Original Research

Effect of Using Self-Etching Primer for Bonding Orthodontic Brackets

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Abstract: Questions over the use of self-etching primers with composite resin adhesives in the bonding of orthodontic brackets remain unsolved. In addition, there are no previous reports on the efficacy of self-etching primers with resin-modified glass ionomer cements for bonding orthodontic brackets in orthodontic dentistry. The purpose of this study was to determine the shear bond strengths of orthodontic brackets bonded with one of four protocols: (1) a composite resin adhesive used with 40% phosphoric acid, (2) the same composite resin used with Megabond self-etching primer, (3) a resin-modified glass ionomer cement adhesive used with 10% polyacrylic acid enamel conditioner, and (4) the same resin-modified glass ionomer cement used with Megabond self-etching primer. The appearance of the tooth surfaces after acid etching or priming was observed with a field-emission scanning electron microscope (FE-SEM). When used with resin-modified glass ionomer cement, Megabond self-etching primer gave no significantly different shear bond strength compared with polyacrylic acid etching. But when used with composite resin adhesive, Megabond self-etching primer gave significantly lower shear bond strength than phosphoric acid etching. However, the shear bond strength of orthodontic brackets bonded with composite resin adhesive after Megabond priming was almost the same as that of brackets bonded with resin-modified glass ionomer cement after polyacrylic acid etching. FE-SEM observation revealed that Megabond self-etching primer produced less dissolution of enamel surface than did phosphoric acid and polyacrylic acid etching. Megabond self-etching primer may be a candidate for bonding orthodontic brackets using the resin-modified glass ionomer cement for minimizing the amount of enamel loss. (*Angle Orthod* 2002;72:558–564.)

Key Words: Self-etching primer; Shear bond strength; Adhesive Remnant Index; Phosphoric acid etching; Polyacrylic acid etching

INTRODUCTION

Direct bonding of orthodontic brackets is now routinely performed for esthetic reasons. Direct bonding adhesives provide clinically acceptable bond strength. Orthodontists commonly use the acid-etch bonding technique when attaching brackets to the enamel surface. Manufactures recommend phosphoric acid etching for a composite resin adhesive and polyacrylic acid etching for a resin-modified glass ionomer cement.

Both phosphoric acid etching and polyacrylic acid etching require rinsing and drying after application of the etching reagent. The etching procedure is sometimes troublesome, and there is a risk of contamination during the etching process. Moreover, phosphoric acid etching has been blamed for decalcification and the development of white spot lesions around bonded orthodontic appliances.[1,2] Some reports have mentioned the mechanical damage to the enamel during debonding and removal of the remaining resin after acid etching.[3–5]

In conservative dentistry, self-etching primers are being increasingly used in place of phosphoric acid etching for composite resin restorations, and their efficacy with respect to adhesion to dentin and enamel has been reported.[6–9] Self-etching primers function both as an etching agent and a primer. Rinsing of enamel is not required after application of the self-etching primer. Thus the use of a self-etching primer reduces the clinical steps and saves clinical operation time because the separate acid-etching and water-rinsing steps are eliminated and the application requires simply drying with air.

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TABLE 1. Materials Used in this Study[a]

Material	Component	Composition	Batch No.	Manufacturer
Kurasper F	K-etchant	40% phosphoric acid	204	Kuraray Medical Inc, Tokyo, Japan
	F-bond	Methacryloyl fluoride-MMA copolymer, HEMA, dimethacrylates	0020	
	Kurasper F paste	Dimethacrylates, silica filler	0009	
Fuji Ortho LC	Conditioner	10% polyacrylic acid	060571	GC Dental Industrial Corp, Tokyo, Japan
	Cement powder	Fluoroaluminosilicate glass	060571	
	Cement liquid	HEMA, maleic/acrylic acid copolymer, camphorquinone	060571	
Megabond self-etching primer		MDP, HEMA, polyfunctional dimethacrylates	00103A	Kuraray Medical, Tokyo, Japan

[a] MMA = methyl methacrylote; MDP = 10-methacryloxydecyl dihydrogen phosphate; HEMA = hydroxylethyl methacrylate.

Bishara et al[10,11] evaluated the effectiveness of using acidic self-etching primers to bond orthodontic brackets with composite resin adhesives. They reported that an acidic self-etching primer containing phenyl-P provided a clinically acceptable shear bond force when used with a highly filled composite adhesive (Panabia 21, Kuraray Medical Inc, Tokyo, Japan) but did not give sufficient bond strengths when used with a lightly filled composite adhesive (Clearfil Liner Bond 2, Kuraray Medical) or the traditional composite resin adhesive Transbond XT (3M Unitek, Monrovia, Calif). The use of a newly developed self-etching primer, Prompt L-Pop (ESPE Dental AG, Seefeld, Germany) resulted in clinically acceptable bond strengths when used with Transbond XT.[12] These findings indicated that more research is needed to define the effective orthodontic self-etching primer bonding system.

A new one-bottle type of acidic self-etching primer, Megabond self-etching primer (Kuraray Medical), was developed for composite resin restorations.[13] Megabond self-etching primer is a component of the Clearfil Megabond System (Kuraray Medical; also known as Clearfil SE Bond outside Japan) and contains a phosphoric acid ester monomer, 10-methacryloxydecyl dihydrogen phosphate (MDP). We intended to apply the Megabond self-etching primer to bonding orthodontic brackets not only with a composite resin adhesive but also with resin-modified glass ionomer cement. However, a consensus over the effectiveness of using Megabond self-etching primer with orthodontic composite resin adhesive has not been obtained. In addition, to our knowledge, there is no report on the shear bond strength of resin-modified glass ionomer cement bonded to enamel surface treated with a self-etching primer in orthodontic dentistry.

In this study, we determined the shear bond strengths of orthodontic brackets bonded with one of four procedures: (1) a composite resin adhesive used with 40% phosphoric acid etchant, (2) the same composite resin used with Megabond self-etching primer, (3) a resin-modified glass ionomer cement adhesive used with 10% polyacrylic acid enamel conditioner, and (4) the same resin-modified glass ionomer cement used with Megabond self-etching primer. The surface appearances of teeth after etching or self-etch priming were observed with a field-emission scanning electron microscope (FE-SEM).

MATERIALS AND METHODS

A total of 72 freshly extracted bovine incisors was randomly allocated to four groups, with 18 teeth in each group. The roots of the teeth were cut off, leaving the crown to be embedded. The teeth were embedded in acrylic resin with the buccal surfaces available for bonding. After the acrylic resin was cured, the tooth surfaces to be bonded were cleansed and then polished with pumice and rubber prophylactic cups for 10 seconds.

Orthodontic metal brackets (Standard Edgewise 100-1100, Dentsply-Sankin K.K., Tokyo, Japan) were used in this study. The average bracket surface area was determined to be 9.64 mm^2. The brackets were bonded to the teeth according to one of the four protocols (n = 18) described in the following. The materials used in this study are listed in Table 1.

Protocol 1: phosphoric acid etching + Kurasper F

The teeth were etched with 40% phosphoric acid gel for 40 seconds, washed for 20 seconds, and air-dried. The bonding agent, F bond (Kuraray Medical), was applied and light-cured for 10 seconds. Then the brackets were bonded with Kurasper F paste (Kuraray Medical) and light-cured for 20 seconds following the manufacturer's instructions.

Protocol 2: self-etching primer + Kurasper F

An acidic self-etching primer (Megabond self-etching primer) that contained MDP, hydroxylethyl methacrylate

(HEMA), and polyfunctional methacrylates was placed on the enamel for 30 seconds. Excessive primer solution was evaporated using compressed air. Then the bonding agent and the same composite resin adhesive used in Protocol 1 were applied as described previously.

Protocol 3: polyacrylic acid etching + Fuji Ortho LC

The teeth were etched with Fuji Ortho LC Conditioner (10% polyacrylic acid) for 20 seconds, washed for 20 seconds, and air-dried. The brackets were bonded with Fuji Ortho LC resin-modified glass ionomer cement (GC Dental Industrial Corp, Tokyo, Japan) and light-cured for 20 seconds following the manufacturer's instructions.

Protocol 4: self-etching primer + Fuji Ortho LC

An acidic self-etching primer, Megabond self-etching primer, was placed on the enamel for 30 seconds. Excessive primer was then evaporated using compressed air. The cement used to bond the brackets was Fuji Ortho LC as in protocol 3.

Each bracket was subjected to a 300 *g* force, and excess bonding resin was removed with a small scaler. All samples were stored in deionized water at 37°C for 24 hours. Shear bond strength was measured according to Noguchi's method[14] as shown in Figure 1, using a testing machine (TCM-500CR, Shinkoh, Tokyo, Japan) at a crosshead speed of 2 mm/min.

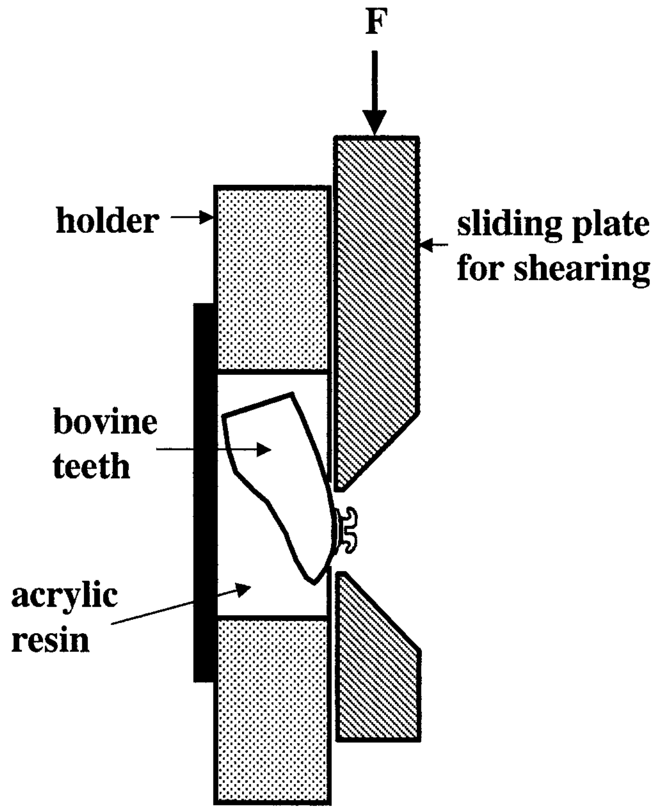

FIGURE 1. Schematic drawing of shear bond strength measurements.

After debonding, the teeth and brackets were examined under 10× magnification. The debonding characteristics for each specimen were determined using the Adhesive Remnant Index (ARI).[15] The amount of residual material adhering to the enamel surface was scored according to the reported method.[16] The ARI score has a range between 0 and 3 as follows: score 0, no adhesive remained on the enamel; 1, less than half of the adhesive remained on the tooth surface; 2, more than half of the adhesive remained on the tooth; 3, all the adhesive remained on the tooth, with a distinct impression of the bracket base.

Statistical analysis

Eighteen specimens were tested for each protocol. Significant differences in measurement were determined by analysis of variance and Scheffe's test for multiple comparisons among the means of the four protocols. The chi-squared test was used to determine significant differences in the ARI scores among the four protocols. Significance for all statistical tests was predetermined at $P < .05$.

FE-SEM observation

The bovine enamel surfaces were cleansed and polished with pumice and rubber prophylactic cups as described previously. The bovine teeth surfaces were etched with K-etchant for 40 seconds or Conditioner for 20 seconds and were washed for 20 seconds. After washing, each specimen was dehydrated through a graded series of ethanol, dried in a critical drying apparatus, and ion-coated with platinum.

Another specimen was prepared after Megabond self-etching primer treatment. The tooth was treated with Megabond self-etching primer for 30 seconds, and the excess solution was evaporated using compressed air. The specimen was also dehydrated, dried, and ion-coated by the method described previously.

The surface appearances of the etched and self-etch primed tooth specimens were observed using an FE-SEM (JSM-6340F, JEOL, Tokyo, Japan). The appearance of the enamel surface polished with pumice and rubber prophylactic cups was also observed.

RESULTS

Comparison of shear bond strengths

The results of shear bond strength measurements are listed in Table 2, and the *P* values obtained by Scheff's test are listed in Table 3.

Protocol 1 (phosphoric acid etching + Kurasper-F) showed a significantly higher shear bond strength than did the other three protocols ($F = 6.704$, $P < .05$). There were no significant differences among protocol 2 (Megabond

TABLE 2. Shear Bond Strengths Between Brackets and Enamel

Protocol	Shear Bond Strength (MPa) Mean	Standard Deviation	Range
Protocol 1 (phosphoric acid etching + Kurasper F)	12.0[a]	3.3	5.4–16.7
Protocol 2 (Megabond self-etching primer + Kurasper F)	8.8[b]	2.9	3.3–12.4
Protocol 3 (polyacrylic acid etching + Fuji Ortho LC)	8.6[b]	3.0	3.9–16.5
Protocol 4 (Megabond self-etching primer + Fuji Ortho LC)	7.9[b]	2.7	3.4–14.4

[a,b] Mean values with the same superscripts are not significantly different within the same pretreatment ($P > .05$). Significant differences were found between a and b, and no significant difference among b.

TABLE 3. *P* values Obtained From Scheffe's Test

	Protocol 1	Protocol 2	Protocol 3	Protocol 4
Protocol 1	—	.0021	.0011	.0001
Protocol 2	—	—	.8198	.3577
Protocol 3	—	—	—	.4880

self-etching primer + Kurasper F), protocol 3 (polyacrylic acid + Fuji Ortho LC) and protocol 4 (Megabond self-etching primer + Fuji Ortho LC).

Comparison of ARI

The results of the ARI scores are shown in Table 4. The chi-squared test showed no significant difference in the ARI score among the four protocols (chi-square value = 10.313, $P = .1121$).

FE-SEM observation

Figure 2 shows the SEM pictures of enamel surfaces that have been (1) polished, (2) etched with phosphoric acid, (3) polyacrylic acid, or (4) treated with Megabond self-etching primer.

After cleansing and polishing, the tooth surface was still covered with organic pellicle. The presence of circles, presumably indicating enamel rods, was identified (Figure 2a; arrow), and minute focal holes were observed on the surface (arrowhead).

Phosphoric acid etching produced roughened enamel surfaces and preferentially dissolved enamel peripheries (Figure 2b). Enamel rods were identified.

Polyacrylic acid etching produced a less roughened surface than did phosphoric acid etching (Figure 2c). The surface was partly dissolved. The number and size of focal holes (Figure 2c, arrowhead) were increased compared with Figure 2a.

In the FE-SEM picture of the enamel surface after treatment with Megabond self-etching primer (Figure 2d), the dissolution pattern was different from that observed after phosphoric or polyacrylic acid etching. Residual organic pellicles were present on the surface (Figure 2d, arrow), and the presence of holes (arrowhead) was also observed.

DISCUSSION

In the present study, we determined the effectiveness of a one-bottle–type self-etching primer, Megabond self-etching primer, on the shear bond strength when used with composite resin adhesive or resin-modified glass ionomer cement. The manufacturer recommended phosphoric acid etching for the composite resin adhesive and polyacrylic acid etching for the resin-modified glass ionomer cement used in this study.

The composite adhesive used in the present study contains fluoride, as does the resin-modified glass ionomer cement. We selected the fluoride-containing composite resin adhesive in order to control for the influence of fluoride on the shear bond strength.

Direct bonding of orthodontic brackets using the acid-etching technique has become a common technique in the orthodontic field. Phosphoric acid etching produces a roughened enamel surface by dissolving calcium components and forms enamel resin tags. Although the enamel-etching technique is a useful and accepted orthodontic procedure for bonding orthodontic brackets, there is a need to improve the ability to maintain clinically useful bond strengths while minimizing the amount of enamel loss. FE-SEM observation in the present study revealed a smaller

TABLE 4. Frequency Distribution of the Adhesive Remnant Index (ARI)

Protocol	ARI scores 0	1	2	3	N
Protocol 1 (phosphoric acid etching + Kurasper F)	12	6	—	—	18
Protocol 2 (Megabond self-etching primer + Kurasper F)	10	8	—	—	18
Protocol 3 (polyacrylic acid etching + Fuji Ortho LC)	11	4	3	—	18
Protocol 4 (Megabond self-etching primer + Fuji Ortho LC)	6	9	3	—	18

Chi-square value = 10.313, $P = .1121$.

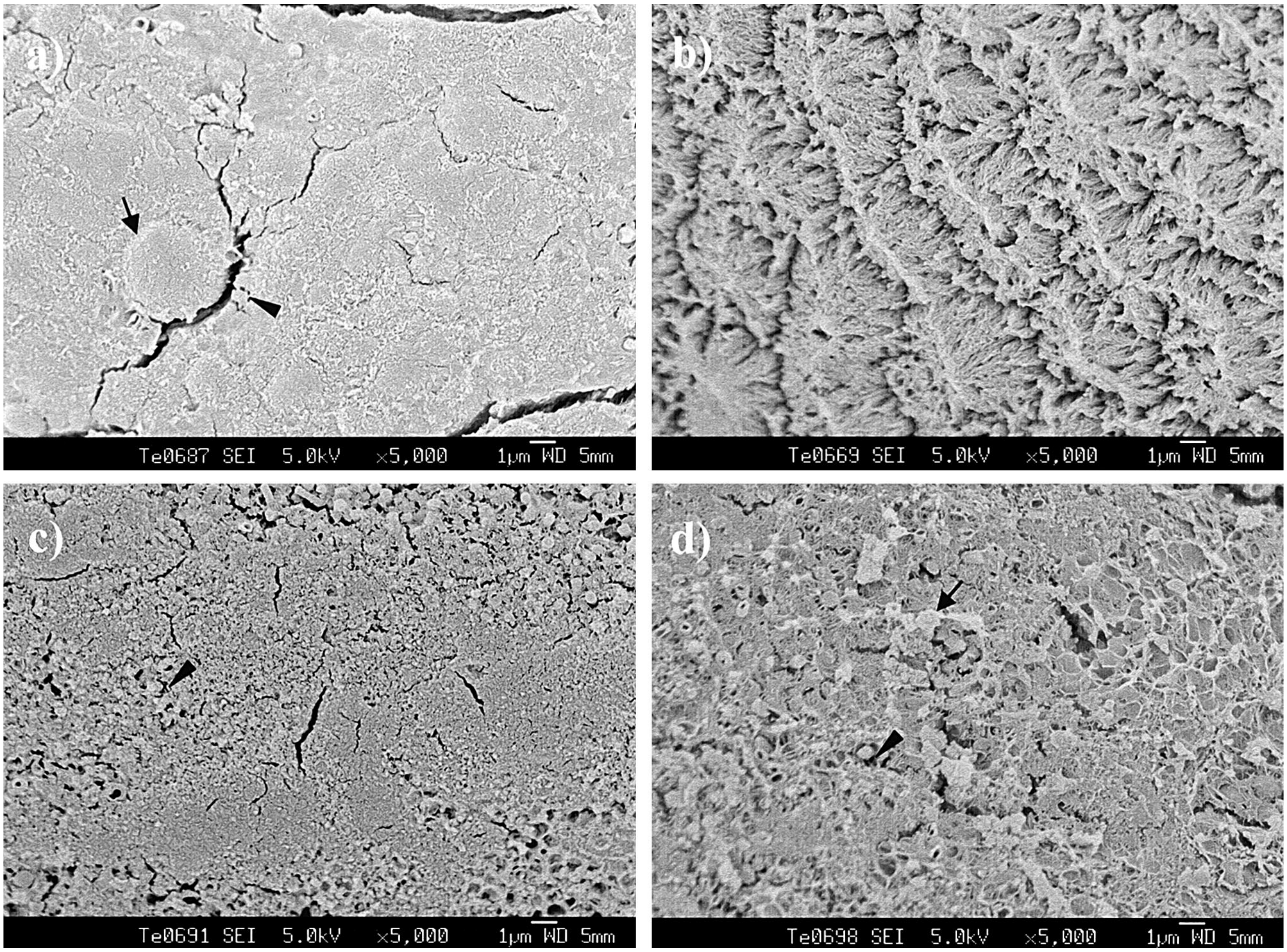

FIGURE 2. FE-SEM pictures of enamel surfaces. (a) Cleansed surface: circles are presumably enamel rods (arrow), and minute focal holes (arrowhead) are observed. (b) Phosphoric acid etched surface: highly roughened enamel surfaces and enamel rods are evident. (c) Polyacrylic acid etched surface: number and size of focal holes (arrowhead) are increased compared with Figure 2a. (d) Megabond self-etching primed surface: residual organic pellicles are present (arrow), and holes are also identified (arrowhead).

extent of enamel dissolution by treatment with Megabond self-etching primer than with phosphoric acid or polyacrylic acid etching. Reduction of enamel loss may be achieved using Megabond self-etching primer.

The ARI scores were comparable for Megabond self-etching primer and acid etching when used with composite resin adhesive or resin-modified glass ionomer cement. Bishara et al[11] maintained that bond failure at the bracket-adhesive interface or within the adhesive is more desirable and safer than failure at the adhesive-enamel interface because enamel fracture and crazing have been reported at the time of bracket debonding. The present results indicate that the use of Megabond self-etching primer presents no serious problems at debonding of the orthodontic brackets.

When used with resin-modified glass ionomer cement, we found that Megabond self-etching primer gave no significantly different bond strength compared with polyacrylic acid etching. The results obtained from the present study suggest that Megabond self-etching primer may be used as an alternative to polyacrylic acid etching when bonding orthodontic brackets with resin-modified glass ionomer cement. In contrast, when used with composite resin adhesive, the use of Megabond self-etching primer resulted in significantly lower bond strength than when using phosphoric acid etching. Recent studies of conservative dentistry have suggested that self-etching primers with milder actions are less effective than phosphoric acid when used to bond ground enamel with a thick smear layer or intact unground enamel.[17–19] These previous results are substantiated by the results for a composite resin adhesive obtained in the present study.

It has been supposed that the main contribution to the shear bond strength of orthodontic brackets bonded with composite resin adhesive is the mechanical interlocking of cured resin that is formed on the roughened enamel surface.[20,21] However, there is no significant difference in shear bond strength between protocols 2 and 3. The shear bond strength of orthodontic brackets bonded with composite resin adhesive after Megabond priming (protocol 2) was almost the same as that of those bonded with resin-modified glass ionomer cement after polyacrylic acid etching (protocol 3). If protocol 3 is clinically acceptable, then protocol 2 also has a possibility of clinical application. Reynolds[22] suggested that a tensile bond strength of approximately 5 MPa was adequate for clinical success. Although the clinically acceptable shear bond strength is still unknown, shear bond strengths of about 8–9 MPa were obtained for Megabond self-etching primer used with composite resin and resin-modified glass ionomer cement. Nevertheless, in the absence of a clinically acceptable shear bond strength, it is difficult to evaluate the efficacy of Megabond self-etching primer for composite resin adhesives from the present results. Further studies are required to establish the clinically acceptable shear bond strength and to identify the efficacy of Megabond self-etching primer for the bonding of orthodontic brackets.

In the present study, bovine teeth were used as a substitute for human teeth because of the morphological similarity between bovine and human enamel and the difficulties in obtaining human teeth. The similarities in physical properties and composition of bovine and human enamel have been reported.[23,24] Furthermore Komori and Ishikawa[25] and Shinha et al[26] evaluated the bond strength of light-cured glass ionomer cements and/or light-cured composite resin adhesive using bovine enamel. However, some differences exist between bovine and human teeth, and the results obtained from bovine teeth sometimes cannot be extrapolated to human teeth. The present tests using bovine teeth should be evaluated as screening tests, whereas the final evaluation of the efficacy of self-etching primers for clinical usefulness will be conducted using human teeth.

CONCLUSIONS

When applied to bonding of orthodontic brackets, Megabond self-etching primer gave the same shear bond strength as acid-etching when used with a resin-modified glass ionomer cement, but Megabond gave a significantly lower shear bond strength when used with a composite resin adhesive. However, Megabond self-etching primer treatment produced less enamel dissolution than did etching with phosphoric acid and polyacrylic acids. The present findings provide evidence that Megabond self-etching primer is a candidate for bonding orthodontic brackets using the resin-modified glass ionomer cement, with the advantage of minimizing the amount of enamel loss. However, it was difficult to determine the efficacy of Megabond self-etching primer when used with composite resin adhesive in the present study.

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