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Shear Bond Strength Comparison between Two Orthodontic Adhesives and Self-Ligating and Conventional Brackets

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Original Article

Shear Bond Strength Comparison between Two Orthodontic Adhesives and Self-Ligating and Conventional Brackets

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ABSTRACT

Objective: To evaluate and compare the shear bond strengths of two adhesives using two types of brackets: a conventional and a self-ligating bracket system.

Materials and Methods: Sixty extracted human premolars were collected. The premolars were randomly divided into three groups of 20 teeth. All three groups were direct bonded. Groups 1 and 2 used light-cured adhesive and primer (Transbond XT) with a conventional (Orthos) and a self-ligating bracket (Damon 2), respectively. Group 3 used a light-cured primer (Orthosolo) and a light-cured adhesive (Blūgloo) with a self-ligating bracket (Damon 2). The specimens were stored in distilled water at 37°C for 40 $\pm$ 2 hours, after which they were debonded and inspected for Adhesive Remnant Index (ARI) scoring.

Results: The mean shear bond strength was 15.2 MPa for group 1, 23.2 MPa for group 2, and 24.8 MPa for group 3. A one-way analysis of variance and post hoc Tukey test showed significant differences in bond strength ($P < .001$) between group 1 and groups 2 and 3 but no significant difference ($P > .05$) between groups 2 and 3. A Weibull analysis demonstrated that all three groups provided sufficient bond strength with over 90% survival rate at normal masticatory and orthodontic force levels. A Kruskal-Wallis test showed no significant difference ($P > .05$) in ARI scores among all three groups.

Conclusions: All three groups demonstrated clinically acceptable bond strength. The Damon 2 self-ligating bracket exhibited satisfactory in vitro bond strength with both adhesive systems used.

KEY WORDS: Bond strength; Adhesive; Self-ligating brackets; In vitro

INTRODUCTION

Direct bonding, which has been in practice since 1965, was a significant milestone in the practice of orthodontics.[1] As stated by Owens and Miller,[2] the efforts of Buonocore, Bowen, Wilson, and Tavas made the concept of direct bonding brackets to teeth a reality. However, despite the material advancements of direct bonding and the increase in efficiency of treatment, bond failures continue to be a challenge in clinical practice.

Bond failure of brackets not only can be frustrating for the practitioner, but also can significantly affect treatment efficiency and have an economic impact on a practice. Often, the wire has to be removed to rectify the situation, and the progress of treatment can be significantly delayed. One reason for this occurrence, and one focus of this study, can be the differing bond strength of the adhesives used in addition to the type of orthodontic brackets to which the adhesive is placed.

Research and development to improve the quality and properties of the bonding agents used in orthodontics is ongoing. Recently, Ormco Corporation developed an adhesive, Blūgloo, in which the company claims 150% greater bond strength when used with their own esthetic Damon 3 bracket. Blūgloo also possesses the property of color change with temperature;

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cooler temperatures retain the blue color and change to tooth color with activation by light. This allows for easy and identifiable cleanup when the adhesive is cooled with air or water. With the advantage of easy and identifiable cleanup as a result of the color change, the question remains as to whether the bond strength when using Blūgloo is also sufficient or improved with stainless steel brackets, especially self-ligating brackets.

Harradine[3] reported the advantages of self-ligating brackets to be lower friction between archwire and bracket, better archwire engagement, and faster archwire removal and ligation. These advantages coupled with an adhesive possessing better bond strength to combat normal masticatory and orthodontic forces and ideal cleanup around brackets to aid in better hygiene would suggest a more efficient and improved treatment for orthodontic patients. Although there have been multiple studies completed on bond strengths of adhesives, few, if any, have been completed regarding the adhesive Blūgloo. Furthermore, despite the increasing popularity of self-ligating brackets, even fewer studies have been accomplished to look at the bond strength of these brackets themselves. In a recent study, Miles et al[4] reported that the self-ligating Damon 2 brackets debonded more often than a conventional twin bracket.

The purpose of this study was twofold. The first purpose was to compare the bond strength of Ormco's Damon 2 bracket with a conventional stainless steel bracket (Orthos) by using a traditional adhesive system (Transbond XT). This was to determine whether the bond strength of the self-ligating bracket is acceptable or if some other factor is responsible that may explain the clinical observation of increased bond failure associated with the Damon 2 self-ligating brackets.[4] The second purpose was to compare two adhesives by measuring the bond strength of Damon 2 brackets by using either the traditional adhesive system (Transbond XT) or a newer adhesive with "color change" properties (Blūgloo). Because it is known that bracket bases with different mesh patterns result in different bond strengths,[5] the two brackets were chosen because each possesses a similar bracket base mesh incorporated via Ormco's Optimesh characteristic.

MATERIALS AND METHODS

Sixty extracted premolars without caries were collected and stored in distilled water at room temperature. The teeth were divided randomly into three groups.

Group 1 used a direct bond technique with a light-cured, highly filled orthodontic adhesive, Transbond XT (3M/Unitek Corporation, Monrovia, Calif), along with Transbond XT Light-Cure Adhesive Primer (3M/Unitek Corporation). The bracket was a conventional stainless steel 0.022-inch slot maxillary right second bicuspid twin bracket with $-9°$ torque and $+3°$ of tip (Orthos, Ormco Corporation, Glendora, Calif).

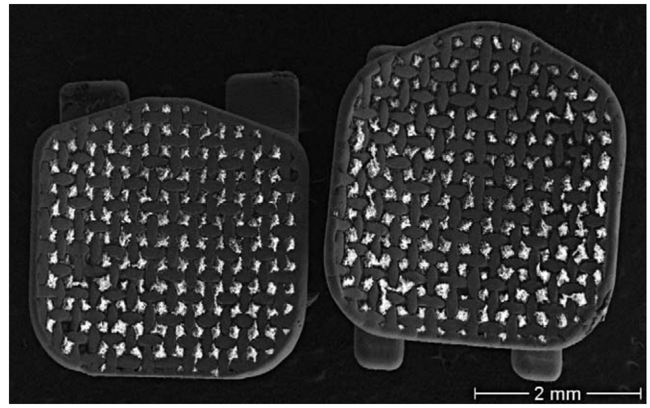

Figure 1. Scanning electron microscope micrograph displaying the Optimesh base of the Orthos (left) and Damon 2 (right) brackets.

Group 2, also direct bonded, similarly consisted of the light-cured adhesive, Transbond XT, along with Transbond XT Light-Cure Adhesive Primer. The bracket used was a 0.022-inch slot maxillary right second bicuspid stainless steel self-ligating bracket (Damon 2, Ormco Corporation).

Group 3 used light-cured adhesive Blūgloo (Ormco Corporation) and light-cured primer Orthosolo (Ormco Corporation) to bond a 0.022-inch slot maxillary right bicuspid stainless steel self-ligating bracket (Damon 2, Ormco Corporation).

The area of the base of the brackets was measured by image-analysis software (Image-Pro Plus, Media Cybernetics Inc, Silver Spring, Md). The area measurements were 9.92 mm^2 for the Orthos brackets and 10.79 mm^2 for the Damon 2, and both of the bracket bases included Ormco's Optimesh design. A scanning electron microscope (JSM-35, Jeol Ltd, Tokyo, Japan) micrograph displaying the Optimesh design is shown in Figure 1. The brackets shown are debonded brackets after removing any surface remnant adhesive by sonication in methanol.

Bonding

The teeth were handled and prepared solely by the same operator. All teeth were cleaned with coarse, oil-free pumice with a manual handheld rubber prophylaxis cup for 10 seconds and then rinsed and dried with an air-water syringe for 5–10 seconds. A 35% phosphoric acid etching gel was applied for 20 seconds, followed by a thorough rinse for another 15 seconds. The teeth were again dried with the air-water

Table 1. Mean shear bond strength

Group	Bond strength, MPa				
	Mean	Standard deviation	Minimum	Maximum	Range
1—Orthos, Transbond XT	15.2*	4.5	6.5	21.4	14.9
2—Damon 2, Transbond XT	23.2**	5.3	11.6	33.0	21.4
3—Damon 2, Blūgloo	24.8**	4.2	17.6	32.8	15.2

* Group 1 was significantly different ($P < .001$) from groups 2 and 3; ** groups 2 and 3 were not significantly different ($P > .05$) from each other.

syringe for 20 seconds and inspected to ensure a dull, frosty appearance.

For groups 1 and 2, a thin layer of Transbond XT primer was applied to each individual tooth by a direct bonding technique and light-cured for 5 seconds with an Ortholux LED Curing Light (3M/Unitek Corporation). Transbond XT adhesive was then applied to the bracket base, and a bracket was applied to each tooth. The bracket was centered on the crown of the tooth mesiodistally and along the long axis of the tooth. After the bracket was centered, the excess adhesive was cleaned off with an explorer hand instrument and the bracket was light-cured for 10 seconds on the mesial and 10 seconds on the distal. For group 3, also direct bonded, a thin coat of Orthosolo primer (Ormco Corporation) was applied to the tooth. The adhesive in this group was Blūgloo, which was applied in the same manner as described above.

Preparation and Bond Strength Testing

After bonding, each tooth was sectioned approximately 2–3 mm from the cemento-enamel junction with a high-speed hand piece and a cross-cut carbide bur. The specimens were then mounted in acrylic and stored in distilled water at 37°C for 40 ± 2 hours. After storage, the brackets were debonded with a shear load applied with a universal testing machine (Instron Corporation, Canton, Mass) with a crosshead speed of 0.1 mm/min.[6,7] The samples were placed into the machine so that the shearing blade used to debond the brackets was as close as possible to the bracket base and tooth interface and parallel to the long axis of the tooth in order apply the shear force. The maximum load to debond the bracket was recorded.

Adhesive Remnant Index

After debonding, each tooth and bracket was viewed with a Spenser optical stereomicroscope with an external light source and given a value according to the Adhesive Remnant Index (ARI).[8] The possible values for the ARI are as follows: 0, no adhesive left on the tooth; 1, less than half of the adhesive left on the tooth; 2, more than half of the adhesive left on the tooth; and 3, entire adhesive amount left on the tooth with an impression of the bracket mesh.

Statistical Analysis

A one-way analysis of variance (ANOVA) and post hoc Tukey test were used to analyze for differences in shear bond strength among the three groups. A Weibull analysis was performed to determine the bond strength reliability at certain loads. In addition, a Kruskal-Wallis test was used to determine any statistically significant differences in the ARI scores among the groups. The level of statistical significance was set at .05.

RESULTS

Twenty samples in each group, for a total of three groups, were tested for shear bond strength. The mean shear bond strength, standard deviation, minimum and maximum, and range for the groups are shown in Table 1. A one-way ANOVA and post hoc Tukey test showed the Orthos brackets with Transbond XT (group 1) were significantly lower in bond strength ($P < .001$) than the Damon 2 brackets with Transbond XT and Blūgloo (groups 2 and 3). No significant difference ($P > .05$) was found between the Damon bracket groups.

The Weibull analysis is shown in Figure 2. This analysis is a useful survival analysis tool and aids in determining the bond reliability and the probability of failure at specific loads. Additional information as to the specifics of this analysis can be found in the article by Fox et al.[9] Table 2 shows the Weibull modulus and characteristic strength along with the bond strengths at a 10% and 90% probability of failure.

The results for the ARI tests are shown in Table 3. A Kruskal-Wallis test shows no significant difference ($P > .05$) in the ARI scores among the three groups. All three groups showed similar bracket failure modes.

DISCUSSION

Reynolds[10] stated that the tensile bond strengths need to be in the range of 5.9–7.8 MPa to overcome

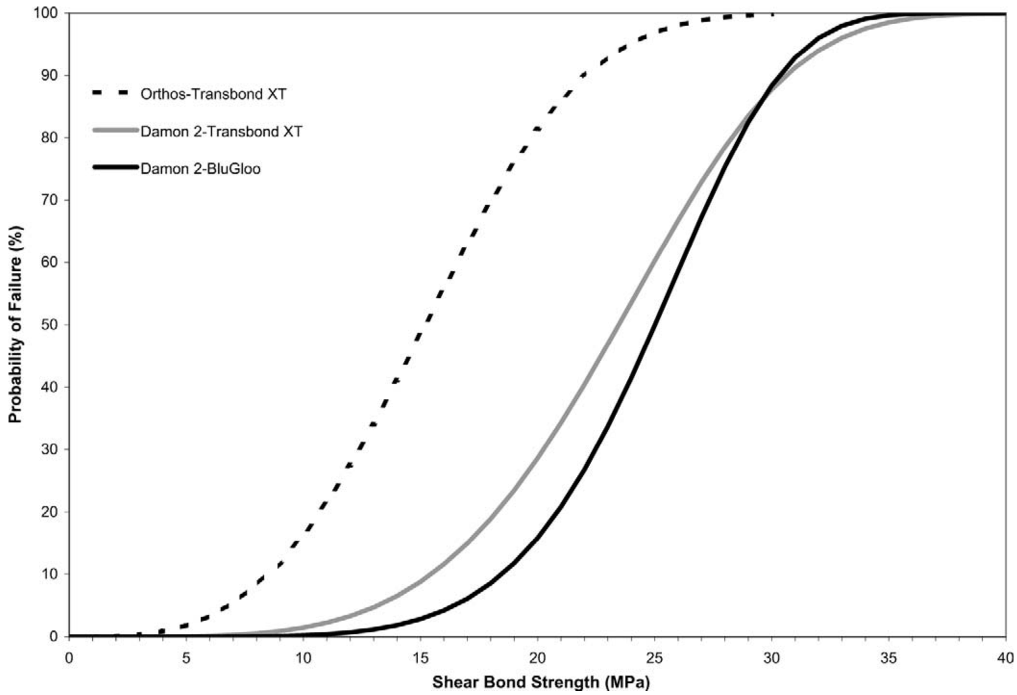

Figure 2. Weibull curves for the shear bond strength of the three groups.

normal intraoral forces and forces from orthodontic treatment. Tavas and Watts[11] reported that shear or peel strengths of direct bonded adhesives should develop to 4 kg in 5 minutes and 6 kg in 24 hours. Although there was a statistically significant difference between group 1 and groups 2 and 3, the mean shear bond strength of all three groups was well above this range. Similarly, although the Weibull curves show group 1 to have a comparatively higher failure rate at lower forces that are the more clinically relevant, the mean shear bond strength, Weibull parameters, and failure rates were remarkably similar to those found for a 3M Victory Series stainless steel bracket light-cured with Transbond XT.[12]

The increased mean bond strength and survival probability of the self-ligating Damon 2 bracket was surprising given the account of a clinical study done by Miles et al,[4] in which they reported increased clinical debonds associated with these brackets as compared with conventional stainless steel brackets. Given that the Damon 2 brackets performed well in this in vitro bond strength study, this may suggest that any clinical bond failures with the Damon 2 self-ligating brackets may be caused by another factor such as the mechanical design of the ligation system in opening and closing the slide or simply operator error in technique. An unintentional shear force while operating the ligation system can easily be applied, resulting in bracket failure. Perhaps an update by Ormco in 1999 provided an insight on this when it warned against generating more mechanical advantage than is needed for opening the slide.[13] As manufacturers continue to promote self-ligating brackets, and as the popularity of these brackets increases, further research may be necessary to evaluate their bond strength in a clinical situation, especially regarding the design of the ligation system.

In comparing groups 2 and 3, which consisted of the self-ligating bracket Damon 2 with either a traditional adhesive or the newer Blūgloo adhesive, no significant difference in shear bond strength was found. Not only were groups 2 and 3 similar, but the bond strengths were well above the required strengths for combating the masticatory and orthodontic treatment forces.

Table 2. Weibull modulus and characteristic strength results

Group	Weibull modulus, β	Characteristic strength, α	Shear bond strength at 10% probability of failure, MPa	Shear bond strength at 90% probability of failure, MPa
1—Orthos, Transbond XT	3.2	17.0	8.5	22.0
2—Damon 2, Transbond XT	4.5	25.5	15.5	30.6
3—Damon 2, Blūgloo	6.2	26.5	18.5	30.3

Table 3. Adhesive Remnant Index (ARI) scores by group

Group	ARI scores*			
	0	1	2	3
1—Orthos, Transbond XT	0	0	2	18
2—Damon 2, Transbond XT	1	0	1	18
3—Damon 2, Blūgloo	0	1	4	15

* There was no significant difference ($P > .05$) among the groups.

These results suggest that there is no compromise in bond strength when using the Blūgloo adhesive for its advantageous color change properties in aiding adhesive removal during bonding or debonding of brackets.

An interesting side note regarding the different primers used must be mentioned. A previous study by Vicente et al[14] found a significant increase in bond strength when brackets were bonded with Ormco's Orthosolo primer compared with using Transbond XT primer or All-Bond 2 primer with Transbond XT adhesive. However, in this study, there was no significant increase in bond strength when Orthosolo was used, albeit with the Blūgloo adhesive, compared with the other primer-adhesive combination of Transbond XT. Additional studies may be needed to address the claim by Ormco of enhanced bond strength with the Orthosolo primer with various adhesive systems.

The mean bond strengths for groups 2 and 3 were approximately 23–25 MPa. Newman et al[15] stated that shear bond strengths should be less than 23 kg to avoid damage to enamel. In the current study, this corresponds to bond strengths of approximately 21 MPa. However, there were no instances of enamel fracture in any of the groups tested, similar to some other studies that had high bond strength values without incidence of enamel fracture.[16,17]

The ARI scores of all three groups were very consistent yet unexpected, for 85% of the specimens showed ARI scores of 3. A common claim by manufacturers of orthodontic adhesives is the characteristic of the adhesive to adhere more to the bracket base than to the tooth upon removal. This is more efficient for the orthodontic practitioner because less time is required to remove adhesive from the tooth and the removal process is less burdensome for the patient. Thus, a lower ARI score, meaning less adhesive remaining on tooth structure, would seem to be favorable. However, it can be argued that it may be better for the adhesive to remain on the tooth, and for failure to occur between bracket and adhesive, so as not to cause fracturing of the enamel during the debonding process. This may reduce the efficiency of the cleanup but ensures structural integrity of the enamel surface.

Bishara et al[18] obtained similar ARI scores, where the majority of the adhesive remained on the tooth when testing shear bond strength of other metal brackets. Maijer and Smith[19] suggest some variables and observations on differing bond strengths and failure modes. Such variables included air entrapment from the design of the base or weld spots inhibiting proper resin-mesh seals. These variables may explain the ARI scores obtained in this present study. To ascertain the reason for the ARI scores, further testing with the above-mentioned variables in mind may need to be accomplished.

CONCLUSIONS

a. Despite a statistically significant difference in bond strength between the conventional bracket group and both self-ligating bracket groups, all three groups produced clinically acceptable mean shear bond strengths in vitro.
b. There is no compromise in bond strength when using Ormco's color-changing Blūgloo with self-ligating stainless steel brackets.
c. ARI scores for all three groups were not significantly different.

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