Original Article

Comparisons of Two Approaches for Removing Excess Adhesive During the Bonding Procedure

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Abstract: The purpose of this study was to compare the effects on shear bond strength of removing excess adhesive from around the bracket base at 2 time periods: (1) immediately after placing the bracket on the tooth, and (2) after subjecting the adhesive to 5 seconds of light curing to initially secure the bracket in its proper position. The debonding forces were evaluated at 2 times; within half an hour after bonding and after storing for 24 hours in water at 37°C. These comparisons will help determine the most advantageous time for the clinician to remove excess adhesive from around the brackets during the bonding process. The teeth were randomly divided into 4 groups according to: (a) the time of removal of the excess adhesive from around the bracket base namely; immediately after placing the bracket or after 5 seconds of light cure and (b) the time of debonding the brackets, namely within half an hour or after 24 hours. Shear bond strength was measured using a Zwick test machine and calculated in Megapascals. The results of the analysis of variance ($F = 35.05$) comparing the 4 experimental groups indicated the presence of significant differences between all 4 groups ($P = .0001$). In general, the shear bond strengths were significantly larger for the 2 groups debonded after 24 hours, whether they were light cured for a total of 40 seconds ($\bar{X} = 8.8 \pm 3.6$ MPa) or 45 seconds ($\bar{X} = 6.9 \pm 3.4$ MPa). On the other hand, the shear bond strengths was significantly lower in the 2 groups debonded within half an hour from their initial bonding, whether light cured for 40 seconds ($\bar{X} = 0.4 \pm 1.0$ MPa) or 45 seconds ($\bar{X} = 3.4 \pm 2.7$ MPa). In conclusion, the additional 5 seconds of light cure significantly increased the initial shear bond strength. On the other hand, removing excess adhesive after 5 seconds of light cure significantly decreased the shear bond strength at 24 hours. (*Angle Orthod* 2000;70:149–153.)

Key Words: Glass Ionomer; Shear bond strength; Brackets; Excess adhesive

INTRODUCTION

Since Buonocore introduced the acid etch bonding technique in 1955, the concept of bonding various resins to enamel has developed applications in all fields of dentistry[1] including the bonding of orthodontic brackets.[2–8] This approach has several advantages such as enhanced ability for plaque removal by the patient,[5,9] minimizing soft tissue irritation and hyperplastic gingivitis,[5,9] minimizing the danger of decalcification with loose bands,[9,10] and a much more esthetic appearance for the patient.[2] By the late 1970s, bonding of orthodontic brackets became an accepted clinical technique.[11–14]

With the introduction of photosensitive (light-cured) restorative materials in dentistry, various methods were suggested to enhance the polymerization of the materials used, including layering and the use of more powerful light-curing devices. Orthodontics has benefited from the introduction of these materials and manufacturers have introduced numerous light-cured adhesive systems to bond orthodontic brackets. The greatest advantage of a light-cured adhesive system is that it provides the clinician with ample time to accurately position the bracket on the enamel surface before using the light to polymerize the adhesive. A disadvantage of the light-cure approach is the time it takes to expose each bonded bracket to the light (10 to 40 seconds). This exposure time is needed to insure adequate polymerization of the adhesive to sustain the orthodontic forces that will be immediately applied to the tooth at the time of insertion and initial ligation of the archwires.

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In addition, there are a number of other factors that can potentially affect bond strength including the type of enamel conditioner, acid concentration, length of etching time, composition of the adhesive, bracket base design, the bracket material, the oral environment, and the skill of the clinician.[1–17]

One variable that still needs to be explored is the effect of the mechanical removal of excess adhesive from around the bracket base after initially securing the position of the bracket during the bonding procedure. This is particularly important when all the brackets in 1 arch are first properly placed by the clinician then light-cured by the assistant.

The purpose of this study was to compare the effect on shear bond strength, of removing excess adhesive from around the bracket base at 1 of 2 time periods: (1) immediately after placing the bracket at the initial stage of the bonding process while the adhesive is still relatively soft, or (2) after subjecting the adhesive to 5 seconds of light curing when the adhesive is partially polymerized in order to secure the bracket in its proper position. The debonding forces were then evaluated at 2 times; within half an hour after bonding and 24 hours after bonding. These comparisons will help determine the most advantageous time for the clinician to remove excess adhesive from around the brackets.

MATERIALS AND METHODS

Teeth

Ninety freshly extracted human molars were collected and stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included intact buccal enamel, not subjected to any pretreatment chemical agents (eg, hydrogen peroxide), with no cracks due to the pressure of the extraction forceps, and no caries.

The teeth were cleansed and then polished with nonfluoridated pumice and rubber prophylactic cups for 10 seconds.

Brackets used

Maxillary central incisor brackets (Victory Series, 3M Unitek, Monrovia, Calif) were bonded to all teeth. The average surface area of the bracket base was determined to be 11.6 mm.[2] The brackets were bonded to the least curved part of the buccal enamel surface.

Adhesive system used

Fuji Ortho LC bonding system (GC America Inc, Alsip, Ill) was used in the study. This light cured adhesive is a resin reinforced glass polyalkenoate (ie, a modified glass ionomer). It has an aluminofluorosilicate matrix that initially releases fluoride and can re-acquire additional fluoride ions from toothpastes or oral rinses used by the patient. It is suggested that the continuous fluoride release over the course of treatment will help protect teeth from decalcification and prevent caries.[18]

Bonding protocol

The bonding procedure followed the manufacturer's instructions as follows:

1. The enamel conditioner was applied for 20 seconds. The tooth was then thoroughly rinsed with water. Excess water was blotted away with a moist cotton roll. The conditioner contains 10% polyacrylic acid.
2. The refrigerated capsules containing the adhesive were activated and triturated for 10 seconds. Each capsule was used to bond approximately 5 brackets at a time.

Groups Tested

The teeth were randomly divided into 4 groups according to: (a) the time of removal of the excess bonding adhesive from around the bracket base (immediately after placing the bracket while the adhesive is soft or after 5 seconds of exposure when the adhesive has partially hardened), and (b) the time of debonding (within half an hour or after 24 hours of storage at 37°C).

Group I

The bracket with the adhesive was placed on the tooth and a 300 gm force was applied to the bracket to squeeze excess adhesive from under the bracket. The soft excess adhesive was immediately removed with a sharp scaler. Each tooth was then light cured for a total of 40 seconds, 10 seconds at a time from the mesial, distal, occlusal, and gingival plane.

Group II

The brackets with the adhesive were placed in a similar manner as in group I, except that each bracket was light cured for 5 seconds to secure the bracket position. After the 5 second light cure, the partially set excess adhesive was removed with a sharp scaler. The tooth was then light cured for an additional 40 seconds.

Groups I and II were then debonded within half an hour to simulate the timing of the initial archwire placement.

Group III and IV were treated as groups I and II, respectively, but were debonded after 24 hours when most of the bond strength has been achieved.[19] The teeth were stored in deionized water at 37°C.

Debonding Procedure

The teeth were embedded in acrylic placed in phenolic rings (Buchler Ltd., Lake Bluff, Ill). The facial surface of the tooth was aligned to be perpendicular with the bottom of the mold (ie, each tooth was oriented so its labial surface would be parallel to the force during the shear strength

test). A steel rod with 1 flattened end was attached to the crosshead of a 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 electronically connected with the Zwick test machine recorded the results of each test. Shear bond strengths were measured at a crosshead speed of 5 mm/minute.

Evaluation of residual adhesive

After debonding, the teeth and brackets were examined under ×10 magnification. Any adhesive remaining after bracket removal was assessed using a modified Adhesive Remnant Index (ARI) and scored with respect to the amount of resin material adhering to the enamel surface.[20] The ARI scale has a range between 5 and 1, with 5 indicating that no adhesive remained on the enamel; 4, less than 10% of the adhesive remained; 3, more than 10% but less than 90% of the adhesive; 2, more than 90% of the adhesive remained; and 1, all of the adhesive remained on the tooth, along with the impression of the bracket base. The ARI scores were also used as a more complex means of defining the site of bond failure between the enamel, the adhesive, and the bracket base.

Statistical analysis

Descriptive statistics including the mean, standard deviation and minimum and maximum values were calculated, for each of the 4 groups of teeth tested. The analysis of variance was used to determine whether significant differences existed between the various groups. If a significant difference was present, a Duncan's multiple range test was used to identify which of the groups were different. The Chi square test was used to determine significant differences in the ARI scores between the different groups. For the purpose of the statistical analysis, ARI scores of 1 were combined with ARI scores of 2 and ARI scores of 4 were combined with ARI scores of 5. Significance for all statistical tests was predetermined at $P \leq .05$.

RESULTS

Shear bond strength

The descriptive statistics for the shear bond strength are presented in Table 1. The results of the analysis of variance comparing the 4 experimental groups ($F = 35.05$) indicated the presence of significant differences between all 4 groups ($P = .0001$). In general, the shear bond strengths were significantly larger in the 2 groups debonded after 24 hours from their initial bonding, whether they were light cured for 40 seconds ($\bar{X} = 8.8 \pm 3.6$ MPa) or 45 seconds ($\bar{X} = 6.9 \pm 3.4$ MPa). On the other hand, the shear bond strengths were significantly lower in the 2 groups debonded within a half hour from their initial bonding, whether light cured for 40 seconds ($\bar{X} = 0.4 \pm 1.0$ MPa) or 45 seconds ($\bar{X} = 3.4 \pm 2.7$ MPa).

TABLE 1. Descriptive Statistics and the Results of the Analysis of Variance Comparing the Shear Bond Strengths in MPa

Groups Tested[a]	N[a]	Mean[a]	SD[a]	Range[a]	Duncan Test[b]
Group I	22	0.4	1.0	0.1–4.7	D
Group II	23	3.4	2.7	0.2–8.2	C
Group III	22	8.8	3.6	3.1–15.4	A
Group IV	23	6.9	3.4	3.4–18.0	B
	F-Ratio = 35.05		$P = .0001$		

[a] N = Sample size; SD, standard deviation; Group I, tested within ½ hour after bonding + 40 seconds of light cure; Group II, tested within ½ hour after bonding + 45 seconds of total light cure; Group III, tested 24 hours after bonding + 40 seconds of light cure; and Group IV, tested 24 hours after bonding + 45 seconds of total light cure.

[b] Groups with different letters are significantly different from each other.

TABLE 2. Frequency Distribution of the Modified Adhesive Remnant Index (ARI) Scores

Groups Tested[a]	ARI Scores[b]					
	1	2	3	4	5	N
Group I	—	6	7	5	4	22
Group II	—	1	5	10	7	23
Group III	1	—	—	17	4	22
Group IV	—	—	—	6	17	23
	$X^2 = 30.50$		$P = .0001$			

[a] Group I, tested within ½ hour after bonding + 40 seconds of light cure; Group II, tested within ½ hour after bonding + 45 seconds of total light cure; Group III, tested 24 hours after bonding + 40 seconds of light cure; and Group IV, tested 24 hours after bonding + 45 seconds of total light cure;

[b] The ARI scale has a range between 5 and 1, with 5 indicating that no adhesive remained on the enamel; 4, less than 10% of adhesive remained on the tooth surface; 3, more than 10% but less than 90% of the adhesive remained on the tooth; 2, more than 90% of the adhesive composite remained; and 1, all of the adhesive remained on the tooth, along with the impression of the bracket base.

Adhesive remnant index

The ARI scores for the 4 groups tested are presented in Table 2. The Chi square test results ($X^2 = 30.50$) indicated the presence of a significant difference between the 4 groups ($P = .0001$). Further examination indicated that the group debonded within half an hour from the initial bonding and light cured for 40 seconds only, had a greater frequency of an ARI score of 2. This indicated that bond failure in this group occurred more frequently at the bracket-adhesive interface.

DISCUSSION AND CLINICAL IMPLICATIONS

In the process of bonding a whole arch, clinicians are concerned that the brackets on 1 side of the arch might be

displaced while they are still placing the brackets on the rest of the teeth. As a result, light curing the adhesive for 5 seconds will help secure each bracket in place after it is properly positioned. After bracket placement is completed, the assistant then light cures the adhesive for the appropriate time. This is a relatively lengthy process since each tooth will require 40 seconds of light cure.

With the most frequently used bonding protocol, the excess adhesive (whether glass ionomer or composite) is usually removed while it is still soft (immediately after placing the bracket on the enamel surface). The alternative bonding protocol (initially light curing the adhesive for 5 seconds to temporarily secure the bracket in place) also causes the adhesive to become partially set (hardened). What effect the removal of the partially set excess adhesive has on the shear bond strength, both short and long-term, should be of interest to the clinician.

The findings indicated that the shear bond strength of the resin modified glass ionomer is relatively low during the first half hour from its initial setting, whether light cured for 40 seconds ($\bar{X}$ = 0.4 MPa) or 45 seconds ($\bar{X}$ = 3.4 MPa). The additional 5 seconds significantly increased the bond strength in the initial half hour even though the excess adhesive was removed after it has partially polymerized. In these 2 groups, the standard deviations were large relative to their corresponding means. Within 24 hours, bond strength significantly increased from a mean of 0.4 to 8.8 MPa for the 40-second exposure groups and from 3.4 to 6.9 MPa for the 45-second exposure groups.

The long-term effect (after 24 hours) of removing the excess adhesive during the bonding procedure seems to be minimal if performed before exposing the adhesive to any light cure while it is still relatively soft. On the other hand, removing excess adhesive after 5 seconds of light cure significantly decreased bond strength after 24 hours. A possible explanation for this difference is that instrumentation to remove the excess adhesive after light curing for 5 seconds may disturb the bond during the initial stage of polymerization of the adhesive when it has partially set. Therefore, the present findings suggest that the effect of instrumentation is less of a detrimental factor long-term if the excess adhesive is removed when it is still in its relatively ''soft'' initial state. This is particularly true with the resin reinforced glass ionomer because it hardens relatively faster than the composite resin even before being light cured.

The additional 5 seconds of light cure significantly increased the initial bond strength (first half hour) from a mean of 0.4 $\pm$ 1.0 MPa to a mean of 3.4 $\pm$ 2.7 MPa. This increase in bond strength is advantageous when tying the initial archwires to the brackets.[21]

The evaluation of the ARI scores indicated that there was a higher frequency of bond failure at the bracket-adhesive interface in the glass ionomer group debonded within half an hour and light cured for only 40 seconds.

CONCLUSIONS

The present findings indicated that:

1. The additional 5 seconds of light cure significantly increased the initial mean shear bond strength in the first half-hour after bonding, from 0.4 to 3.4 MPa.
2. Removing excess adhesive after an initial 5 seconds of light cure significantly decreased the shear bond strength after 24 hours, from 8.8 to 6.9 MPa.
3. Excess adhesive should be removed from around the brackets while the adhesive is in a relatively soft stage (ie, before being light cured).
4. The glass ionomer adhesive had a relatively low initial bond strength in the first half-hour after bonding; bond strength significantly increased to acceptable levels within 24 hours.[21] This increase in bond strength occurred whether the adhesive was exposed to 40 or 45 seconds of light cure.

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