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Comparison of Shear Bond Strength and Adhesive Remnant Index of Brackets Bonded with APC Flash free Adhesive Precoated System and a Conventional Adhesive System – An In-Vitro Study

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Abstract

Objectives: This study intends to compare the shear bond strength of APC flash free adhesive pre coated brackets (Group I) with that of clarity advanced ceramic brackets (Group II) and to compare the Adhesive Remnant Index.

Material and Method: A total of 60 extracted premolar, divided into 2 groups mounted on acrylic block. Each tooth was etched, rinsed and air dried. 30 samples were bonded with APC flash free adhesive pre-coated brackets, rest 30 samples were bonded conventionally. Force was applied at a cross-head speed of 3mm/min; the load at failure (N) was recorded. Enamel surface was evaluated with a stereomicroscope & ARI were recorded. Results were subjected to Mann- Whitenny U test for statically analysis.

Result: Group I had comparatively lesser mean SBS value when compared to Group II. The APC flash free adhesive pre-coated brackets have higher ARI score than the conventionally bonded ceramic brackets.

Conclusion: The SBS for APC flash free adhesive pre-coated brackets was lesser when compared to conventionally bonded ceramic brackets. Both had clinically acceptable bond strength. Therefore APC flash free adhesive pre-coated brackets can be advantageous as fewer steps in bonding process results in fewer errors. Further In- Vivo performance of the product are yet to be analyzed.

Keywords: Shear bond strength (SBS), Adhesive Remnant Index (ARI).

Introduction

In 1955, Buonocore introduced the use of phosphoric acid to adhere acrylic materials to enamel.[1] The concept of bonding resin to enamel has developed a niche nearly in all the areas of dentistry, including the bonding of orthodontic brackets, which has become an accepted technique by the 1970's. [2]

Mechanical theories propose that adhesion occurs primarily through microscopic interlocks between the adherend and the adhesive. The clinical significance of utilizing these microscopic interlocks for bonding followed the introduction of the enamel acid-etch. Buonocore opened the door to modern adhesive dentistry techniques.[3]

During the bonding of orthodontic brackets to enamel, conventional adhesive systems use three different agents: an enamel conditioner, a primer solution and an adhesive resin.[4] Studies have reported substantially higher bond strengths of the conventional acid-etching and bonding systems.[5]

Phosphoric acid is the most commonly used acid for enamel conditioning before bonding. Gardner *et al.*

found the quantity of good-quality etch produced by phosphoric acid at 37% was time specific. Findings support the use of 37% phosphoric acid and suggest an optimum application time of 30 seconds.[6]

After the completion of etching, which leaves an opaque enamel surface, a resin primer is applied in a thin layer onto the etched tooth surface. The primer allows for resin tags to form in the enamel. [6]

When approaching the subject of removal of metal or ceramic brackets, several variables are taken into consideration, including the bracket retention mechanism as well as the type of enamel conditioner and adhesive used.[7] In 1965, Bowen introduced a bis-GMA resin that made cleanup easier after debonding. Debonding procedures can damage the enamel and be time-consuming if large amounts of resin remain on the enamel rather than on the brackets. Therefore, an adhesive resin and bonding technique that leave the least amount of resin on the enamel with significant bonding strength is optimal.[1]

Bracket failure at each of the two interfaces has advantages and disadvantages. Bracket failure at the bracket adhesive interface is advantageous since 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 while the cleaning process. On the other hand, 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.[3]

Later the self-etching primer (SEP) systems have been introduced, which simplified the bonding procedure, reduced the chair time and technique-sensitivity. Furthermore, the major role of the operator in the conventional technique on the bracket's shear bond strength (SBS) has been eliminated with the introduction of SEP technique.[4]

To further save chair time through more efficient bonding, manufacturers precoated the brackets with the adhesive. They reduce the number of steps in the procedure, provide convenience to the clinician, minimizing enamel dissolution, and have predictable consistency and thickness of the adhesive and unlimited working time. The recent introduction of the APC Plus system (3M Unitek Dental Products) has provided greater tolerance to humidity than have its predecessors, and the adhesive also releases fluoride.[8,9] But the presence of excessive adhesive flash is still limitation to the material, as it leads to gingival irritation, plaque accumulation, bacterial colonization and increased incidence of white spot lesions.[10]

To tackle this issue in 2014, 3M Unitek (Monrovia, California) introduced the APC flash-free technology (APC Flash-Free Adhesive Coated Appliance System), which supposedly eliminated the need for excess material removal. The proposed advantages of this adhesive system are the lack of necessity of adhesive cleanup, proper marginal seal, the reduced time for bracket positioning and bonding, and the improved ability to concentrate on bracket positioning.[11]

Bond quality, failure mode upon debonding and ease of adhesive remnant cleanup after debonding are important factors for clinicians when choosing an adhesive for orthodontic bracket bonding. The clinicians' preference and the acceptance in the orthodontic community will ultimately determine the success of a new adhesive.[11, 6] Reynolds (1975) stated that successful clinical bonding can be achieved with bond strengths from 6-8 MPa and above. Adhesive remnant index (ARI; Artun and Bergland, 1984) and modified adhesive remnant index (Bishara et al, 1999) can be used to determine the nature of bond failure and determine the site of fracture when a bracket debonds.[12]

Various studies comparing the bond strengths of APC brackets and conventional uncoated brackets have yielded contradictory results. Certain in vitro studies show that APC brackets have bond strength similar to conventional brackets whereas other studies maintain that their bond strength is low. Very few studies compare the bond strength of APC flash free adhesive precoated bracket system with a conventionally bonded ceramic bracket.[12]

For the above mentioned reasons, the aim of this study is to assess the quality of the bond at the enamel–bracket interface and the amount of adhesive remaining on the tooth surface after debonding of APC flash free adhesive precoated brackets in comparison to ceramic brackets bonded with conventional bonding method.

Aims & Objectives of the Study

1. To compare the shear bond strength of adhesive pre-coated brackets (Clarity Advanced, 3M) using a system having a flash-free adhesive (APC Flash-Free Adhesive Coated Appliance System, 3M) with that of ceramic brackets bonded with a conventional adhesive system (Clarity Advanced, 3M Unitek).
2. To compare the Adhesive Remnant Index between the same

Materials and Methods

The present in vitro study was conducted on 60 extracted human premolar teeth in the Department of Orthodontics and Dentofacial orthopedics, HKE'S. S.N. Dental College, Gulbarga. These premolars were obtained from a group of patients who underwent therapeutic extractions. Only morphologically well defined teeth with no caries, fractures, structural defects or any restoration were included.

Armamentarium

1. Brackets

Group 1: APC Flash free adhesive precoated brackets (Clarity Advanced, 3M).

Group 2: Ceramic brackets (Clarity Advanced ceramic brackets, 0.022" slot, MBT, 3M Unitek, USA)

2. Bonding material

Group 1: Etchant- phosphoric acid (37% orthosource), Primer- Transbond – XT primer (3M Unitek, USA)

Group 2 : Etchant- phosphoric acid (37% orthosource), Primer- Transbond – XT primer (3M Unitek, USA), Adhesive - Transbond-XT (3M Unitek) paste

3. Bonding accessories

a. Applicator brush
b. Bracket holder
c. Bracket positioner
d. Explorer (figure 1)
e. Polishing rubber cup and pumice powder
f. Contra-angled hand piece

4. Light curing unit- (coltolux LED) (figure 2)
5. Universal testing machine (Star testing systems, India) (figure 5)
6. Stereo microscope: 10x- 40x magnification (Wuzhou New found instrument co. Ltd, China. Model : XTL 3400E)
7. Distilled water.(Indian Fine Chem)
8. 0.1%wt/vol Thymol solution (S.D.Fine Chem)

Fig- 1 (Armamentarium)

Fig – 2 (Light Curing Unit)

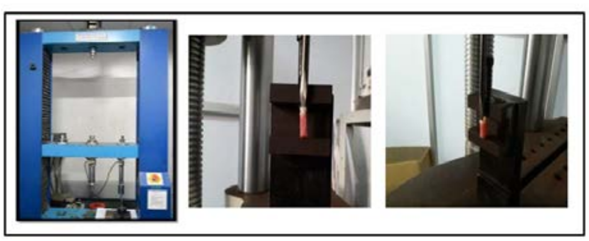


Fig 5- Universal Testing Machine

1. Sample preparation

The extracted premolar teeth were cleaned with distilled and were stored in 0.1% wt/ vol thymol solution to prevent bacterial contamination and dehydration.

These sixty teeth were mounted on clear acrylic. The buccal surface of each tooth was polished with pumice slurry using rubber cup mounted on a low speed hand piece.

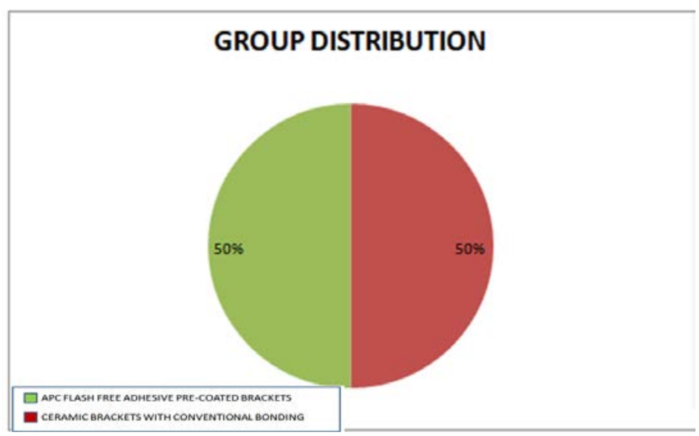
2. Sample Distribution

The sixty extracted premolar teeth were divided into two groups (I and II) of thirty teeth each. Group I represented the teeth to be bonded with APC Flash free adhesive precoated brackets and Group II the teeth to be bonded with clarity advanced clear ceramic brackets.

Table 1: Sample distribution

Groups	Materials Used	Sample Size
Group I	Flash free adhesive pre-coated brackets (Clarity Advanced, 3M)	**30**
Group II	Clarity Advanced ceramic brackets	**30**

CHART – I



Graph 1: Sample Size Distribution

3. Bonding procedure

A standard bonding procedure was employed for bonding of all brackets except for the Group 2 brackets which did not require separate adhesive for bonding.

Group I

The polished and dried buccal surface of each tooth was etched with 37% phosphoric acid for 30sec.

The acid was then rinsed for 15sec with water and dried with oil –free and moisture free air until the enamel had a faint white appearance.

A thin film of Transbond XT primer was applied to the etched enamel surface with a brush which is provided by the manufacturer in the Transbond XT bonding kit.

This was followed by the placement of the APC Flash free adhesive precoated brackets with the help of bracket holder.

The brackets were pressed gently at the centre of the buccal surface of the teeth to ensure uniformity in the bracket seating. Then, the adhesive was light cured for 10sec each on mesial and distal sides with a light curing gun.(figure 3)

Fig 3- APC Flash Free Adhesive Precoated Bracket

For Group II

The polished and dried buccal surface of each tooth was etched with 37% phosphoric acid for 30sec.

The acid was then rinsed for 15sec with water and dried with oil –free and moisture free air until the enamel had a faint white appearance.

A thin film of Transbond XT primer was applied to the etched enamel surface with a brush which is provided by the manufacturer in the Transbond XT bonding kit.

This was followed by the application of Transbond adhesive to the base of the clarity advanced clear brackets.

The brackets were pressed gently at the centre of the buccal surface of the teeth to ensure uniformity in the bracket seating. Then, the adhesive was light cured for 10sec each on mesial and distal sides with a light curing gun.(figure 4)

Fig 4- Clarity Advanced Ceramic Brackets

4. Storage after Bonding

Both the specimens were stored in distilled water separately.

5. Shear bond strength testing

Bond strength testing was carried out on a universal testing machine (Star testing systems, Made in India, Model STS 248) using a customized mounting jig.

This machine consists of two cross heads, upper and lower. The upper crosshead is movable, while the lower crosshead is stationary. The crosshead of the universal testing machine is mounted on a hydraulic framework connected to a force recording unit. An occlusogingival load was applied to the bracket by moving the upper jaw downwards producing shear force at the bracket adhesive interface and parallel to the bracket base. Jig attached to the upper cross head will apply shear force to debond the bracket. (Figure 6)

The cross head of the universal testing machine moved at a uniform speed of 3mm/min. The load was progressively increased till the bracket debonded from the tooth surface. The deboning force was measured in terms of Newton's. This was repeated for the entire sample. The bond strength value obtained in terms of Newton's was converted into Megapascals (MPa) by dividing the values in terms of Newton's by the surface area of bracket base. (MPa= N/mm).

Fig 6: Stereomicroscope

Shear bond strength (Mpa) = debonding force in Newton's / D x L mm2 (bracket base area)

Where D = width of the bracket base.

L = height of the bracket base.

The bracket base area for premolar ceramic brackets: APC flash free adhesive precoated and clarity advanced ceramic bracket is 13.3 mm^2 as per information provided by the manufacturer.

6. Evaluation of the residual adhesive

After debonding each enamel surface was evaluated on a stereomicroscope (Wuzhou New found instrument co. Ltd, China. Model: XTL 3400E) under 15x magnification and rated according to the ARI scores proposed by Artun & Bergland, as follows.

0 = No composite remaining on the enamel.

1 = Less than half the composite remaining on the enamel.

2 = More than half the composite remaining on the enamel.

3 = All composite remaining on the enamel.

Results

The shear bond strength of the two groups was recorded using universal testing machine and subjected to statistical analysis. Table 2 shows the shear bond strength values of both groups.

The descriptive statistics for shear bond strength of the two groups included the mean, standard deviation; Z values (P value) were calculated and presented in Table 3.

The Mann Whitney U test revealed that there was a highly significant difference between the two groups as the P value was less than 0.001. The mean shear bond strength of Flash Free Adhesive Precoated ceramic bracket was 34.44±6.07 Mpa and the mean SBS of clarity advanced bracket was 37.88±0.56 Mpa.

Stereomicroscopic Examination Results:

The ARI scores of the two groups examined are presented in Table 4. The descriptive statistics of the ARI included the mean, SD and P value which are tabulated in Table 5.

The Mann Whitney U test revealed that there was statistically significant difference between the two groups with a p value that is less than 0.001. Mean ARI score was found to be 2.40±0.50 in group I, and 1.46±0.50 in group II. When this difference in mean ARI score was compared between two group using Mann- Whitney U tests, it was found to be statistically significant i.e mean ARI score was found to be significantly high in group I.

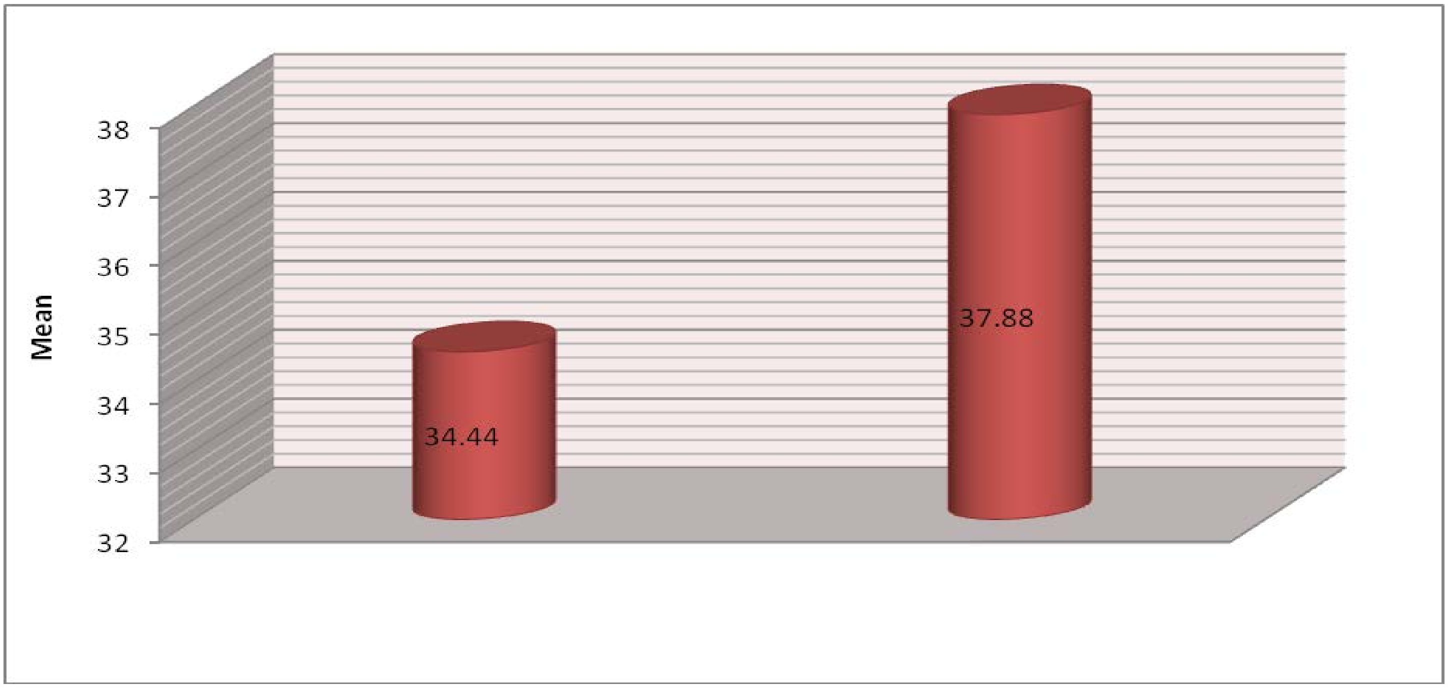
Table 2: Shear bond strength values of both groups in Mpa

Group 1 : APC Flash Free Adhesive Precoated brackets				Group 2: Clarity Advanced ceramic brackets (Conventional Bonding Method)		
Sample ID	Maximum Load (N)	Shear Bond Strength (MPa)		Sample ID	Maximum Load (N)	Shear Bond Strength (MPa)
1.	489	37.33		1.	510	36.98
2.	475	36.26		2.	523	37.93
3.	463	35.34		3.	532	38.58
4.	425	32.44		4.	523	37.93
5.	457	34.89		5.	512	37.13
6.	463	35.34		6.	506	36.69
7.	421	32.14		7.	518	37.56
8.	402	30.69		8.	529	38.36
9.	452	34.50		9.	512	37.13
10.	475	36.26		10.	523	37.93
11.	489	37.33		11.	529	38.36
12.	464	35.32		12.	529	38.36
13.	474	36.25		13.	512	37.13
14.	457	34.89		14.	514	37.15
15.	475	36.26		15.	535	38.59
16.	464	35.32		16.	532	38.58
17.	463	35.34		17.	527	37.94
18.	475	36.26		18.	518	37.56
19.	463	35.34		19.	518	37.56
20.	487	37.32		20.	535	38.59
21.	489	37.33		21.	532	38.58
22.	475	36.26		22.	532	38.58
23.	457	34.89		23.	518	37.56
24.	489	37.33		24.	529	38.36
25.	489	37.33		25.	528	38.35
26.	474	36.25		26.	518	37.56
27.	474	36.25		27.	524	37.94

28.	476	36.27		28.	524	37.94
29.	468	35.35		29.	518	37.56
30.	468	35.35		30.	523	37.93
	Average : 34.44				Average : 37.88	

Table 3: Group-wise distribution based on mean shear-bond strength

Groups	N	Mean	Std. Deviation
1	30	34.44	6.07
2	30	37.88	0.56
Total	60	36.16	4.61
P value		0.0001 (Significant)	



GRAPH - 2 : Shear bond strength values of both groups

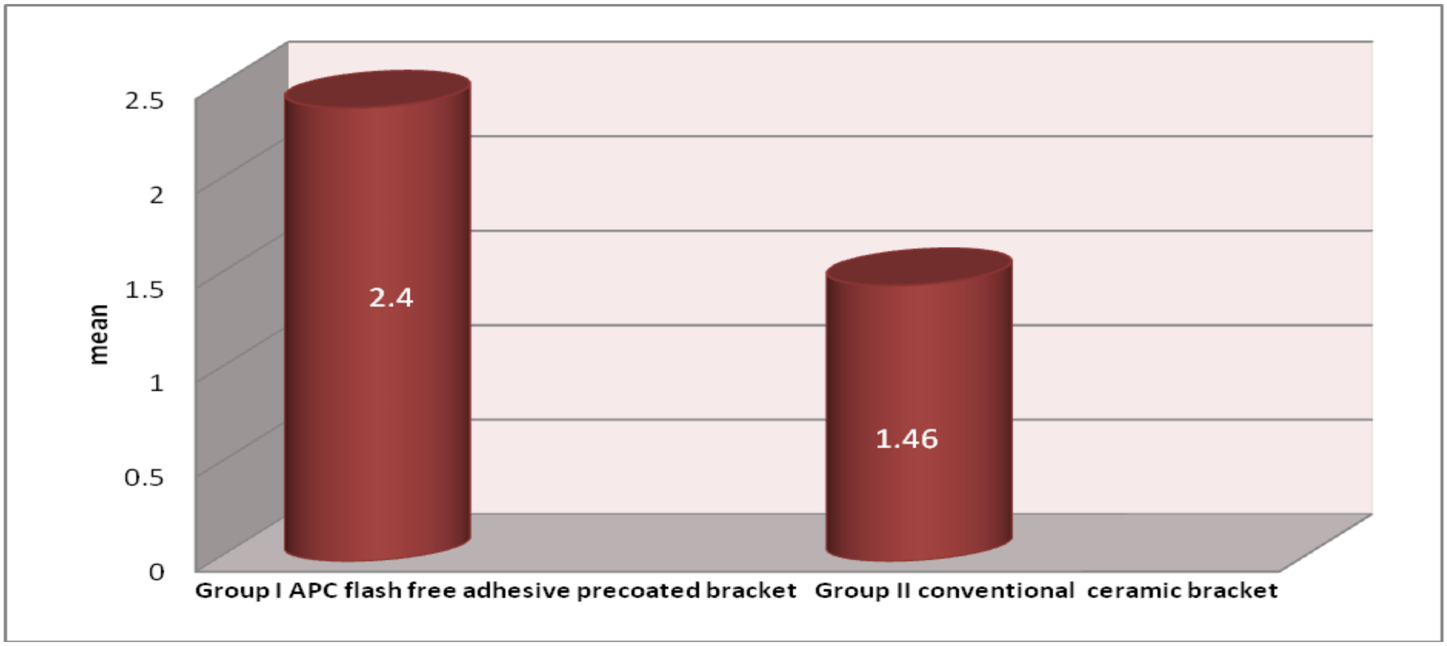
Table – 4: Adhesive Remnant Index values of two groups

Group 1 : APC Flash Free Adhesive Precoated brackets			Group 2: Clarity Advanced ceramic brackets (Conventional Bonding Method)	
Sample ID	ARI Score		Sample ID	ARI Score
1.	3		1.	1
2.	3		2.	1
3.	3		3.	1
4.	3		4.	2
5.	3		5.	2

6.	3		6.	1
7.	2		7.	1
8.	2		8.	2
9.	2		9.	2
10.	2		10.	2
11.	3		11.	1
12.	2		12.	1
13.	2		13.	2
14.	3		14.	2
15.	3		15.	2
16.	2		16.	1
17.	2		17.	1
18.	2		18.	1
19.	2		19.	1
20.	3		20.	1
21.	2		21.	1
22.	3		22.	2
23.	3		23.	1
24.	2		24.	2
25.	2		25.	2
26.	3		26.	1
27.	2		27.	2
28.	2		28.	2
29.	3		29.	2
30.	2		30.	1

TABLE 5: Mean and Standard Deviation (SD) of ARI Score Comparsion by Mann- Whiteny U Test

Group	N	Mean	Std. Deviation
1	30	2.4	0.50
2	30	1.46	0.50
Total	60	1.967	0.71
P value	0.0001 (SIGNIFICANT)		



Graph 3 – ARI scores of both groups

Discussion

In the present study the result showed that the mean SBS of APC Flash-free adhesive pre- coated bracket (34.44±6.07) was lesser than that of Clarity Advanced ceramic bracket (37.88 ± 0.56) bonded with Transbond^{XT} showing a significant statistical difference (P<0.001) (table 3).These results were in accordance with Bearn et al[17]., Oliver BM et al[18]., Wong M and Power S and Cal Neto JP et al[19] who reported that the mean SBS of ceramic brackets which were manually coated and bonded with Transbond XT was significantly higher than the adhesive precoated brackets and also the rate of bond failure was higher with adhesive precoated brackets .Our results are similar to those of Ansari et al. (2016)[15], who found in their in vitro study a mean SBS value of the ceramic brackets of 20.13 MPa for the APC Flash-Freegroup (n = 10), and of 27.26 MPa for the brackets manually bonded with Transbond XT (n = 10). The surface treatment of the enamel surface was similar.

The mean values obtained in our study were higher than those mentioned by Lee et al[11]., Sibi et al[14]., Gabriela et al[16]., in their studies, where the enamel surface treatment was performed using a self-etching primer .For example, Lee et al. (2016), reported a mean shear bond strength value of ceramic brackets recorded on extracted maxillary premolars of 13.7 MPa for the APC Flash-Free group (n = 12), and 10.8 MPa for the APC Plus group (n = 12), and 10.4 Mpa for the group of ceramic brackets manually coated with Transbond XT (n = 12) . The significant differences concerning the SBS values between our study and the latest published studies, could be due mainly to the different enamel surface treatment and the type of bracket used - ceramic brackets presenting higher adhesive values than metal brackets.[16]

In contrast, a study by Bishara et al[7] showed that the precoated ceramic brackets that uses a slightly modified adhesive have similar SBSs as that provided by Transbond

XT adhesive on uncoated ceramic brackets. They have used the first version of precoated brackets by 3M Unitek that was marketed as APC. These brackets were having more filler content than the Transbond XT adhesive which was used to bond the uncoated brackets used in this particular study. The similar bond strengths of both the brackets may be because of this.

It was reported that clinically adequate SBS for metal orthodontic brackets to enamel should range from 5.9 to 7.8 MPa in terms of clinical and 4.9 MPa in terms of laboratory performances as suggested by Reynolds[20] and the maximum bond strength for clinical use as recommended by Lopez[21] is 7 MPa. Although these values are suggested as adequate bond strength values for most clinical orthodontic needs, the minimum clinically acceptable SBS is not known.[14] Considering the minimum SBS value, the APC flash free adhesive precoated bracket can be successfully used for orthodontic treatment purpose.

Amount of adhesive remaining on the tooth surface after bracket debonding

In the present study, the flash-free adhesive failed more reliably and predictably at the bracket-adhesive interface or, more likely, the bracket-mesh interface. This bracket-mesh interface is of a new design in the flash-free product compared to the conventional product. Although the exact design and mechanism of fracture is trade secret, we hypothesize that fracture is more likely at the bracket-mesh interface due to lower bracket density at the site.

Upon bracket removal, the flash-free adhesive left more adhesive on the tooth surface after debonding than the conventional adhesive. In 94% of the brackets bonded with the flash-free product, all or most of the adhesive remained on the tooth after bracket removal, while that was the case in only 64% of the brackets bonded with the conventional product. A recent study showed the majority of ARI scores being either 2 or 3 (Sharma, 2014)[13]. The findings of the present study suggest that typically more adhesive is left on the enamel surface after debonding when using the flash-free adhesive. This is beneficial to orthodontic patients as it minimizes the risk of enamel tear-outs. However, more material remains on the tooth surface, which requires cleanup. .

The primary concern to the clinicians are the maintenance of a sound, unblemished enamel surface after removal of the bracket, yet bracket failure at bracket-adhesive and adhesive- enamel interfaces has its own advantages and disadvantages. For an example, bracket failure at the bracket/adhesive interface is advantageous, because it leaves the enamel surface relatively intact. However, considerable chair side time is required 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.[14]

The mean ARI score for APC flash free adhesive precoated bracket was 2.4 ± 0.50 in group I and for uncoated clarity advanced ceramic bracket bonded with Transbond XT was 1.46 ± 0.50. Mann-Whitney's U test was used as the nonparametric tool to compare ARI scores of different groups. It showed that there was statistically significant difference between the mean ARI values of groups I and II ($P<0.001$).

A higher ARI score seems to be more desirable to minimize the enamel damage. The mean value for the ARI scores of the precoated ceramic brackets being 1.46 ± 0.50 implies that more enamel fractures and damage tend to occur compared to the APC flash free product. Bishara et al[22] in their observation has quoted the safer mode of debonding should be at the bracket-adhesive site that would protect the enamel. He also mentioned that failure occurred at enamel-adhesive interface could damage the enamel.[14]

Limitation of the study

In this study the ranges and standard deviations of bond strength were high in both the groups even though the technique inconsistencies were minimized. This may be due to the variations in the buccal surface morphology of the premolar teeth, the amount of the adhesive resin applied to the bracket base, and the application force during bonding.

Another limitation of the study, however, is that the laboratory conditions do not fully represent the dynamic environment of the oral cavity. Clinically, the adhesives are subject to stresses, temperature fluctuations, variable electrolytes, microorganisms, and other factors that may affect the performance.

Also, a study on all permanent tooth including first molars would give a clear picture of SBS, unlike on premolars only. Nevertheless, the in vitro bond strength evaluations are found to be an acceptable methodology in determining future in vivo comparative trials. Being an in vitro bond strength study, caution is advised in extrapolating the results of the present study to the clinical situation.

Conclusion

The SBS of APC flsh free adhesive precoated ceramic brackets were significantly lower than that of uncoated ceramic brackets bonded with conventional orthodontic adhesive. However, the mean bond strengths of both the adhesives were adequate and acceptable for clinical use since their values were significantly above the clinically acceptable range.

The flash-free adhesive fails more reliably and predictably at the bracket-adhesive interface, which is considered the preferred failure mode by most orthodontists as it minimizes the risk of enamel tear-outs.

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