Original Article

Comparison of shear bond strength and bonding time of a novel flash-free bonding system

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ABSTRACT

Objective: To evaluate the bonding time, shear bond strength (SBS), and adhesive residue index (ARI) of APC(TM) Flash-Free bonding system.

Materials and Methods: Thirty-six extracted human maxillary premolars were randomly divided into three groups (12 per group) and used for this in vitro study: group 1, APC Flash-Free Adhesive Coated Appliance System; group 2, Clarity ADVANCED Ceramic Bracket pasted manually; group 3 (control group), 3M APC PLUS Adhesive prepasted brackets bonded with the extruded flash removed. Bonding time was measured using a stopwatch. Bond strength was measured using an Instron at a cross-head speed of 1 mm/min. The ARI was graded on a scale from 1 to 5. Repeated-measures analysis of variance and post hoc Tukey tests were used for statistical analysis.

Results: It took significantly ($P < .001$) less time to bond in the APC Flash-Free Adhesive group (30.7 $\pm$ 3.3 seconds) compared with the control group (41.8 $\pm$ 4.0 seconds) and the manual group (39.2 $\pm$ 2.8 seconds). The APC Flash-Free Adhesive coated bracket had significantly ($P < .001$) greater SBS (13.7 $\pm$ 2.2 MPa) compared with the control group (10.8 $\pm$ 2.0 MPa) and the manual group (10.4 $\pm$ 1.4 MPa). The ARI was significantly ($P < .001$) greater with the APC Flash-Free Adhesive coated bracket compared with that of the other two groups.

Conclusions: Compared with other methods of bonding, the APC Flash-Free Adhesive Coated System can potentially reduce bonding time while increasing SBS. (*Angle Orthod.* 2016;86:265–270.)

KEY WORDS: Bonding time; Shear bond strength; Flash free bonding; Bonding systems

INTRODUCTION

Most orthodontists use one of two bonding systems when directly placing brackets: (1) manual application of orthodontic adhesive to the base of the bracket prior to placement or (2) use of a precoated bracket system in which each bracket already has orthodontic adhesive applied to the bracket base. In both systems, there is often flash that remains around the bracket-tooth interface that needs to be removed. While complete removal is desirable, clinicians often leave flash behind after bracket placement,[1] which exposes a rough composite surface that becomes a critical site for mature plaque accumulation.[2–4]

Accumulation of plaque around orthodontic appliances for extended periods of time can contribute to enamel demineralization and the development of white spot lesions,[5] which diminish the final esthetic outcome.[6] Complete elimination of flash, therefore, is desirable.

Attempts to minimize the amount of flash have led to the creation of different bonding systems and techniques. The company 3M Unitek (Monrovia, Calif) has developed a new APC Flash-Free Adhesive Coated Appliance System as an attempt to eliminate the need for flash removal; each bracket is individually packaged with an optimal amount of adhesive prepasted on the bracket base, allowing the practitioner to place the bracket and cure the composite without the need for flash removal. While 3M Unitek reports reliable bond strength, reduced bonding time, and no adhesive flash clean up, the APC Flash-Free System has not been independently studied or compared with conventional bonding techniques.

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The purposes of this study were to determine (1) if there is a significant difference in the shear bond strength (SBS) between the APC Flash-Free Adhesive Coated System and the manually pasted Clarity ADVANCED Ceramic Bracket, (2) if there is a significant difference in the time it takes to bond a bracket (bonding time) between the two bonding techniques, and (3) if there is a significant difference in the adhesive residue index (ARI) values between the two bonding techniques.

MATERIALS AND METHODS

Sample

Teeth. Newly extracted human maxillary premolars were collected from Tufts University School of Dental Medicine Department of Oral Surgery and Pediatric Dentistry and stored in a solution of 0.1% (weight/volume) thymol. The inclusion criteria for tooth selection were intact buccal enamel, not subject to any pretreatment chemical agents (such as hydrogen peroxide), no cracks due to the presence of extraction forceps, and no caries. There was no link between the extracted teeth and the patients from which the teeth came from. The teeth were polished with pumice and rubber prophylactic cup for 10 seconds and randomly divided into three groups (12 teeth per group), using a random sequence generator.[7] Each tooth was embedded into a cold-cure acrylic resin prior to orthodontic bonding.

Brackets. Ceramic maxillary premolar APC Flash-Free Adhesive and Clarity ADVANCED Ceramic maxillary premolar brackets (3M Unitek) were used for the experimental groups. APC PLUS Adhesive Coated brackets (3M Unitek) were used as a control group. All brackets were reported by 3M Unitek to have the same bracket base area of 11.694 mm^2.

Methodology

Bonding procedure. All teeth were prepared with Transbond Plus Self Etching Primer (3M Unitek) for 5 seconds, followed by a gentle burst of dry air to thin the primer. The brackets were bonded by a single operator according to one of the three following procedures:

- APC Flash-Free group: 3M APC Flash-Free Adhesive Coated bracket was applied to the tooth with a constant force at the ideal occluso-gingival and mesio-distal position.
- Manual bonding group: Transbond XT Light Cure Adhesive Paste (3M Unitek) was applied onto a Clarity ADVANCED Ceramic bracket base with a plastic instrument, and the bracket was applied to the tooth with a constant force at the ideal occluso-gingival and mesio-distal position.
- APC PLUS/control group: 3M APC PLUS Adhesive Coated bracket was applied to the tooth with a constant force at the ideal occluso-gingival and mesio-distal position. Excess adhesive resin was removed with an explorer.

All adhesive resin was polymerized for a total of 12 seconds with a Ortholux Luminous Curing Light (3M Unitek) at an intensity of 1600 mw/cm^2. After bonding, the teeth were stored in distilled water at 37°C for 24 hours to allow complete polymerization of the bonding material.

Measurement of bonding time. The bonding time was measured by an independent observer with a stopwatch. The time was started after the teeth were prepared and stopped after the practitioner deemed the bracket was in the ideal occluso-gingival and mesio-distal position. The total time was recorded in seconds.

Debonding procedure. A 0.016-inch stainless steel wire was attached to a universal test machine (Instron Model 5566A, Norwood, Mass) and placed under the gingival tie wings of the bonded bracket; a gingival-occlusal shear tension load was performed at a cross-head speed of 1 mm/min until the bracket was debonded. Each tooth was oriented so the buccal surface was parallel to the force during the shear strength test. The bond strength was calculated in megapascals (MPa).

Evaluation of residual adhesive. After the SBS was calculated, the bracket and tooth were examined with a digital microscope under 8× magnification. The residual adhesive on the bracket and enamel was assessed using the modified ARI as described by Bishara and Trulove[8] and graded on a scale between 1 and 5 (5, no adhesive left on the tooth; 4, less than 10% of composite remained on the tooth; 3, more than 10% but less than 90% of the composite remained on the tooth; 2, more than 90% of the composite remained on the tooth; 1, all of the composite remained on the tooth, along with the impression of the bracket base). The ARI score was used to define the site of bond failure between the enamel, the adhesive, and the bracket base.

Statistical Analysis

A pilot study was conducted initially on nine teeth, which were not included in the final study sample, to calculate sample size and power. The power calculation was conducted using nQuery Advisor (version 7.0, Statistical Solutions, Boston, Mass). Assuming means of 15.9 MPa for the APC Flash-Free group, 24.2 MPa for the APC PLUS/control group, and 22.3 MPa for the manual group, as well as a common standard deviation of 4.8 MPa, a sample size of 12 per group was

Table 1. Collected Data From All 12 Samples in Each of the Three Groups[a]

	APC Flash-Free (FF)			Manual Transbond XT Adhesive (M)			APC PLUS (PLUS)		
	SBS, MPa	Bonding Time, s	ARI (1–5)	SBS, MPa	Bonding Time, s	ARI (1–5)	SBS, MPa	Bonding Time, s	ARI (1–5)
1	15.94	30.46	4	8.00	40.71	1	12.50	35.38	1
2	12.44	33.78	4	10.27	35.61	1	11.73	38.20	1
3	14.56	30.97	3	9.78	41.25	1	7.72	49.26	2
4	16.55	29.82	3	9.30	40.43	3	9.31	44.13	1
5	15.27	31.21	3	10.83	37.06	4	10.80	42.59	1
6	12.10	25.58	3	12.73	44.03	1	9.38	43.50	1
7	12.19	25.42	3	12.32	40.25	2	12.62	42.12	1
8	12.13	29.24	4	9.12	37.78	1	12.63	36.95	1
9	12.07	30.14	4	12.09	33.63	1	11.95	41.84	2
10	11.24	36.78	4	10.30	41.05	3	7.59	46.84	2
11	12.45	30.82	4	10.07	39.00	1	9.74	38.42	2
12	17.70	34.56	4	10.34	40.11	1	13.41	41.97	1
Mean	13.7[a]	30.7[a]	3.6[a]	10.4[b]	39.2[b]	1.7[b]	10.8[b]	41.8[b]	1.3[b]
SD	2.16	3.29	0.51	1.39	2.82	1.07	1.99	4.04	0.49

[a] The mean values with the same letter are not significantly different.

adequate to obtain a type I error rate of 5% and a power greater than 99%. A repeated-measure analysis of variance (ANOVA) was conducted using SAS (version 9.3, SAS Institute Inc, Cary, NC) to explore the differences between the three groups. Post hoc Tukey tests were performed to determine statistical significance between pairs of groups.

RESULTS

All of the data collected from the study, including SBS (MPa), bonding time (seconds), and ARI (1–5), for all 12 samples in each of the three groups (APC Flash-Free, manual, and APC PLUS) are displayed in Table 1.

The mean SBS for the APC Flash-Free, manual, and APC PLUS groups were 13.7, 10.4, and 10.8 MPa, respectively. The repeated-measures ANOVA found a significant difference between the groups and a P value $<.001$. A post hoc Tukey test found that the significant difference was between the APC Flash-free group, with the manual and APC PLUS groups not being significantly different from one another. A comparison of SBS between the three groups can be seen in Figure 1.

The mean boding time for the APC Flash-Free, manual, and APC PLUS groups was 30.7, 39.2, and 41.8 seconds, respectively. The repeated-measures ANOVA found a significant difference between the groups and a P value $<.001$. A post hoc Tukey test found that the significant difference was between the APC Flash-Free group, with the manual and APC PLUS groups not being significantly different from one another. A comparison of bonding time between the three groups can be seen in Figure 2.

The mean ARI scores for the APC Flash-Free, manual, and APC PLUS groups were 3.6, 1.7, and 1.3, respectively. The repeated-measures ANOVA found a significant difference between the groups and a P value $<.001$. A post hoc Tukey test found that the significant difference was between the APC Flash-Free group, with the manual and APC PLUS groups not being significantly different from one another. A comparison of ARI between the three groups can be seen in Figure 3.

DISCUSSION

This study explored the differences between three different bonding techniques in bonding time, SBS, and ARI. In contrast to previously conducted studies on bond strength, we used an alternate debonding procedure. Rather than using a chisel or rod to place an occluso-gingival load at the enamel-bracket interface,[9–13] a 0.016-inch stainless steel wire was placed under the tie wings to exert a gingivo-occlusal load. This decision was made after samples from our initial pilot study revealed a high rate of bracket fracture and incomplete debond when an occluso-gingival load was placed. For all 36 samples in the current study, a gingivo-occlusal force resulted in complete bond failure without any bracket fractures.

The SBS of the ceramic brackets in each group was less than the bond strength reported by Reddy et al.[9] and Uysal et al.[10] but comparable to the bond strength demonstrated by Bishara et al.[11] and Zielinski et al.[12] Although the SBS of the APC Flash-Free group was significantly greater than that of the other two groups, all three methods of bonding displayed bond strengths greater than 10 MPa, which is sufficient for orthodontic purposes. The overall bond strength, however, may be reduced with thermocycling or with increased time between bonding and the shear test. Future studies could evaluate the SBS of these different bonding systems in conditions that simulate the oral environment.

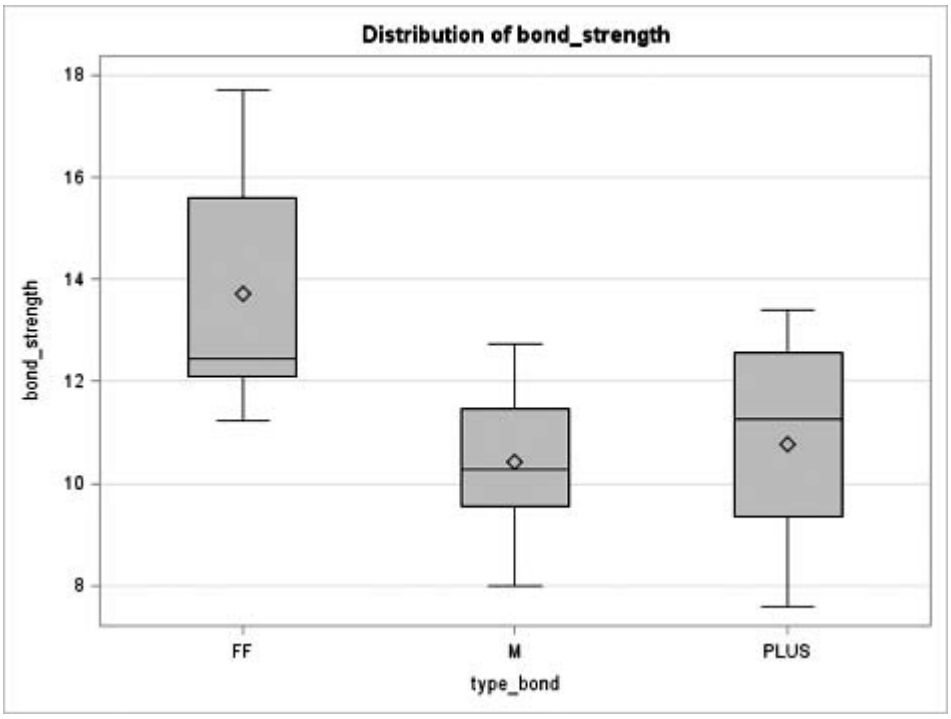

Figure 1. Box plot distribution of shear bond strength in MPa between the three groups: APC Flash-Free (FF), manual Transbond XT adhesive (M), and APC PLUS (PLUS).

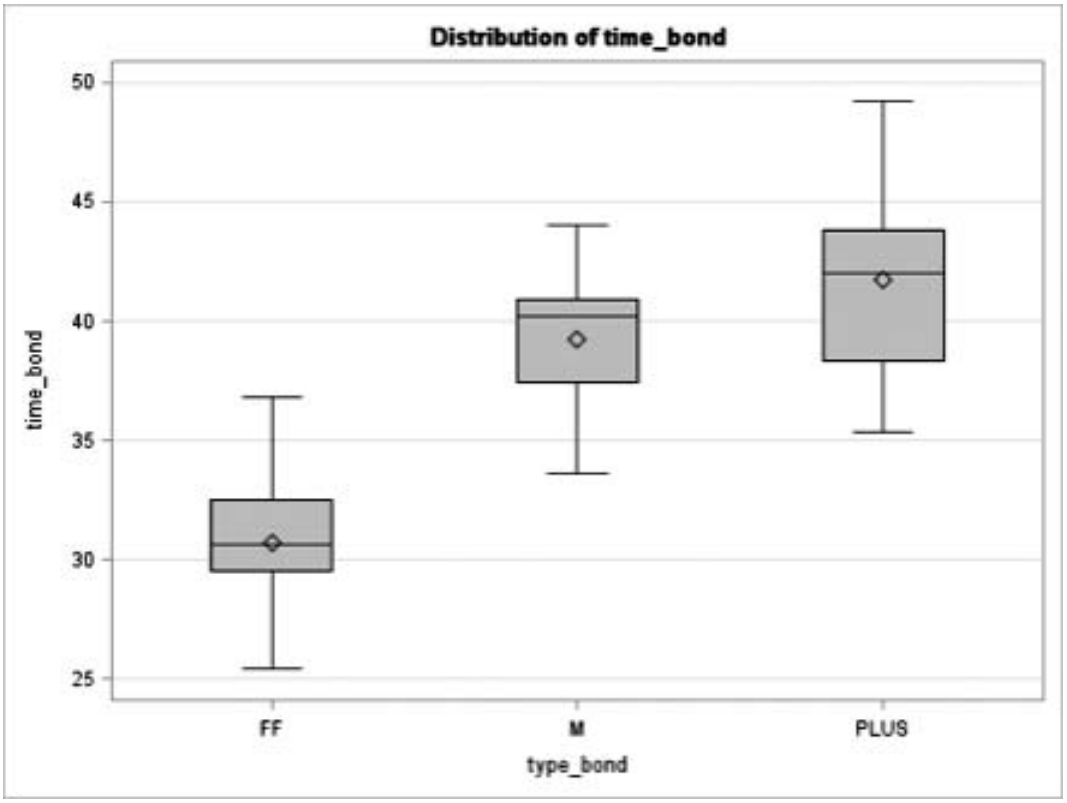

Figure 2. Box plot distribution of bonding time in seconds between the three groups: APC Flash-Free (FF), manual Transbond XT adhesive (M), and APC PLUS (PLUS).

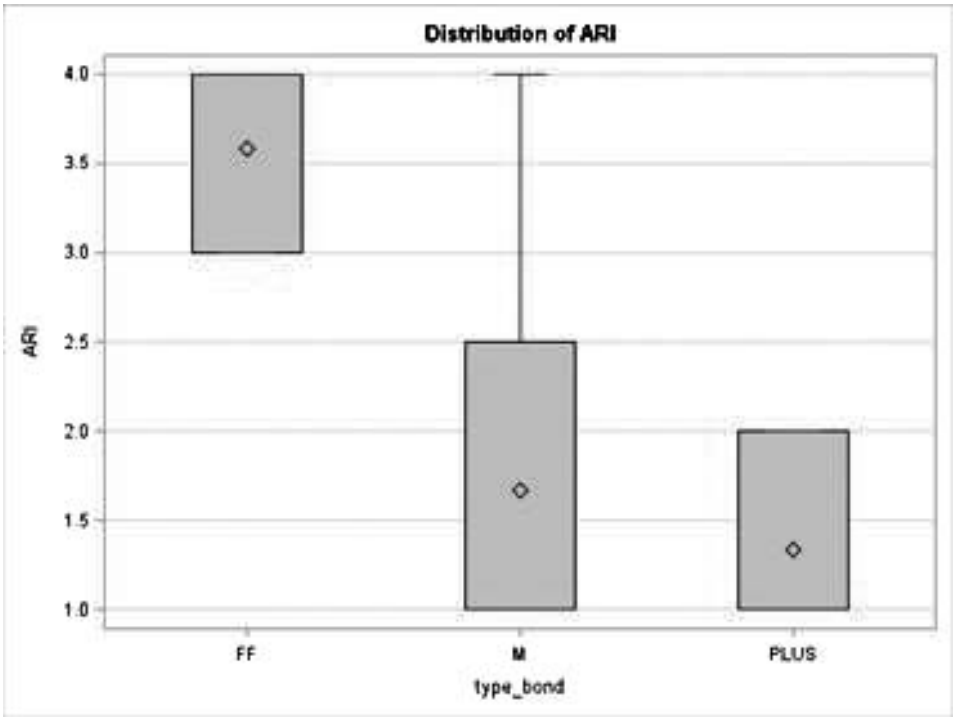

Figure 3. Box plot distribution of ARI (1–5) between the three groups: APC Flash-Free (FF), manual Transbond XT adhesive (M), and APC PLUS (PLUS).

The average bonding times for each of the three bonding groups in this study were longer than previously reported bonding times.[11] This difference may be associated with our variation in bracket placement protocol. In the current study, all efforts were made to position the brackets as ideally as possible in the occluso-gingival and mesio-distal position prior to curing, while similar earlier studies[11] did not present a specific protocol for bracket placement. Attempting to position each bracket ideally could result in a longer bonding time. In addition, the experience of the operator might have influenced the results. In this study, all brackets were bonded by an operator who has 3 years of postresidency clinical experience; it is likely that a more experienced practitioner could have achieved shorter bonding times. The bonding time of the APC Flash-Free group was 8.5–11.1 seconds faster compared with the other two groups, which is equivalent to 2.8–3.7 minutes per full bonding. These results should be interpreted with caution as the bonding procedure was performed in a nonclinical environment. A clinical maxillary/mandibular, right/left split mouth study could further clarify the difference in bonding time between the three systems.

The mean ARI scores for the manual and APC PLUS groups were similar to those reported by Mirzakouchaki et al.,[13] with 67% (16/24) of bracket failures occurring at the adhesive-bracket interface. All of the bracket failures in the APC Flash-Free group occurred within the adhesive and had an average ARI that was significantly greater than that of the other two groups. These results were similar to the values reported by Uysal et al.[10] Overall, the mode of bracket failure among the three groups was favorable with a reduced risk of enamel fracture during the debonding procedure. Further studies are necessary to elucidate the role of thermocycling or increased time between bonding and the shear test on the site of bracket failure.

We attempted to evaluate and quantify the actual amount of adhesive flash that remained around the bracket base with an 8× digital microscope and a 25× scanning electron microscope, but the margins of the adhesive could not be consistently visualized in order to produce reliable measurements. The flash-free nature of the novel bonding system, therefore, could not be evaluated. Future studies could use dyes to help quantify the adhesive around the bracket base and clinically measure and evaluate decalcifications or white spot lesions around brackets bonded with the flash-free system.

CONCLUSIONS

- The APC Flash-Free Adhesive Coated bracket system had a higher SBS compared with the APC PLUS adhesive and manual bonding systems, but all three methods exhibited favorable bond strength and favorable mode of bracket failure.

- Using the APC Flash-Free Adhesive bracket system could potentially save 3–4 minutes of chairside time per complete bonding.

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