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Shear Bond Strength of Orthodontic Brackets Bonded using Conventional vs One and Two Step Self-etching/adhesive Systems

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ABSTRACT

Objective: To assess and compare the effects of one- and two-step self-etching primer and adhesive with conventional acid-etching and bonding system on the shear bond strength of orthodontic brackets.

Materials and Methods: The one-step self-etching primer and adhesive used was Clearfil tri-S bond, the two-step fluoride-releasing antibacterial self-etching primer and adhesive was Clearfil Protect Bond, and the fluoride-releasing conventional acid-etching and bonding system was Kurasper F Bond. Brackets were bonded to defect-free human premolars (n = 14 per group) according to each manufacturer's recommendations by using light-cured bracket adhesive Kurasper F Paste with a light-emitting diode of a light-curing unit. The specimens were stored in deionized water at 37°C for 48 hours and then tested in shear with a universal testing machine at a crosshead speed of 5 mm/min until the brackets debonded. The mode of failure of the brackets was determined by a modified adhesive remnant index.

Results: Mean shear bond strength values were 9.00 MPa for Kurasper F Bond, 9.55 MPa for Clearfil Protect Bond, and 9.48 MPa for Clearfil tri-S Bond. One-way analysis of variance detected no statistically significant difference among groups ($P = .98$, $P > .05$). The predominant failure for the three groups was at the bracket-adhesive interface leaving less than 25% of the adhesive on the bracket base.

Conclusions: One-step self-etching adhesive and two-step fluoride-releasing antibacterial self-etching adhesive have sufficient mechanical properties for the bonding of orthodontic brackets.

KEY WORDS: Orthodontic bracket, Self-etching primer/adhesive, Shear bond strength, ARI score.

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INTRODUCTION Return to TOC

In 1955, Buonocore introduced the acid-etching bonding technique, and the concept of bonding resins to enamel has developed applications in all fields of dentistry,[1] including the bonding of orthodontic brackets.[1–3] By the 1970s, bonding of orthodontic brackets had become an accepted clinical technique.[4,5] Bonding brackets has some advantages, including ease of placement and removal, minimal soft tissue irritation and hyperplastic gingivitis, minimal danger of decalcification with loose bands, and being more esthetic.[6]

Different materials and methods for bonding brackets are constantly being developed, but in certain cases the problem of decalcification still remains.[7] A lower pH environment, increased retention sites for food particles, and increased retentive sites for *Streptococcus mutans* may be responsible for the occurrence of postorthodontic treatment decalcification.[8–11]

Conventional adhesive systems use three different agents: (1) an enamel conditioner, (2) a primer solution, and (3) an adhesive resin to bond orthodontic brackets to enamel.[12] Orthodontists generally use the conventional acid-etching bonding technique to attach brackets to the enamel surface.[12] The self-etching adhesives have recently become available and combine the functions of primer and adhesive components, not requiring a separate acid-etching step and thus eliminating the need for rinsing. The self-etching systems are capable of etching the tooth surface and simultaneously preparing it for adhesion. Combining conditioning and priming into a single step reduces the bonding time and increases the cost effectiveness for the clinician and indirectly for the patient.[12] However, effective bonding by self-etching systems is controversial.

A two-step fluoride-releasing antibacterial bonding agent was developed by combining the physical advantages of dental adhesive technology and an antibacterial effect.[13–16] A one-step self-etching primer and adhesive system was also recently introduced.

A variety of curing lights are available to photopolymerize light-cured dental resins and adhesives. The most common is the conventional halogen light-curing unit (LCU). Several surveys have reported that halogen LCUs deliver an inadequate light intensity.[17] Light-emitting diode (LED) technology may overcome some of the drawbacks of halogen; consequently, LED technology has a promising future.[17]

The bond strength of one- and two-step self-etching adhesives has been reported comparable with conventional adhesive systems.[18,19] In other studies, newer self-etching primers were evaluated and were found to provide acceptable shear bond values for orthodontic brackets.[12,20–22] The findings are encouraging, but several in vitro studies must support these findings before they become routinely used. Therefore, the purposes of this study were to evaluate the shear bond strengths of brackets bonded with one-step self-etching primer and adhesive and two-step fluoride-releasing antibacterial self-etching primer and compare them with a fluoride-releasing conventional acid-etching and bonding system. The mode of failure of the brackets was determined by a modified adhesive remnant index (ARI).

MATERIALS AND METHODS Return to TOC

Forty-two human premolars (21 maxillary and 21 mandibular) extracted for orthodontic purposes were collected and stored in deionized water. Teeth having hypoplastic enamel, fractures, or caries were excluded. Each tooth was mounted vertically in self-cure acrylic so that the crown was exposed. The teeth were cleaned and polished with nonfluoridated flour of pumice (Moyco Industries, Philadelphia, Pa) in a rubber prophylactic cup for 10 seconds and then rinsed with a stream of water for 10 seconds. The 42 premolars were randomly divided into three groups, including seven maxillary and seven mandibular premolars in each group. The compositions of the adhesive systems used in this study are listed in Table 1. The brackets were bonded by three different protocols according to the manufacturers' instructions.

For group 1 (control group), enamel surfaces were etched with 40% phosphoric acid K etch and acid gel (Kuraray Medical, Inc, Osaka, Japan) for 20 seconds and rinsed with oil-free compressed air. Kurasper F Bond (Kuraray Medical, Inc, Osaka, Japan) was applied on acid-etched surfaces with a brush tip and was light cured for 10 seconds.

Group 2 received Clearfil Protect Bond (Kuraray Medical), a two-step self-etching primer and adhesive system. The Clearfil Protect Bond primer was applied on the enamel for 20 seconds and gently air dried. The Clearfil Protect Bond bonding agent was then applied, followed by a mild airflow and 10 seconds of light curing.

For group 3, Clearfil tri-S Bond (Kuraray Medical, Inc), a one-step self-etching primer and adhesive system, was applied on the enamel for 20 seconds, gently air dried for 5 seconds, and light cured for 10 seconds.

Stainless steel premolar brackets (Generous Roth Brackets of GAC International Inc, Islandia, NY) were used in all teeth, with an average bracket base surface area of 12.13 mm.[2] All the brackets were bonded with the same material (Kurasper F Paste, Kuraray Medical, Inc) and light cured for 20 seconds from the mesial and distal sides of the brackets, respectively. All light curing was performed with a LED LCU (Elipar Free Light, 3M ESPE, St Paul, MN, USA).

All samples were stored in deionized water at 37°C for 48 hours. A mounting jig was used to align the facial surface of the tooth perpendicular to 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 Test Machine, Zwick GmbH & Co, Ulm, Germany). An occlusogingival load was applied to the bracket, producing a shear force at the bracket-tooth interface. A computer that was connected to the Zwick test machine recorded the results of each test. Shear bond strengths were measured at a crosshead speed of 5 mm/min. The force was directly recorded in newtons (N) and converted into megapascals (MPa) with the following equation: shear force (MPa) = debonding force (N)/(w/l) (mm^2), where w = width of the bracket base, l = height of the bracket base, and 1 MPa = 1 N/mm^2.

After debonding, the teeth and brackets were examined under a stereomicroscope (Leica MS5, Singapore) at 10× magnification for any adhesive remaining on the bracket surface and were scored by using the modified ARI.[23] ARI scores range from 5 to 0 (5 = 100% of adhesive left on the bracket, 4 = 100%–75% of adhesive left on the bracket, 3 = 75%– 50% of adhesive left on the bracket, 2 = 50%–25% of adhesive left on the bracket, 1 = less than 25% of adhesive left on the bracket, 0 = no adhesive left on the bracket). Two test teeth, one from group 1 and one from group 3, were lost during the ARI scoring.

Descriptive statistics, including the mean, standard deviation, and minimum and maximum values, were calculated for each of the three test groups. One-way variance of analysis was used for statistical analysis. Significance was determined at a probability value of $P < .05$.

RESULTS Return to TOC

The descriptive statistics for the shear bond strength of three groups tested are presented in Table 2 and Figure 1. There were no statistical significances among the three groups ($P = .98$, $P > .05$). The brackets bonded with either the one- or two-step self-etching primer and adhesive compared with the conventional acid-etching and bond system can withstand equal amounts of force during the shear bond strength test.

The frequency distribution of ARI scores for all groups is shown in Table 3 and Figure 2. The predominant failure for the three groups was at the bracket-adhesive interface leaving less than 25% of the adhesive on the bracket base, as shown by a score of1.

DISCUSSION Return to TOC

In spite of all the developments in orthodontic material and treatment mechanics, demineralization around orthodontic brackets still presents a major problem for the orthodontic patient.[7] The development of fluoride-releasing glass ionomer cements and composites for bracket bonding has attracted considerable interest because they may inhibit the decalcification of the enamel around the bracket by offering fluoride delivery to the environment.[24–26] Remineralization by release of fluoride is important, but the antibacterial property of fluoride is a direct strategy to eliminate the cause of dental caries.[13] The surface phenomena of fluoride on teeth might not be clinically significant, but the physiologic effect of fluoride in tooth enamel must be considered.[27] Fluoride deposits in hydroxyapatite to form fluorapatite, but fluorapatite might affect the bond strength.[28] Some reports have shown that the topical application of fluoride can interfere with the etching effect of phosphoric acid on enamel surfaces, resulting in reduced bond strength of dental resins.[29,30] Other studies, however, have demonstrated that the topical application of fluoride to enamel surfaces did not negatively affect the etch pattern on enamel or the bond strength of composite resin.[31–33]

The two-step self-etching adhesive system used in this study (Clearfil Protect Bond) contains 12-methacryloyloxydodecylpyridinium bromide (MDPB), an antibacterial monomer found in antibacterial adhesives. Imazato et al[14,15] have been conducting investigations on the utilization of MDPB since 1995 and reported incooperation of MDPB into the self-etching primer and adhesive resin. An unpolymerized MDPB shows a strong bacterial activity residual in the cavity and can be inactivated when MDPB containing DBS (dentin bonding system) is applied.[13,16] The antibacterial effect of Clearfil Protect Bond has also been validated in in vivo animal models.[34] Unlike its fluoride-release effect, the antibacterial activity of MDPB may not extend around the bracket, thus producing a potential limitation.[20]

The self-etching primer and adhesive agents have substantially lower bond strength compared with conventional acid-etching and bonding systems. Comparison with other studies in which self-etching primer and adhesive systems were used for orthodontic purposes can be made to some extent, though differences between the enamel surface preparation techniques and the testing methodologies used must be considered with caution. Bishara et al[12] reported that self-etching primer and adhesive systems provide significantly lower but clinically acceptable shear bond strength when compared with a conventional etching and primer technique before bonding brackets with Transbond XT adhesive paste (3M Unitek, Monrovia, Calif). Cal-Neto et al[21] tested Adper Prompt L-Pop in comparison with a conventional acid-etching and bonding system (Transbond XT light-cured adhesive and primer, 3M ESPE). In both groups, no significant difference was observed in bond strengths.

It has been suggested that bond strengths between 8 and 9 MPa are sufficient to withstand normal orthodontic forces.[35] The maximum bond strength should be less than the breaking strength of the enamel, which is about 14 MPa.[36,37] In this study the bond strength values were 9.00 MPa for Kurasper F Bond, 9.55 MPa for Clearfil Protect Bond, and 9.48 MPa for Clearfil tri-S Bond. The results of one- and two-step self-etching primers compared with the conventional acid-etching and bond system are quite satisfactory for orthodontic purposes, and decalcification by phosphoric acid may be avoided by using self-etching primer and adhesives.[20]

Clean tooth surfaces have a higher surface energy that is amenable to bonding,[27,38] but fluoride on the surface can lower the surface energy of the adherent, decreasing the ability of the adhesive to spread. In this study all teeth were cleaned with nonfluoridated flour of pumice before bonding the brackets.

In orthodontics, the bonding procedure is performed on unground intact enamel. In restorative dentistry it is clinically advisable to use the simplified self-etching no-rinse adhesive systems only on enamel that has been ground.[27,39] However, when the self-etching adhesives were bonded to unground intact enamel, the bond strength values were significantly lower.[39] In this study, enamel was etched with phosphoric acid in group 1, but in the other groups the brackets were bonded to intact enamel with two different self-etching adhesives. In this study there was no significant difference between the bond strength of two different self-etching adhesives compared with the conventional acid-etching and bonding system.

Many studies have demonstrated that when self-etching primers are preferred, the degree of penetration by the adhesive to the etched enamel is less compared with the use of the conventional acid-etching technique. The more deeply the enamel surface is penetrated by the adhesive, the greater the penetration of the adhesive and the greater the risk of damage to the enamel.[12,20]

The sites of failure within the bracket-adhesive-enamel complex can occur within the bracket, between the bracket and the adhesive, within the adhesive, and between the tooth surface and the adhesive.[40] A modified ARI has been developed to quantify the amount of adhesive that remains on the bracket after a bracket base debonds.[23] There are two basic opinions on the remnant adhesive on the teeth surface after bracket debonding. One opinion recommends failure at the bracket-adhesive interface, leaving the adhesive resin mainly on the enamel surface.[6,12] The second opinion supports failure at the interface of the enamel and adhesive resin, maintaining that there will be less adhesive left to remove from the enamel surface after debonding.[41] According to the first opinion, when a heavy-filled resin is used to bond the orthodontic attachments to the enamel, the microporosites created by etching are filled with the resin and provide mechanical retention. The findings by Bennett et al[42] also support that opinion.[42] In their study, the dominant ARI score was 1, which means that 25% or less adhesive was left on the bracket. Our findings of ARI scores mainly supported this opinion. Eminkahyagil et al[20] also tested self-etching primer and adhesives by using ARI scores, and their dominant score was also1.

CONCLUSIONS Return to TOC

- One-step self-etching adhesive and two-step antibacterial self-etching adhesive have sufficient mechanical properties for the bonding of orthodontic brackets.
- The antibacterial effect and simplified application procedures of these systems make them a good choice for orthodontic bonding.

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TABLES Return to TOC

Table 1. Composition of adhesive systems used

Test material	Type	Batch no.	Composition[a]
Clearfil Protect Bond	Two-step self-etching adhesive	61118	Primer: MDP, MDPB, HEMA, water, hydrophilicdimethacrylate. Bond: MDP, Bis-GMA, HEMA, hydrophilicdimethacrylate, dl-Camphorquinone, N,N-Diethanolp-toluidine, silinated collaidal silica, sodium fluoride.
Clearfil tri-S Bond	One-step self-etching adhesive	41111	MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, dl-Camphorquinone, ethyl alcohol, water, silanated colloidal silica.
Kurasper F Bond	Bond	00033A	Bis-GMA, TEGDMA, HEMA, NaF, MF-MMA copolymer containing fluorine.
Kurasper F Paste	Bracket adhesive	00024D	Bis-GMA, TEGDMA inorganic filler 0.01 to 20 μm, average particle size 2.5 μm.

[a] MDP indicates 10-methacryloyloxydecyldihydroges phosphate, MDPB, 12-methacryloxydodecyl-pyridinium bromide, HEMA, 2-hydroxyethylmethacrylate, Bis-GMA, bisphenol-glycidyl methacrylate, and TEGDMA, triethyleneglycol dimethacrylate.

Table 2. Descriptive statistics in megapascals (MPa)

	n	Mean ± standard deviation	Range
Group 1 (acid + Kurasper F Bond)	14	9.00 ± 3.15	5.10–15.48
Group 2 (Clearfil Protect Bond)	14	9.55 ± 2.32	7.24–16.45
Group 3 (Clearfil tri-S Bond)	14	9.48 ± 1.57	6.01–12.93

Table 3. The frequency distribution of adhesive remnant index scores of the three groups evaluated

	n	Score					
		0	1	2	3	4	5
Group 1 (acid + Kurasper F Bond)	13	7	4	2	0	0	0
Group 2 (Clearfil Protect Bond)	14	5	6	1	2	0	0
Group 3 (Clearfil tri-S Bond)	13	2	11	0	0	0	0

FIGURES Return to TOC

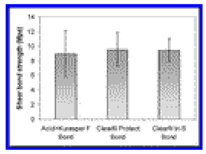

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Figure 1. Mean shear bond strengths and standard deviations of the three groups evaluated

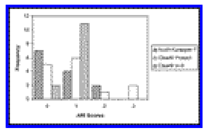

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Figure 2. Frequencies distribution of the adhesive remnant index scores of the three groups evaluated

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