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Novel flash free APC brackets: An *in vitro* study

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Abstract
Objective: To analyze the time taken for the bonding, degree of flash, marginal leakage, bond strength and Adhesive Remnant Index of APC flash free brackets and APC PLUS brackets.
Materials and Methods: 80 extracted human teeth (group A: APC flash-free adhesive n = 40, group B: APC Plus adhesive n = 40) were used to evaluate all the parameters mentioned above.
Results: The time needed for bonding differed significantly between the two groups (A: 22.8s/ tooth; B: 35.8 s/tooth). The adhesive excess ranged from 206.6 µm to 87.7 µm (group A) and 872.9 µm to 325.5 µm (group B). The marginal leakage was observed to be higher in group B. The mean shear bond strength of group A was found to be 12.7 Mpa while group B had shown 10.47 Mpa. The maximum percentage of the group A and group B sample had shown ARI of 2. All the parameters had shown significant difference ($p< 0.05$) between the two groups.
Conclusion: The flash free brackets had significantly reduced the time taken for bonding, reduced the degree of flash and had shown adequate bond strength. The new technology seems to facilitate a smooth adhesive-bracket and adhesive-tooth surface, which clinically might improve reduction of plaque accumulation.

Keywords: Flash-free, Stereomicroscopic study, Shear bond strength, Microleakage, Adhesive Remnant Index, Bracket bonding

1. Introduction
The introduction of acid etching technique by Michael Buonocore [1] in the year 1955 to bond dental restorations to tooth structure was a breakthrough point in the history of orthodontic bonding [2, 3, 4, 5]. This was followed by the introduction of Bis-GMA by Rafeal Bowen in the mid 1960's [6, 7, 8] which revolutionized the field of orthodontics from "banding to bonding" which became the preferred choice to many orthodontists because it offers less patient discomfort, improved oral hygiene and reduced chair side time.
Usually, the process of bonding the brackets is performed by the manual application of an adhesive to the bracket base. However, in an attempt to perform easier and faster bonding procedure, in 2014 3M Unitek introduced Adhesive Pre-Coated (APC) Flash Free Adhesive Appliance System which eliminated the need for flash removal [9, 10]. Here, each bracket is individually packed with ideal amount of adhesive pre-coated on to the bracket base, thereby allowing the practitioner to position the bracket on tooth and cure it without any need of removing the flash [10, 11, 12].
APC Flash Free Adhesive is a unique combination of compressible nonwoven mat, soaked in relatively low viscosity adhesive resin. When APC Flash Free Adhesive Coated bracket is seated in place on a tooth, the compressible mat lets the resin seep out to fill the space between the bracket base and the tooth. The surface tension of the low viscosity resin allows it to wet the tooth surface well and forms a smooth fillet around the bracket base and the tooth unlike other adhesives which forms irregular rough adhesive flash [10, 12, 13, 14].

2. Materials and methods
Eighty recently extracted premolar teeth were collected and stored in 0.1% thymol solution. A prophylactic treatment was performed with a pumice paste and rubber cups on the surfaces of the teeth to be bonded.

Prior to the bonding process, the teeth were positioned in a typodont and put in a phantom head to simulate real clinical setting. The situation in both the upper and lower jaw was simulated.

These 80 Premolar teeth were divided in to two groups, i.e. group A and group B with each group containing 40 samples.

Group A**:** 40 Premolar teeth bonded with APC Flash Free Adhesive Coated brackets. (Yellow blocks; Fig. 2)

Group B**:** 40 Premolar teeth were bonded using APC PLUS Adhesive Coated brackets. (Red blocks; Fig. 2)

In each group the teeth were subdivided in to 2 groups i.e. subgroup 1 and subgroup 2 with 20 samples in each.

Bonding procedure

All teeth were prepared with Transbond Plus Self Etching Primer (3M Unitek) for 5 seconds. Brackets were placed on to the teeth and excess adhesive resin was removed with an explorer for subgroup 2 of both the samples and then the adhesive was cured with a Light Emitting Diode. Curing was done for 20 seconds on each side. All the procedures were done by a single operator to avoid inter operator variability. After bonding, the specimens were stored in distilled water at 37°C in an incubator for 24 hours. The teeth were removed after 24 hours for the experiment.

2.1 Time taken for bonding

In both the groups subgroup 2 sample was used for evaluating the time taken for bonding. Time was calculated using the stopwatch. The time was started after tooth was prepared with primer and stopped after the bracket was placed ideally in occluso-gingival and mesio-distal position. The time was noted in seconds.

2.2 Degree of flash

In both the groups, subgroup 1 sample was used for stereomicroscopic evaluation of degree of excess adhesive in relation to bracket edge margin. The mounted bracket was placed under the stereomicroscope and the objective focus was aimed at 90° to the surface of the bracket and the tooth.

With the help of computer measurement tool of the microscope, the distance (µm) between the bracket edge and the most and least leaked margin was metrically registered for both groups. For each side of the bracket multiple (four maximum and four minimum) measurements were made and average of them was considered.

2.3 Colour penetration

Subgroup1 specimens were subjected for colour penetration test to know the marginal leakage. The teeth were stored in 0.5% methylene blue solution for 24 hours. Then they are thoroughly rinsed with distilled water and dried with air blower. After that they were examined under microscope.

The photos of all the four sides i.e. incisal, cervical, mesial and distal surfaces were taken. The bracket-adhesive and adhesive-tooth interface was checked for discoloration. Area found with atleast one discolored spot, was considered as positive.

2.4 Bond strength

All the subgroup 2 specimen were subsequently tested for evaluation of shear bond strength with a universal testing machine, (DAK System Inc. India) after 24 hours of placing them in the incubator in test tubes with distilled water. The rod applied an occluso-gingival load to the bracket, producing a shear force at the bracket tooth interface at a cross head speed of 1mm/min.

2.5 Evaluation of residual adhesive

After debonding, each tooth surface was examined by visual inspection or if necessary, using a dental loupe for the adhesive remained on the tooth. The residual adhesive was assessed using Adhesive Remnant Index given by Artun and Bergman in the year 1984. As per his grade chart:

Score 0 = No adhesive left on the tooth.

Score 1 = Less than half of the adhesive left on the tooth.

Score 2 = More than half of the adhesive left on the tooth.

Score 3 = All the adhesive is left on the tooth, with distinct impression of bracket mesh.

3. Results & Discussion

The descriptive statistics for the time taken for bonding, degree of flash, colour penetration, shear bond strength and Adhesive remnant index of APC flash free and APC PLUS bonding systems evaluated are shown in the Tables 1-5.

The mean bonding time values of the APC flash free brackets and APC PLUS adhesive coated brackets as observed from the table 1, were 22.8 seconds and 35.8 seconds respectively with a P value of 0.001 (< 0.05) which is statistically significant.

As observed from the table 2, APC flash free brackets showed maximum mean flash of 206.69 µm and the minimum mean flash of 87.71 µm. The APC PLUS adhesive coated brackets showed maximum mean flash of 872.97 µm and the minimum mean flash of 325.53 µm. The difference is statistically significant with a P value of zero. (≤0.001)

The chi- square test was computed to assess the difference between the colour penetration of the APC flash free brackets and APC PLUS adhesive coated brackets. The table 3 shows that the 40.6% of the APC flash free brackets and 95.6% of the APC PLUS adhesive coated brackets had shown the colour penetration. The difference is statistically significant with a P value of 0.001.

APC flash free brackets showed the mean shear bond strength value of 12.73 MPa and the APC PLUS adhesive coated brackets showed 10.47 MPa. The difference is statistically significant with a P value of zero. (≤0.001) (Table 4).

As observed from the table 5, 65% of the APC flash free brackets showed the ARI score of 2 and 55% of the APC PLUS adhesive coated brackets showed the ARI score of 2. The difference is statistically significant with a P value of 0.05.

3.1 Tables and Figures

Table 1: Descriptive statistics and the results of the Analyses of Variance comparing the time taken for bonding (seconds) of APC Flash free and APC PLUS bracket systems

	Bonding time					F Value	P value
	N	Minimum	Maximum	Mean	Std. Deviation		
APC flash free	20	17	28	22.80	2.821	6.091	**0.001***
APC Plus	20	28	46	35.80	5.05		

Table 2: Descriptive statistics and the results of Analyses of Variance comparing the degree of flash (µm) of APC Flash free and APC PLUS bracket system

							F	P
	Degree of flash	N	Minimum	Maximum	Mean	SD		
APC flash free	**Maximum excess**	80	0	586.2	206.6	105.8	128.4	**≤ 0.001***
	Minimum excess	80	0	166.4	87.71	26.3		
APC Plus	**Maximum excess**		261.1	1939.8	872.9	423.1	49.2	**≤ 0.001***
	Minimum excess		114.11	1091.6	325.5	167.6		

Table 3: Descriptive seconds which was significantly less compared to test comparing the Colour penetration of APC Flash free and APC PLUS bracket systems

Color penetration	Group		Total
	APC flash free adhesive coated brackets	APC Plus adhesive coated brackets	
YES	65 (40.6%)	153 (95.6%)	218 (68.1%)
NO	95 (59.4%)	7 (4.4%)	102 (31.9%)
Total	160 (100%)	160 (100%)	320 (100.0%)
$\chi^2 = 111.445^a$, p - 0.001* χ^2- chi square test			

Table 4: Descriptive statistics and the results of the Analyses of Variance comparing the shear bond strength (SBS) (MPa) of APC Flash free and APC PLUS bracket systems

Group	SBS (MPa)					F Value	P value
	N	Minimum	Maximum	Mean	Std. Deviation		
APC flash free	20	11.20	15.27	12.7375	1.10192	7.999	≤ 0.001*
APC Plus	20	7.21	14.41	10.4700	2.11047		

Table 5: Descriptive statistics and the results of Chi-square test comparing the Adhesive Remnant Index (ARI) of APC Flash free and APC PLUS bracket systems

ARI score	Group		Total
	APC flash free	APC Plus	
1	7 (35%)	4(20%)	11(27.5%)
2	13 (65%)	11 (55%)	24 (60%)
3	0 (0.0%)	5(25%)	5 (12.5)
Total	20(100%)	20 (100%)	40(100.0%)
$\chi^2 = 5.985^a$, P = 0.05* χ^2- chi square test			

Fig 1: Bonding kit (APC Flash free brackets, APC PLUS brackets, Transbond Plus self etching primer, applicator tip and curing light)

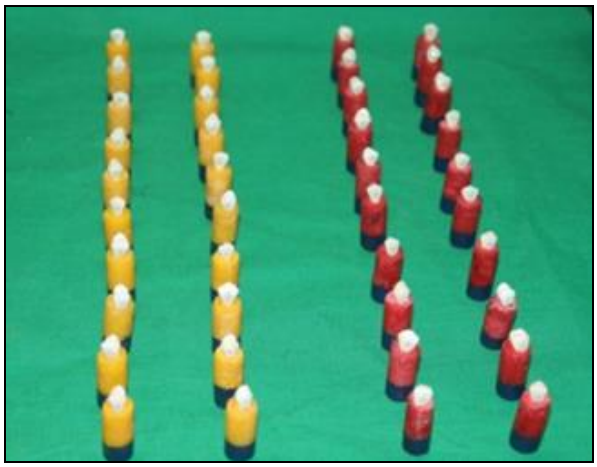

Fig 2: Samples colour coded

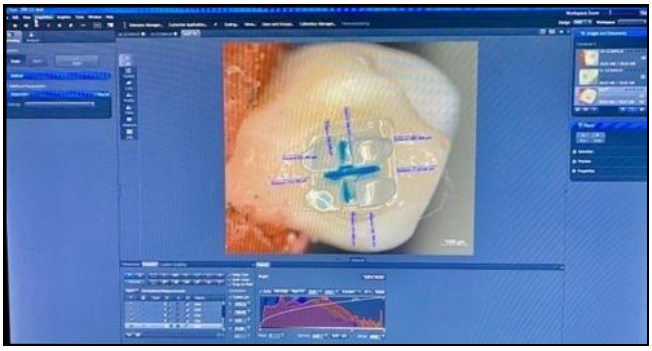

Fig 3: Stereomicroscopic view of the sample

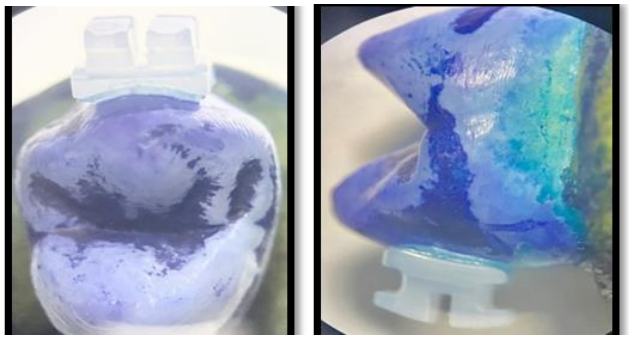

Fig. 4 Sample checked for colour penetration under microscope

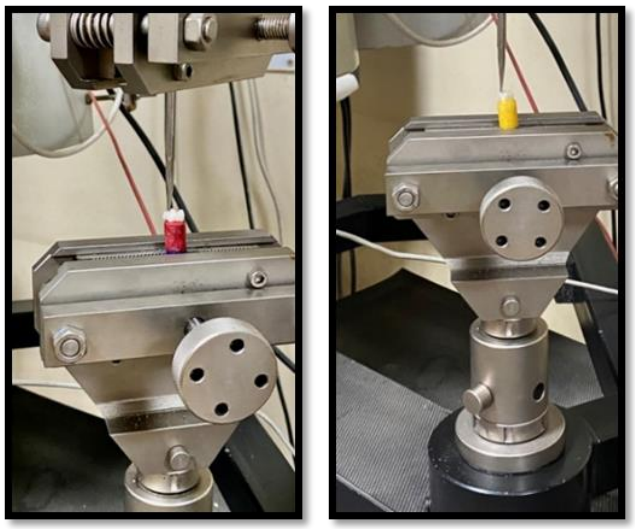

Fig 5: Shear bond strength testing

In study conducted by Lee *et al*. [15] the time taken for bonding the APC Flash free brackets was 30.7 seconds which was significantly less compared to the APC PLUS brackets i.e. 39.2 seconds. The APC Flash free brackets had shown the bond strength of 13.7 Mpa whereas for APC PLUS brackets it was 10.8 Mpa. These values are similar with the studies conducted by Szuhanek *et al*. [16] and Carl Bernstein [17].

Foersch *et al*. [10] analyzed that the time needed for bonding differed significantly in both groups i.e. it took 19.5 seconds per tooth with APC Flash free brackets and 33.8 seconds per tooth with APC PLUS brackets. The adhesive excess measured from the edge of the bracket ranged from 166.27 µm to 81.66 µm in flash free brackets whereas in APC PLUS brackets it ranged from 988.53 µm to 690.81 µm. The colour penetration was seen in 35%of the sample in APC Flash free brackets whereas 97.5% of the sample had shown the colour penetration in APC PLUS brackets. The ARI value of APC Flash free group was 2, lesser in comparison to APC PLUS group where it was 2.8 which are in accordance with the present study. However the difference in the bonding time might be associated with experience of the operator and the specific protocol of bracket placement. In current study, all efforts were made to position the brackets in ideal occluso-gingival and mesio-distal position.

The shear bond strength of both the bracket systems was comparable to the bond strength demonstrated by Bishara *et al*. [18] and Zielinski *et al*. [19] Although the shear bond strength was higher than the clinically acceptable bond strength i.e. 5.9-7.8 MPa which was given by Reynolds [24], it was observed that the bond strength decreases with the thermocycling or with the increase in time between the bonding and shear bond testing.

The ARI values obtained were similar to the study conducted by Uysal *et al*. [25] and Sarah Dheeya Abd *et al*. [26] This indicates that the bracket failure occurred within the adhesive or at bracket-adhesive interface which is an advantage as this reduces the chances of enamel fracture during debonding procedure. Further studies are needed to evaluate the ARI after thermocycling or after increasing the time between bonding and shear test.

The microleakage beneath the APC flash free brackets was found to be less when compared to the APC Plus brackets which was similar to the study conducted by Foersch *et al*.[10] However, the similar study was conducted by Kim *et al*.[13] which had shown that the microleakage under the APC flash free brackets was more. This difference might be because of the methodology followed where we have evaluated the microleakage using a yes or no decision by recording only the colour penetration at the bracket-adhesive and enamel-adhesive interface without sectioning of the tooth as done by Kim *et al*. It was observed that the detailed extent of microleakage can be noted as we increase the number of sections per tooth.

4. Conclusion

As per our study, the following conclusions have been obtained:

- The APC flash free brackets are able to reduce the time needed for the orthodontic bonding.
- The APC flash free bracket system had higher SBS compared with the APC PLUS adhesive coated bracket system.
- In both the systems, the site of bond failure was at bracket-adhesive interface or within the adhesive, indicating a favorable mode.
- There is no need of cleaning the excessive adhesive,

which simplifies bracket positioning process. The resulting bracket-adhesive margins facilitate smooth and narrow surface which extends over 206.6 µm to 87.7 µm over the bracket edge. This appears to improve the marginal integrity and it will reduce the plaque accumulation.

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