at the adhesive-enamel interface because enamel fracture and crazing have been reported at the time of bracket debonding especially with ceramic brackets.⁵ As a result, alternative

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enamel conditioners, such as maleic acid and acidic primers, have been tested to find whether they can attain a clinically useful orthodontic bracket bond strength while decreasing the depth of enamel dissolution and decreasing the number of steps during the bonding procedure.⁶⁻⁸

Self-etch primers were introduced as an all-in-one adhesive for composites and compomers. The material can be light cured separately or after the application of the cavity restoration or the orthodontic adhesive. One of the systems tested earlier contained methacrylated phosphoric acid esters that combine an acidic component for etching the enamel and the primer.⁹

In other studies, newer self-etch primers were evaluated and were found to provide similar shear bond strengths as those obtained when using conventional adhesive systems.¹⁰⁻¹² These self-etch primer/adhesive systems have two components that need to be applied separately to the enamel and the brackets during the bonding procedure.¹⁰⁻¹⁴

A new self-etch, self-adhesive, one-step resin cement/adhesive system has recently been introduced.¹⁵ It is suggested that this dual-cure system can be used on both enamel and dentin without the need for any surface preparation because the product combines the etchant, primer, and adhesive resin that are mixed into a single paste before being used. This approach could potentially save the clinician significant chair side time and would also minimize the possibility of contamination during the bonding procedure. The material is recommended for use on dentin, enamel, metal, composite, and porcelain surfaces.¹⁵

The purpose of this study was to assess and compare the shear bond strength of one- and two-component self-etch primer/adhesive systems when used to bond orthodontic brackets.

MATERIALS AND METHODS

Teeth

Forty freshly extracted human molars were collected and stored in a solution of 0.1% (wt/vol) thymol. The criteria for tooth selection included intact buccal enamel, not subjected to any pretreatment chemical agents, eg, hydrogen peroxide, no cracks because of the presence of the extraction forceps, and no caries. The teeth were cleansed and then polished with pumice and rubber prophylactic cups for 10 seconds.

Brackets used

Orthodontic central incisor metal brackets (Victory Series, 3M Unitek, Monrovia, Calif) were used in this study. The average bracket base surface area was determined to be 11.9 mm².

Bonding procedure

The brackets were bonded to the teeth according to one of two protocols following the manufacturer's instructions.

- Group I (control). On 20 teeth, the self-etch primer Transbond Plus (3M Unitek) containing both the acid and the primer was placed on the enamel for 15 seconds and gently evaporated with air. The system has two compartments: one contains methacrylated phosphoric acid esters, initiators, and stabilizers, whereas the other contains water, fluoride complex, and stabilizers. For activation, the two compartments are squeezed into each other and the resulting mix can be applied directly on the tooth surface. The brackets were then bonded with Transbond XT adhesive and light cured for 20 seconds.
- Group II. Twenty brackets were bonded using Maxcem (Kerr, Sybron Dental Specialties, Orange, Calif). Maxcem is a two-paste, dual-cure resin cement that combines the etchant, primer, and adhesive resin into one material.¹⁵ It contains a proprietary Redox Initiator system, an efficient dual-cure mechanism, that allows the resin to set up quickly in the absence of light curing.¹⁵ Without light curing, the material sets within 2-3 minutes, but for a quicker set it is suggested that the material be light cured for 20 seconds.¹⁵

The teeth were cleaned, polished, and air-dried as in group I. The auto-mixing tip was placed on the dual syringe cartridge that contains the two pastes. The mixed paste was placed directly on the bracket base, and the bracket was then placed on the tooth.

In both groups, each bracket was subjected to a 300-g compressive force using a force gauge (Correx Co, Bern, Switzerland) for 10 seconds, after which the excess bonding resin was removed using a sharp scaler. The brackets were light cured for 20 seconds as recommended by the manufacturer.¹⁵ All samples were debonded within half an hour from the time of bonding to simulate the clinical conditions when archwires are first tied to the newly bonded teeth.

Debonding procedure

The teeth were embedded in acrylic in phenolic rings (Buehler Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surface of the tooth perpendicular with the bottom of the mold. Each tooth was oriented with the testing device as a guide such that its labial surface was parallel to the force during the shear strength test. A steel rod with one flattened end was attached to the crosshead of a Zwick test machine (Zwick Gm bH & Co, Ulm, Germany). An occlusogingival load was applied to the bracket producing a

TABLE 1. Descriptive Statistics and the Results of the Student's *t*-test Comparisons of the Shear Bond Strengths (in MPa) of the Two Groups Evaluated^a

Groups Tested	\bar{x}	SD	Range
One component Maxcem	3.1	1.7	1.1–7.7
Self-etch primer + Transbond	5.9	2.7	1.1–10.4
	<i>t</i> -test = 3.79		<i>P</i> = .001

^a \bar{x} indicates mean; SD, standard deviation; *P*, probability.

shear force at the bracket-tooth interface. A computer, electronically connected with the Zwick test machine, recorded the results of each test. Shear bond strengths were measured at a crosshead speed of five mm/min.

Evaluation of the residual adhesive

After bond failure, the teeth and brackets were examined under 10 \times magnification. Any adhesive remaining after bracket removal was assessed using a modified Adhesive Remnant Index (ARI) and scored with respect to the amount of resin material adhering to the enamel surface. The ARI scale has a range between 5 and 1, with 5 indicating that no composite remained on the enamel; 4, less than 10% of the composite remained on the surface; 3, more than 10% but less than 90% of the composite remained; 2, more than 90% of the composite remained; and 1, all the composite remained on the tooth along with the impression of the bracket base. The ARI scores were used to better define the site of bond failure between the enamel, the adhesive, and the bracket base.

Statistical analysis

Descriptive statistics including the mean, standard deviation, minimum, and maximum values were calculated for each of the two test groups. The Student's *t*-test was used to determine whether significant differences were present in the bond strength between the two groups. The chi-square test was used to compare the sites of bond failure after debonding. Significance for the statistical test was predetermined at *P* \leq .05.

RESULTS

The descriptive statistics for the shear bond strengths of the two groups are presented in Table 1. The results of the Student's *t*-test (*t* = 3.79) indicated that the shear bond strengths of the two groups were significantly different (*P* = .001) from each other. The two-step self-etch primer/adhesive system had a mean shear bond strength of 5.9 ± 2.7 MPa, whereas the one-step self-etch primer/adhesive system had a mean shear bond strength of 3.1 ± 1.7 MPa.

TABLE 2. Frequency Distribution of the ARI and the Results of Chi-square Comparisons of the Two Groups Evaluated^a

Groups Tested	ARI Scores ^b				
	1	2	3	4	5
One component Maxcem	11	3	4	2	—
Self-etch primer + Transbond	3	8	8	1	—
	$\chi^2 = 8.51$ <i>P</i> = .037				

^a ARI indicates Adhesive Residual Index.

^b The ARI scale has a range between 5 and 1, with 5 indicating that no composite remained on the enamel; 4, less than 10% of the composite remained on the surface; 3, more than 10% but less than 90% of the composite remained; 2, more than 90% of the composite remained and 1, all of the composite remained on the tooth, along with the impression of the bracket base.

Adhesive Remnant Index

The ARI scores for the two groups tested are presented in Table 2. The chi-square test results ($\chi^2 = 8.51$) indicated the presence of a significant difference between the two groups (*P* = .037). A closer look at the data indicated that there was a greater incidence of bracket failure at the bracket-adhesive interface with the new one-step system, ie, most of the adhesive remained on the bracket.

DISCUSSION

The direct bonding of orthodontic brackets has revolutionized and advanced the clinical practice of orthodontics. However, there is a need to improve the bonding procedure by saving time and also minimizing enamel loss, without jeopardizing the ability to maintain clinically useful bond strength. Although the more recent bonding systems have been proven to be more reliable,^{13,14} improvements are still necessary to minimize technique sensitivity as well as reduce the chair time by reducing the number of steps during the bonding procedure. Traditionally, the use of acid etchants followed by a primer was an essential part of the bonding procedure of composite adhesives to allow good wetting and penetration of the sealant into the enamel surface.^{7,8} In general, the self-etch primers are believed to simplify the clinical handling of the adhesive systems by combining the etchant and the primer in one application.^{1,3,6,9–14} Earlier generations of acidic primers were selectively compatible with different adhesives and as a result either produced significantly lower bond strength or needed significantly more working time.⁶

This study evaluated the use of two adhesive systems, Maxcem that mixes all the components of the adhesive system into one paste that can be applied in one step and Transbond XT system that is applied in two steps during the bonding procedure. The findings indicated that the one-step bonding system provided

less shear bond strength ($\bar{x} = 3.1 \pm 1.7$ MPa) than the two-step, self-etch primer ($\bar{x} = 5.9 \pm 2.7$ MPa).

It needs to be remembered that this is an in vitro study, and care should be taken in interpreting the results to those that might be obtained in the oral environment. In addition, more research is needed to determine the shear bond strength of these new systems over a longer time period, eg, 24 hours and one week after bonding as well as after thermocycling.

CONCLUSIONS

- By reducing the number of steps during bonding orthodontic brackets to the teeth, clinicians are able to save time as well as reduce the potential for error and contamination during the bonding procedure.
- A one-step adhesive system has the potential to be successfully used in bonding orthodontic brackets if its shear bond strength can be increased.

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