Original Article

Shear Bond Strength Comparison of Two Adhesive Systems Following Thermocycling

A New Self-Etch Primer and a Resin-Modified Glass Ionomer

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ABSTRACT

Objective: To compare the effects of a standardized thermocycling protocol on the shear bond strength (SBS) of two adhesive systems: a resin-modified glass ionomer and a composite resin used with a new self-etching primer.

Materials and Methods: Forty human molars were cleaned, mounted, and randomly divided into two groups. In group 1, brackets were bonded to the teeth using Fuji Ortho LC adhesive, and in group 2, the Transbond Plus system was used. The teeth were stored in water at 37°C for 24 hours, thermocycled between 5 and 55°C, and debonded using a universal testing machine. The enamel surface was examined under 10× magnification to determine the amount of residual adhesive remaining on the tooth. Student's *t*-test was used to compare the SBS and the chi-square test was used to compare the adhesive remnant index (ARI) scores.

Results: The mean SBS for the brackets bonded using the Fuji Ortho LC was 6.4 ± 4.5 MPa, and the mean SBS for the Transbond Plus system was 6.1 ± 3.2 MPa. The result of the *t*-test comparisons ($t = 0.207$) indicated that there was no significant difference ($P = .837$) between the two groups. The comparisons of the ARI scores ($\chi^2 = 0.195$) indicated that bracket failure mode was not significantly different ($P = .907$) between the two adhesives.

Conclusion: Although SBS and ARI scores were not significantly different for the two adhesives, clinicians need to take into consideration the other properties of the adhesives before using them.

KEY WORDS: Self-etch composite resin; Resin-modified glass ionomer; Thermocycling; Orthodontic bracket

INTRODUCTION

Direct bonding of orthodontic brackets has been advocated since the 1960s.[1] With the introduction of newer adhesive systems as well as photosensitive (light-cured) restorative materials in dentistry, additional methods have been suggested to enhance the polymerization of the materials used, including layering and more powerful light-curing devices.[2–8] In addition, other factors can potentially contribute to the strength of the bond between the enamel and the orthodontic bracket, including type of enamel conditioner, acid concentration, length of etching time, composition of the adhesive, bracket base design, bracket material, oral environment, and skill of the clinician.[3,4]

The traditional three-step acid-etch procedure has been used for years to successfully bond orthodontic brackets to teeth. Newer bonding systems used in operative dentistry combined the conditioning and priming agents into a single acidic primer solution.[5,6] It has been demonstrated that the shear bond strength (SBS) of brackets bonded using three different self-etch primers was not significantly different from that of brackets bonded with the conventional acid-etch technique and that these primers provided clinically acceptable bond strengths.[7,8]

Glass ionomer cements (GICs) were initially introduced as orthodontic bonding adhesives to take advantage of the fluoride-releasing capabilities of the

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material.[9,10] Fluoride release was shown to increase in the plaque adjacent to brackets bonded with GICs,[10] but the use of GICs in orthodontics was limited because of their lower bond strengths.[11–14] In an attempt to increase the bond strengths of GICs, resin particles were added to their formulation to create resin-modified glass ionomers (RMGIs). These adhesives release fluoride like conventional GICs and can be successfully used to bond orthodontic brackets because of their relatively higher bond strengths.[15,16] Although RMGIs have lower SBS compared to composite resins,[17,18] particularly within the first half hour after bonding,[19] they are still able to bond orthodontic brackets successfully.[18–20]

Effects of Thermocycling on Various Adhesive Systems

Because orthodontic adhesives are routinely subjected to thermal changes in the oral cavity, it is important to determine whether such temperature variations introduce stresses in the adhesive that might influence bond strength. Following thermocycling, studies have shown that brackets bonded with RMGIs have weaker SBS than those bonded with a traditional three-step composite resin.[17–22] A study conducted by Arici et al indicated that an RMGI experienced a 11.1% decrease in SBS following 200 thermocycles and a 26.5% decrease after 20,000 thermocycles; this compares to respective reductions of only 5.7% and 17.9% observed with a no-mix adhesive control.[23] Cyanoacrylate adhesives, on the other hand, were weakened by 80%.[24]

Because various studies have indicated that self-etching primers can be used to successfully bond brackets,[7,25] the question is whether these new adhesive systems weaken after thermocycling. Cehreli et al[26] found that following thermocycling, the SBSs of brackets bonded with four separate self-etch adhesive systems were all significantly lower than the SBSs of those bonded using a conventional acid-etch bonding adhesive. They concluded that self-etching primers "might not be suitable for orthodontic bracket bonding" following thermocycling. In vivo tests conducted by Ireland et al[27] showed a bond failure rate of 10.99% in brackets bonded using a self-etching primer, whereas brackets bonded with a traditional system experienced a failure rate of 4.95%. Although the failure rate was higher for the self-etch group, the authors concluded that the study did not provide enough evidence to assume that bond failure will be higher when using a self-etching primer.

Gale and Darvell[28] pointed to the lack of consistency between the conclusions of different studies on the SBS of various adhesive systems following thermocycling. They attributed this to the lack of standardization between the various thermocycling studies they reviewed. Such large variation between the thermocycling protocols led the International Organization for Standardization to provide specific criteria for conducting such tests to enable investigators and industry to interpret and compare results.[29]

In summary, some investigators found that the SBS of RMGIs is clinically acceptable following thermocycling,[21,22] whereas others concluded that bond strengths were acceptable only when phosphoric acid is used as an etchant.[30] There is also a scarcity of research on how thermocycling affects the SBS of brackets bonded with self-etch primers, and studies have provided controversial results on their clinical acceptability.[26,27] Therefore, the purpose of the present study was to compare the effects of a standardized thermocycling protocol on the SBS of two widely used adhesive systems: a resin-modified glass ionomer (Fuji Ortho LC, GC America, Alsip, Ill) and a composite resin used with a new self-etching primer (Transbond XT Plus, 3M Unitek, Monrovia, Calif).

MATERIALS AND METHODS

Teeth

Forty 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 H_2O_2), had no surface cracks from the 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 so that they were 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

Central incisor metal brackets (Victory Series, 3M Unitek) were used in the study. Before bonding, the average surface area of the bracket base was determined to be 11.8 mm.[2]

Groups Tested

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

Group 1. 20 teeth were etched using 10% polyacrylic acid enamel conditioner. The conditioner was applied for 20 seconds and the tooth was then thoroughly rinsed with water. Excess water was blotted away using a moist cotton roll. The capsules containing the RMGIs were activated and triturated at 4000 rpm for 10 seconds. Capsules were placed in the GC Capsule Applier (GC America) to place the adhesive on each bracket. Excess adhesive was removed using a sharp scaler, and the bracket was light-cured with a halogen light for 40 seconds (10 seconds from the mesial, distal, occlusal, and gingival sides).

Group 2. On the remaining 20 teeth the self-etch primer Transbond Plus was placed on the enamel for 15 seconds and gently evaporated with air. The ''lolipop'' system has two compartments: one contains methacrylated phosphoric acid esters, initiators, and stabilizers, whereas the other compartment contains water, fluoride complexes, and stabilizers. To activate the product, the two compartments are squeezed so that the contents of each compartment are allowed to mix. The resulting mix is then applied to the tooth surface. The bracket with the Transbond XT adhesive was placed on the tooth and a 300-g force 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 the enamel. Each bracket was then light-cured for 20 seconds (10 seconds from each proximal side).

Thermocycling

Following the recommendations of the International Organization for Standardization, test specimens were prepared at 23 ± 2°C and stored in water at 37 ± 2°C for 24 hours to discriminate between those materials that can and those that cannot withstand a wet environment.[29] After 24 hours, the mounted teeth were thermocycled between 5°C and 55°C for 500 cycles. The exposure to each bath was 20 seconds, and the transfer time between the two baths was 5–10 seconds. Debonding was performed at room temperature.[29]

Debonding Procedure

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. 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 MPa at a crosshead speed of 5.0 mm per minute.

Table 1. Descriptive Statistics (in MPa) of the Fuji Ortho LC and Transbond Plus Adhesive Systems[a]

Group	n	$\bar{x}$	SD	Range
Fuji Ortho LC	19	6.4	4.5	1.8–16.8
Transbond Plus	19	6.1	3.2	1.5–11.1

[a] *t*-test = 0.207; $P = .837$. n indicates sample size; $\bar{x}$, mean; SD, standard deviation.

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 composite remained on the tooth with the imprints of the bracket base; 2 = more than 90% of the composite remained on the tooth; 3 = 10–90% of the composite remained on the tooth; 4 = less than 10% of the composite remained on the tooth, and 5 = no composite remained on the tooth.

Statistical Analysis

Student's *t*-test was utilized to determine whether there was a significant difference in SBS between the two test groups, and the chi-square test was used to compare the bond failure mode (ARI scores) between the two groups. For the purpose of statistical analysis, ARI scores 1 and 2 were combined, and ARI scores 4 and 5 were combined as well. Significance for all statistical tests was predetermined at $P \leq 0.05$.

RESULTS

Shear Bond Strength

One bracket in each group failed before registering any force on the Zwick machine and was eliminated from the statistical analysis. The descriptive statistics, including the mean, standard deviation, minimum, and maximum values for the two adhesive systems, are presented in Table 1. The mean SBS for the brackets bonded using Fuji Ortho LC was 6.4 ± 4.5 MPa, and the mean SBS for the brackets bonded using the Transbond Plus adhesive system was 6.1 ± 3.2 MPa. The *t*-test comparisons ($t = 0.207$) indicated that these values were not significantly different from each other ($P = .837$).

Adhesive Remnant Index

The failure modes of the two types of brackets are presented in Table 2. The χ^2 comparisons of the ARI scores between the two groups ($\chi^2 = 0.195$) indicated that the two adhesive systems did not differ signifi-

Table 2. Frequency Distributions of the Modified ARI Scores of the Two Groups[a]

Group	n	Modified ARI scores[b]				
		1	2	3	4	5
Fuji Ortho LC	19	1	5	3	7	3
Transbond Plus	19	4	3	4	1	7

[a] $\chi^2 = 0.195$; $P = .907$. ARI indicates adhesive remnant index; n, sample size.

[b] 1, all composite remained on the tooth with the imprints of the bracket base; 2, more than 90% of the composite remained on the tooth; 3, 10–90% of the composite remained on the tooth; 4, less than 10% of the composite remained on the tooth; 5, no composite remained on the tooth.

cantly ($P = .907$) from each other. For both groups, the distribution of the ARI scores was similar.

DISCUSSION

The present study evaluated two contemporary adhesive systems marketed for use to bond orthodontic brackets—a resin-modified glass ionomer, Fuji Ortho LC, and a new self-etching primer/composite resin system, Transbond Plus XT. The present findings indicated that following thermocycling, the SBS of brackets bonded using Fuji Ortho LC was 6.4 ± 4.5 MPa and the SBS of those bonded with Transbond Plus XT was 6.1 ± 3.2 MPa. It has been suggested that an SBS of 6.0–8.0 MPa is adequate for bonding orthodontic brackets to teeth.[31,32]

In vivo tests conducted by Ireland et al[27] showed a bond failure rate of 10.99% in brackets bonded using a self-etching primer, whereas brackets bonded with a traditional system experienced a failure rate of 4.95%. It is of interest to note that in the present study, one bracket in each group (5%) failed following thermocycling and did not register any force during debonding. Such occurrence might partly explain why some brackets fail in vivo.

Of primary concern to the clinician is the maintenance of a sound, unblemished enamel surface after removal of the bracket, yet bracket failure at each of these two interfaces has its own advantages and disadvantages. As an example, bracket failure at the bracket/adhesive interface is advantageous because 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. 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. The results of ARI scores indicated that brackets bonded with either system showed a similar range of bond failure modes. For both groups, debonded brackets showed failure at the enamel/adhesive interface as well as the bracket/adhesive interface.

In summary, self-etching primers offer the advantage of reduced steps for bonding and subsequently save the clinician chair time, whereas RMGIs provide sustained fluoride release and can be used in a moist environment. However, RMGIs need a longer preparation and curing time during bonding and have a lower SBS in the first half hour after bonding.[19] The clinician should consider all the properties of the adhesives available on the market and be aware of how these products perform in different environments.

CONCLUSIONS

- Following thermocycling, the SBS of a new self-etching primer adhesive system and a resin-modified glass ionomer adhesive are not significantly different from each other and are at clinically acceptable levels.

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