Original Article

The Effect of Modifying the Self-etchant Bonding Protocol on the Shear Bond Strength of Orthodontic Brackets

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ABSTRACT

Objective: To compare the shear bond strength (SBS) of orthodontic brackets when the self-etching primer (SEP) and the bracket adhesive are light cured either separately or simultaneously.

Materials and Methods: Seventy-five human molars were randomly divided into five equal groups. Brackets precoated with Transbond XT composite adhesive were used. The five protocols were: Group 1 (control), the SEP Transbond Plus was applied, brackets placed, and adhesive light cured for 20 seconds; Group 2, SEP Adper Prompt L-Pop was applied, light cured, brackets placed, and light cured; Group 3, the same SEP as in Group 2 was used, however, the SEP and bracket adhesive were light cured together; Group 4, SEP Clearfil S3 Bond was applied, light cured, brackets placed, and light cured; and Group 5, the same SEP as in group 4 was used, however, the SEP and the adhesive were light cured together. The teeth were debonded using a universal testing machine, and the enamel was examined for residual adhesive. Analysis of variance was used to compare the SBS.

Results: The SBS of Clearfil S3 Bond after one light cure and two light cures were significantly greater than the bonds of brackets using Transbond Plus. Brackets bonded using Adper Prompt L-Pop after one light cure and two light cures were not significantly different from the other groups. The groups did not differ significantly in their bracket failure modes.

Conclusion: Only one light curing application is needed to successfully bond brackets when using SEPs and adhesives. This approach can potentially reduce technique sensitivity as well as chair time.

KEY WORDS: Self-etch; Bonding; Light cure time; Brackets

INTRODUCTION

Direct bonding of orthodontic brackets has resulted in an improved oral environment[1–8] because it has enhanced the ability for plaque removal by the patient, minimized soft-tissue irritation and hyperplastic gingivitis,[5–9] and eliminated the need for separation. In addition, direct bonding benefits have included the absence of posttreatment band spaces, easier application of attachments to partially erupted teeth, elimination of decalcification under loose bands,[9,10] and easier detection and treatment of caries, while providing the patient with a more esthetic orthodontic appliance.[2]

Phosphoric acid had remained the primary etchant in direct bonding since its initial introduction. Studies indicated that a phosphoric acid concentration between 30% and 40% resulted in the most retentive etching pattern.[11,12] With the introduction of the acid-etch primers/adhesives that combined both the acid etchant and the primer/adhesive, it had become possible for the clinician to eliminate one of the steps during the bonding procedure while minimizing the amount of enamel lost during etching.[13] Typically, self-etch primers/adhesives (SEPs) do not penetrate or dissolve the enamel surface to the same depth as conventional systems that use phosphoric acid.[13]

Two self-etching adhesives used in restorative dentistry, Adper Prompt-L-Pop (Adper PLP) and Clearfil S3 Bond (S3 Bond), were recently evaluated for bonding brackets.[14] According to the manufacturers' instructions, self-etching adhesives should be

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light cured following their application. Following the placement of the bracket with the adhesive, the teeth are then light-cured a second time. However, it has been demonstrated in an earlier study that modifying the bonding protocol does not always significantly and adversely influence the shear bond strength (SBS) of orthodontic brackets.[15] While not only saving clinical chair time, reducing the number of light exposures would shorten the bonding procedure and allow less time for contamination, thereby reducing technique sensitivity. Thus, the purpose of this study was to determine the effect of simultaneously light-curing both the SEP and bracket adhesive on the SBS of orthodontic brackets.

MATERIALS AND METHODS

Teeth

Seventy-five freshly extracted human molar teeth were collected and stored in a solution of 0.2% (weight/volume) thymol. To meet the criteria for use in the study, the teeth were selected only if they had intact buccal enamel, had not been pretreated with chemical agents (eg, hydrogen peroxide), had no surface cracks from extraction forceps, and were free of caries. The teeth were embedded in dental stone placed in phenolic rings (Buehler Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surfaces of the teeth perpendicular with the bottom of the mold. This kept the buccal surface of the tooth parallel to the applied force during the shear test. Following mounting, the teeth were cleaned and polished with pumice and rubber prophylactic cups for 10 seconds.

Brackets

Lateral incisor metal brackets (Victory Series, 3M Unitek, Monrovia, Calif) were used in the study. Before bonding, the average surface area of the bracket base was determined to be 10.3 mm^2. The brackets were supplied from the manufacturer precoated with the adhesive Transbond XT. Transbond XT is a light cured composite adhesive that contains silane-treated quartz, bisphenol A diglycidyl ether dimethacrylate, bisphenol A bis(2-hydroxyethyl ether) dimethacrylate, and dichlorodimethylsilane reaction product with silica.

Groups Tested

The brackets were bonded to the mounted teeth following one of five protocols.

Group 1 (control). On 15 teeth the SEP Transbond Plus (3M Unitek) was placed on the enamel for 15 seconds and gently evaporated with air. The L-Pop system has two compartments: one contains methacrylated phosphoric esters, initiators, and stabilizers, whereas the other contains water, fluoride complex, and stabilizers. To activate the product, the two compartments are squeezed so that the contents of the compartments are allowed to mix; the product is then applied to the tooth surface. The bracket with the Transbond XT adhesive (3M Unitek) was placed on the tooth and a 300-g force was applied (Correx force gauge, Bern, Switzerland) for 10 seconds. The force gauge is used to help assure a uniform adhesive thickness between the bracket and enamel. Each bracket was then light cured for 20 seconds (10 seconds from each proximal side).

Group 2. On 15 teeth Adper Prompt L-Pop (3M ESPE, St Paul, MN) was used following the manufacturers' instructions. Adper PLP has been classified as a ''strong'' self-etching adhesive and has been shown to dissolve enamel prisms, leaving a highly porous enamel surface that is similar to enamel treated with phosphoric acid.[16–18] Similar to Transbond Plus, Adper PLP uses an L-Pop system that contains components in two compartments that must be mixed before use. One compartment contains methacrylated phosphoric esters, bisphenol A glycidyl methacrylate (Bis-GMA), initiators, and stabilizers; the other compartment contains 2-hydroxyethyl methacrylate (2-HEMA) and water. After proper activation, the SEP was rubbed on the enamel surface for 15 seconds with a micro-tip applicator. The SEP was thoroughly dried with a stream of compressed air and then light cured for 10 seconds. The brackets were bonded with Transbond XT adhesive and light cured as described for Group 1.

Group 3. Fifteen teeth were bonded using Adper PLP as the self-etchant following the same protocol as Group 2, but with one exception. After the SEP was applied to the tooth, the bracket with Transbond XT adhesive was immediately placed on the tooth, and the tooth was light cured for 20 seconds. This bonding protocol did *not* follow the manufacturers' recommendations because the SEP was *not* light cured separately before placement of the bracket.

Group 4. On 15 teeth, S3 Bond (Kuraray America Inc, New York, NY) was used as the self-etchant. S3 Bond contains 2-HEMA, bisphenol A diglycidyl methacrylate, silanated colloidal silica, 1-camphorquinone, ethanol, and water. In addition, it also contains 10-methacryloyloxydecyl dihydrogen phosphate, which is claimed as having the unique ability to chemically bond to enamel and dentin.[19] Following the manufacturers' instructions, S3 Bond was applied to the teeth using an applicator brush and allowed to sit for 20 seconds. The SEP was dried for 5 seconds using compressed air and then light cured for 10 seconds. The brackets were bonded with Transbond XT adhesive and light cured as described for Group 1.

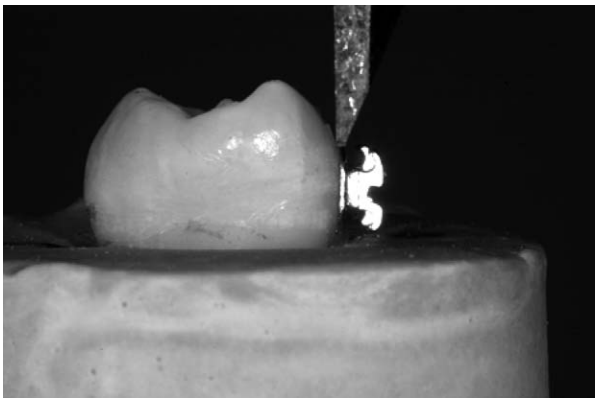

Figure 1. Picture of the experimental design for shear bond testing using the Zwick machine.

Group 5. Fifteen teeth were bonded using S3 Bond as the self-etchant following the same protocol as Group 4, but with one exception. After the SEP was applied, the bracket with Transbond XT adhesive was immediately placed on the tooth, and the tooth was light cured for 20 seconds. This bonding protocol did *not* follow the manufacturers' recommendations because the SEP was *not* light cured separately before placement of the bracket.

Debonding Procedure

The shear bond strength of each group was determined within half an hour from the time of bonding, to simulate the clinical conditions when archwires are tied to newly bonded teeth. A steel rod with a flattened end was attached to the crosshead of a Zwick testing machine (Zwick GmbH, Ulm, Germany). The rod applied an occlusogingival load to the bracket, producing a shear force at the bracket-tooth interface (Figure 1). The results of each test were recorded by a computer that is electronically connected to the testing machine. The Zwick machine (cell capacity = 50 kN) recorded the results from each test in megaPascals (MPa) at a crosshead speed of 5.0 mm/min.

Adhesive Remnant Index

Once the brackets were debonded, the enamel surface of each tooth was examined under 10× magnification to determine the amounts of residual adhesive remaining on each tooth. A modified adhesive remnant index (ARI) was used to quantify the amount of remaining adhesive using the following scale: 1 = all the adhesive remained on the tooth, 2 = more than 90% of the adhesive remained on the tooth, 3 = between 10–90% of the adhesive remained on the tooth, 4 = less than 10% of the adhesive remained on the tooth, and 5 = no adhesive remained on the tooth.

Table 1. Descriptive Statistics in Megapascals (MPa) and the Result of the Analysis of Variance for the Comparisons Between the Five Groups Tested[a]

Group	Self-Etching Primer[b]	$\bar{x}$	SD	Range
1	Transbond Plus[A]	4.2	1.9	1.3–8.0
2	Adper (2 light exposures)[AB]	5.9	3.4	1.1–10.9
3	Adper (1 light exposure)[AB]	5.9	3.6	0.5–14.3
4	S3 bond (2 light exposures)[B]	6.5	1.9	3.1–10.8
5	S3 bond (1 light exposure)[B]	7.3	2.7	0.7–12.7

* F-ratio = 2.45; $P = .05$.

[a] Sample size of each group is 15; $\bar{x}$ indicates mean.

[b] Groups with the same letters are not significantly different from each other.

Statistical Analysis

Analysis of variance (ANOVA) was used to determine whether there was a significant difference in shear bond strengths between the five test groups, and the Duncan multiple range test was used to determine which groups differed significantly. The chi-square (χ^2) test was used to compare the bond failure mode (ARI scores) between the groups. For the purpose of statistical analysis, the ARI scores 1 and 2 as well as 4 and 5 were combined. Significance for all statistical tests was predetermined at $P \leq .05$.

RESULTS

Shear Bond Strength

The descriptive statistics including the mean, standard deviation, minimum and maximum values for the adhesive systems are presented in Table 1. The results of the ANOVA (F = 2.45) indicated there were statistically significant differences in the SBS between the groups. The Duncan multiple range test indicated that brackets bonded using S3 Bond after one light cure ($\bar{x} = 7.3 \pm 2.7$ MPa) and two light cures ($\bar{x} = 6.5 \pm 1.9$ MPa) were significantly greater ($P = .05$) than brackets bonded using Transbond Plus ($\bar{x} = 4.2 \pm 1.9$ MPa). Brackets bonded using Adper PLP after one light cure ($\bar{x} = 5.9 \pm 3.6$ MPa) and two light cures ($\bar{x} = 5.9 \pm 3.4$ MPa) were not significantly different from the other groups.

Adhesive Remnant Index

The failure modes of the five groups are presented in Table 2. The χ^2 comparisons of the ARI scores between the groups ($\chi^2 = 10.0$) indicated that the groups did not differ significantly ($P = .265$) in their bracket failure modes. While all three groups showed a wide distribution of bracket failure modes, a significant percentage of teeth bonded with Adper PLP (using one light exposure) and Transbond Plus had little adhesive remaining on the teeth (Groups 4 and 5), which is consistent with previous findings.[18]

Table 2. Frequency Distribution of the Modified ARI Scores and the Result of the X^2 Comparisons Between the Five Groups Tested[a]

Group[b]	Self-Etching Primer	Modified ARI Scores				
		1	2	3	4	5
1	Transbond Plus	5	—	4	1	5
2	Adper (2 light exposures)	4	2	2	2	5
3	Adper (1 light exposure)	6	4	2	—	3
4	S3 bond (2 light exposures)	6	4	—	3	2
5	S3 bond (1 light exposure)	3	5	4	3	—

[a] ARI indicates adhesive remnant index. $X^2 = 10.0$; $P = .265$.

[b] Group 1, all composite remained on the tooth; Group 2, more than 90% of the composite remained on the tooth; Group 3, 10–90% of the composite remained on the tooth; Group 4, less than 10% of the composite remained on the tooth; Group 5, no composite remained on the tooth; Sample size of each group is 15.

DISCUSSION

Traditional orthodontic bracket bonding systems require the use of a three-step procedure involving three separate agents, an enamel conditioner, a priming agent, and an adhesive resin. Self-etching primers were introduced in an effort to reduce the three-step procedure to two steps, effectively reducing chair time and increasing cost-effectiveness, and subsequently resulting in increased convenience and potentially reducing costs to the patient. While typically designed for use in operative bonding procedures, self-etching primers/adhesives have been used to successfully bond orthodontic brackets with SBS values similar to the conventional acid-etch technique.[20]

The present study evaluated the effect of reducing the number of light curing steps when using self-etching primers on the SBS of orthodontic brackets. While manufacturers suggest light curing the SEP before placing the composite adhesive, it was interesting to realize that in both new SEPs tested, the SBS values were not adversely affected when using one instead of the two recommended light exposures. Actually, for one of the SEPs tested, light curing the SEP and bonding adhesive simultaneously resulted in a slight increase in SBS. While this increase was not statistically significant, the results nevertheless indicated that only one light curing step is sufficient to successfully bond brackets when using SEPs and composite adhesives.

It has been suggested that a shear bond strength of 6.0–8.0 MPa is adequate for bonding orthodontic brackets to teeth.[21,22] In this study, only the brackets bonded with S3 Bond and light cured with either one or two exposures have reached this optimal range in the first half hour. However, from a clinical standpoint, forces of the archwires used for initial leveling are typically lighter than those applied later in treatment.

The SBS values for Transbond Plus and Adper PLP observed in this study are much lower than those observed in a previous study conducted by Vicente et al.[18] However, in the present study, brackets were debonded within half an hour from the initial bonding and at a crosshead speed of 5.0 mm/min, whereas Vicente et al debonded brackets after storage for 24 hours at 37°C and at a speed of 1.0 mm/min.[18] The lower values for shear bond strength at half an hour following bonding are consistent with previous studies demonstrating that composite adhesives have significantly lower shear bond strength at half an hour as compared to 24 hours following bonding.[23–24] This increase in bond strength over time has been reported to occur with both metal and plastic brackets.[25] Additionally, it has also been shown that the crosshead speed is indirectly proportional to the shear bond strength.[26]

The present results indicated that brackets bonded in all five groups showed a similarly broad range of bond failure modes. For all groups, debonded brackets showed failure at the enamel/adhesive interface as well as at the bracket/adhesive interface. Bracket failure at each of the two interfaces has its own advantages and disadvantages. As an example, bracket failure at the bracket/adhesive interface is advantageous since it leaves the enamel surface relatively intact; however, considerable chair time is needed to remove the residual adhesive with the added possibility of damaging the enamel surface during the cleaning process.[27] Conversely, when brackets fail at the enamel/adhesive interface, less residual adhesive remains, but the enamel surface can be damaged when failure occurs in this mode.[28]

Aljuburi et al[29] calculated the time it took to bond 30 premolar teeth in the laboratory using conventional bonding as compared to bonding with an SEP. They found that with conventional bonding the time was 170 seconds, while with an SEP the bonding time was 111 seconds. The difference of 59 seconds was statistically significant. In the present study, by light curing both the SEP and the adhesive simultaneously, the clinician can potentially achieve an additional 10 seconds reduction in the bonding time for each tooth. During routine bonding procedures involving 20 teeth, such reduction in working time would amount to at least 200 seconds or 3+ minutes per patient.

CONCLUSIONS

- Light curing the SEP and bonding adhesive simultaneously in one step did not adversely affect the shear bond strength of brackets when compared to light curing the SEP and bonding adhesive separately.
- This suggested approach reduces the bonding procedure by one step and could potentially save the clinician chair time.

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