SCIENTIFIC SECTION

An *ex vivo* assessment of a bonding technique using a self-etching primer

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Abstract

Objective: This study assessed a new self-etch/priming system for use in orthodontic bonding.

Setting: An *ex vivo* study.

Method: Three groups of 20 extracted premolar teeth were bonded with metal orthodontic brackets. Group 1 was bonded with Transbond using the conventional technique (control). Group 2 was bonded using the new Transbond-Plus™ combined etch/primer system to wet enamel and Group 3 to dry enamel. The teeth were debonded using an Instron Universal Testing Machine. The mean debond force was calculated for each group and compared statistically. The teeth were examined under the stereomicroscope to assess the site of debond and adhesive remnant index.

Results: Group 2 (etch/primer on wet enamel) had the lowest mean debond value at 5.2 MPa. ANOVA and Tukey tests confirmed that the bond strength results of Group 2 were significantly lower than Groups 1 ($P < 0.01$) and 3 ($P < 0.05$). The enamel/resin interface was the commonest site of bond failure for both etch/primer groups (Groups 2 and 3). They had less retained resin and significantly ($P < 0.001$) lower ARI scores compared with Group 1 (control).

Conclusions: The results of this *ex vivo* study suggest that the self-etch primer should achieve adequate bond strengths when applied to dry enamel surfaces. In addition there should be less retained resin requiring removal at debond.

Index words: Adhesive remnant index, orthodontic bonding, self-etching primer

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Introduction

Orthodontic attachments are now routinely bonded to teeth using the acid etch technique. This technique was first outlined by Buonocore.[1] Its use in orthodontics was pioneered by Newman[2] and later refined by Miura *et al.*[3] Typically, current techniques involve applying phosphoric acid to dry tooth enamel for approximately 15–30 seconds prior to thoroughly washing and drying the enamel surface.[4] 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 adhesive. Any etch procedure is therefore technique sensitive, and requires adequate isolation to prevent moisture contamination of the etched enamel surface and resulting reduced bond strength.[5]

Modern orthodontic bonding adhesives in routine use are Bis-GMA based composite resin systems with variable amounts of filler. Polymerization can be initiated chemically (chemically cured) or with a visible blue light source (light cured) or a combination (dual cured) depending on the system. Most systems require the application of a layer of unfilled resin or primer onto the etched enamel surface prior to bonding. Due to this the bonding process has an added step, which adds to the clinical time required for fixed appliance placement.

Recently, to overcome this problem, the manufacturers of a light-cured bonding system, Transbond™ (3m Unitek, Moravia, California, USA) have introduced a combined etch primer system, Transbond-Plus™. This system by combining the etching and priming steps in the bonding process aims to reduce the clinical time required for appliance placement. It comprises methacrylated

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phosphoric acid esters, which will both etch and prime the enamel surface prior to bonding. The manufacturers also claim that it can be applied to a wet enamel surface and achieve adequate etching and priming in a 3-second period. Obviously, from a clinical perspective this would be very advantageous since isolation should be less of a problem and enamel preparation would be less technique sensitive, and could be achieved more rapidly compared to a conventional etch/priming procedure.

The present *ex vivo* study aims to assess the bond strength of brackets bonded with the new self-etch/priming system compared with those bonded using a conventional etch/priming technique.

Methods

Sixty sound extracted premolar teeth were divided randomly into three groups of 20 teeth. They were mounted in polyester blocks with the long axis of each tooth vertical.

The teeth were bonded with pre-adjusted 0.022-inch 3M minitwin™ brackets using the following bonding techniques:

- *Group 1:* The brackets were bonded with Transbond™ using a conventional acid etch and bonding technique. This group served as the control.
- *Group 2:* The brackets were bonded with Transbond™ using the new etch/primer system to a wet enamel surface.
- *Group 3:* The brackets were bonded with Transbond™ using the new etch/primer system to a dry enamel surface.

The materials were all mixed and applied according to the manufacturers instructions by one operator. Group 1 (control) was bonded conventionally with a 30-second acid etch time and separate application of conventional Transbond™ primer. Groups 2 and 3 were bonded with the new self-etching primer system, which was applied for less than 5 seconds as recommended by the manufacturer. Light curing for all groups was carried out with a 60-second exposure to a blue light source (Visilux 2 3M, St Paul, Mn, USA). This was split into two 30-second durations from the mesial and distal of each specimen. A longer than conventional curing time was used to ensure complete polymerization of the specimens.

The bonded teeth were stored in distilled water at 37°C. The teeth were debonded using the Instron Universal Testing Machine (Instron Ltd, High Wycombe, U.K.) as recommended previously.[6]. The debonding technique involved the application of a force to the bracket via a wire loop located under the gingival aspect of the bracket. The steel wire and polyester blocks were mounted on universal joints to ensure perpendicular pull to the bracket. The force was applied by the Instron with a cross-head speed of 1 mm/minute. The maximum force applied to produce bond failure was measured in Newtons and recorded. The force per unit area was then calculated and recorded in MPa as the shear bond strength.

Following debond each tooth was examined under the stereomicroscope and the site of bond failure recorded along with the Adhesive Remnant Index.[7] This index consists of the following scoring : 0 = no retained resin, 1 = <50 per cent retained resin, 2 = >50 per cent retained resin, and 3 = all resin retained with bracket imprint.

The data was assessed using summary statistics before being analysed using analysis of variance and Tukey tests. Weibull analysis was also carried out which relates the probability of bracket failure to the applied load. This analysis has been advocated previously.[6,8] The ARI data was assessed using chi-square tests.

Results

The bond strength characteristics of the test groups are illustrated in Table 1. The control Group 1 (conventional etch/bond technique) and Group 3 (etch/primer on dry enamel) had similar mean debond values at 7.1 and 7.2 MPa, respectively. Group 2 (etch/primer on wet enamel) had the lowest mean debond value at 5.2 MPa. ANOVA and Tukey tests confirmed that the bond strength results of Group 2 were significantly lower than Groups 1 ($P < 0.01$) and 3 ($P < 0.05$).

Table 2 demonstrates the Weibull analysis of the test groups. The reliability of the material is a function of the Weibull modulus and normalizing parameter (characteristic strength). The correlation coefficient describes how closely the data fits the curve produced by the Weibull equation. The data is presented graphically in Figure 1

Table 1 Bond strength values (MPa) for test groups

	Group 1	Group 2	Group 3
Mean	7.1	5.2	7.2
SD	2.4	1.5	2.5
SE	0.5	3.6	0.6
Max. value	12.9	7.4	11.3
Min. value	2.9	1.7	3.1

Group 1 = control; Group 2 = etch/primer (wet); Group 3 = etch/primer (dry).

Table 2 Weibull analysis of test groups

Group	Weibull Modulus	SE	Normalizing parameter	Correlation coefficient	Probability of failure (75 N)
Group 1	2.97	0.08	84.6	0.99	52%
Group 2	2.44	0.22	62.7	0.88	86%
Group 3	2.66	0.1	86.1	0.98	52%

Table 3 Site of bond failure and adhesive remnant index scores for test groups

Group	Enamel/ resin (%)	Bracket/ resin (%)	Adhesive Remnant Index (total)
Group 1	15	85	44
Group 2	72	28	27
Group 3	63	37	29

and consists of the cumulative probability of bond failure plotted against applied load. The probability of bond failure at 75 N (7.1 Mpa) was calculated for each group as this approximated to the mean debond force level required to debond the control group. The probability of bond failure at 75 N (7.1 Mpa) was calculated at 52 per cent for Groups 1 and 3, and 86 per cent for group 2.

The sites of bond failure (percentages for each group) are presented in Table 3 along with the adhesive remnant index (ARI) scores. The bracket/resin interface was the commonest site of failure for Group1(control). However, the enamel/resin interface was the commonest site for both etch/primer groups (Groups 2 and 3). Chi-square testing demonstrates that the etch/primer groups (Groups 2 and 3) had significantly ($P < 0.001$) lower ARI scores and therefore, less retained resin compared with Group 1 (control).

Discussion

The results of any *in vitro* bond strength study should be interpreted with caution, especially when predicting clinical performance. The present study has followed guidelines outlined previously[6] and used in previous bond strength studies.[9,10] At present, there is not a universally accepted minimum clinical bond strength. However previous studies[11,12] suggest that orthodontic bond strength should be in the order of 3–7 Mpa.

The results of the present *ex vivo* study suggest that adequate bond strengths can be achieved with the new self-etching primer system when bonding is carried out to a dry enamel surface. (7.2 Mpa) No significant differences in bond strength measurements were found compared to

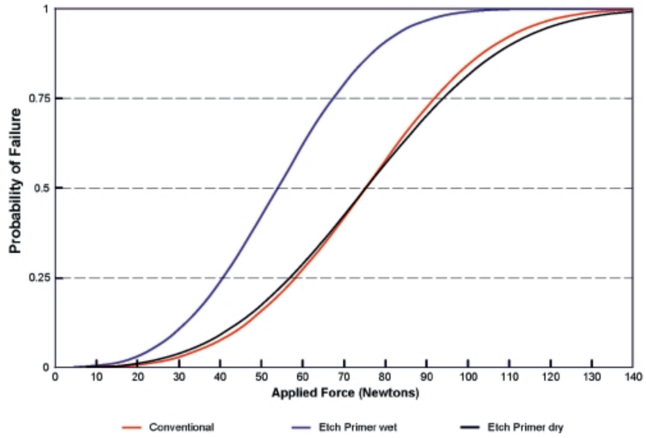

Fig. 1 Weibull curves for test groups.

the conventionally bonded control group (7.1 Mpa). A previous study[13] utilizing a different self-etch primer system reported a similar mean bond strength (7.1 Mpa).

The manufacturers of the new self-etching primer system suggest that adequate bond strengths can be achieved bonding to a wet enamel surface. This would obviously be very advantageous from a clinical point of view. However, the results of the present study suggest that brackets bonded in this way have significantly lower bond strengths (5.2 MPa) compared with a conventionally bonded control. Weibull analysis relating probability of failure to applied load suggests that 86 per cent of brackets will fail at 75 N (7.1 Mpa) compared with 52 per cent of the control. A previous study[14] using a different self-etch primer reported similar results bonding to wet enamel with a mean bond force of 4.8 MPa. Interestingly, the reported reduced bond strength occurred irrespective of whether the contamination of the enamel surface occurred before or after application of the etch primer.

In the present study, when assessing the site of bond failure, the percentage of brackets failing at the enamel/resin interface was increased with the new self-etch primer (72 and 63 per cent) compared with the conventionally bonded control (15 per cent). They also had correspondingly lower adhesive remnant scores. This would be an advantage in the clinical situation as less time will be required at the end of treatment removing retained resin from enamel surfaces.

Conclusions

1. The new Transbond-Plus™ self-etch priming system can achieve adequate bond strength levels when applied to a dry enamel surface.

2. Lower bond strength levels were achieved when bonding to a wet enamel surface with a higher probability of failure at any applied load.
3. The self-etch primer groups failed more often at the enamel/resin interface with less retained resin compared with the control.
4. The results of this *ex vivo* study suggest that in the clinical situation the self-etch primer should achieve adequate bond strengths when applied to dry enamel surfaces. In addition, there should be less retained resin requiring removal at the end of treatment.
5. A randomized clinical trial is recommended to confirm the findings of this study.

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